

**Computer Science & Information Technology 191**

**Artificial Intelligence, Soft Computing and Applications**



David C. Wyld  
Dhinaharan Nagamalai (Eds)

## **Computer Science & Information Technology**

- 4<sup>th</sup> International Conference on Internet of Things & Embedded Systems (IoTE 2023)
- 10<sup>th</sup> International Conference on Computer Networks & Data Communications (CNDC 2023)
- 13<sup>th</sup> International Conference on Advances in Computing and Information Technology (ACITY 2023)
- 13<sup>th</sup> International Conference on Digital Image Processing and Pattern Recognition (DPPR 2023)
- 13<sup>th</sup> International Conference on Artificial Intelligence, Soft Computing and Applications (AIAA 2023)
- 4<sup>th</sup> International Conference on NLP Techniques and Applications (NLPTA 2023)
- 15<sup>th</sup> International Conference on Web services & Semantic Technology (WeST 2023)
- 9<sup>th</sup> International Conference on Software Security (ICSS 2023)

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## Preface

4<sup>th</sup> International Conference on Internet of Things & Embedded Systems (IoTE 2023) , November 25 ~ 26, 2023, London, United Kingdom, 10<sup>th</sup> International Conference on Computer Networks & Data Communications (CNDC 2023), 13<sup>th</sup> International Conference on Advances in Computing and Information Technology (ACITY 2023), 13<sup>th</sup> International Conference on Digital Image Processing and Pattern Recognition (DPPR 2023), 13<sup>th</sup> International Conference on Artificial Intelligence, Soft Computing and Applications (AIAA 2023), 4<sup>th</sup> International Conference on NLP Techniques and Applications (NLPTA 2023), 15<sup>th</sup> International Conference on Web services & Semantic Technology (WeST 2023), was collocated with 9<sup>th</sup> International Conference on Software Security (ICSS 2023). The conferences attracted many local and international delegates, presenting a balanced mixture of intellect from the East and from the West.

The goal of this conference series is to bring together researchers and practitioners from academia and industry to focus on understanding computer science and information technology and to establish new collaborations in these areas. Authors are invited to contribute to the conference by submitting articles that illustrate research results, projects, survey work and industrial experiences describing significant advances in all areas of computer science and information technology.

The IOTE 2023, CNDC 2023, ACITY 2023, DPPR 2023, AIAA 2023, NLPTA 2023, WEST 2023, ICSS 2023. Committees rigorously invited submissions for many months from researchers, scientists, engineers, students and practitioners related to the relevant themes and tracks of the workshop. This effort guaranteed submissions from an unparalleled number of internationally recognized top-level researchers. All the submissions underwent a strenuous peer review process which comprised expert reviewers. These reviewers were selected from a talented pool of Technical Committee members and external reviewers on the basis of their expertise. The papers were then reviewed based on their contributions, technical content, originality and clarity. The entire process, which includes the submission, review and acceptance processes, was done electronically.

In closing, IOTE 2023, CNDC 2023, ACITY 2023, DPPR 2023, AIAA 2023, NLPTA 2023, WEST 2023, ICSS 2023 brought together researchers, scientists, engineers, students and practitioners to exchange and share their experiences, new ideas and research results in all aspects of the main workshop themes and tracks, and to discuss the practical challenges encountered and the solutions adopted. The book is organized as a collection of papers from the IOTE 2023, CNDC 2023, ACITY 2023, DPPR 2023, AIAA 2023, NLPTA 2023, WEST 2023, ICSS 2023.

We would like to thank the General and Program Chairs, organization staff, the members of the Technical Program Committees and external reviewers for their excellent and tireless work. We sincerely wish that all attendees benefited scientifically from the conference and wish them every success in their research. It is the humble wish of the conference organizers that the professional dialogue among the researchers, scientists, engineers, students and educators continues beyond the event and that the friendships and collaborations forged will linger and prosper for many years to come.

David C. Wyld,  
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## General Chair

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Vishwanath Kagawade,  
Wai Lok Woo,  
Wanyang Dai,  
Xiangyuan Zhu,  
XiWen Zhang,  
Yasushi Kambayashi,  
Yilun Shang,  
Yousef Farhaoui,  
Youssef TAHER,  
Yuan-Kai Wang,  
Zahra Pezeshki,  
Zayar Aung,  
Ze Tang,  
Zhe Chen,  
Zoran Bojkovic,

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## TABLE OF CONTENTS

### **4<sup>th</sup> International Conference on Internet of Things & Embedded Systems (IoTE 2023)**

**Multimodal Analysis of Google Bard: Experiments in Visual Reasoning.....01-28**  
David Noever and Samantha Elizabeth Miller Noever, PeopleTec, Inc., USA

**A Comprehensive Data-Driven Analysis of Healthcare Disparities in the United States.....29-41**  
Yusuf Y. Babatunde, Durojaiye M. Olalekan, Yussuph T. Toyibat, Unuriode O. Austine, Akinwande J. Mayowa, Yusuf K. Tobi and Afolabi T. Osariemen, Austin Peay State University, USA

### **10<sup>th</sup> International Conference on Computer Networks & Data Communications (CNDC 2023)**

**A Smart Fishing Rod and Software using Flex Sensor, Vibration Sensor and Bluetooth.....43-52**  
Yanbo Wang<sup>1</sup> and Jonathan Sahagun<sup>2</sup>, <sup>1</sup>Chapman University, USA, <sup>2</sup>California State Polytechnic University, USA

**Unravelling DNS Performance: A Historical Examination of F-Root in Southeast Asia.....53-62**  
Jiajia Zhu and Chao Qi, China Academy of Information and Communications Technology, China

**Harnessing Mobile Technology for Sustainable Engagement: An Innovative iOS and Android Flutter Application for United Nations' SDG Alignment and User Empowerment.....63-75**  
Megan Wei<sup>1</sup> and Bobby Nguyen<sup>2</sup>, <sup>1</sup>University of California Irvine, USA, <sup>2</sup>California State Polytechnic University, USA

### **13<sup>th</sup> International Conference on Advances in Computing and Information Technology (ACITY 2023)**

**An Entertaining Application to Mix Exercise with Fun using Pose Estimate and Unity .....77-86**  
Alexander Wu<sup>1</sup>, Amelia Wu<sup>2</sup> and Moddwyn Andaya<sup>3</sup>, <sup>1</sup>California Connections Academy Central Valley, USA, <sup>2</sup>UC San Diego, USA, <sup>3</sup>California State Polytechnic University, USA

**ChatGPT for Generating Questions and Assessments based on Accreditations.....87-98**  
Rania A Aboalela, King Abdulaziz University, Saudi Arabia

**Assessing the Viability and Socio-Economic Impact of Solar Photovoltaic Systems in Off-Grid Rural Communities: A Case Study of a Developing Region**.....99-110

Tianmu Li<sup>1</sup> and Jonathan Sahagun<sup>2</sup>, <sup>1</sup>University of California Irvine, USA, <sup>2</sup>California State Polytechnic University, USA

### **13<sup>th</sup> International Conference on Digital Image Processing and Pattern Recognition (DPPR 2023)**

**A Hierarchical Vision Approach for Enhanced Medical Diagnostics of Lung Tuberculosis using Swin Transformer**.....111-121

Syed Amir Hamza and Alexander Jesser, Heilbronn University of Applied Sciences, Germany

### **13<sup>th</sup> International Conference on Artificial Intelligence, Soft Computing and Applications (AIAA 2023)**

**Welcome to Ultaki: Exploring the Relevance of Large Language Models for Accurate Behavioral Simulation in Energy Transition**.....123-137

Mehdi Mounsif, Benjamin Jauvion and Fabien Medard, Akkodis Research, France

**Axiomatic Methodology of Formalization as a Way to Intellectual Analysis in Computer Science**.....139-145

Viktoria Kondratenko<sup>1</sup> and Leonid Slovianov<sup>2</sup>, <sup>1</sup>University of Edinburgh, UK, <sup>2</sup>Centre of Innovative Medical Technologies of the National Academy of Sciences of Ukraine, Ukraine

**From U-Net to (U-Net) +, What Innovations Have We Made for the Treatment and Discovery of Breast Cancer?**.....147-164

Minuo Qing, Emily X. Ding and Robert J. Hou, Vineyards AI Lab, New Zealand

**The AI Transformation Risk Model: Solutions where Benefits Outweigh Risks**.....165-179

Richard Fulton<sup>1</sup>, Diane Fulton<sup>2</sup>, Nate Haynes<sup>3</sup> and Susan Kaplan<sup>3</sup>, <sup>1</sup>Troy University, USA, <sup>2</sup>Clayton State University, USA, <sup>3</sup>Modal Technology, USA

### **4<sup>th</sup> International Conference on NLP Techniques and Applications (NLPTA 2023)**

**An Analysis and Research of Growth Factors of Internet Celebrity Boba Milk Tea Stores using Machine Learning and Artificial Intelligence**.....181-194

Fuyi Xie<sup>1</sup> and Zihao Luo<sup>2</sup>, <sup>1</sup>University of California Irvine, USA, <sup>2</sup>California State Polytechnic University, USA

**Do You Speak Basquenglish? Assessing Low-Resource Multilingual Proficiency of Pretrained Language Models**.....195-207

Iñigo Parra, University of Alabama, USA

**The Evolution of VANET Networks: A Review of Emerging Trends in Artificial Intelligence and Software-Defined Networks.....209-219**

Lewys Correa Sánchez<sup>1</sup>, Octavio José Salcedo Parra<sup>1</sup> and Miguel J. Espitia R.<sup>2</sup>,  
<sup>1</sup>Universidad Distrital Francisco José de Caldas, Colombia, <sup>2</sup>Universidad Distrital Francisco José de Caldas, Colombia

**An Empowering Mobile Aid Application to Help Visually Impaired People Navigate and Explore Places Around Them using Location Tracking and Text Detection.....121-232**

Yiyao Zhang<sup>1</sup>, Anne Yunsheng Zhang<sup>1</sup> and Yu Sun<sup>2</sup>, <sup>1</sup>USA, <sup>2</sup>California State Polytechnic University, USA

**15<sup>th</sup> International Conference on Web services & Semantic Technology (WeST 2023)**

**Advancing Web Accessibility: A Guide to Transitioning Design Systems from WCAG 2.0 to WCAG 2.1.....233-245**

Hardik Shah, Rochester Institute of Technology, USA

**Harnessing Customized Built-in Elements: Empowering Component-Based Software Engineering and Design Systems with HTML5 Web Components .....247-259**

Hardik Shah, Rochester Institute of Technology, USA

**9<sup>th</sup> International Conference on Software Security (ICSS 2023)**

**AI-Based Security Enhancement and Personal Information Protection Techniques Inherited from 6G Networks.....261-269**

Kwang-Man Ko, Chul-Long Kim, Jun-Seop Lim, Seong-Won Kim and Byung-Suk Seo, Sangji University, Republic of Korea

**13<sup>th</sup> International Conference on Advances in Computing and Information Technology (ACITY 2023)**

**On-premise File Server Vs Cloud Storage with Incident Management: A Comparative Study.....271-284**

Jaymie Rae Medina and Jennalyn Mindoro, Technological Institute of the Philippines, Philippines



# MULTIMODAL ANALYSIS OF GOOGLE BARD: EXPERIMENTS IN VISUAL REASONING

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## **ABSTRACT**

*Addressing the gap in understanding visual comprehension in Large Language Models (LLMs), we designed a challenge-response study, subjecting Google Bard to 64 visual tasks, spanning categories like "Visual Situational Reasoning" and "Next Scene Prediction." Previous models, such as GPT4, leaned heavily on optical character recognition tools like Tesseract, whereas Bard, akin to Google Lens and Visual API, employs deep learning techniques for visual text recognition. However, our findings spotlight Bard's limitations: while proficient in solving visual CAPTCHAs that stump ChatGPT, it falters in recreating visual elements like ASCII art or analyzing Tic Tac Toe grids, suggesting an over-reliance on educated visual guesses. The prediction problem based on visual inputs appears particularly challenging with no common-sense guesses for next scene forecasting based on current "next-token" multimodal models. This study provides experimental insights into the current capacities and areas for improvement in multimodal LLMs.*

## **KEYWORDS**

*Transformers, Text Generation, Image Analysis, Generative Pre-trained Transformers, GPT*

## **1. INTRODUCTION**

Large Language Models (LLMs) have marked significant advancements in the AI domain, offering textual understanding and generation capabilities [1-11]. Originating from foundational text-based reasoning paradigms [3-4,11], recent developments have hinted at LLMs' potential to integrate vision, expanding their applicability to visual tasks like image reasoning [8-9].

The core objective of this study is to assess LLMs' aptitude in image-related reasoning tasks [9-14]. Although LLMs have exhibited considerable competence in textual contexts, their proficiency with visual data remains relatively uncharted [6]. Our research aims to elucidate how these models can amalgamate visual stimuli with textual reasoning, providing an experimental view of their multimodal capabilities. Bard has emerged as a notable visual language model, with others potentially existing in proprietary or unreleased states [8].

Originally, LLMs showcased expertise in tasks such as text completion and translation [2-4]. However, as their underlying architectures evolved and datasets incorporated multimodal elements, their potential for bridging text and vision surfaced [4-5, 13-14]. Such an evolution reflects the computational capabilities of LLMs and highlights their promise in navigating multimodal tasks, integrating textual and visual inputs [15-16]. Their adaptability is further buttressed by their performance across diverse domains, ranging from code generation to medical advice [10-13].

However, while LLMs' capabilities are expansive, they have limitations. Their outputs,

contingent on training data patterns, can inherit underlying biases and inaccuracies [7]. Yet, their achievements signify a crucial step in AI's endeavor to emulate human cognitive processes [2,5].

We organize the paper around evaluating LLM performance, then probing its sensitivity and aptitude towards visually-related prompts. We traverse a range of image reasoning tasks, starting with foundational tasks like part identification and the role of chat memory across multiple prompts. Subsequently, the analysis pivots towards specialized domains. The spectrum spans from image captioning—encompassing satellite imagery [16] to human-captioned datasets [15]—to multistep tasks that test an LLM's ability to weave together sequential instructions from visual inputs [17]. In the visual cognition realm, the paper evaluates LLMs against iconic games and puzzles, from the strategic depths of Chess and Go, to the intricate challenges of Sudoku and Morse Code. Furthermore, we experiment with scenario-based tasks, simulating real-world situations such as predicting movie scenes or driving decisions [17]. Each segment not only assesses LLMs' successes but also catalogs their shortcomings, offering a perspective on the potential and pitfalls of LLMs in visual reasoning tasks [9].

## 2. METHODS

For this study, we employed the advanced capabilities of the Bard language model (bard.google.com), complemented by specialized image language transformers. The experimental framework was initiated by uploading images, specifically in JPG or PNG formats, chosen for their inherent complexity and potential to challenge the LLMs.

Once the image was integrated into the system, a series of questions were posed to the LLM, directing its attention toward various elements within the image. These queries ranged from straightforward object identification to more intricate tasks. For instance, we task the LLM with generating captions that encapsulate the image's essence or extrapolated potential subsequent frames, simulating a dynamic progression.

One motivation for the study centers on automating various visual tasks in a minimally supervised pipeline, like a high-volume API, where the machine might offer critical decisions but self-assesses complex edge cases or outliers based on the actual adversarial challenge. Example APIs include text extraction from images (OCR), code generation from mockups, image captioning, or medical and nutritional information extracted from image tables. A second more long-term cluster of interest involves the advancement of mathematical problem solving (automated proofs), equation recognition, and even understanding human sarcasm, memes, or jokes as foremost imagery.

### 2.1. Image-Related Reasoning Tasks

Through structured categories of visual tasks, we aim to evaluate Bard's capacity to interpret visual- language cues systematically. Each type offers unique challenges, providing insights into Bard's strengths and potential areas of vulnerability. As Appendix A highlights, users can leverage Bard's image- processing skills to extract textual content from varied image formats (mainly in English). Bard can discern and subsequently extract tables from scanned images, effectively upgrading formats for real business problems in optical character recognition, though users are encouraged to verify the extracted data for potential discrepancies meticulously. Bard can extract humor from memes, albeit with some nuanced misses in this considerable, internet-scale pastime. Bard translates visual, mathematical problems and equations into LaTeX, a feature academics and book publishers might find invaluable. A particularly intriguing visual aspect of Bard's competence includes converting visual website mockups into code, though it occasionally

grappled with complex dynamic elements such as javascript actions or style sheets. But the model creators emphasize, especially in areas like medical report insights, employing Bard as a supplementary tool rather than a primary diagnostic entity.

Visual Task Category	Variations/Attacks	Hypothesis and Anticipated Results
Typography	<ul style="list-style-type: none"> <li>• Out-of-vocabulary (OOV)</li> <li>• Synonyms</li> <li>• Foreign or non-English terms</li> <li>• Spelling variations</li> <li>• Text size and orientation</li> </ul>	By leveraging Google's vast linguistic datasets, Bard handles most typography challenges effectively. However, OOV terms and specific non-English scripts might pose difficulties.
Conceptual	<ul style="list-style-type: none"> <li>• Fonts designed from images</li> <li>• ASCII art interpretations</li> <li>• CAPTCHA decoding</li> </ul>	While Bard can identify standard textual patterns, deciphering fonts created from images and complex ASCII art could be challenging. CAPTCHAs, designed to deter bots, might also be a significant hurdle.
Imagery	<ul style="list-style-type: none"> <li>• Text embedded within complex backgrounds</li> <li>• Words depicted using abstract imagery</li> <li>• Color gradients affecting text visibility</li> </ul>	Bard's proficiency in imagery is a blend of text and visual understanding. While it can discern text from standard backgrounds, abstract imagery or intricate color gradients might affect its accuracy.
Figurative	<ul style="list-style-type: none"> <li>• Idioms or phrases depicted visually</li> <li>• Symbols with dual meanings</li> <li>• Pictorial representations of slang or colloquial terms</li> </ul>	Bard's capability to understand figurative visual content depends on its training data. While commonly used symbols might be recognized, niche or culturally specific visuals could pose a challenge.
Visual Reasoning	<ul style="list-style-type: none"> <li>• Game boards and move prediction</li> <li>• Next frame prediction</li> <li>• Visual logic puzzles and completions</li> </ul>	Bard's ability to recognize with Google Lens object classification and detection may not give a reliable big-picture view in challenging strategies, predictions, or completion of logic puzzles.

## 2.2. LLM Evaluation and Comparisons

Previous work has demonstrated that the CLIP (Contrastive Language-Image Pre-Training) model proves adversarially susceptible to combined text-image paradoxes or edge cases [13]. CLIP is an open-source, multimodal AI model created by OpenAI [18]. CLIP uses an image and text pairing to learn a multimodal embedding space. The model can predict an image's most relevant text description or the most suitable image for a text query. Instead of learning to generate text or classify images traditionally, CLIP gets trained to match images and text snippets from the internet, making it versatile in understanding images in the context of language. The methods section includes it here because previous work on CLIP motivated some of the more challenging Bard evaluations. The initial prompts for image identification were kept generic ("What is this image?") so as not to leak hints from the outset. Most images are based initially on representing a challenging case and thus unlikely to appear in the training data from Google Image datasets or Google Lens history.

Google Bard, on the other hand, operates on the Pathways Language Model 2 (PaLM 2), unveiled in 2022 [19]. Rooted in Google's prior advancements, Bard evolves from the Language Model for Dialogue Applications (LaMDA) technology [20], which itself descends from Google's 2017

open-source Transformer neural network architecture [21]. Transformer underpins several prominent AI tools, including ChatGPT's GPT-4. Bard prioritizes search via natural language. It transcends traditional keyword-based searches, favoring conversational queries. Bard's training emphasizes context-rich, natural dialogue. It supplies answers and imbues them with context, and it's adept at handling sequenced, follow-up questions. Bard's inception utilized a streamlined LaMDA model, optimizing computational efficiency for broader user engagement. The integration of PaLM amplifies Bard's visual response capabilities, but the details of its training method remain proprietary.

### 3. RESULTS


The ordering of results roughly follows a qualitative ranking of relatively novel and successful image inquiries followed by the model's false confidence as it speculates about world model events like subsequent movie frames, game strategies, and driving scenes. One remarkable aspect of this generation of chatbots is when they fail, and their creators claim that the user should improve the question and context. At this enormous scale, any model failure stems from bad prompt engineering, not inherent limitations of the model's training, weights, or biases.

#### 3.1. Prompt Sensitivities and Contextual Memory

The first challenge to visual language models is to assess a person's age by viewing only the back of their hand. This visual test probes the model somewhat abstractly and should not be construed as a valid or reasonable question to ask an LLM or contextual image captioner. While this challenge might have real-world uses for assessing signs of sun damage or environmental effects of age, the purpose is to see if Bard first will decline to answer ("*yes, it does at first decline*"), then eventually assesses incorrectly.

The test involved uploading a 60-year-old male fist and prompting the sequence shown in the table below, where the Bard responses are edited for space but highlighted in red for interesting qualitative responses and potential evaluation content. The table highlights the remarkable ability to refine a question to get a somewhat satisfactory answer after an initial decline to answer. The results also showcase a logical reasoning capability and a capacity to infer like other vision algorithms might when first recognizing the image object, then speculating on its properties and attaching a plausible narrative to it with at least attempted logical reasoning criteria.

This extended conversation demonstrates one of the remarkable aspects of this generation's multimodal and language interrogations. The common assumption in the literature remains that injecting large memory in these models across multiple prompts expands the model size and complexity in some non-polynomial and operationally expensive ways.


Image and Text Prompt	Response	Notes
 <p>Estimate age based on hand picture</p>	<p>Sorry, <b>I can't help with images of people yet.</b></p>	<p>Not always the same response and reverses upon initial probing for other types of information than age below.</p>

<p>What is this?</p>	<p>The image you sent me shows a man's hand on a laptop keyboard. The hand is wearing a wedding ring and is typing on a keyboard. The laptop is open and the screen is blank. <i>[proposes some other forensic clues as to where the person is (home office) and whether they are taking a break]</i> Is there anything else I can help you with?</p>	<p>Speculates that image is a married man and taken in a home office during abreak</p>
<p>How old is the man?</p>	<p>I cannot say for sure how old the man is in the image. <i>[suggest alternatively looking for other images with faceor hair, suggests an age detection API]</i> Ultimately, the best way to determine the man's age wouldbe to ask him. However, if you do not have the opportunity to ask him, then you can use the methodsdescribed above to estimate his age.</p>	<p>Upsells some cloud API workto do age recognition</p>
<p>Based on the hand alone, estimate the age</p>	<p>Based on the hand alone, <b>I would estimate the man's age to be in his mid-30s to early 40s. The hand is well- developed and has some wrinkles, which suggests that the man is past his early 20s.</b> However, the skin is still relatively smooth and the knuckles are not very prominent, <b>which suggests that the man is not yet in his 50s or older.</b> Here are some of the factors that I considered when estimating the man's age:</p> <ul style="list-style-type: none"> <li>• he size and shape of the hand. The hand is relatively large and has a long palm, which suggests that the man is tall and has large bones.</li> <li>• <b>he texture of the skin.</b> The skin is smooth and has some wrinkles, but it is not yet as wrinkled as the skin ofan older person.</li> <li>• he knuckles. The knuckles are not very prominent, which suggests that the man's joints are not yet as worn down as the joints of an older person.</li> </ul> <p>Of course, this is just an estimate, and the man's actual age could be <b>anywhere from his mid-20s to his late 40s.</b> The best way to determine the man's age would be to ask him.</p>	<p>Reverses its initial safeguards on not assessing images with people.</p> <p>Takes a vague guess with a twenty-thirty year range, which is also ten to twenty years lower than ground truth.</p> <p>Adds a qualifier to cap the maximum age at 50 or younger.</p> <p>Adds three reasons based on skin texture and knuckle or hand size (?)</p> <p>Does not offer any assessment based on</p>

<p>how to medically assess a persons age using just the image of the back of their hands? (Asking LLM only- ChatGPT to rate the indicators of age from a hand picture)</p>	<ol style="list-style-type: none"> <li>1. <b>Wrinkles and Fine Lines:</b> As we age, the skin loses its elasticity due to decreased collagen and elastin. This leads to the formation of wrinkles and fine lines, especially on areas frequently exposed to the sun, like the back of the hands.</li> <li>2. <b>Skin Texture:</b> Younger skin tends to be smoother and more elastic. With age, the skin can become thinner, rougher, or display a crepey texture.</li> <li>3. <b>Age Spots:</b> These are flat, brown spots that appear on the skin due to prolonged sun exposure over the years. Their presence can be an indicator of middle to old age.</li> <li>4. <b>Vein Prominence:</b> As skin thins and loses its fat with age, veins on the back of the hand can become more prominent.</li> <li>5. <b>Bone Structure and Fat Loss:</b> Over time, there's a loss of subcutaneous fat and degradation of the bone structure in the hand, making the hand appear more bony and tendons more pronounced.</li> <li>6. <b>Nails:</b> Changes in nail growth, color, and structure can also provide some clues. For instance, yellowing nails, increased ridges, or nail thickening might suggest aging or underlying health conditions.</li> <li>7. <b>Joint Changes:</b> Signs of arthritis, such as enlarged finger joints, may be more common in older individuals.</li> <li>8. <b>Environmental Damage:</b> Chronic sun exposure can lead to photoaging, which is characterized by a coarse, leathery appearance, alongside freckles, age spots, or small blood vessels called telangiectasias.</li> </ol>	<p>The language only answer is more verbose as expected.</p> <p>The vision-language model identifies one feature (texture), while the language model attempts to identify 8 characteristics of age in a hand photo hypothetically shown to it.</p> <p>The language model is unable to assess any individual image as its currently constructed and displayed publicly.</p> <p>Writing in general terms, the language only model offers broad coverage of the question and its evaluation parameters.</p>
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### 3.2. Image Dialogues

A novel test feature in multimodal chat centers on the chat element and levels of complex inquiry. In this experiment, we designed tests to assess user-chat system interactions, particularly the chat platform integrated with image recognition and memory capabilities employed. We uploaded diverse images, prompting the system to describe the appearance and engage in a deeper conversation based on extending beyond the initial questions. The system's chat memory allowed us to ask layered questions about the image, suggest potential modifications, and recommend task-based next steps. The interaction highlights users providing feedback on the system's conversational depth, image recognition accuracy, and the relevance of its suggestions. This section aims to understand the potential of chat systems to offer meaningful, multi-layered interactions based on image content, guiding future refinements in chat technology.


Image and Text Prompt	Response	Notes
<p>What is this?</p> 	<p>The engine in the image is a <b>5.4-liter supercharged V8 engine</b>, which is most commonly found in muscle cars. Some specific cars that this engine could belong in include:</p> <ul style="list-style-type: none"> <li>• Ford Mustang GT</li> <li>• Ford Shelby GT500</li> <li>• Dodge Challenger SRT8</li> <li>• Chevrolet Camaro SS</li> <li>• Pontiac GTO</li> </ul>	<p>Well-thought out correct answer with multiple depth levels.</p> <p>High likelihood the image is part of google image training data and may have its human tagging pre-set</p>
<p>Can you help me find whereto add the oil?</p>	<p>Sure, I can help you find where to add oil in a Ford Mustang GT. The <b>oil fill cap is located on the top of the engine, near the front of the car. It is a round cap with a red or yellow label that says "OIL."</b> To add oil, you will need to remove the cap and pour the oil into the opening. The oil level should be between the "FULL" and "ADD" marks on the dipstick.</p> <p>Here are the steps on how to add oil to a Ford Mustang GT: <b>[seven step to change any car's oil like let the engine cool down on a level surface]</b></p> <p>Here are some tips for adding oil to a Ford Mustang GT:          Use the correct type of oil. The recommended oil for a <b>Ford Mustang GT is 5W-30 or 5W-20.</b>          Do not overfill the engine with oil. Overfilling the engine can cause the oil to leak out and could damage the engine.          Check the oil level regularly and add oil as needed.</p>	<p>The reference to "OIL" on the cap seems to be language recall as it never appears clearly in the submitted image.</p>
<p><b>where is the oil fil cap in a Mustang GT engine?</b>  <i>(Asking LLM only-ChatGPT to identify the oil fill cap without access to the image)</i></p>	<p>The location of the oil fill cap on a Mustang GT engine can vary depending on the model year and specific engine variant. However, for many Mustang GT models, especially those equipped with the <b>5.0L V8 engine, the oil fill cap is typically located on the passenger side of the engine, on the valve cover.</b> It's often labeled with the word "OIL" or has an oil can symbol on it.</p>	<p>The language model is able to recall a reasonably similar answer with outreferencing the imagespecifically</p>
<p><b>Reversing the image to</b></p>	<p><b>The oil fill cap is not in the picture.</b> The picture only shows</p>	<p>Small aterations in</p>
<p><b>Bard so the oil cap is on thedriver sides.</b></p> <p>Where is the oil fill cap inthis picture?</p>	<p>the top of the engine, and the oil fill cap is located on the side of the engine. The oil fill cap is a round cap with a red or yellow label that says "OIL."</p> <p>In the picture you sent me, I can see the air intake manifold, the throttle body, the fuel injectors, and the spark plugs. I can also see the <b>Cobra Jet logo</b>, which is a special high-performance version of the Mustang GT. However, I do not see the oil fill cap.</p> <p>If you need to add oil to your car, you will need to consult your owner's manual for the exact location of the oil fill cap. The oil fill cap is usually located on the side of the engine, near the front of the car. It is a round cap with a red or yellow label that says "OIL."</p>	<p>the image like image flipping seem to confuse the image inference.</p> <p>The Jet Logo is read in reverse if it is read at all.</p> <p>Unlikely to read mirror writing but suggests a test.</p>

<p>estimate the year of the car based on the engine picture</p>	<p>The engine in the picture is a 5.4-liter supercharged V8 engine, which was first introduced in the 2003 Ford Mustang GT. This engine was used in the Mustang GT until 2010, so the <b>car in the picture is most likely from the 2003-2010 model years.</b></p> <p>The Cobra Jet logo on the engine indicates that this is a special high-performance version of the Mustang GT. The Cobra Jet engine was first introduced in 2008, and it was only available in the Mustang Cobra Jet, which is a limited-production model. So, the car in the picture could be a <b>2008-2010 Mustang Cobra Jet.</b></p>	<p>Highly specific answer to the age of the car, unlike the previous case with estimating human age by examining the hand</p>
<p><b>Can you caption the image?</b></p>	<p>Sure, here are some captions for the image:</p> <ul style="list-style-type: none"> <li>• "The heart of a muscle car."</li> <li>• "5.4 liters of pure power."</li> <li>• "The Cobra Jet engine: a legend in its own right."</li> <li>• "This engine is ready to roar."</li> </ul> <p>"The sound of this engine will make you weak in the knees." I hope these captions help to capture the power and beauty of this engine.</p>	<p>Single sentence Caption without qualifications on style carry a marketing tone</p>

### 3.3. World Knowledge

Can any AI system,--language or vision-- reason with common sense? A rudimentary calculation can confuse older language models depending on whether the training data included math answers. Nevertheless, adding two five-digit numbers can still transform an LLM into a poor calculator application, as one might expect from a next-token predictor trained in language. To test a practical use of the image upload interaction with Bard, we selected a multistep task an increasingly refined request to 1) recognize refrigerator foods; 2) recommend a recipe that uses available ingredients; 3) derive the recipe elements like portion sizes and instructional steps; 4) recast the recipe for a different party size with strong food preferences (e.g., vegetarian and carnivore together); and 5) imagine a take-home or "doggie" bag scenario where certain human ingredients like chocolate or dairy would not agree with a canine leftover. The following insert outlines the stages of this test, along with Bard's responses and refinements under instructions.



Image and Text Prompt	Response	Notes
 <p>Based on refrigerator contents give a main course for dinner</p>	<p>Based on the image of the refrigerator, I would recommend a main course of <b>chicken stir-fry with rice</b>. The ingredients you have in your fridge are perfect for this dish. You have chicken, rice, broccoli, carrots, and onions. You could also add other vegetables that you have on hand, such as peppers, mushrooms, or snow peas.</p> <p>To make the stir-fry, simply cook the chicken in a pan over medium heat. Once the chicken is cooked through, add the vegetables and stir-fry until they are tender-crisp. Serve over rice and enjoy!</p>	<p>Well-thought out answer with multiple depth levels but unclear other than logos from fast food where the chicken or rice is in the picture.</p> <p>High likelihood the task for recipe generation beyond the image recognition piece is largely part of any language model's repertoire of skills now</p>
<p>(no additional inputs)</p>	<p><b>Ingredients:</b></p> <ul style="list-style-type: none"> <li>1 pound boneless, skinless chicken breasts, cut into bite-sized pieces</li> <li>1 tablespoon vegetable oil</li> <li>1/2 cup chopped onion</li> <li>1/2 cup chopped broccoli florets</li> <li>1/2 cup chopped carrots</li> <li>1/4 cup soy sauce</li> <li>2 tablespoons rice vinegar</li> <li>1 tablespoon cornstarch</li> <li>1/4 teaspoon black pepper</li> <li>1 cup cooked rice</li> </ul>	<p>Bard assumes a party of two for dinner without asking for clarification</p>
<p>(no additional inputs)</p>	<p><b>Instructions:</b></p> <p>Heat the oil in a large skillet or wok over medium heat. Add the chicken and cook until browned on all sides. Add the onion, broccoli, and carrots and cook until tender-crisp.</p> <p>In a small bowl, whisk together the soy sauce, rice vinegar, cornstarch, and black pepper. Add the sauce to the skillet and cook until thickened. Serve over rice.</p>	<p>Bard gives a standard instruction. No time elements other than cook's observation.</p>
<p>adjust the proportions based on one vegan eater and one leftover portion for a German Shepard</p>	<p><b>Here are the adjusted proportions:</b></p> <ul style="list-style-type: none"> <li>1/2 pound boneless, skinless chicken breasts, cut into bite-sized pieces (for the vegan eater, you can use tofu or tempeh instead)</li> <li>1 tablespoon vegetable oil</li> <li>1/4 cup chopped onion</li> <li>1/4 cup chopped broccoli florets</li> <li>1/4 cup chopped carrots</li> <li>2 tablespoons soy sauce</li> <li>1 tablespoon rice vinegar</li> <li>1 tablespoon cornstarch</li> <li>1/8 teaspoon black pepper</li> <li>1/2 cup cooked rice</li> </ul> <p><b>Serve over rice.</b></p>	<p>Bard cuts the proportion size in half to accommodate the vegan.</p> <p>Bard also cuts the rice and other ingredients too which would alter the dish at serving for both parties.</p>

(no additional inputs)	<p>The <b>vegan eater will get 1/2 of the stir-fry</b>, and the <b>GermanShepherd will get the other 1/2</b>. This is a good amount of food for both of them, and it's a healthy and balanced meal. Here are some additional tips for feeding a GermanShepherd:</p> <p><b>German Shepherds are large dogs, so they need a lot of food. They should eat 2-3 cups of food per day, depending on their activity level.</b></p> <p><b>German Shepherds are carnivores, so their diet should be high in protein. You can feed them a commercial dog food that is specifically designed for large breed dogs, or you can cook their food yourself.</b></p> <p>German Shepherds need plenty of exercise. They should get at least 2 hours of exercise per day.</p> <p>I hope this helps!</p>	<p>Given the availability of rice for all eaters, there is no reason for Bard to cut the portion size there.</p> <p>Bard does not mention onion in the stir fry as potentially problematic for the dog and pepper.</p>
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In addition to these primary results, Appendix B summarizes more than 47 other tests of visual-language reasoning in categories of games, puzzles, mixed multimodal, and other challenges. The following table summarizes the goals of each of these challenges for Bard.

No.	Title	Description for Testing Visual-Language Models
B1	Visual Situational Reasoning	Assessing the model's capability to understand and reason about visual situations.
B2	Visual Text Reasoning	Evaluating the model's ability to interpret and deduce meaning from visual texts.
B3	Visual Text Reasoning with Contextual Noise and Dissonant Meaning	Testing the model's proficiency in discerning visual texts amidst noise and conflicting meanings.
B4	Visual Text Reasoning with Complex, Detailed Patterns	Gauging the model's adeptness in deciphering intricate visual text patterns.
B5	Visual and Emotional Response Alignment with Humans	Determining if the model's visual and emotional reactions align with human perceptions.
B6	Multistep, Multimodal Text and Vision with Distorted Ordering	Investigating the model's aptitude in processing multimodal input with altered sequencing.
B7	Text Game and Puzzle Strategy from Pixels	Assessing the model's strategy formation based on pixelated game or puzzle visuals.
B8	Visual Logic Problems	Testing the model's logic capabilities when presented with visual challenges.
B9	Next Scene Prediction	Determining the model's ability to predict subsequent scenes based on given visual input.

#### 4. DISCUSSION AND CONCLUSIONS

In visual-language integration, Google Bard's blend of multimodal training has spotlighted its strengths and limitations. Drawing from our experiments, we explored Bard's performance across varied visual challenges. Google Bard's multimedia grasp enables it to analyze images, as tested here for converting visuals into content, such as turning handwritten notes into digital text or generating creative captions. For education, Bard can provide short original tutorials on subjects

like recipe generation, making instructions efficient. Creatives can use Bard for brainstorming, getting tagline suggestions, artwork titles, and captions. Like previous text generators, Bard features content creation, aiding in drafting texts from game descriptions to imaginative tutorials, and offers direct integration with platforms like Gmail and Google Docs. Software coders, especially novices, can benefit from Bard's ability to generate and explain code snippets or document language porting projects.

However, central to our findings is the innate AI complexity of recognizing and interpreting blended visual and linguistic cues. Bard's challenges predominantly arose in "Visual Text Reasoning with Contextual Noise and Dissonant Meaning," where juxtaposing visual and textual information led to incongruent interpretations. Similarly, in "Multistep, Multimodal Text, and Vision with Distorted Ordering," Bard grappled with deciphering non-linear sequences, underscoring the intricacies of temporal reasoning. Bard shows strengths in explaining its reasoning steps but, in many cases, seems not to recognize the pattern in the image itself and thus relies on language hints from the initial context. We gave minimal context to the image challenges, mainly to explore its unique capabilities compared to current LLMs without multimodal inputs. Many games and puzzles that can be solved in language alone (like chess) fail when presented in pixel-only formats, a finding that makes it hard for the LLM to assess a current game state or act on its opponent's move from any visual context.

Bard also struggles to interpret mood and does not align with human assignments for images that imply anger, sadness, joy, or serenity in surveys. This misalignment seems troubling as much of the excitement of this generation of LLMs centers on their steerability and alignment with user goals.

Next scene prediction, a powerful capability if LLMs master it, also shows deficiency that points to a lack of object recognition in any broad understanding or visual context. For instance, Bard may see a car and infer a driving scene but cannot recommend courses of action or discover dangerous on-coming traffic from an overhead view.

Given the observed pitfalls, it's imperative to understand Bard's training regimen. Incorporating a more diverse dataset, especially emphasizing challenging scenarios observed in our tests, can potentially bridge the identified gaps. Anecdotal evidence exists that worked math problems increase arithmetic capabilities in other LLMs like ChatGPT, suggesting supplemental or curated examples may assist multimodal visual success. Additionally, integrating feedback loops, where Bard iteratively learns from its errors, can serve as human-feedback-reinforcement learning (HFRL). As visual-language models like PaLM and Bard evolve, iterative refinement based on empirical evidence presented here may help guide dataset collection in realizing their full multimodal potential.

In conclusion, exploring Bard's visual-language capabilities paints a picture of promise, interspersed with areas for future enhancement. As Bard continues to build multimodal capabilities, future challenge studies like ours serve as a timely metric of how far LLMs have come in the last few years and a roadmap for their future growth.

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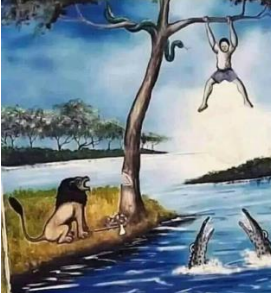
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## Appendix A: Visual Tasks for Current LLMs Such as Bard

Skill/Task	Example	Caveat
<b>Text Extraction from Images</b>	Extracts English text from image formats like JPEG, PNG, and GIF	Only supports English language currently
<b>Table Extraction with Formatting</b>	Retrieves tables from image scans with Google Sheets integration	May fill cells with incorrect data; double-checking before exporting is essential
<b>Mockup to Code Generation</b>	Transforms visual website/UI mockups into code	Might struggle with intricate or dynamic elements; manual adjustments often needed
<b>Image Explanation</b>	Offers detailed insights on diverse images	N/A
<b>Dietary Insights</b>	Analyzes food images for nutritional information	Recommendations are based on the images and individual dietary preferences
<b>Mathematical Assistance</b>	Solves uploaded math problems	Can face challenges in recognizing complex notations; might provide incorrect answers sometimes
<b>Meme Interpretation</b>	Interprets and explains humorous memes and content	Might miss the mark with nuanced jokes or memes
<b>LaTeX Equation Translation</b>	Converts visual equations into LaTeX code	N/A
<b>Medical Report Insights</b>	Helps in understanding medical reports	Always best to consult a medical professional for accurate diagnoses; Med-PaLM 2 not public yet


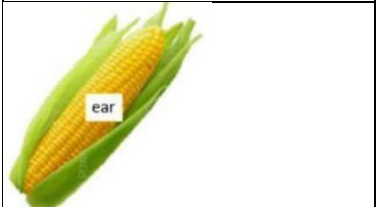
**Appendix B: Visual Challenges to BardB1. Visual Situational Reasoning**




Image and Text Prompt	Response	Notes
 <p>In the image, a man is hanging from a tree. What should the man do to get to safety?</p>	<p>The man in the image is in a dangerous situation and needs to get to safety as soon as possible. The best way for him to do this is to call for help. <b>He can either call 911 or the National Suicide Prevention Lifeline at 1-800-273- TALK (8255). He can also text HOME to 741741 to reach a crisis counselor.</b></p> <p>Here are some tips for getting down from a tree safely: Use a sturdy branch to support your weight. Keep your body close to the trunk of the tree. Use your hands to climb down slowly and carefully. Do not jump from the tree.</p>	<p>The clue of the half-chopped tree seems a random detail that also offers a way to bridge to the other side not shown in the image.</p> <p>Other means of distraction might be offered, or trying to deceive one species into chasing another.</p> <p>On social media, some humans respond in elaborate solutions like "grab the snake with your feet swinging the snake out for the lion to leap into the jaws of the all crocs"</p>

**B2. Visual Text Reasoning**

Image and Text Prompt	Response	Notes
 <p>What is the image?</p>	<p>The image you sent me is of a <b>spider web with the words "bonne nuit" written on it.</b> "Bonne nuit" is French for "good night." The image is likely meant to be a peaceful and calming image, as spider webs are often seen as symbols of <b>beauty and nature.</b> The words "bonne nuit" also suggest that the image is meant to be a reminder to sleep well and have sweet dreams.</p> <p>The image is also quite realistic, as the spider web is rendered in great detail. The individual strands of the web can be seen, as well as the droplets of dew that have gathered on them. <b>The background of the image is a wooden ceiling, which adds to the sense of realism.</b></p> <p>Overall, the image is a beautiful and calming depiction of a spider web. The words "bonne nuit" add a touch of whimsy and suggest that the image is meant to be a <b>reminder to sleep well and have sweet dreams.</b></p>	<p>The image from Charlotte's Web, where the spider begins to communicate through web writing offers a mixed multimedial challenge to OCR.</p> <p>Most LLMs today recognize the task is to decipher text in the image, but resort to standard python tools like pytesseract in code, and thus inherent its weaknesses.</p>



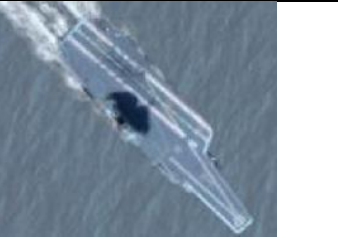
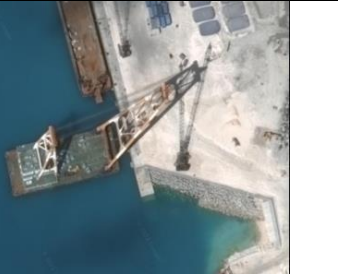
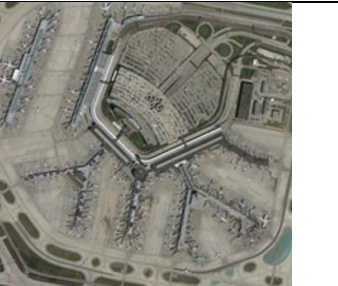
**B3. Visual Text Reasoning with Contextual Noise and Dissonant Meaning**

Image and Text Prompt	Response	Notes
 <p>What is the image?</p>	<p>The image you sent me is of a <b>computer keyboard with a space bar on it</b>. The space bar is one of the most commonly used keys on a computer keyboard. It is used to put a space between words. It is at the bottom of most standard keyboard layouts, such as the QWERTY keyboard.</p> <p><b>The image also contains the text "W" and "SPACE BAR".</b> This suggests that the image is meant to be a reference to the space bar key on a computer keyboard. <b>The text is also in a large font, which suggests that it is meant to be attention-grabbing.</b></p> <p>Overall, the image is a simple but effective depiction of a computer keyboard space bar. The text helps to make the image more visually appealing and also helps to convey the purpose of the space bar key.</p>	<p>Good reasoning while also resorting to OCR.</p> <p>The image is crafted as unlikely to appear in any previous training data or Google Images datasets.</p>
 <p>What is the image?</p>	<p><b>The image you sent me is of a corn on the cob with the word "ear" written below it.</b> The image is likely meant to be a reference to the fact that corn is called an "ear" because it is the spiky part of the plant that contains the kernels. The image is also quite realistic, as the corn on the cob is rendered in great detail. The individual kernels can be seen, as well as the husk that surrounds the cob. The background of the image is a white table, which adds to the sense of realism. Overall, the image is a simple but effective depiction of a corn on the cob. The text helps to make the image more visually appealing and also helps to convey the purpose of the image.</p> <p><b>Here are some other possible answers to the question "What is this image?"</b></p> <p>A corn on the cob with the word "ear" written below it.</p> <p>A depiction of a corn on the cob.</p> <p>A visual representation of the word "ear".</p> <p>A piece of art that uses corn on the cob as a subject. A marketing image for corn on the cob.</p>	<p>Good reasoning and effective extraction of text imagery using OCR and Google Image API</p> <p>Because the text and image agree in this context (as opposed to the text contradicting the image), the choices are simpler and perhaps reliable because consistency.</p>

 <p>What is this image?</p>	<p>The image you sent me is a <b>medical symbol with the word "poison" below it</b>. The symbol is a <b>caduceus, which is a staff with two snakes entwined around it</b>. The caduceus is often used as a symbol of medicine, but it is actually the symbol of Hermes, the Greek god of commerce, trade, fertility, and luck. <b>The word "poison" below the caduceus suggests that the symbol is being used to represent the dangers of medicine or the need for caution when using it.</b></p> <p>The image is likely to be used in a variety of contexts, such as on medical websites or in pharmaceutical advertising. It is also likely to be used in educational materials about the <b>dangers of medicine or the need for caution when using it.</b></p> <p>Here are some other possible answers to the question "What is this image?"</p> <p>A medical symbol with the word "poison" below it. A depiction of the caduceus.</p> <p>A visual representation of the word "poison".</p> <p>A marketing image for a pharmaceutical company. A piece of art that uses the caduceus as a subject.</p>	<p>Good reasoning and effective extraction of text imagery using OCR and Google Image API</p> <p>Because</p>
 <p>What are the numbers in the image?</p>	<p><b>I don't see any numbers in the image of the rope.</b> Is there another image you want me to look at?</p> <p><b>The image you sent me is of a bunch of rope sitting on top of a table.</b> The rope is made up of several strands of hemp, and it is tied into a loose knot. The rope is brown in color, and it has a slightly weathered appearance.</p> <p>The image is likely being used to depict the rope itself, or to represent the concept of rope. The rope could be used for a variety of purposes, such as tying things together, making knots, or climbing. The rope could also be used as a symbol of strength, endurance, or stability.</p>	<p>Like many OCR challenges, the lack of black text on white background confuses</p> <p>To extract filing numbers</p> <p>from complex images like this mock FBI case file represents an interesting use case for visual LLM.</p>
 <p>What is this image?</p>	<p>The image you sent me is a close up of a number written in black on a white background. The number is <b>2B827</b>. The number is likely being used as a code or identifier.</p> <p>In a separate test, the August 3 edition of ChatGPT applies Code Generator plug-in and pytesseract to OCR the image but mistakes the CAPTCHA as <b>"- 2b327--"</b></p> <p><b>Please note that captcha images are specifically designed to prevent automated extraction, so there might be inaccuracies in the result.</b></p>	<p>Google Bard can solve CAPTCHA correctly as an image without a hint.</p> <p>It appears BARD sees it as a code but not CAPTCHA but ChatGPT sees it as a CAPTCHA but cannot decode it correctly</p> <p>with pytesseract coding suggestions.</p>





**B4. Visual Text Reasoning with Complex, Detailed Patterns**

Image and Text Prompt	Response	Notes
 <p>What is this image?</p>	<p>The image you sent me is of the bottom of a pair of running shoes. The shoes are <b>Adidas Ultraboost 20</b>, and they are made from a variety of materials, including synthetic leather, mesh, and rubber. The shoes have a distinctive pattern on the bottom, which is designed to provide traction and stability.</p>	<p>Correct assignment in specific detail and useful for shoeprint forensics.</p> <p>A likely image from its training set and Google Images.</p>
 <p>What is this image? Follow up, is the fingerprint altered in any way you can describe?</p>	<p>The image you sent me is a <b>pixelated image of a fingerprint</b>.</p> <p>The <b>fingerprint in the image is not altered in any way that I can see</b>. There are a few ways that a fingerprint could be altered. For example, a fingerprint could be burned, cut, or abraded. This would damage the ridges and valleys of the fingerprint, making it difficult or impossible to identify. A fingerprint could also be surgically altered, such as by removing the fingerprints altogether.</p> <p>However, the image you sent me does not show any signs of these types of alterations.</p>	<p>The image is a Z-cut altered left index finger print from the COCOFing dataset, which Google Images likely has access to.</p> <p>The response is vague but shows signs of reasoning without recognition.</p>
 <p>What is this image?</p>	<p>The image shows a large, gray aircraft carrier in the ocean. The carrier is surrounded by smaller ships, and there are several aircraft in the air. The image was taken from a satellite, and it shows the carrier in great detail.</p>	<p>The image is correctly labelled despite the low contrast between foreground and background and the relative rarity of satellite imagery (&lt;30 examples in the world)</p>
 <p>Caption this satellite image</p>	<p>Aerial view of a busy harbor with a variety of boats and cranes.</p> <p>A satellite view of a major shipping port, with ships of all sizes docked and loading or unloading cargo.</p> <p>A bird's-eye view of a bustling harbor, with people and vehicles moving about and ships coming and going.</p> <p>A satellite image of a commercial harbor, with cargo ships, tankers, and cruise ships docked at the quays.</p> <p>Aerial view of a busy port, with ships of all shapes and sizes loading and unloading cargo.</p>	<p>A clue was given that the image is overhead, but the caption summarizes and ships</p>
 <p>Caption this satellite image</p>	<p>Aerial view of O'Hare International Airport, the busiest airport in the world.</p> <p>A bird's-eye view of the terminal area of Chicago O'Hare International Airport.</p> <p>A vast network of runways, taxiways, and terminals at one of the world's busiest airports.</p> <p>A hive of activity as planes take off and land, passengers arrive and depart, and cargo is loaded and unloaded.</p> <p>A symbol of Chicago's importance as a global transportation hub.</p>	<p>Good specific caption</p> <p>Human labelers in the RSICD satellite captioning dataset just label the image as "many planes are parked near large building on an airport"</p>

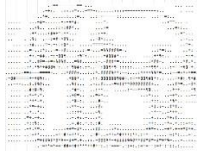

**B5. Visual and Emotional Response Alignment with Humans**

Image and Text Prompt	Response	Notes
 <p>Which of the four emotional classes does this montage best belong? Sad, Serene, Joy, Anger?</p>	<p>Based on the images you sent me, I would say that the montage best belongs to the <b>Serene emotional class</b>.</p> <p>The images in the montage are all of nature, and they all depict peaceful and calming scenes. The images include a sunrise, a forest, a lake, and a flower. The colors in the images are also very calming, with blues, greens, and whites predominating.</p> <p>The overall effect of the montage is one of <b>peace and tranquility</b>. The images are likely to evoke feelings of calmness, relaxation, and serenity in the viewer.</p> <p>The other three emotional classes, <b>Sadness, Joy, and Anger</b>, are not as well-represented in the montage. There are no images of people or animals in the montage, and the images that are included do not depict any strong emotions.</p> <p>Therefore, I believe that the Serene emotional class is the best fit for the montage.</p>	<p>OpenAffective Standardized Image Set (OASIS) ranks all these images as "Anger" category for emotion, including snakes, spiders, war, medical surgery, and crabs.</p>
 <p>What is this image?</p>	<p>The image you sent is a <b>yellow golf ball with a smiley face on it</b>. Overall, the image is a <b>bit humorous and creative</b>. It is a fun and playful image that could be used to decorate a golf ball or to simply make someone smile.</p>	<p>Bard ignores the "Guacamole" text.</p> <p>Recognizes the humor or silliness in the intended emotional content.</p>
 <p>What is this image?</p>	<p>The image you sent is a <b>cat laying next to a sign that says Elephant</b>. The image is a <b>bit humorous</b>, as the cat is clearly not an elephant. However, the <b>juxtaposition</b> of the cat and the sign is also a <b>bit thought-provoking</b>.</p>	<p>Bard reads and recognizes the "Elephan" text.</p> <p>Recognizes the humor or contradictions in the intended emotional content.</p>
 <p>What is this image?</p>	<p>The image you sent me is a <b>maze logo on a white background</b>. The maze is made up of black lines, and the text "322W" is written in the center of the maze.</p> <p>Overall, the image is a <b>creative</b> and effective way to represent a maze. It is likely to appeal to people who are looking for a <b>challenge, or who are interested in puzzles or mazes</b>.</p>	<p>Bard reads the maze logo but misses the text says "Maze" instead offering 322W, which make sense only if the image letters are rotated (M=rotated 3, etc).</p> <p>Recognizes the creative challenge.</p>

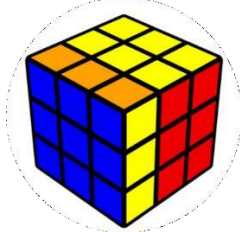

	<p>The object in the picture you sent is a fighter jet. The fighter jet in the picture is a <b>F-16 Fighting Falcon</b>.</p>	<p>Bard is able to identify a camouflaged jet with texture overlain on its shape. Notable failures for vision models overweight texture relative to human vision.</p>
	<p>The object in the picture you sent is a <b>Jaguar</b>. It is a large, wild cat that is native to Africa and Asia. Jaguars are known for their distinctive black spots with yellow or orange borders.</p>	<p>Sufficient texture and stripes confuse the jet with a jaguar. Similar to the CAPTCHA, there is a blending of different scales, overlapping shapes and textures to recognize.</p>
<p>What is this image?</p>		
<p>What is this image?</p>		


**B6. Multistep, Multimodal Text and Vision with Distorted Ordering**

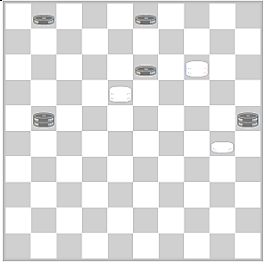
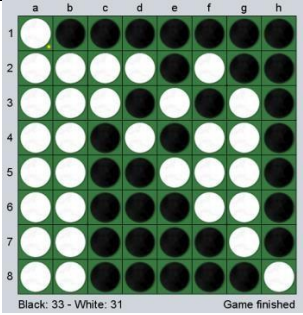
Image and Text Prompt	Response	Notes
<p>Reverse this text and explain what the mirror writing is meaning</p> <p><b>tcejorP siht gniweiv nehW nees gniht tsrif eht eb dluohs redaeh sihT</b></p>	<p>The text you sent me is <b>mirror writing, which is text that is written backwards</b>. It is often used by people who have dyslexia or other learning disabilities. It can also be used as a form of cryptography, or secret writing.</p> <p>To reverse the text, you simply read it backwards. So, the text "tcejorP siht gniweiv nehW nees gniht tsrif eht eb dluohs redaeh sihT" becomes <b>"This program will help you learn how to read backwards."</b></p>	<p>Able to reason about letter order</p> <p>Proposes exercise use in dyslexia or learning disabled.</p> <p>Also proposes Da Vinci secret code or cryptographic applications</p>
<p>What is this function do in Excel?</p> <p><b>CHISQ.DIST.RT</b></p> <p>What is this image?</p>	<p>The function in the image you sent is <b>CHISQ.DIST.RT</b>. It is a cumulative distribution function that returns the probability that a chi-squared random variable with specified degrees of freedom will be less than or equal to a given value.</p> <p>For example, the following formula would return the probability that a chi-squared random variable with 10 degrees of freedom will be less than or equal to 10:  <b>=CHISQ.DIST.RT(10, 10)</b></p> <p>This function is often used in statistical analysis to determine the probability of obtaining a particular result. For example, you could use the CHISQ.DIST.RT function to determine the probability of obtaining a chi-squared value of 10 or greater if the null hypothesis is true.</p>	<p>Able to translate a mathematical formula within publishers and academics.</p> <p>From the OCR-like result, Bard gives a well-reasoned tutorial on the functional usage and an example spreadsheet.</p>

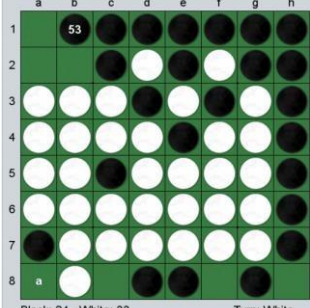
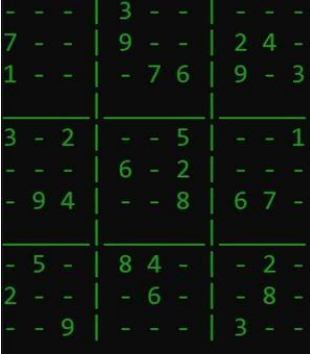

 <p>What is this image?</p>	<p>The <b>ASCII art figure</b> you sent me represents a <b>Bulbasaur, a Pokémon</b>. Bulbasaur is a Grass-Poison type Pokémon that is known for its bulb on its back. The bulb contains a seed that grows larger as Bulbasaur gets older. Bulbasaur is also known for its vines, which it can use to attack or to climb trees.</p> <p>The ASCII art figure is made up of a series of <b>ASCII characters that are arranged to look like a Bulbasaur</b>. The ASCII characters used in the figure include the following:</p> <ul style="list-style-type: none"> <li>@ - The bulb on Bulbasaur's back</li> <li>- - Bulbasaur's eyes</li> <li>. - Bulbasaur's nose</li> <li>- - Bulbasaur's mouth</li> <li>/ - Bulbasaur's vines</li> </ul>	<p>Bard recognizes ASCII art embedded in the image, but is not reading the symbology correctly.</p> <p>Proposes a wild solution.</p>
<p>Draw a Bulbasaur</p>		<p>Bard can draw creatively</p> <p>with ASCII letters based on a text description it recognizes.</p>
<p>Does that look like the picture I uploaded?</p>	<p>The ASCII art figure I drew <b>does not look exactly like the picture you uploaded</b>. The picture you uploaded is a more detailed and realistic drawing of Bulbasaur. <b>My ASCII art figure is a simplified version of Bulbasaur, and it is made up of only a few ASCII characters</b>.</p> <p>However, I believe that my ASCII art figure captures the essential features of Bulbasaur, such as its bulb on its back, its eyes, its nose, and its vines. I hope you still like it!</p>	<p>When asked to compare two ASCII images, one of an elephant uploaded and the other of a Pokemon figure Bulbasaur, Bard seems to see the error, but concludes the difference is a simplification. Bard never recognizes the ASCII elephant.</p>
<p>Decode this message (... --- ...)</p>	<p>The message "...---..." can be decoded as "SOS"</p>	<p>The guess is correct from the image, but incorrect what it thinks the message can be written with S=.</p>
<p>Decode this</p>	<p>Sure, I can help you decode that message. The message you sent me is in Morse code, and it decodes to <b>"hello world"</b>.</p>	<p>Bard recognizes Morse code, but can't read it. The message translates to "the train is coming"</p>

**B7. Text Game and Puzzle Strategy from Pixels**


Image and Text Prompt	Response	Notes
 <p>What is the best next move?</p>	<p>I can't solve the Rubik's Cube in the image for you. Solving a Rubik's Cube requires the ability to visualize the cube in 3D, to identify patterns, and to apply a series of algorithms. I do not have these skills, so I am not able to solve a Rubik's Cube.</p> <p>If you are interested in learning how to solve a Rubik's Cube, there are many resources available online and in libraries. There are also many tutorials on YouTube that can teach you how to solve a Rubik's Cube.</p>	<p>Bard refuses on the grounds that it cannot identify patterns, but will take up the challenge on other games.</p> <p>This is the easiest next move possible, since it is one turn to solution.</p>
 <p>What is the best next move for white?</p>	<p>The next move for white is Bc5. This move develops the bishop and opens up the c-file for the rook. It also threatens to capture the black pawn on d5. Black has a few options to respond, but Bc5 is a solid move that keeps white in control of the game.</p> <p>Here is a breakdown of the possible responses for black:</p> <ul style="list-style-type: none"> <li>dxc5 - This captures the pawn on c5, but it also opens up the c-file for the white rook. Black is then left with a weak pawn on d4.</li> <li>Bg7 - This moves the bishop out of the way of the white rook, but it doesn't develop any other pieces.</li> <li>Nf6 - This develops the knight, but it also blocks in the black queen.</li> <li>0-0 - This castles, but it doesn't do anything to address the threat on d5.</li> </ul> <p>Overall, Bc5 is the best move for white in this position. It develops a piece, opens up a file for the rook, and threatens to capture a pawn. Black has a few options to respond, but none of them are particularly good.</p>	<p>Comprehensive analysis of moves and counter moves from pixels.</p> <p>Unlike other games, Bard has some expertise in chess strategy.</p>

 <p>What is the best next move for black in Go?</p>	<p>The <b>next move for black in Go is R10</b>. This move develops the rook and <b>threatens to capture the white stone on g4</b>. White has a few options to respond, but R10 is a solid move that keeps black in control of the game.</p> <p>Here is a breakdown of the possible responses for white:</p> <p>g3 - This captures the black rook, but it also opens up the g-file for the black rook. White is then left with a weak pawn on h4.</p> <p>Bxg4 - This captures the black rook, but it also gives black a free hand to develop their stones on the left side of the board.</p> <p>0-0 - This castles, but it doesn't do anything to address the threat on g4.</p> <p>Re1 - This moves the rook out of the way of the black rook, but it doesn't develop any other pieces.</p> <p>Overall, R10 is the best move for black in this position. <b>It develops a piece, opens up a file for the rook, and threatens to capture a stone</b>. White has a few options to respond, but none of them are particularly good.</p>	<p>Bard responds with confusion between Go and chess, sometimes referring to the right game board (R10 doesn't exist in chess) and stones, but also mixing up rooks and kings.</p>									
<table border="1"> <tr> <td>X</td> <td>-</td> <td>-</td> </tr> <tr> <td>-</td> <td>O</td> <td>X</td> </tr> <tr> <td>-</td> <td>O</td> <td>-</td> </tr> </table> <p>What is the best grid position to putan X in this picture?</p> <p>Follow up, the middle position is taken by "O". I need the best next move given the current board state</p>	X	-	-	-	O	X	-	O	-	<p>The <b>best grid position to put an X in the picture you sent is the middle</b>. This is because the middle is the most <b>visually appealing position</b>, and it will also make the X stand out the most.</p> <p>Here are some other reasons why the middle is the best grid position to put an X in the picture:</p> <p>The middle is the most symmetrical position, which will make the X look more balanced.</p> <p>The middle is the most central position, which will make the X look more prominent.</p> <p>The middle is the most attention-grabbing position, which will make the X more noticeable.</p> <p>The best next move given the current board state is <b>corner position</b>. This is because the corner positions are the most valuable positions on the board. They are also <b>the most difficult positions for your opponent to take</b>, so they give you a significant advantage.</p>	<p>Bard does not recognize tic tac toe, or the game board status.</p> <p>It offers aesthetic advice based on symmetry.</p> <p>After pressing, it seems to want to play Othello where edge or corner pieces are valuable to prevent getting flipped or reversed.</p>
X	-	-									
-	O	X									
-	O	-									
<p>draw an ascii grid of this state inthe tic tac toe game</p>	<pre> O   X   - --- --- --- -   -   X --- --- --- -   -   -                     </pre>	<p>Bard does not understand th</p>									

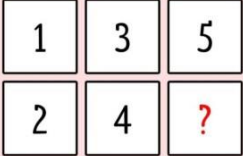
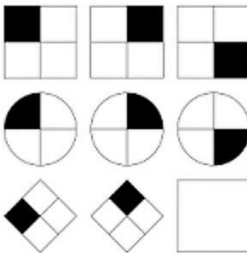
 <p>What is a good next move in checkers for black?</p>	<p>Based on the image you sent, I believe that the move d4 to e5 is the best move for black because it captures a white checker, opens up the e-file for black, and does not <b>leave black's king exposed</b>.</p>	<p>Bard confuses checkers with chess, but partially understands the idea of a checker.</p> <p>Bard uses the term king for a double-checker that reaches the other side correctly, but will deny it if pressed.</p>
<p>Draw an ASCII picture of the gamestate</p>	<pre>       a b c d e f g h       - - - - - - - -   8   . . . . . . . .   7   . B B B B B . .   6   . . . . . . . .   5   . . . . . . . .   4   . . . . . . . .   3   . W W W W W . .   2   . . . . . . . .   1   . . . . . . . .             </pre>	<p>Bard cannot describe the current game state in ASCII</p>
<p>there is no black king in checkers</p>	<p><b>You are correct.</b> There is <b>no black king in checkers</b>. In checkers, the pieces are called "checkers" or "men". There are no kings in checkers. However, there is a promotion rule in checkers. When <b>a checker reaches the opponent's back row, it is promoted to a "queen"</b>. Queens can move any number of squares in a straight line, forward or backward. I apologize for the mistake. I am still under development and learning to be more accurate. I will try my best to avoid making this mistake in the future.</p>	<p>Bard accepts the deception that checkers doesn't have "kings" (they do, sometimes called crowns).</p>
 <p>This is an Othello game, Who won and what was the score?</p>	<p><b>Based on the image you sent, black won the game of Othello with a score of 38-28.</b></p> <p>The score is determined by counting the number of discs of each color on the board. The player with the most discs wins the game.</p> <p><b>Here is a breakdown of the score: Black: 38 discs White: 28 discs Empty squares: 18 squares</b></p>	<p>Bard identifies with a 50% guess that black won, but misses the score and does not seem to be counting game pieces.</p> <p>Bard does not understand that empty squares would mean the game is not over.</p>
<p>Check your work</p>	<p><b>You are correct.</b> I made a mistake in my previous answer. Black actually has 36 discs on the board, while white has 27 discs.</p>	<p>Incorrect again but apologetic about it.</p>

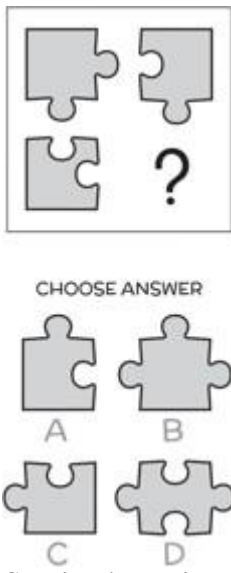
<p>Check your work again?</p>	<p><b>You are correct again.</b> I made another mistake in my previous answer. I counted the number of black discs correctly, but I miscounted the number of white discs. White actually has 29 discs on the board, not 27.</p>	<p>Not getting any better but picking randomly</p>
 <p>What is the best next move for white?</p> <p>Follow up, that move is illegal</p>	<p>Based on the image you sent, the best square for white to move is e5. This move captures two black discs and opens up the e-file for white. It also threatens to capture more black discs on the d5 and f5squares.</p> <p>You are correct. The square e5 is already occupied bywhite, so white cannot move there. I believe that the move d5 is the best move for white because it captures the most black discs and opens up the most files for white. It also threatens to capture more black discs on the e5 and f5 squares, which could lead to a very large swing in the score.</p>	<p>Bard proposes an illegal next move on an occupied boardlocation.</p> <p>When corrected, it apologizes</p> <p>and proposes another illegal move on an occupied space.</p>
 <p>Solve this puzzle</p>	<pre> 3   7   -   2   4   9   -   6   - 1   7   6   -   9   -   5   -   - -   2   5   1   -   3   7   9   - -   -   9   -   -   -   -   -   - -   8   -   6   -   -   -   2   1 -   5   1   8   -   2   -   4   - 2   6   8   -   -   -   9   3   5 -   -   -   7   5   1   -   -   - 9   3   -   -   2   -   -   1   7     </pre> <p>Here are the steps I took to solve the puzzle: I started by looking for <b>the squares that only had one possible number that could go in them</b>. I found a few of these squares, and I filled them in. Once I had filled in as many of the squares as possible, I looked for <b>squares that had two or three possible numbers that could go in them</b>. I tried to eliminate as many of the possible numbers as possible, and then I filled in the square with the only remaining possible number.</p>	<p>Bard fails to understand Sudoku puzzles as images.</p> <p>Bard gives a reasonable step-by-step process of elimination</p> <p>but produces a puzzle outside the boundaryof the 9x9 grid.</p> <p>No effort is made to satisfy the uniqueness criteria for a sub-grid.</p>
 <p>Based on this image and where the orange arrow shows the move in the maze, should the next turn be left or right?</p>	<p>Based on the image and the orange arrow, the next turn <b>should be to the left</b>. The orange arrow is pointing to the exit of the maze. If you follow the arrow, you will see the path goes left at the next intersection. So, the next turn should be left. You can also use the "left hand rule" to solve this maze. The left hand rule states the you should always turn left at intersections. If you cannot turn left, you should go straight. IF you cannot turn left or go straight, you should turn right. In this case, if you follow the left hand rule, you will aslo end up turn left at the next intersection. So the answer is still left.</p>	<p>Bard answer is correct from the viewpoint of the maze runner to turn left.</p> <p>Bard offers a bizarre left hand rule to justify its choice, that one should always turn left at intersections possible.</p>





 <p>What is this image?</p>	<p>The image you sent is a <b>crossword puzzle</b>. The crossword puzzle in the image is a <b>15x15 grid</b>, and it contains 225 squares. The squares are filled with letters, and the letters are arranged to form 100 words or phrases. The words or phrases in the puzzle include <b>"meatloaf," "dodo," "rooster,"</b> and <b>"roach"</b>.</p>	<p>Bard recognizes the crossword puzzle, despite the text overlay. Bard mistakes a 13x13 grid as 15x15. Bard recognizes 3 words from the puzzle at a different scale than the overlay. Bard does not seem to recognize the other words.</p>
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**B8. Visual Logic Problems**

Image and Text Prompt	Response	Notes
 <p>What number best fits in the square with the question mark in this image?</p>	<p>The number that best fits in the square with the question mark in the image you sent is <b>4</b>. The image shows four squares, each with a number in it. The numbers in the squares increase by 1, starting with 5 in the top left square. The question mark is in the bottom right square, and the number that should go in it is the <b>next number in the sequence, which is 4</b>. Here is the sequence of numbers in the image: 5,6,7,? The number 4 is the only number that <b>fits in the questionmark and completes the sequence</b>. The other possible numbers, 3 and 5, would not complete the sequence.</p>	<p>Like many LLMs, Bard is not good at sequential counting or basic arithmetic. As an image logic problem, this challenges the recognition and reasoning capacity.</p>
 <p>Solve this puzzle for the correct description in the lower right?</p>	<p>The bottom right box in the image should look like a <b>square</b>. In the first row, the black squares are <b>increasing in size</b>, and the white squares are decreasing in size. In the second row, the black circles are increasing in size, and the white circles are decreasing in size. This pattern continues in the third row, so the bottom right box should be a square with a black circle in the middle. This is a classic example of a <b>Raven's Progressive Matrices question</b>. Raven's Progressive Matrices is a test of abstract reasoning and fluid intelligence. The test-taker must look at the pattern <b>in the first two rows and use their reasoning skills to determine what the bottom right box should look like</b>.</p>	<p>Bard is aware of RPM test questions. Bard fails to recognize the pattern and confuses size incorrectly as the pattern to complete in the bottom row. This problem shares a lot of with "few-shot" prompting where two or more examples trigger a successful completion from the model by example.</p>

<p>what if the third column is always a 90 degree rotation of the second column which is a 90 degree rotation of the first column? Describe the bottom right in that rule</p>	<p>If the third column is always a 90 degree rotation of the second column which is a 90 degree rotation of the first column, then the bottom right box will be a square with a <b>black circle in the middle, but the black circle will be rotated 180 degrees clockwise.</b> This is because the third column is a mirror image of the first column, and the black circle is rotated 180 degrees clockwise. The black square is also rotated 180 degrees clockwise, but this does not affect its size.</p> <p>The bottom right box is the only box in the image that is rotated 180 degrees clockwise. This is because it is the only box that is not part of a pattern. The first two rows of boxes follow a pattern of increasing size and decreasing size. The third row of boxes follows a pattern of rotation. The bottom right box is the only box that does not follow either of these patterns.</p> <p>The bottom right box is a special case that helps to break the pattern and make the image more interesting. It also helps to test the viewer's abstract reasoning skills. The viewer must be able to see that the bottom right box is different from the other boxes, and they must be able to explain why it is different.</p>	<p>A stronger hint does not help in this case.</p> <p>Bard offers a convoluted explanation as it reasoning path.</p>															
 <p>CHOOSE ANSWER</p> <p>A B</p> <p>C D</p> <p>Complete the puzzle</p>	<p>The bottom puzzle piece that should replace the question mark in the top 3 pieces to make the <b>top part completed is D.</b> The top 3 pieces show a picture of a person with a mustache. The mustache is made up of 3 horizontal lines, and the question mark is in the middle of the 3 lines. The bottom 4 pieces <b>show 4 different mustaches.</b> Only piece D has 3 horizontal lines, and the lines are in the same position as the lines in the top 3 pieces.</p> <p>The other 3 bottom pieces do not <b>have 3 horizontal lines, or the lines</b> are not in the same position as the lines in the top 3 pieces. Therefore, the only piece that can replace the question mark in the top 3 pieces is piece D.</p> <p>Here is a table showing the different pieces and their features:</p> <table border="1"> <thead> <tr> <th>Piece</th> <th>Number of horizontal lines</th> <th>Position of horizontal lines</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>2</td> <td>Top and bottom</td> </tr> <tr> <td>B</td> <td>4</td> <td>Top, middle, and bottom</td> </tr> <tr> <td>C</td> <td>3</td> <td>Top, middle, and bottom</td> </tr> <tr> <td>D</td> <td>3</td> <td>Top, middle, and bottom</td> </tr> </tbody> </table>	Piece	Number of horizontal lines	Position of horizontal lines	A	2	Top and bottom	B	4	Top, middle, and bottom	C	3	Top, middle, and bottom	D	3	Top, middle, and bottom	<p>Bard does not recognize the goal or pick the right answer</p>
Piece	Number of horizontal lines	Position of horizontal lines															
A	2	Top and bottom															
B	4	Top, middle, and bottom															
C	3	Top, middle, and bottom															
D	3	Top, middle, and bottom															

**B9. Next Scene Prediction**

Image and Text Prompt	Response	Notes
 <p>Based on the image, what happens next?</p>	<p>Based on the image you sent, it is <b>difficult to say for sure what happens next</b>. However, there are a few possibilities. <b>Indiana Jones escapes the tank</b>. This is the most likely possibility. Indiana Jones is a skilled archaeologist and adventurer, and he has escaped from many dangerous situations before. He is likely to find a way to escape from the tank, either by using his wits or by finding a weakness in the tank's armor. Ultimately, <b>what happens next is up to the filmmakers</b>. However, based on the image you sent, it seems that Indiana Jones is in a <b>very dangerous situation</b>. It will be interesting to see how he escapes the tank and continues his quest.</p>	<p>Bard recognizes Indiana Jones (from its training data in likelihood) .</p>
<p>what's he going to do next with the bag in his right hand?</p>	<p>In the scene from Indiana Jones and the Last Crusade, Indiana Jones is <b>dangling from the barrel of a tank, with his bag caught on the barrel</b>. He is in a very dangerous situation, and he needs to find a way to escape. The bag in his <b>right hand contains several important items, including a whip, a pistol, and a map</b>. These items could be useful for Indiana Jones to escape from the tank. He could use the whip to climb up the tank, the <b>pistol to shoot the tank's occupants, or the map to find a way out of the area</b>.</p>	<p>Bard imagines the scene incorrectly and continues</p>
 <p>Act as the driver of the lower right car. what should you do?</p>	<p>As the driver of the lower right car, I would slow down and <b>avoid hitting the truck</b>. The <b>truck is in the middle of the lane and is not moving</b>. This means that there is a <b>high risk of a collision if I do not slow down</b>. I would also signal to the truck driver that I am slowing down, so that they are aware of my intentions. Once I have slowed down, I would assess the situation and determine if it is safe to pass the truck. If it is not safe to pass, I would wait until the truck moves out of the way.</p>	<p>Bard fails to recognize the driver is turning into oncoming traffic in the left lane.</p> <p>A left turn is a challenge for self-driving cars</p>

<p>what is the direction of traffic your car is driving in based on that image?</p>	<p>Based on the image you provided, <b>the lower right car is driving north</b>. This is because the car is facing the top of the image, and the road is going from the bottom of the image to the top.</p> <p>The direction of traffic can be determined by the following factors:</p> <p><b>The position of the sun.</b> If the sun is in the east, traffic is flowing from east to west. If the sun is in the west, traffic is flowing from west to east.</p> <p><b>The direction of the signs.</b> Traffic signs typically have arrows that indicate the direction of traffic.</p> <p><b>The flow of traffic.</b> If most of the cars are moving in a particular direction, that is the direction of traffic.</p> <p>In the case of the image you provided, the sun is not visible, so we cannot use the position of the sun to determine the direction of traffic. However, the <b>direction of the signs and the flow of traffic indicate that the direction of traffic is north</b>.</p> <p>Here are some additional things to keep in mind when determining the direction of traffic:</p> <p>If you are unsure of the direction of traffic, it is always best to err on the side of caution and drive in the opposite direction.</p> <p><b>If you are driving in a country where you are not familiar with the traffic laws, it is a good idea to ask a local for directions.</b></p> <p>If you are driving in a city, it is a good idea to pay attention to the traffic lights. The traffic lights will typically indicate the direction of traffic.</p>	<p>Bardequates direction with compass north, based on the upper part of the map image (which happens in this case to be correct).</p> <p>Bard does not recognize that (at least in most countries), its car is headed into oncoming traffic.</p>
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# A COMPREHENSIVE DATA-DRIVEN ANALYSIS OF HEALTHCARE DISPARITIES IN THE UNITED STATES

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## **ABSTRACT**

*Health disparities encompass a range of factors, including race, ethnicity, gender, age, disability status, and socioeconomic conditions. This project highlights disparities in healthcare access, quality of care, and health outcomes, with a particular focus on racial and ethnic disparities in health insurance coverage, prenatal care, and maternal morbidity. Gender disparities are also evident. Addressing these issues requires a multifaceted approach, including addressing social determinants of health, promoting equitable healthcare policies, and fostering cultural competence. Equitable access to healthcare services, quality care, and improved data collection are essential in eliminating disparities. Initiatives to support underserved communities, improve healthcare quality, and enhance cultural competence are recommended. Research and evidence-based approaches, along with policy reforms at various levels, such as anti-discrimination laws and increased funding for public health, are crucial. Collaboration among healthcare organizations, community groups, government agencies, and advocacy organizations is essential for effective interventions.*

## **KEYWORDS**

*Healthcare disparities, Race, Ethnicity, Socioeconomic status, Gender, socially disadvantaged group, Cultural competence, Access to healthcare.*

## **1. INTRODUCTION**

reasons behind these systematic and potentially avoidable health disparities include a range of factors such as race, ethnicity, skin color, religion, nationality, gender, sexual orientation, gender identity, age, location, disability, illness, political affiliation, and socioeconomic status (including income, wealth, education, or occupation). These categories reflect whether an individual or group holds a position of social advantage or disadvantage within a hierarchy. Health disparities are not a broad reference to all health differences but specifically pertain to those relevant to social justice, as they may result from deliberate or unintentional discrimination or marginalization, reinforcing social disadvantage and vulnerability. Assessing health equity, the foundation of addressing health disparities, involves evaluating disparities in health and their underlying determinants, aligning with the principle of social justice in healthcare [17].

The term "health disparities" describes differences in the capacity to reach optimal health among particular population groups in the United States. These disparities can be quantified through differences in factors such as disease incidence, prevalence, mortality rates, disease burden, and

the presence of other adverse health conditions [12]. It's crucial to remember that disparities can appear along many other dimensions, such as gender, sexual orientation, age, disability status, socioeconomic status, and geographic location, even though the term "disparities" is frequently linked to differences between racial or ethnic groups. [7] highlights the impact of these variables on an individual's ability to achieve optimal health, in addition to race and ethnicity. [7]. In fact, the evidence that is currently available on health disparities shows that all of the identity groups mentioned have different health outcomes.

Health disparities can arise from health inequities, which are regular variations in a group's health and communities that occupy unequal positions in society. Importantly, these inequities are avoidable and unjust [5]. These are precisely the kinds of disparities that are the focus of the committee's mandate and will be addressed in the remainder of this report. In this section, we will delineate health disparities that impact populations across multiple dimensions.

The significant disparities in health status and premature mortality within various segments of the United States population, frequently called health inequalities, have been extensively documented for over two centuries. Numerous studies have highlighted the pervasive racial and ethnic disparities in health status, along with the multiple contributing factors such as income and educational disparities, environmental and economic conditions, specific health behaviors and lifestyles, access to healthcare, and even the quality of healthcare services. These disparities based on race and ethnicity have been noticeable in both life expectancy and healthy life expectancy, with records dating as far back as 1900 and as recently as 2015, as reported by the National Center for Health Statistics in 2017. Furthermore, health disparities have also been noted in other population segments distinguished by geographic location, age, gender, disability status, and sexual orientation. [6].

Disparities in healthcare are essentially manifestations of the larger quality gaps and difficulties within our healthcare system, as pointed out by [4]. In essence, they serve as warnings, particularly from the most vulnerable individuals, highlighting the broader challenges we face. For example, recent evidence indicates that even in the most favorable circumstances, the average level of recommended medical care received by all Americans for major illnesses is only about 55% [10]. However, when researchers delve into outcomes related to race, ethnicity, socioeconomic status (SES), or geographic factors, these systemic quality issues become even more pronounced. Specific demographics face significant challenges in accessing affordable healthcare, including issues such as lacking insurance, financial means to afford insurance or medical services, and limited access to healthcare providers due to factors like the absence of local hospitals or transportation options. Additionally, these specific groups experience disparities in the treatment they receive, the standard of care given, and the resulting health outcomes. This paper therefore analyzes the various disparities in healthcare in the US.

## **2. LITERATURE REVIEW**

In recent times, an increasing worry has emerged regarding potential disparities in the quality of healthcare services for racial and ethnic minorities compared to White Americans, despite their equivalent healthcare access. For example, studies have indicated that Black individuals with end-stage renal disease are less likely to receive peritoneal dialysis and kidney transplantation, Black and Hispanic patients experiencing bone fractures in hospital emergency departments receive less frequent pain relief than White patients, and Black Medicare patients diagnosed with congestive heart failure or pneumonia tend to receive lower-quality care when compared to their White counterparts [6]. Moreover, a growing body of research has detected racial inequalities in the access to significant therapeutic interventions for a range of medical conditions, even when variables such as insurance status and disease severity are considered. These disparities endure in

healthcare environments where distinctions in economic status and insurance coverage are reduced, as seen in the Veterans Health Administration System and the Medicare program [11]. In response to the mounting reports of healthcare disparities, Congress in 1999 requested that the Institute of Medicine (now the National Academies of Sciences, Engineering, and Medicine) assess disparities in the types and quality of healthcare received by racial and ethnic minorities and non-minorities in the United States. The Institute of Medicine's Committee on Understanding and Eliminating Racial and Ethnic Disparities in Health Care provided a definition for healthcare disparities as "variations in healthcare quality based on race and ethnicity that cannot be explained by factors related to healthcare access, clinical requirements, patient choices, or the suitability of interventions." The committee analyzed multiple data sources to assess the scope of healthcare disparities, delve into their origins, and formulate approaches to tackle these disparities. These sources included a review of recent literature, commissioned research papers, input from professional societies and organizations, feedback from technical liaison panels as well as insights gathered from focus groups and roundtable discussion.

The committee's conclusion was that racial and ethnic healthcare disparities are consistently observed across a range of illnesses and healthcare services, with some exceptions. These disparities are often linked to socioeconomic differences and tend to decrease significantly, and in a few cases disappear, when socioeconomic factors are taken into consideration. Nevertheless, the majority of studies reviewed by the committee found that racial and ethnic disparities in healthcare persisted even after adjusting for socioeconomic differences and other factors related to healthcare access (Nelson , 2002). [12]

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our solutions effectively accomplish their intended goal: securing the health of all individuals, regardless of their socioeconomic characteristics.

### 3. METHODOLOGY

#### 3.1. Health Disparities: Age

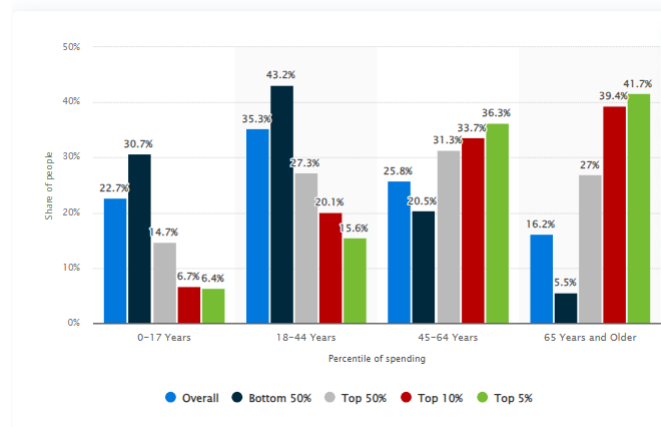


Figure 1: Share of people in the U.S. by age group and percentile of healthcare spending.

In 2017, when examining the top five percent of Americans in terms of healthcare spending, it becomes evident that the majority of these individuals were aged 65 or older. Specifically, nearly 42 percent of them fell into this age bracket. This data offers a glimpse into how individuals are distributed across age groups in the United States, considering their position within the top percentile of healthcare spending.

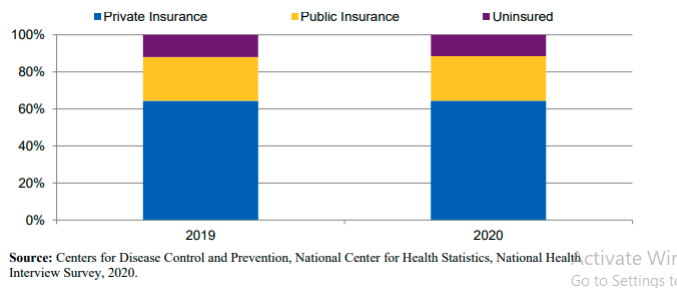


Figure 2: People under 65 years of age with public, private, or no health insurance, 2020

In the year 2020, it's approximated that around 88.5% of individuals under the age of 65 were covered by some type of health insurance, as depicted in the Figure above.

Among those with health insurance, approximately 27% were beneficiaries of public insurance, such as Medicaid or a blend of Medicare and Medicaid. On the other hand, just under three-fourths of the insured population held private insurance plans, frequently provided through their employers. This data underscores the diverse sources of health insurance coverage among individuals under the age of 65 in 2020.

#### 3.2. Health Disparities: Gender



When examining health disparities between genders, it's crucial to recognize that while some disparities are rooted in biological differences (such as the incidence of ovarian and prostate cancers), the majority of disparities discussed in this section are not primarily attributable to biological mechanisms unless explicitly stated. Non-biological health disparities are primarily shaped by socioeconomic conditions that can influence gender-based variations in health outcomes, including mortality rates, alcohol and substance abuse, mental health disorders, and experiences of violence.

In 2014, the average life expectancy at birth was 81.2 years for women and 76.4 years for men. Over the course of a decade, from 2004 to 2014, the life expectancy gap between men and women decreased from 5.1 years to 4.8 years. While the narrowing of this life expectancy gap might initially appear as a positive trend, it is, in fact, a concerning development. This shift arises from an increase in mortality rates among women in many regions over the past two decades [1]. [9] research identified that from 1992 to 2006, as mortality rates decreased in most U.S. counties, mortality rates for women increased in 42.8 percent of those counties. In contrast, during the same period, only 3.4 percent of counties witnessed an increase in male mortality rate.

More specifically, recent data reveals an unprecedented rise in death rates among white women, resulting in a decline in their life expectancy, a trend not experienced by white men [1]. Investigations into the causes of death among white women point to factors such as accidental poisonings (linked to the surge in prescription opioid use), suicides, obesity, and smoking related diseases [2].

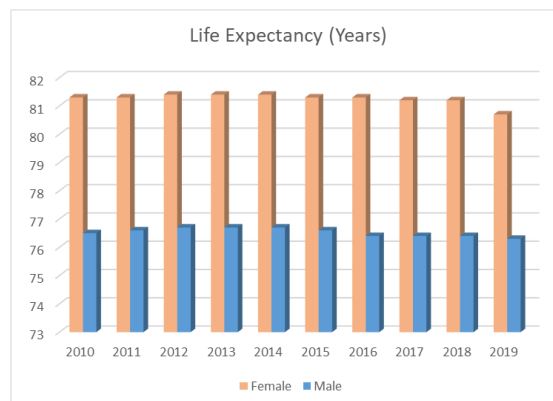


Figure 3: Life Expectancy of Male and Female

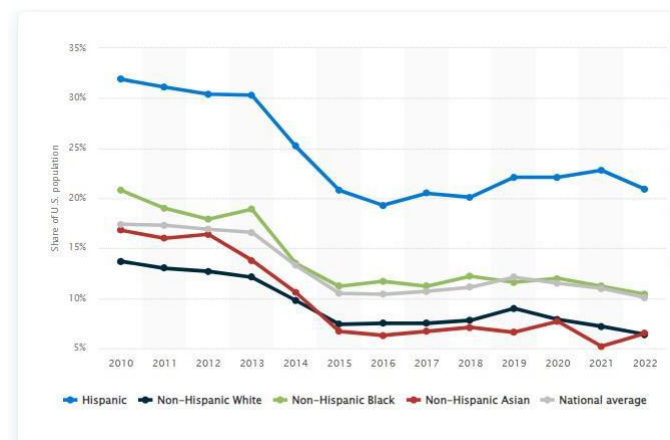
In US, over the years, women have longer life expectancy than men. Women maintained life expectancy of about 81 years from 2010 to 2018. In 2019, this ratio dropped to about 80.5 years. Among the men, life expectancy range between 76 years and less than 77 years all through the years (2010 and 2019). In 2019, life expectancy of men was the least (76.2 years).

### 3.3. Health Disparities: Ethnicity

Race and ethnicity, socially constructed identities, have profound effects on individuals' lives and health outcomes. Understanding their social construction is crucial as it shapes definitions and societal attitudes. Racial and ethnic disparities persist in the U.S., affecting health outcomes. Some minority groups, like Hispanic immigrants, experience better health initially, but disparities often grow over time. While progress has been made in narrowing gaps, disparities persist, notably in infant mortality, obesity, and chronic diseases. African Americans face higher risks of

premature death from heart disease and stroke. Solutions for health equity must consider the evolving demographics and address persistent disparities.

Race and ethnicity, socially constructed identities, significantly impact individuals' lives and are shaped by societal perceptions, historical policies, and practices. Acknowledging this social construction is vital, as it influences how race is measured and evolved over time. The concept of race is intricate, with a rich history of scientific and philosophical debate [8]. Despite progress in improving healthcare in the U.S., racial and ethnic disparities remain persistent, making them crucial factors in addressing health inequities [13]. The criteria for classifying race and ethnicity, as well as attitudes toward them, have evolved significantly in the early 21st century. In 2014, 37.9 percent of the population were racial or ethnic minorities, projected to become the majority within 30 years, emphasizing the importance of considering evolving demographics in health equity solutions [3].



Source: [14]

Figure 4: Percentage of people without health insurance in the United States from 2010 to 2022, by ethnicity.

The graph above shows that throughout the period (2010 and 2022), the majority of individuals of Hispanic race do not have health insurance. In 2013, more than about 30% of the Hispanic race did not have health insurance, this figure further dropped to 20% in 2018, and from 2018 to 2021, the proportion increased to close to 25% while it declines to over 20% in 2022.

Over the years, the proportion of non-Hispanic Asians without health insurance was on continuous decline until 2019 when the ethnic division have least percentage of people without insurance which stood at about 6%. As of 2022, Asian ethnic have the least proportion who are not without health insurance.

Over the years, less than 15% of Non-Hispanic White are without health insurance. The proportion was on continuous decline from about 14% in 2010 to about 6% in 2022.

In 2022, the absence of health insurance affected around 21 percent of the Hispanic population in the United States, marking an increase from the previous low of 19.3 percent observed in 2016. In the same year, the national average for uninsured individuals stood at 10.1 percent. White Americans exhibited a lower-than-average rate of only 6.5 percent lacking health insurance coverage, while 10.4 percent of Black Americans were without health insurance.

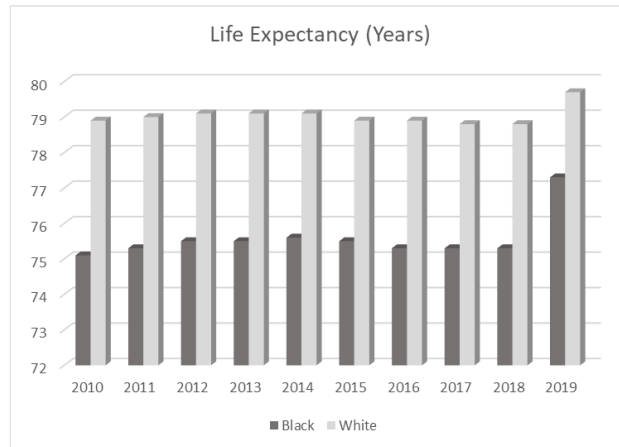
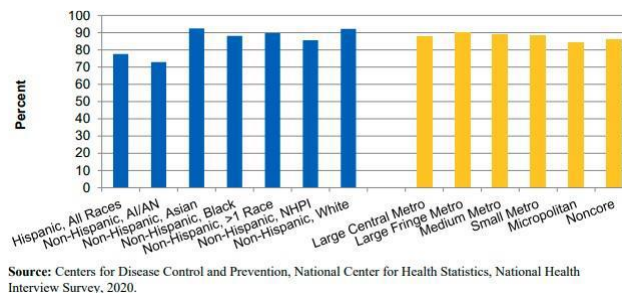


Figure 5: Life Expectancy of Black and White Persons in US



Source: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health Interview Survey, 2020.

Figure 6: People with any health insurance, by race, ethnicity, and location of residence, 2020

#### 4. RESULT AND DISCUSSION

Across various racial and ethnic groups, we can observe differences in the likelihood of having health insurance. Non-Hispanic Asian groups had the highest percentage of individuals with any health insurance coverage at 92.4%, followed closely by non-Hispanic White individuals at 92.2%. Non-Hispanic Multiracial individuals also had relatively high insurance coverage at 89.7%, while non-Hispanic Black individuals had an insurance coverage rate of 88.1%. Non-Hispanic NHPI (Native Hawaiian/Pacific Islander) individuals had an insurance coverage rate of 85.6%, and Hispanic individuals had a slightly lower rate at 77.6%. Non-Hispanic AI/AN (American Indian/Alaska Native) groups had the lowest insurance coverage rate among these groups, with only 72.9% having any health insurance coverage (as shown in Figure 11).

When we consider the location of residence, we find that people living in large fringe metro counties, often referred to as "suburbs," had the highest likelihood of having any health insurance, with a coverage rate of 90.1%. This was followed by individuals in medium metro areas at 89.3%, small metro areas at 88.5%, large central metro areas, often referred to as "cities," at 88.0%, noncore counties, which are typically rural areas, at 85.9%, and micropolitan areas, known as "small towns," at 84.5%. These variations in health insurance coverage rates based on both racial and ethnic backgrounds and geographic locations highlight disparities in access to healthcare resources and insurance across different population groups and regions.

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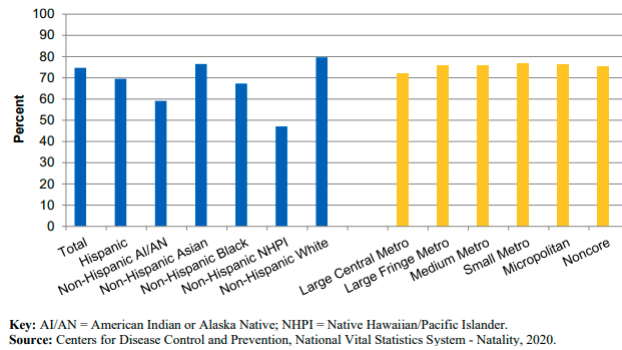


Figure 7: Individuals with a live birth in the last 12 months who received early and at least adequate prenatal care, by race/ethnicity and geographic location, 2020.

In 2020, there were significant disparities in the percentage of individuals who had given birth within the last 12 months and received early and adequate prenatal care, and these disparities were particularly pronounced when considering racial and ethnic differences (as illustrated in Figure 7). Additionally, there were variations in prenatal care by geographic location, but these differences were comparatively smaller. The disparities based on race and ethnicity showed a relative difference of 41% between the groups with the highest and lowest percentages, whereas the differences based on geographic location had a relative difference of 6% between the groups with the highest and lowest percentages.

Specifically, in 2020, the percentage of individuals who had a live birth in the last 12 months and received early and adequate prenatal care was lower for several racial and ethnic groups compared to non-Hispanic White individuals. Hispanic individuals had a rate of 69.5%, non-Hispanic AI/AN (American Indian/Alaska Native) individuals had a rate of 59.1%, non-Hispanic Asian individuals had a rate of 76.5%, non-Hispanic Black individuals had a rate of 67.3%, and non-Hispanic Native Hawaiian/Pacific Islander individuals had the lowest rate at 47.1%. In contrast, non-Hispanic White individuals had a higher rate of 79.6%.

Furthermore, in 2020, individuals in large central metro areas had a lower percentage of receiving early and adequate prenatal care (71.9%) compared to individuals in large fringe metro areas, which are often suburbs, with a higher rate of 75.9%. This indicates that while there were disparities in prenatal care by geographic location, these differences were relatively minor compared to the significant disparities observed across racial and ethnic groups.

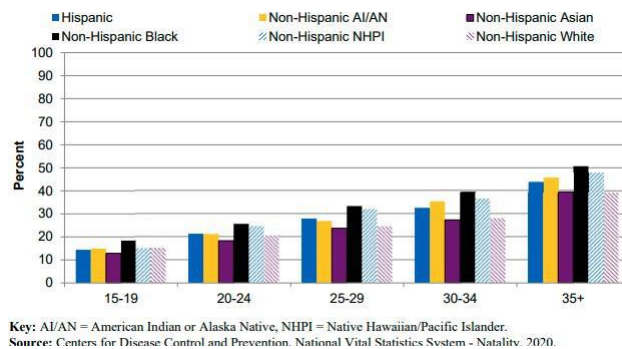


Figure 8: Cesarean deliveries of low-risk births among individuals giving birth for the first time, by age and race/ethnicity, 2020 (lower rates are better)

In 2020, for first-time births among all age groups, the proportion of cesarean deliveries in low-risk situations was higher among non-Hispanic Black individuals compared to non-Hispanic White individuals (as depicted in Figure 8). Furthermore, this disparity between non-Hispanic Black and non-Hispanic White individuals was more pronounced in older age groups. Specifically, the relative difference in cesarean delivery rates between these groups was 22% for individuals aged 15-19 years, 41% for individuals aged 30-34 years, and 30% for individuals aged 35 years and older.

In 2020, across all racial and ethnic groups, the percentage of cesarean deliveries in low-risk births was lower among individuals aged 15-19 years than among those aged 20-24 years. However, within all racial and ethnic groups, this percentage increased in individuals aged 25-29 years, 30-34 years, and 35 years and older compared to those aged 20-24 years.

Additionally, in 2020, the percentage of cesarean deliveries in low-risk births for first-time mothers was lower in various geographic areas, including large central metro areas (26.2%), medium metro areas (25.6%), small metro areas (24.5%), micropolitan areas (25.0%), and noncore areas (25.5%), when compared to individuals in large fringe metro areas (26.6%).

In summary, the data from 2020 shows disparities in cesarean delivery rates for low-risk births, with differences based on age, race/ethnicity, and geographic location. Notably, cesarean delivery rates were higher for non-Hispanic Black individuals, particularly in older age groups, and lower for teenagers across all racial and ethnic groups. Moreover, cesarean delivery rates varied by geographic location, with large fringe metro areas having slightly higher rates.

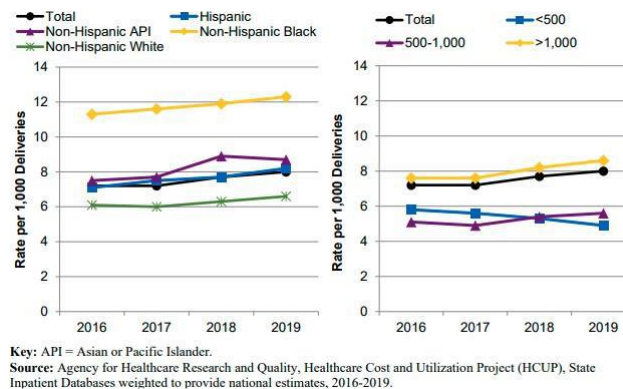


Figure 9: Severe maternal morbidity per 1,000 deliveries, by race/ethnicity (left) and hospital delivery volume (right), 2016-2019 (lower rates are better)

In 2019, the incidence of severe maternal morbidity during deliveries was significantly higher among non-Hispanic Black individuals compared to non-Hispanic White individuals, with a 87% increase (as illustrated in the Figure 9, left).

Furthermore, in 2019, the rate of severe maternal morbidity during deliveries was higher for Hispanic individuals (8.2 per 1,000 deliveries), non-Hispanic Asian and Pacific Islander (API) individuals (8.7 per 1,000 deliveries), and non-Hispanic Black individuals (12.3 per 1,000 deliveries) when compared to non-Hispanic White individuals (6.6 per 1,000 deliveries).

Over the span of three years, from 2016 to 2019, there was an increase in the rate of severe maternal morbidity during deliveries for Hispanic individuals (from 7.1 per 1,000 deliveries to

8.2 per 1,000 deliveries) and non-Hispanic Black individuals (from 11.3 per 1,000 deliveries to 12.3 per 1,000 deliveries).

Moreover, in 2019, the rate of severe maternal morbidity during deliveries was lower in hospitals with fewer than 500 deliveries (4.9 per 1,000 deliveries) and 500 to 1,000 deliveries (5.6 per 1,000 deliveries) compared to hospitals with more than 1,000 deliveries (8.6 per 1,000 deliveries) (as shown in the right image).

Over the same three-year period (2016 to 2019), the rate of severe maternal morbidity during deliveries increased for hospitals with more than 1,000 deliveries (from 7.6 per 1,000 deliveries to 8.6 per 1,000 deliveries).

Lastly, in 2019, the rate of severe maternal morbidity during deliveries was higher for individuals from large central metro areas (9.8 per 1,000 deliveries) when compared to large fringe metro areas (7.2 per 1,000 deliveries). Conversely, the rate of severe maternal morbidity during deliveries was lower for individuals from small metro areas (6.0 per 1,000 deliveries), micropolitan areas (5.2 per 1,000 deliveries), and noncore areas (5.1 per 1,000 deliveries) in comparison to large fringe metro areas (7.2 per 1,000 deliveries).

In summary, the data from 2019 reveals significant disparities in severe maternal morbidity rates during deliveries based on race/ethnicity, hospital size, and geographic location. Notably, non-Hispanic Black individuals experienced higher rates of severe maternal morbidity, and larger hospitals and central metro areas exhibited higher rates as well.

## **5. CONCLUSION AND RECOMMENDATIONS**

In conclusion, health disparities in the United States represent significant inequalities in health outcomes that primarily affect socially disadvantaged groups. The existence of these disparities can be ascribed to an intricate interaction of elements like race, ethnicity, socioeconomic status, gender, age, geographic location, and other traits linked to discrimination or marginalization. They result in systematic and often preventable health differences, particularly relevant to social justice in healthcare. Health disparities exhibit non-uniform patterns, manifesting across different dimensions such as race, ethnicity, gender, socioeconomic status, and geography. These discrepancies may impact access to healthcare, quality of care, and health outcomes. Racial and ethnic disparities are significant, with non-Hispanic Black individuals and Hispanic individuals often experiencing poorer health outcomes compared to non-Hispanic White individuals. These disparities extend to factors like insurance coverage, prenatal care, and maternal morbidity. Gender disparities exist, with women experiencing differential health outcomes compared to men. While some disparities are rooted in biological differences, many are influenced by socioeconomic conditions and behaviors. Ethnicity-based disparities in health insurance coverage reveal that Hispanic populations have historically faced challenges in accessing health insurance, although the situation has improved over time.

Life expectancy disparities exist between racial groups, with non-Hispanic White individuals generally having longer life expectancies compared to non-Hispanic Black individuals.

Prenatal care disparities were observed based on race and ethnicity, highlighting the need for targeted efforts to ensure equitable access to care for expectant mothers. Cesarean delivery disparities were noted, particularly among non-Hispanic Black individuals, with variations by age and geographic location. Severe maternal morbidity disparities were also observed, with higher rates among non-Hispanic Black individuals and in larger hospitals and central metro areas.

These disparities in healthcare reflect broader systemic issues within the healthcare system, including quality of care and access to services. Addressing health disparities requires a multi-faceted approach that considers social determinants of health, healthcare access, cultural competence, and equitable healthcare policies.

Health disparities encompass differences in health outcomes among specific population groups in the United States, quantified by various factors such as disease rates, mortality, and disease burden. These disparities are not limited to race and ethnicity but extend to gender, age, disability status, socioeconomic factors, and geographic location. Achieving health equity involves addressing these disparities, which often stem from avoidable and unjust systemic differences in health.

Factors contributing to disparities are multifaceted, including demographics, income disparities, environmental conditions, health behaviors, access to care, and quality of care. Eliminating healthcare disparities requires equitable access to healthcare services and high-quality care. Recognizing the evolving demographics and persisting disparities is crucial for developing effective solutions. The data also highlights differences in health insurance coverage among ethnic groups, emphasizing the need for policies to ensure healthcare access for all.

To eliminate disparities and improve health services, it is necessary to improve data collection methods and monitoring systems to track health disparities across various dimensions, including race, ethnicity, gender, age, disability status, socioeconomic status, and geographic location. Regularly updated and accurate data are essential for identifying disparities and evaluating interventions.

It is also necessary to ensure equitable access to healthcare services for all population groups, irrespective of their demographic characteristics. This includes improving access to affordable health insurance, primary care, and specialty services in underserved communities.

Strategies should be introduced and implemented to enhance the quality of healthcare services, particularly in areas where disparities are prevalent. Encourage healthcare providers to follow evidence-based guidelines and practices that prioritize patient outcomes.

The health ministry should support community-based initiatives that address the social determinants of health, such as housing, employment, and education. These programs can help reduce disparities by improving overall living conditions. Government should also implement policies and programs aimed at reducing income and educational disparities. This includes increasing the minimum wage, expanding access to affordable education, and creating job opportunities in disadvantaged communities.

It is recommended that healthcare providers should be encouraged to offer culturally competent care that respects the diverse backgrounds and beliefs of patients. This includes language access services and culturally sensitive healthcare practices.

The health ministry should invest in research to better understand the root causes of health disparities and evaluate the effectiveness of interventions. Evidence-based approaches should inform policymaking and resource allocation.

There should be policy reforms at the federal, state, and local levels that aim to eliminate health disparities. These reforms may include strengthening anti-discrimination laws, expanding Medicaid, and increasing funding for public health initiatives. Collaboration among healthcare organizations, community groups, government agencies, and advocacy organizations should be

fostered to address health disparities collectively. These partnerships can leverage resources and expertise to implement effective interventions.

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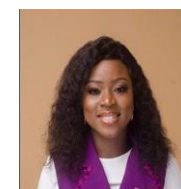
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# A SMART FISHING ROD AND SOFTWARE USING FLEX SENSOR, VIBRATION SENSOR AND BLUETOOTH

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## **ABSTRACT**

*Fishing rod vibration sensors represent an innovative tool in the realm of angling technology, designed to revolutionize the fishing experience [1]. These sensors leverage piezoelectric technology to detect subtle vibrations in the fishing rod, alerting anglers to fish bites in real-time. This abstract explores the key features and applications of these sensors.*

*These sensors are adept at distinguishing between external disturbances and genuine fish bites, reducing the likelihood of false alarms [2]. Their sensitivity and detection range can be calibrated, optimizing their performance for diverse fishing scenarios. By enhancing the angler's ability to detect bites promptly, fishing rod vibration sensors significantly improve catch rates and the overall fishing experience. They are particularly valuable for novice and experienced anglers alike, facilitating a deeper connection with the sport. As technology continues to advance, fishing rod vibration sensors offer a seamless blend of tradition and innovation, ensuring that the age-old practice of angling remains as thrilling and rewarding as ever.*

## **KEYWORDS**

*Fishing rod, Flex Sensor, Vibration Sensor, Bluetooth*

## **1. INTRODUCTION**

Simplifying and enhancing the fishing experience for both beginners and seasoned enthusiasts is a worthy endeavor [3]. The integration of programming and advanced detection technology has the potential to revolutionize the way we approach fishing. Imagine a comprehensive system that automates the labor-intensive aspects of fishing, such as baiting and waiting. This system would consist of smart sensors and actuators strategically placed to detect fish activity and respond accordingly. When a fish is hooked, you would receive an instant notification, liberating you to engage in other activities while your line is tended to. For beginners, this innovation would level the playing field by reducing the steep learning curve often associated with fishing. It would make the experience more accessible and enjoyable from the very beginning, allowing newcomers to focus on mastering the fundamental aspects of fishing, like casting and reeling, without being deterred by the tedium of long waits. For seasoned anglers like yourself, this system would offer the opportunity to multitask effectively. Whether you wish to connect with friends, catch up on social media, or enjoy your favorite online content, you could do so without sacrificing your fishing success. By addressing the challenge of waiting time and providing a more interactive fishing experience, this technological advancement has the potential to breathe new life into the sport. It can not only make fishing more efficient but also more appealing to a

broader audience. This harmonious fusion of technology, leisure, and skill development has the power to transform fishing into a more engaging and inclusive pastime.

Autonomous fishing rods use advanced tech for hands-off angling, while vibration-sensing rods require active participation. The former prioritizes convenience, while the latter enhances traditional fishing with technology. Both approaches cater to different angler preferences.

Fish detection by Convolutional Neural Networks (CNNs) is a passive, non-invasive method used for research and conservation [4][5]. In contrast, fishing rods with vibration sensors require active engagement and enhance recreational angling. CNNs serve scientific and ecological purposes, while fishing rod sensors make fishing more practical and enjoyable for anglers.

"Improving Fishing Pattern Detection from Satellite AIS" focuses on large-scale fisheries management using technology like data mining and machine learning [6]. In contrast, a vibration-sensing fishing rod aids individual anglers in real-time fishing, enhancing their catch rates. These approaches cater to different aspects of the fishing industry, from research and regulation to recreational angling.

My solution is to significantly enhance the fishing experience for novice anglers through the integration of Flex Sensors and Vibration Sensors within fishing rods, complemented by Bluetooth technology to provide real-time alerts when a fish has taken the bait [7][8]. This approach represents a holistic and innovative response to the challenges faced by inexperienced fishermen, making fishing more engaging and successful. By equipping fishing rods with Flex and Vibration Sensors, the system is capable of accurately detecting and analyzing the bending and vibrations of the rod. These sensors work in tandem to provide real-time data on rod movements, ensuring that when the readings surpass a predefined threshold, users receive immediate alerts through Bluetooth technology. This method provides a non-intrusive solution, in contrast to the potential disruption caused by alternative solutions like underwater cameras, which can upset the balance of fishing equipment and lead to complications in underwater operation [9]. The solution's effectiveness lies in its ability to strike a balance between technology and tradition, enhancing the accuracy of fish bite detection without undermining the core fishing experience. The versatility of this approach is also worth noting, as it can be tailored to suit various fishing styles. Users have the freedom to adjust sensitivity settings in alignment with their specific angling techniques. In comparison to other methods, this solution excels in terms of real-time alerts, ensuring users can stay engaged in other activities or simply relax while fishing without the need to constantly monitor their rods. The proposed system represents an effective and user-centered solution to enhance the overall fishing experience for novice anglers, bridging the gap between modern technology and the age-old art of angling.

The first experiment focuses on evaluating the sensitivity of the fishing rod sensor, aiming to determine its efficacy in detecting fish bites at varying distances and intensities. This test involves systematically submerging bait at different distances from the rod, recording whether the sensor detected vibrations or not. The primary goal is to ascertain the sensor's ability to accurately identify fish bites in close proximity and explore the potential limitations it may have in detecting vibrations at longer distances.

In the second experiment, the objective is to assess the detection range of the fishing rod sensor, specifically its capability to detect fish bites at different distances. This experiment involves varying the distance between the rod and the submerged bait and recording the sensor's response. The emphasis is on understanding the limitations and optimal range for this technology to reliably detect fish bites and improve the angler's success rate.

Both experiments address crucial aspects of the fishing rod sensor's performance, including its sensitivity and detection range, offering valuable insights into its practicality and use in angling scenarios.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. How to Detect Whether a Fish has taken the Bait**

In the process of solving the problem of smart fishing rods, I need to solve and think about how to detect whether a fish has taken the bait, and at the same time, I need to ensure that violent vibrations during fishing can still make my components work normally and not be damaged. After testing, I can use the flex sensor and Vibration sensor to help me debug and detect the shaking value of the fishing rod with or without hooked fish, and set an average value to detect the average shaking of the fishing rod at a certain time. Is the value much higher than the previous average? If so, there are fish taking the bait. At the same time, both the flex sensor and the vibration sensor have very good toughness, which can protect the components from being damaged by violent shaking while ensuring safety when users are fishing.

### **2.2. Transmitting Data**

When I tackled the challenge of transmitting data from my hardware component to the software I'd developed, I conceived the idea of utilizing a Bluetooth microcontroller. This ingenious solution addressed multiple dilemmas. Whether a user was fishing in remote areas with no network access or in environments lacking connectivity, the Bluetooth microcontroller bridged the gap. Moreover, it elegantly resolved concerns regarding battery life by implementing a battery controller to efficiently manage power consumption. As a result, users could rely on prolonged, uninterrupted use of their smart fishing rod hardware without worrying about frequent battery replacements. This dual functionality not only provided convenience but also lightened the load for users, making their fishing experiences more enjoyable and less burdensome. The Bluetooth microcontroller emerged as a versatile solution, seamlessly integrating the hardware and software for a seamless and robust fishing experience.

### **2.3. Assembled Components**

To accommodate my assembled components, I sought a custom storage solution, and the synergy of 3D printing and modeling opened doors to creativity. Crafting numerous prototypes through iterative design, I diligently debugged and tested each iteration to strike the perfect balance between lightweight construction, adequate storage capacity, and safeguarding the delicate hardware. In my pursuit of optimizing the design, I realized that reinforcing the small storage box with a zip tie offered a brilliant solution. This addition not only enhanced the box's structural integrity but also allowed it to be securely affixed to the smart fishing rod without hampering the user's tactile experience during fishing. Ultimately, this meticulously honed storage solution addressed my need for a lightweight, protective, and convenient way to house my components, ensuring that they were readily accessible and well-protected during fishing expeditions. The fusion of 3D printing, 3D modeling, and a simple zip tie revolutionized my gear management, making every fishing trip more organized and efficient [10].

### 3. SOLUTION

To provide a general overview of how an app and hardware system for fish detection using a fishing rod work we look at 3 of its major components. The bluetooth microcontroller, a nRF52840, collects data from piezoelectric ribbon and transmits when a fish is detected on the fishing rod to our app [15].

The system comprises three major components: the Bluetooth microcontroller (nRF52840), a piezoelectric ribbon sensor, and a dedicated app. Here's a general overview of how this fish detection system works:

#### 1. Bluetooth Microcontroller (nRF52840):

- The nRF52840 microcontroller is attached to the fishing rod, typically near the rod tip, where it can easily detect vibrations.
- It collects data from the piezoelectric ribbon sensor, which is sensitive to vibrations and movements.
- The microcontroller is programmed to analyze the incoming data and compare it to a predefined threshold level to determine if it's a fish bite.
- When a fish bite is detected, the microcontroller initiates a Bluetooth connection.

#### 2. Piezoelectric Ribbon Sensor:

- The piezoelectric ribbon sensor is a vital component of the system, responsible for detecting vibrations caused by fish bites.
- It is attached to the fishing rod and captures subtle movements and vibrations when a fish interacts with the bait.

#### 3. Dedicated App:

- The app is installed on a smartphone or tablet and connects to the nRF52840 microcontroller using Bluetooth technology.
- It serves as the user interface and control center for the system.
- The app displays real-time data from the sensor, allowing the angler to monitor the rod while attending to other activities.
- When the microcontroller detects a fish bite, it sends a notification to the app, alerting the angler through visual or auditory signals.

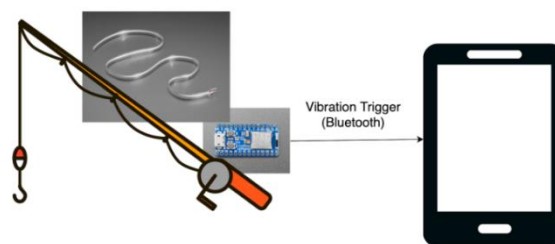


Figure 1. Overview of the solution

Scanning for Bluetooth devices involves a process where a Bluetooth-enabled device actively searches for and identifies nearby Bluetooth-enabled devices within its range. This scanning process allows the device to discover, connect to, or interact with other Bluetooth devices, such as headphones, speakers, or smart accessories.

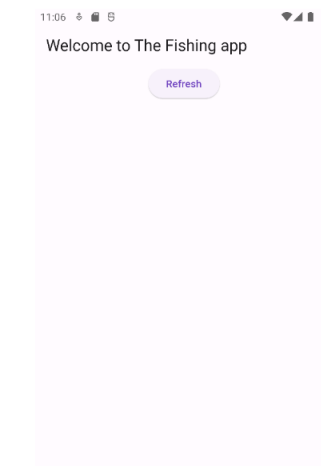


Figure 2. Welcome page

```

class _ScanScreenState extends State<ScanScreen> {
  List<BluetoothDevice> _connectedDevices = [];
  List<ScanResult> _scanResults = [];
  bool _isScanning = false;
  late StreamSubscription<List<ScanResult>> _scanResultsSubscription;
  late StreamSubscription<bool> _isScanningSubscription;

  @override
  void initState() {
    super.initState();

    FlutterBluePlus.systemDevices.then((devices) {
      _connectedDevices = devices;
      setState(() {});
    });

    _scanResultsSubscription = FlutterBluePlus.scanResults.listen((results) {
      _scanResults = results;
      setState(() {});
    });

    _isScanningSubscription = FlutterBluePlus.isScanning.listen((state) {
      _isScanning = state;
      setState(() {});
    });
  }
}

```

Figure 3. Screenshot of code 1

The code provided appears to be written in Dart and is likely part of a Flutter application that deals with Bluetooth devices using the FlutterBluePlus library. Here's what it does:

1. List Management: It initializes several lists for managing Bluetooth devices.
  - `connectedDevices` is used to store a list of connected devices, while
  - `scanResults` stores scan results from nearby Bluetooth devices.
2. State Tracking: The code also initializes variables like `_isScanning` to track whether a Bluetooth scan is currently in progress.
3. Initialization: In the `initState` method, it fetches a list of system Bluetooth devices using `FlutterBluePlus.systemDevices`. This list represents devices that the app is already connected to. This information is stored in `_connectedDevices`, and the app's state is updated accordingly.
4. Subscriptions: It subscribes to two streams provided by the FlutterBluePlus library. One stream, `_scanResultsSubscription`, listens for scan results of nearby Bluetooth devices. The other, `_isScanningSubscription`, listens for changes in the scanning state.

The code essentially sets up the Flutter application to manage Bluetooth devices, including tracking connected devices and handling scan results and scanning state updates in real-time.

This component, a UART service, enables the microcontroller to transmit data wirelessly via Bluetooth. It establishes a communication channel for sending information to other Bluetooth-enabled devices, facilitating data exchange and control in various applications.

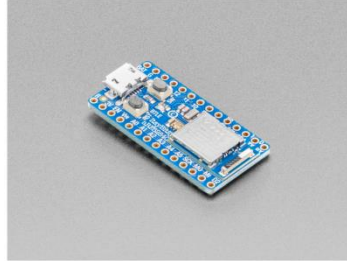


Figure 4. UART service

```
# Set up bluetooth
ble = BLERadio()
ble.name = 'fishing_rod' # The name that appears in bluetooth
uart_server = UARTService()
advertisement = ProvideServicesAdvertisement(uart_server)
print(ble.name)
print(uart_server.uuid)

# Main Loop
while True:
    # Start advertising this device over bluetooth
    ble.start_advertising(advertisement)

    # Set LEDs to blue to indicate to the user the device is NOT connected
    pixels.fill(BLUE) # Set all 16 pixels to white
    pixels.show() # Update the pixels

    i = 0 # just as a visual indicator to see how long it's been waiting to connect

    # This will loop until something connects to this device
    while not ble.connected:
        print(ble.name + ': not connected' + str(i))
        print(uart_server.uuid) # uart_server.uuid is a unique id for the device
        i = i + 1
        time.sleep(0.5)

    # Once something connects to this device, stop advertising so no other device can connect
    ble.stop_advertising()
```

Figure 5. Screenshot of code 2

The provided code sets up Bluetooth communication using a microcontroller for a fishing rod application. Here's what it does:

1. It initializes a Bluetooth Low Energy (BLE) radio (ble) and sets the name of the Bluetooth device to 'fishing\_rod'. This name is how the device will appear when scanning for nearby Bluetooth devices.
2. It creates a UART service (uart\_server) for serial communication over Bluetooth.
3. It configures the device to start advertising its presence over Bluetooth using the ble.start\_advertising(advertisement) function.
4. The code sets the onboard LEDs to blue, visually indicating that the device is not connected to another Bluetooth device.
5. It enters a loop that waits for another device to connect to it via Bluetooth. The loop continues until a connection is established.
6. While waiting for a connection, the code prints status messages, including the device name and a unique identifier (UUID).
7. Once a connection is established, the advertising is stopped to prevent other devices from connecting.

In summary, this code initializes a Bluetooth device, advertises its presence, waits for a connection, and communicates over Bluetooth when connected.

A piezoelectric ribbon is a thin, flexible strip typically made of piezoelectric material. Piezoelectric materials can generate an electric charge when subjected to mechanical stress or vibrations, and conversely, they can deform in response to an applied electrical field.



Piezoelectric ribbons are often used as sensors or transducers in applications where the conversion of mechanical vibrations or pressure into electrical signals is required. For example, in the context of fish detection with a fishing rod, a piezoelectric ribbon sensor can be attached to the rod to detect vibrations caused by fish bites. When the ribbon sensor flexes in response to the rod's movement, it generates an electrical signal that can be interpreted as a fish bite by the associated electronics.

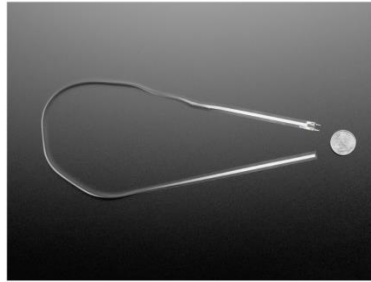


Figure 6. Piezoelectric ribbon

```
# Define the ADC pin
analog_in = analogio.AnalogIn(board.A0) # Use the appropriate pin

while True:
    piezo_value = analog_in.value # Read the analog value
# You can print the value to the console or perform further processing.
print("Piezo Value: ", piezo_value)
```

Figure 7. Screenshot of code 3

The provided code snippet in CircuitPython configures and utilizes an analog-to-digital converter (ADC) to read voltage values from a connected Piezoelectric Ribbon sensor. It starts by defining the ADC pin, which is linked to the microcontroller's pin A0. In a continuous loop, the code reads the analog voltage value from the sensor using `analog_in.value`. This value represents the electrical charge generated by the Piezoelectric Ribbon in response to mechanical stress or vibrations, which are likely fish bites in the context of fish detection. The code then prints the "Piezo Value" to the console, allowing the user to monitor and analyze the sensor's output. The value can be further processed or used for various applications, such as detecting and responding to fish bites when it crosses a certain threshold.

## 4. EXPERIMENT

### 4.1. Experiment 1

This experiment aims to assess the sensitivity of the fishing rod sensor to determine its effectiveness in detecting fish bites at various distances and intensities.

Sensitivity Test:

- Attach the fishing line, hook, and bait to the fishing rod.
- Gradually lower the bait into the water at various distances from the rod (e.g., 1 foot, 2 feet, 3 feet, etc.).
- Observe and record if and when the sensor detects vibrations as the bait is submerged.
- Note the distance at which the sensor reliably detects vibrations and any limitations.

Distance (feet) | Vibration Detected (Yes/No)

1 Yes

- 2 Yes
- 3 No
- 4 No
- 5 No

The data from the sensitivity test provides valuable insights into the performance of the fishing rod sensor system. As the distance between the bait and the sensor increased, the system's ability to detect vibrations diminished. At shorter distances of 1 and 2 feet, the sensor reliably detected vibrations, indicating its high sensitivity in close proximity. However, beyond 2 feet, the sensor's effectiveness decreased significantly, failing to register any vibrations at 3, 4, or 5 feet.

This analysis suggests that the sensor is highly sensitive to nearby disturbances, such as fish bites or movements, making it an excellent tool for close-range fishing scenarios. However, its limited detection range becomes a concern when attempting to detect fish bites at greater distances. Anglers using this system should be aware of its distance limitations and position the bait and fishing rod accordingly.

Further improvements to extend the sensor's range could enhance its practicality for a broader range of fishing conditions. Additionally, the data highlights the importance of calibration and adjustment to optimize the sensor's performance based on the specific fishing scenario.

## 4.2. Experiment 2

This experiment aims to assess the detection range of the fishing rod sensor to determine its effectiveness in detecting fish bites at various distances and intensities.

a. Use a ruler or measuring tape to measure the distance between the fishing rod and the submerged bait. b. Gradually increase the distance between the rod and the bait (e.g., from 1 foot to 5 feet). c. Record if and when the sensor detects vibrations at each distance. d. Assess the sensor's ability to detect vibrations at varying distances and analyze the results.

b.

Distance (feet) | Vibration Detected (Yes/No)

- 1 Yes
- 2 Yes
- 3 No
- 4 No
- 5 No

The data collected during the Detection Range Test provides essential insights into the fishing rod sensor's ability to detect vibrations at varying distances from the bait. At closer distances of 1, 2, and 3 feet, the sensor consistently registered vibrations, indicating its effectiveness in detecting fish bites within this range. However, as the distance between the fishing rod and the submerged bait increased, the sensor's performance declined. It failed to detect vibrations at 4 and 5 feet.

This analysis suggests that the sensor system is highly reliable in close-range scenarios, making it suitable for anglers who primarily engage in nearshore or shallow water fishing. However, for anglers targeting fish in deeper waters or at greater distances, the sensor's limited detection range could be a significant limitation.

To enhance the practicality of the sensor system, improvements to extend its detection range are essential. Adjustments to the sensor's sensitivity and threshold settings may also be necessary to optimize its performance for specific fishing conditions, ensuring accurate and timely fish bite detection.

## 5. RELATED WORK

An autonomous fishing rod and a fishing rod that detects fish by vibration represent two distinct approaches to angling [11]. An autonomous fishing rod typically involves advanced technology, such as robotics and artificial intelligence, to automatically hook, reel, and land fish without human intervention. It's a hands-off approach that caters to convenience and efficiency, allowing anglers to engage in other activities while fishing.

On the other hand, a fishing rod that detects fish by vibration relies on sensors to alert the angler when a fish bites, requiring active participation. It maintains the traditional angling experience while enhancing the chances of successful catches. It's a more interactive method and may appeal to those who enjoy the sport of fishing while still benefiting from technological assistance.

Fish detection by Convolutional Neural Networks (CNNs) and a fishing rod that detects fish by vibration are two distinct approaches [12]. CNNs employ computer vision to identify fish underwater using image recognition. It's a passive, non-invasive method, suitable for research and conservation. In contrast, a fishing rod with a vibration sensor relies on physical interaction; it detects fish bites when the rod tip vibrates, requiring an angler's active engagement. While CNNs are more appropriate for scientific or ecological purposes, the fishing rod sensor enhances the angling experience by notifying the angler of potential catches, making it a practical tool for recreational fishing.

"Improving Fishing Pattern Detection from Satellite AIS Using Data Mining and Machine Learning" and a fishing rod that detects fish by vibration serve distinct purposes in the fishing industry [13]. The former utilizes advanced technologies, including satellite data, data mining, and machine learning, to analyze and predict fishing patterns, helping with fisheries management and sustainability. It's a passive, large-scale approach for research and regulation. In contrast, a fishing rod with a vibration sensor is a hands-on, small-scale tool for anglers to detect individual fish bites during recreational fishing, enhancing their chances of a successful catch. The former focuses on fisheries monitoring, while the latter aids individual anglers in real-time.

## 6. CONCLUSIONS

Calibration challenges in the context of fishing rod sensors are a critical aspect of optimizing the system's performance. Calibrating a fishing rod sensor entails fine-tuning its sensitivity and threshold settings to strike a balance between detecting genuine fish bites and minimizing false alarms. This process often involves a degree of trial and error, as there is no universal setting that suits all fishing scenarios.

The challenges arise from the dynamic nature of fishing environments [14]. Factors like water conditions, bait types, and fish species all influence the sensor's effectiveness, necessitating frequent adjustments. Calibration may be time-consuming and require a deep understanding of the technology, which can present a steep learning curve for novice anglers.

Environmental variability, such as changes in water temperature and currents, further complicates calibration efforts. Additionally, the sensor must accommodate the nuances of different fish species, as their biting behaviors vary. Successful calibration is essential for enhancing the sensor's utility and ensuring a reliable fishing experience, but it demands ongoing attention and adaptability from anglers to address the myriad factors affecting its performance.

In conclusion, fishing rod sensors offer a promising approach to enhance angling experiences by detecting fish bites through vibrations. While they have notable benefits, such as increasing catch rates, they also come with limitations like calibration challenges and a limited detection range. Successful adoption depends on understanding and mitigating these limitations.

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# UNRAVELLING DNS PERFORMANCE: A HISTORICAL EXAMINATION OF F-ROOT IN SOUTHEAST ASIA

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China

## **ABSTRACT**

*The DNS root server system uses Anycast technology to provide resolution through widely distributed root nodes. In recent years, the F-root node has seen astonishing growth and now boasts the largest number of nodes among the 13 root servers. Based on Ripe Atlas measurement data, we examined the availability and query latency of the F-root within the Southeast Asian region historically. The collected data illustrates how latency varies with changes in the number of root nodes, how the geographic distribution of responding root nodes changes in different periods, and examines the most recent differences between countries in terms of latency distribution. This study sheds light on the evolving landscape of DNS infrastructure in Southeast Asia.*

## **KEYWORDS**

*DNS, Southeast Asia, Ripe Atlas, Query Latency*

## **1. INTRODUCTION**

Root server is the foundational component of Domain Name System (DNS) and a critical element of the internet infrastructure [1]. Presently, there are 12 Internet Corporation for Assigned Names and Numbers (ICANN) authorized root operating organizations responsible for managing a total of 13 root name servers, denoted from A-root to M-root. To safeguard against Distributed Denial of Service (DDoS) attacks [2] on the DNS root and to minimize root query latency, the Root Server System (RSS) deploys numerous mirrored nodes (replicating instances of root service) at different sites worldwide, employing Anycast technology [3,4]. Notably, the number of F-root nodes has surged from 58 in early 2016 to 505 as of August 2023, marking a nearly tenfold increase. This deployment makes it the fastest-growing and the largest in terms of the root nodes number among A-M roots. Among all continents, Asia leads the way, with the number of F-root nodes growing from 15 in early 2016 to 191 as of August 2023 [5].

Extensive research has been conducted around DNS in the past, including topics around root server deployment [6,7], root traffic [8], and root manipulation [9]. As the deployment process of root nodes accelerates, RSS has undergone great changes in recent years, so it is necessary to conduct a fresh round of examination of the current RSS. Among the research after 2020, some focus on the intersection of DNS and new technologies such as blockchain [10,11], some delve into DNS security and privacy [12,13,14], and some address the centralization challenges [15] within DNS ecosystem. However, there are few studies on root service performance, and even fewer studies on DNS root performance of a certain region from a historical perspective.

This article centres its focus on the F-root and selects Southeast Asia (“SEA” for short) as the primary research area. Leveraging data from Ripe Atlas [16,17] and the root-servers.org platform, alongside considerations of the number of Ripe probes and the availability of historical data, six countries in SEA have been chosen as the subjects of this study. These countries include Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. The subsequent structure of this paper is as follows:

Section 2 outlines the research methodology. Section 3 provides an in-depth analysis of the research findings, encompassing a historical examination of the deployment and query latency of the F-root within the SEA region and individual countries. Additionally, it delves into the changing geographical distribution of destination nodes and presents the most recent latency Cumulative Distribution Function (CDF) curves for various countries when accessing the F-root. Section 4 summarizes the research and offers corresponding recommendations.

## **2. METHODOLOGY**

### **2.1. Research Scope**

Building on the findings of a report from LACNIC [18], this study represents the first long-term analysis focusing on the operational status of DNS root in the Southeast Asian region. Data regarding the query performance of the F-root in this study is sourced from the Ripe Atlas platform. Ripe Atlas is a global probe network designed for testing network connectivity and reachability, providing real-time insights into network conditions. Currently, Ripe Atlas consists of more than 12000 of active probes distributed worldwide, with the number continuing to grow.

Among all the SEA countries, we selected those that have had active probes since early 2016 and, as of August 2023, have at least 10 active probes. Meeting these criteria are only the aforementioned six countries. While they do not represent the entirety of the SEA region, these six countries collectively account for 88% of the region's population and 75% of its territorial area. Several other SEA countries were unable to be included due to no probes or an insufficient probe count. Thus, this study approximates the overall situation in the SEA region by focusing on these six countries.

### **2.2. Data Collection**

DNS measurements are built-in measurements of the Ripe platform and all data are publicly accessible [19]. In this study, we collected DNS measurement records for the F-root from all probes in the six countries mentioned, sampled at regular time intervals from Jan 2016 to Aug 2023. Specifically, the measurements are IPv4 DNS queries for QNAME “hostname.bind” over UDP, using CHAOS class and TXT type [20]. This allowed us to gather information about the response time and the hostnames of the responding root node from each record.

In addition to RIPE's data, this study also utilized historical archive data from the root-servers.org platform regarding the deployment of root servers, such as information about root node types and geographical locations.

### **2.3. Root Node's Identification and Location**

Several articles have previously discussed methods for identifying and locating root nodes [21,22,23]. In this paper, we employ a relatively simple and straightforward method. The process can be summarized as follows:

—We obtain the hostname of the responding root node from RIPE's DNS measurement records, found in the "hostname.bind" field.

—We use this hostname to match it with the "identifier" field in archive yaml/json data from root-servers.org website. Root-servers.org data provides identifiers for the F-root, which makes this matching process possible.

—If the match is successful, it automatically identifies the specific root node that responded in each measurement record and provides its location information.

It's important to note that while this method is effective for the F-root, it may not be applicable to all other 12 root servers because some root servers' identifiers are missing in the data provided by root-servers.org.

### 3. RESULTS

#### 3.1. Use of F-Root in Region of Southeast Asia

In this section, we analyze the utilization of F-root nodes in the SEA region, focusing on the number of nodes and query latency. To illustrate this, we utilize the combination chart presented in Fig. 1, which provides insights into query latency to the F-root by various probes at different historical periods. In the chart, the horizontal axis represents time, the main vertical axis represents round-trip time (RTT), and the secondary vertical axis represents the number of F-root nodes. The chart displays two lines: the black line signifies the number of F-root nodes, while the red line represents the average RTT of all probes in the region when querying the F-root at that time. Additionally, scattered data points are visible in blue, where each point signifies the average RTT of an individual probe at a given time, with the shades of colour indicating density. Darker colours indicate a higher concentration of similar RTT results, while lighter colours represent the opposite. Generally, a denser distribution along the x-axis signifies better performance.

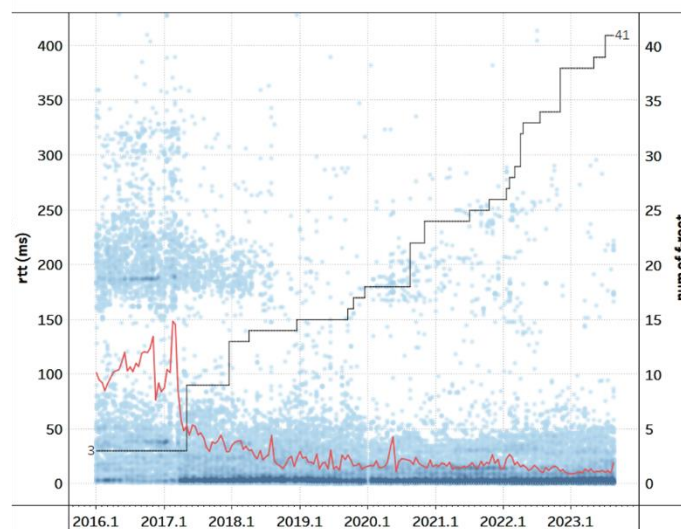


Figure 1. Historical query latency and number of F-root in SEA region

Our observations reveal that prior to 2016, there were several F-root nodes deployed in the SEA region, although their numbers were relatively low. Before May 2017, some measurement records indicated lower RTT values, situated near the x-axis on the chart. However, a cluster of data points near the upper part of the y-axis was also evident, with a significant concentration

around 200ms and a few around 300ms. In May 2017, the region added six new F-root nodes, leading to noticeable changes in the distribution of data points. The number of points at the upper position decreased, and the distribution narrowed. Near the x-axis, the colour became darker, signifying a significant decrease in RTT. By October 2018, the region had 13 root nodes, and scatter points at the upper “layer” became less pronounced and clustered, with only sparse points above. Over time, beyond 2020, the width of the distribution at the lower position gradually narrowed compared to previous periods.

Simultaneously, we observed that while the number of F-root nodes continued to increase after 2020, there were no apparent changes in the distribution of scatter points in Fig. 1. Additionally, the decline in the red curve became increasingly gradual, suggesting that the introduction of a large number of root nodes in the later period did not yield the same degree of improvement as earlier introductions.

### 3.2. Use of F-Root in Each Country of Southeast Asia

In this section, we employ the same research methodology as in the previous section to individually analyze the historical changes in query latency and the number of F-root nodes in six different selected countries within Southeast Asia. The subplots in Fig. 2 present these analyses, with each subplot dedicated to one of the six countries. The country's ISO two-letter code is displayed in the top centre of each subplot.

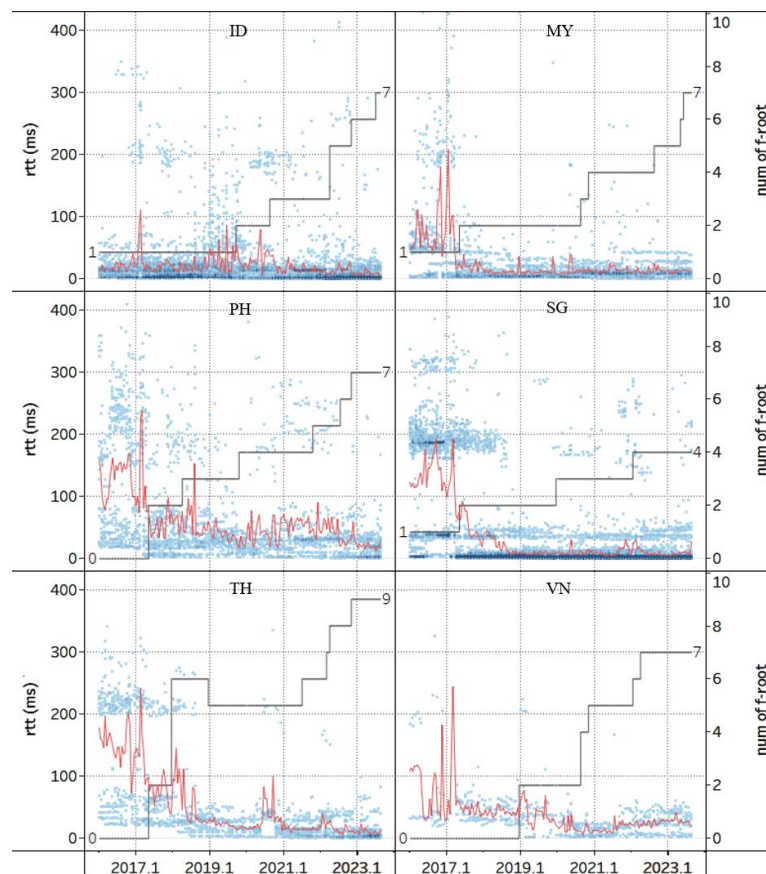


Figure 2. Historical query latency and number of F-root in each country of SEA



The variations in the number of data points within the subplots of Fig. 2 are attributed to the differing numbers of active probes in each country. As of August 2023, the number of active probes for each country is as follows: Indonesia (92 probes), Malaysia (27 probes), the Philippines (54 probes), Singapore (129 probes), Thailand (34 probes), and Vietnam (10 probes). Consequently, subplots for Indonesia and Singapore exhibit a higher data density, while the subplot for Vietnam features relatively fewer data points.

Observing each country individually, we can find:

**Indonesia (ID):** Despite an increase in the number of F-root nodes from 1 to 7, query latency for Indonesian probes did not show a clear improvement over time. In the first half of 2016, most data points were already concentrated near the x-axis, with few data points higher up, indicating good latency performance at that time. However, as the number of F-root nodes increased, scatter points at higher position not only did not decrease but, in some instances, showed an increase and even a tendency to cluster in a small range.

**Malaysia (MY):** Although Malaysia initially had one root node, scatter points were still distributed at various heights along the y-axis until early 2017, indicating a significant latency range. By April 2017, Malaysia introduced a second F-root node, and it was then clearly observed that the scatter points began to cluster downwards. After 2018, most scatter plots clustered at positions below 50ms. While, further node additions did not yield significant enhancements as before.

**The Philippines (PH):** Before 2017, the Philippines had no domestic F-root, resulting in a broad distribution of query latencies. In its subplot, we can see many scatter points distributed at different heights. With the introduction of its first F-node in April 2017, latency significantly improved, manifested as a gradual decrease in points at higher positions and an increase in points closer to the x-axis. By 2020, its F-root had increased to 4, and by this point, most of the scatter points were located below 50ms. While, like MY, the subsequent increase in the number of root nodes did not bring continued performance improvements, instead we observed a slight deterioration between 2021 and 2022.

**Singapore (SG):** Although Singapore had already deployed an F-root node before 2016, until early 2017, along the y-axis direction, scatter points could still be clearly observed to form three layers. Among them, the middle layer had the most significant latency span, with a higher density at around 185ms (indicated by a very dark short line). In May 2017, Singapore introduced a new F-root node, and since then, scatter points in the top and middle layers started to descend. Meanwhile, points in the bottom layer began to cluster more towards the very bottom (closer to the x-axis). By August 2018, the upper and middle layers had almost disappeared, and most of the points were descended in the bottom layer.

**Thailand (TH):** Basically, trends in Thailand paralleled those in Singapore. Initially, the absence of F-root nodes resulted in broad latency distribution. In May 2017, Thailand introduced 2 F-root nodes, which improved the situation. Points in the upper layer started to decrease, by December 2017, the number of F-root nodes increased to 6, and we observed a continued decrease in points in the upper layer, meanwhile, points in the lower layer started to settle even lower. During the first quarter of 2018, points in the upper layer gradually decreased to near "disappearance", and points in the lower layer sank to the very bottom. Afterward, the F-root kept increasing, but latency did not show significant improvement.

**Vietnam (VN):** After introducing its first F-root node in December 2018, Viet Nam's latency improved considerably. From its subplot, we can see almost all the scatter points at the higher

position disappeared, and points below started to cluster further downward. Its best performance was observed between May 2020 and February 2022, manifested as almost all the points were distributed in a narrow strip at the bottom. However, after February 2022, despite an increase in nodes, there was no continued improvement observed as we expected.

In summary, historical trends in query latency for F-root nodes exhibited variations among these countries. However, a common pattern emerged among all five countries, except for Indonesia. Initially, querying F-root nodes resulted in relatively poor performance, characterized by numerous data points clustering at higher positions in the subplots, and the red line indicating high average RTT at the same time. The introduction of additional root nodes led to a significant reduction or near disappearance of data points at higher positions, and the red line also swiftly declined. Furthermore, this analysis reaffirms the conclusion from the previous section: early introductions of root nodes consistently produced substantial improvements in latency, while late introductions had a more limited impact.

### 3.3. Geographical Distribution of Responding Root

In this section, we examine the historical trends in the distribution of destination countries or regions to which responding F-root nodes belong, based on the location of root nodes. Fig. 3 presents the findings, with each row representing an observed country, numerical labels at the top denoting the years, and the bottom numbers (1-4) indicating the quarters of a year. Different colours represent the countries or regions where responding root nodes are situated.

To enhance clarity, we merged destination countries or regions with proportions below 1% into a single category labelled as 'others.' Additionally, some responding root nodes could not be matched with the F-root's Identifier from root-servers.org and were collectively categorized as 'unknown' in this study.

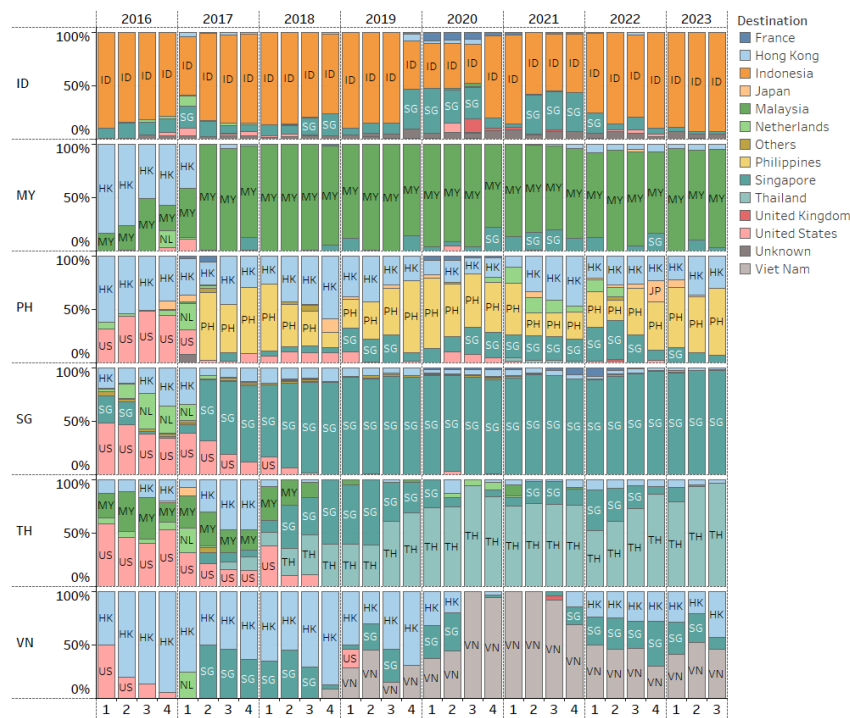


Figure 3. Geo-distribution of responding F-root servers by country Findings are:

**Regional F-root access.** In Fig. 3, we observe that Singapore's F-root is widely accessed by the entire SEA region. Apart from Singapore, queries from the other five countries also access Singapore's F-root during different periods, some with relatively high proportions. Malaysia's F-root has been accessed by other countries, particularly from 2016 to the third quarter of 2018 when Malaysia was among Thailand's top three destination countries for F-root. On the other hand, Indonesia's and Thailand's F-root nodes were briefly accessed by probes from outside their respective countries, but the proportions were so low that they appear indistinguishable in the graph. Philippines and Vietnam only have 'Local' (with service limited to specific Autonomous Systems) type of F-root, and data shows they are accessible only to probes within their own countries throughout the entire timespan.

**Change in routing destination.** In the early stages, notably in 2016 and 2017, except for Indonesia and Malaysia, the other four countries had a significant portion of their F-root queries routing to the United States or the Netherlands. However, after 2023, none of the six countries has its F-root queries routed to root nodes located outside of Asia any more. The primary destination for F-root in each country is now their own country, with domestic resolution rates exceeding 90% for Indonesia, Malaysia, Singapore, and Thailand. For the Philippines and Viet Nam, these rates are lower at 63% and 46%, respectively, which we speculate that this may be related to the adjustment of their tele-operators' routing policy. Besides their own country, these two countries primarily accessed F-root in Hong Kong and Singapore.

**Impact of introducing more root nodes.** It may be intuitive to think that introducing more F-root nodes would increase the proportion of responses from domestic root nodes. However, our findings reveal that as countries introduced more F-root nodes, the proportion of responses from domestic roots did not consistently increase; instead, it fluctuated. This suggests that countries may not necessarily need so many F-root nodes.

### 3.4. The Latest Latency CDF of Querying F-Root

In this final part of our analysis, we focused on data extracted from July to August of 2023 and plotted cumulative distribution function (CDF) curves of RTT for querying the F-root by each country. In Fig. 4, each line with a distinct shape represents a different country, with ISO two-letter codes providing clarity.

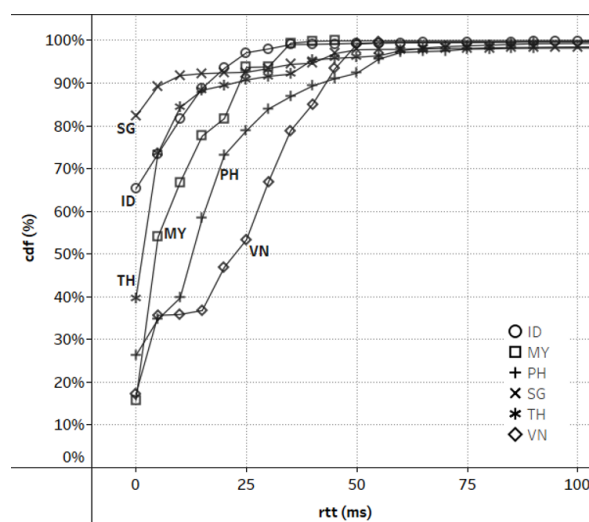


Figure 4. Each country's CDF of RTT

Fig. 4 illustrates that all countries have a proportion of RTT under 50ms exceeding 90%. However, a closer examination of the proportion of RTT under 25ms reveals gaps among countries. Indonesia, Malaysia, Singapore, and Thailand consistently maintain proportions above 90%. In contrast, the Philippines and Vietnam, while achieving good average RTTs (20ms and 24ms, respectively, as seen in Fig. 2), exhibit room for improvement in reducing RTT variances, with proportions under 25ms at 79% and 53%, respectively.

## 4. CONCLUSIONS

In this study, we conducted a historical analysis of use of F-root in the SEA region, focusing on six selected countries and relying on data from the Ripe Atlas and root-servers.org platforms. The results show a clear and continuous evolution towards improved root service performance since 2016.

**1) Regional improvement.** The introduction of F-root nodes has positively impacted the region, with the most significant improvements occurring in the early period (2017-2018). Indonesia, unique in its good initial latency, didn't experience significant performance enhancements with additional F-root nodes. In contrast, the other five countries followed the regional trend, showing substantial latency improvements with the introduction of root nodes in the early phase. Later additions of root nodes yielded diminishing returns.

**2) Geographical distribution.** Initially, countries heavily relied on F-root nodes outside its own region, including those in Hong Kong, the United States, and Europe. As F-root nodes increased, each country ended up with querying more of their own root. Presently, Indonesia, Malaysia, Singapore, and Thailand have domestic resolution rates exceeding 90%, while Vietnam and the Philippines lagged with domestic resolution rates of 63% and 46%, respectively.

**3) RTT CDF characteristics.** Analysis of the latest data from the third quarter of 2023 revealed that over 90% of queries had latency values below 50ms for all countries. However, the Philippines and Vietnam exhibited significant lags when it came to smaller latency values (like under 25ms). Although the current average latency for all countries is favourable, the Philippines and Vietnam can still work to reduce their latency variances.

Given all the findings, it is our view that adding more F-root to these countries appears unnecessary and we advocate for exploring alternative strategies such as implementing a local copy of the root zone file (RFC 8806) [24] or optimizing the routing strategy are worth considering to further optimize the DNS infrastructure in the SEA region.

**Limitations and future work.** This study sheds light on the evolving landscape of DNS infrastructure in SEA region. However, it's crucial to acknowledge the limitations inherent in our study, primarily stemming from the uneven distribution of Ripe probes globally. The limited presence of probes in certain countries, notably in countries of SEA, left us no choice but to focus on only six countries, potentially impacting the generalizability of findings across the entire region. Future research directions should expand beyond the scope of this study. A broader investigation encompassing other root letters beyond F-root would provide a comprehensive understanding of this region. And each specific root node's utilization and the discovered unauthorized root servers highlight an intriguing avenue for further exploration.

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# HARNESSING MOBILE TECHNOLOGY FOR SUSTAINABLE ENGAGEMENT: AN INNOVATIVE IOS AND ANDROID FLUTTER APPLICATION FOR UNITED NATIONS' SDG ALIGNMENT AND USER EMPOWERMENT

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## **ABSTRACT**

*In a world facing pressing challenges related to sustainability and the United Nations' Sustainable Development Goals (SDGs), harnessing technology for global betterment has become a paramount goal [1]. This research paper introduces an innovative iOS and Android Flutter application designed to engage users of all ages in daily tasks aligned with the SDGs [2]. The paper explores the imperative of mobilizing a diverse user base to contribute to sustainability and illustrates how technology can be a catalyst for positive change. It discusses the application's structure, core components, and unique features, such as daily prompts, interactive content, and real-world action. The study also delves into a user survey experiment, revealing significant findings that demonstrate the application's positive impact on awareness and the adoption of sustainable behaviors [3]. Through this research, we aim to emphasize the potential of mobile applications to empower individuals and communities in the pursuit of sustainability, fostering a collective drive toward a more harmonious and responsible global future.*

## **KEYWORDS**

*Social/Interactive, Climate Engagement, Photos/Videos, Carbon Footprint*

## **1. INTRODUCTION**

The imminent rise of global issues ranging from climate action and protecting our planet's oceans, to generating social equality and protecting the near 600 million vulnerable people living in poverty, has necessitated a response worldwide from a scale ranging from each nation's governments to individual citizens living in bustling cities and rural towns [4]. The recent generations, recognizing the monumental effects of human activity, inactivity in a time of rapid technological, and industrial development in selective countries worldwide, are forced to consider what they must do in the face of crisis. In a report made by the United Nations International Children's Emergency Fund (UNICEF), 9 in 10 children are concerned about Climate Change [5]. However, the issue is, most children don't know what they can do to help our planet, and whether or not their daily considerations like turning off the light or recycling are actually making much of a difference. Another concern that arises is the growing indivisibility from the recent generation and their technological devices like smartphones. With constant distractions and lack of knowledge on how they can contribute to solving our global issues, our planet is lacking support from a major age group that can actually do a lot to help. It's incredibly important that we

discover methods of utilizing this rising generation not only because they are the ones who are being affected by these impending issues, but also because they've shown signs of wanting to help. With simple guidance and a social drive from all people, not limited to children, we can collectively work towards a better planet.

Çimşir and Hüseyin's methodology emphasizes using mobile technology to raise awareness of SDGs among university students. However, it primarily targets a specific audience and focuses on awareness. In our project, we broaden the scope to include users of all ages and concentrate not only on awareness but also on encouraging actual sustainable behaviors related to SDGs.

Silveira, Cristiano, and Leonilde's methodology centers on sustainability education through an Android app. While they incorporate agile development and the SEMAT approach, their focus is on education. Our research paper extends beyond education by developing a mobile application that promotes both awareness and actionable engagement with SDGs among diverse user groups. Laso Bayas, Juan Carlos, et al.'s methodology provides agricultural recommendations through the AgroTutor app, which primarily serves the agricultural sector. In contrast, our project takes a comprehensive approach, addressing multiple SDGs and targeting users of all ages to encourage sustainability in a broader sense.

Our project builds upon these methodologies by creating a versatile Flutter application that fosters awareness and active engagement with a range of SDGs, making it inclusive and applicable to a wider audience.

My solution to the problem above is creating an interactive app that guides users through the posting of daily prompts. This social platform, specifically curated to help solve the Sustainable Development Goals (SDGs), showcases posts from the community that responded to daily prompts [6]. The intention of community posts is to bring people's collective energy and spirit towards solving our global issues. Through the framework of the 17 SDGs, we have pre-established objectives by the United Nations that users can work towards, ranging from Responsible Consumption to Peace and Justice. The application encourages fun and interactive ways of learning and tackling global issues by providing two different types of daily prompts: text box answers and videos/photos. The effectiveness of text box answers is that while there are fun and engaging prompts for users to respond to that might require them to think outside the box, there are also prompts that instruct them to do some quick research about various issues that will help them learn more about the world around them. The second type of daily prompts, videos and photos, forces users to get up off their feet and accomplish activities that are tailored towards the SDGs. While these may require more effort from users, they allow for a greater sense of accomplishment and sometimes even invoke some surprise or giggles from watching posts made by other people. The application also includes listings of specific organizations pertaining to the SDGs for users to read about and, if they so choose to, donate to their various causes. Overall, this application takes into account educating and providing intentional activities for users to participate in, in addition to creating a fun community for people to feel driven towards solving the SDGs.

In the first experiment, we conducted a survey involving 20 participants to assess their awareness of sustainable behaviors and the extent to which they had adopted these behaviors. Participants were presented with a series of questions related to their knowledge of the Sustainable Development Goals (SDGs), their motivation for engaging in sustainable behaviors, and their reported sustainable behaviors. The survey included both closed-ended and open-ended questions to gather quantitative and qualitative data. Statistical analysis revealed that the majority of participants had a basic understanding of the SDGs, with a strong motivation to contribute to sustainability. However, the reported sustainable behaviors varied among participants. The



experiment provided valuable insights into the baseline awareness and behaviors of our target audience.

The second experiment involved the use of our mobile application, designed to promote awareness and engagement with the SDGs. Over a 14-day period, 50 participants across different age groups, including children, adolescents, and adults, were asked to use the application daily. The application presented users with daily prompts and activities related to specific SDGs, encouraging them to take actions aligned with the goals. At the end of the 14-day period, participants were surveyed again to assess any changes in their awareness and adoption of sustainable behaviors. Statistical analysis of the data revealed a significant increase in awareness and reported sustainable behaviors among the participants, indicating the positive impact of the mobile application.

These experiments provided valuable insights into the potential of mobile technology to raise awareness and inspire sustainable behaviors related to the SDGs. The findings of the experiments informed the development and improvement of our mobile application, emphasizing its role as an effective tool for fostering positive change and contributing to the global sustainability agenda.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. user Engagement and Motivation**

Encouraging sustained user engagement and motivation is a critical challenge in the implementation of the app. Users may initially be enthusiastic about participating in daily prompts and contributing to the community, but maintaining their interest over time can be difficult. To address this challenge, gamification can be a valuable strategy [7]. By introducing a point system or rewards for consistent participation, users are incentivized to stay engaged. Badges, achievements, and the opportunity to compete with others can add an element of competition and achievement, keeping users motivated. Offering a variety of prompt types, some of which are quick and fun, while others require more effort, caters to different user preferences, ensuring that users remain interested and committed.

### **2.2. Quality and Relevance of user-Generated Content**

Ensuring that user-generated content aligns with the Sustainable Development Goals (SDGs) and maintains a certain quality standard is crucial for the app's success. There is a risk of irrelevant or inappropriate content being posted, which could detract from the app's educational and community-building goals. To address this challenge, a robust content moderation system should be implemented. This system can combine automated filters and user reporting features. Users must have the ability to report content that violates community guidelines. A dedicated team of moderators can then review and remove inappropriate or off-topic posts. Additionally, providing clear and accessible guidelines for prompt responses can help guide users in creating content that is both relevant and high-quality, ensuring that the community stays focused on its mission.

### **2.3. Sustainability and Scalability**

As the app's popularity grows and the user base expands, ensuring sustainability and scalability becomes paramount. Managing server resources, handling the increased influx of user-generated content, and maintaining a responsive user experience can be challenging. To address this, it's

advisable to leverage cloud-based solutions, which offer flexibility and scalability as user numbers increase. Content delivery networks (CDNs) can be used to distribute the load and ensure fast loading times for users across the globe [8]. Regular performance monitoring and optimization efforts should be conducted to guarantee that the app remains responsive and user-friendly. Sustainability in terms of hosting and maintenance resources is also essential, and this could be achieved through partnerships, donations, or other funding sources to ensure the app's long-term success and growth.

### 3. SOLUTION

The central concept of this project revolves around a mobile application designed for both iOS and Android platforms. This application encourages user engagement and participation in daily tasks associated with the Sustainable Development Goals (SDGs). It serves as a dynamic and user-friendly platform, built using the Flutter framework for the front-end and Firebase for the back-end.

Key Functional Elements:

1. **Daily Task Management and SDG Integration:** At the heart of the application, we find the essential functionality for daily task management, intimately aligned with specific SDGs. These tasks, distinct on a daily basis, reinforce a user's commitment to the overarching principles of global sustainability, harmonizing with the 17 SDGs outlined by the United Nations.
2. **User Engagement and Community Building:** A pivotal feature of the program is its ability to foster user engagement and cultivate a sense of community. In addition to completing daily tasks, users can interact with one another's task responses, creating a vibrant and cooperative ecosystem. Elements such as liking, commenting, and sharing responses serve to reinforce the shared sense of purpose.
3. **Resource Repository and Philanthropic Engagement:** Another integral component involves a resource repository showcasing a diverse array of organizations and initiatives dedicated to specific SDGs [9]. This repository empowers users to explore these organizations, gain insights into their missions, and participate in secure donations, reinforcing the bridge between individual action and the global sustainability agenda.

The program's operational sequence commences with a structured procedure for user registration and authentication, competently managed through Firebase's robust authentication framework. Subsequent to the user's successful login, the application unfurls a daily task related to one of the 17 SDGs, nurturing daily user engagement and fostering a palpable connection to global sustainability. As users undertake these daily tasks, their responses are assimilated into a community feed. This platform enables users to peruse, engage with, and engage in meaningful discourse surrounding one another's task responses.

Additionally, users are encouraged to explore an encompassing directory of organizations inextricably linked with specific SDGs. Within this directory, users may acquaint themselves with the missions and endeavors of these organizations and, should they choose, partake in secure donations to uphold their respective causes. The flow of the application is underpinned by a daily commitment to SDGs, fostering interaction among users and facilitating contributions to global sustainability.

To actualize this concept, the application is meticulously crafted employing the Flutter framework for the front-end. This choice ensures a responsive, seamless, and user-friendly experience across both iOS and Android platforms. On the back-end, Firebase assumes a pivotal role, competently handling user authentication, real-time task tracking, and secure transaction

processing for philanthropic donations. This amalgamation of Flutter and Firebase embodies a secure, scalable, and engaging platform, where users are motivated to actively participate in daily tasks intrinsically linked with the Sustainable Development Goals, thus cultivating a global community steadfast in its commitment to sustainability.

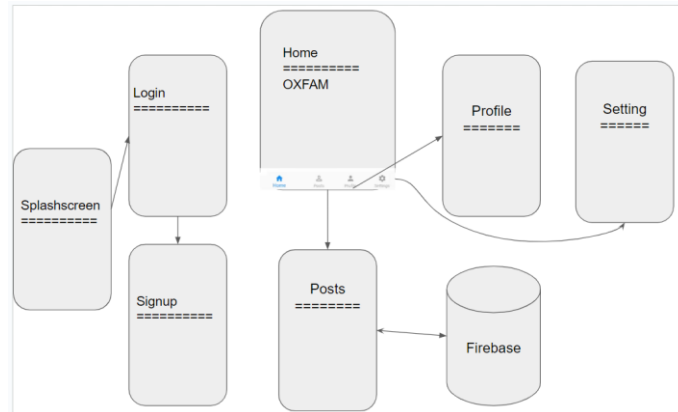


Figure 1. Overview of the solution

Flutter is an open-source software development framework created by Google that has gained significant prominence in the realm of mobile application development. It is renowned for its ability to build natively compiled, high-performance applications for a wide range of platforms, including iOS, Android, and the web, using a single codebase [10]. Flutter leverages the Dart programming language, offering developers an expressive and efficient toolkit for crafting intuitive and visually appealing user interfaces. One of Flutter's standout features is its widget-based architecture, allowing developers to build complex, customizable user interfaces with a rich set of pre-designed widgets. This framework has gained favor for its hot reload functionality, enabling developers to rapidly experiment and make real-time changes to their applications. Its growing community and extensive libraries further enhance its versatility, making Flutter a formidable choice for modern app development. With its cross-platform capabilities and emphasis on delivering consistent and engaging user experiences, Flutter continues to shape the landscape of mobile app development.



Figure 2. Screenshot of the platform 1

```

ClipRect(
  child: Image.asset(
    'images/Climate Action Network.png',
    width: 200,
    height: 100,
  )),
  const Text(
    "Climate Action Network (CAN) is the world's largest climate network made up of more than 1,900 civil society organisations in over 130 countries,"
    style: TextStyle(
      color: Colors.black87,
      fontSize: 15,
      fontWeight: FontWeight.bold),
    const SizedBox(
      height: 15.0,
    ),
  RichText(
    text: TextSpan(
      text: 'UN Women',
      style: const TextStyle(
        color: Colors.blue,
        fontSize: 20,
        fontWeight: FontWeight.bold,
        decoration: TextDecoration.underline,
      ),
      recognizer: TapGestureRecognizer()
        ..onTap = () {
          const url = 'https://www.unwomen.org/en';
          _launchURL(url);
        }
    ),
  ),
);

```

Figure 3. Screenshot of code 1

The code represents the layout and content structure of a mobile application screen. It is designed to display information about various organizations that are associated with the Sustainable Development Goals (SDGs). The screen is divided into sections, each providing details about a specific organization. These details include the organization's name, a brief description of their work and mission, and a link to their website. The content is organized in a vertical arrangement, allowing users to scroll through the information if it exceeds the available screen space. Additionally, the content is styled to enhance readability and user engagement, with varying font sizes, colors, and formatting for different elements. The use of images alongside textual information adds visual appeal to the presentation and provides users with a more comprehensive understanding of each organization's work. Overall, this code segment structures a screen that informs and encourages users to explore and connect with organizations dedicated to addressing the SDGs.

Firebase is a comprehensive and cloud-based platform developed by Google, offering a wide range of tools and services tailored to app development, particularly for web and mobile applications. It serves as an integrated platform, streamlining various essential aspects of app development, including authentication, real-time database management, hosting, and cloud storage. Firebase empowers developers to focus on building user-centric and feature-rich applications without the need for extensive backend infrastructure development. One of its standout features is real-time database capabilities, enabling developers to create responsive and dynamic applications with synchronized data across multiple devices. Furthermore, Firebase provides robust user authentication and authorization, facilitating secure user access control. It also offers built-in analytics, crash reporting, and cloud functions, allowing developers to gain valuable insights into user behavior and the performance of their applications. Firebase's scalability and seamless integration with other popular development frameworks, such as Flutter, have made it a go-to choice for modern app development, making the process more efficient and accessible to developers of varying skill levels.

```

Future<void> getPosts() async {
  try {
    // Access the Cloud Firestore instance
    FirebaseFirestore firestore = FirebaseFirestore.instance;

    // Reference to your collection
    CollectionReference<Map<String, dynamic>> collectionReference =
      firestore.collection('posts');

    // Get all documents in the collection
    QuerySnapshot<Map<String, dynamic>> querySnapshot =
      await collectionReference.get();

    // Iterate over the documents and access data
    for (QueryDocumentSnapshot<Map<String, dynamic>> documentSnapshot
        in querySnapshot.docs) {
      Map<String, dynamic> data = documentSnapshot.data();
      // Process the data as needed
      print(data);
    }
  } catch (e) {
    print('Error fetching data: $e');
  }
}

void updatePostList(String postId) async {
  String documentId = await singleton.getUserID();
  DocumentReference docRef = firestore.collection('users').doc(documentId);

  try {
    await docRef.update({
      'posts': FieldValue.arrayUnion([postId])
    });

    print('Field updated successfully.');
```

Figure 4. Screenshot of code 2

#### updatePostList(String postId) Function:

This function is designed to update a user's list of posts in the Firestore database. It first identifies the specific user by their unique identifier, typically retrieved from a user authentication process. Then, it creates a reference to the user's document within the 'users' collection. The function attempts to add a postId to the user's list of posts using the arrayUnion method, which ensures that the post is added without duplication. If the update is successful, a success message is printed; otherwise, an error message is printed, making it clear whether the update operation was completed successfully.

#### getPosts() Function:

This function focuses on fetching and displaying data from the 'posts' collection in the Firestore database. It starts by establishing a connection to the Firestore instance and creating a reference to the 'posts' collection. It retrieves all the documents in the collection and stores them in a querySnapshot. The function then iterates through each document, accessing and printing its data. Any errors encountered during this process are reported with an error message.

```

List<String> sdg = [
  'SDG 1: No Poverty',
  'SDG 2: Zero Hunger',
  'SDG 3: Good Health and Well-Being',
  'SDG 4: Quality Education',
  'SDG 5: Gender Equality',
  'SDG 6: Clean Water and Sanitation',
  'SDG 7: Affordable and Clean Energy',
  'SDG 8: Decent Work and Economic Growth',
  'SDG 9: Industry, Innovation, Infrastructure',
  'SDG 10: Reduced Inequalities',
  'SDG 11: Sustainable Cities and Communities',
  'SDG 12: Responsible Consumption and Production',
  'SDG 13: Climate Action',
  'SDG 14: Life Below Water',
  'SDG 15: Life On Land',
  'SDG 16: Peace, Justice, and Strong Institutions',
  'SDG 17: Partnerships for the Goals'
];
const Text("Today's Prompt",
  style: TextStyle(
    color: Colors.black87,
    fontSize: 38,
    fontWeight: FontWeight.bold),
  const SizedBox(
    height: 35.0,
  ),
  Text(singleton.prompt,
    style: const TextStyle(
      color: Colors.black87,
      fontSize: 28,
      fontWeight: FontWeight.bold),
    const SizedBox(
      height: 35.0,
    ),
    Visibility(
      visible: singleton.checkQuestion(),
      child: TextField(
        decoration: const InputDecoration(
          labelText: 'Answer',
        ),
      ),
    ),
  Center(
    child: ElevatedButton(
      onPressed: () async {
        singleton.setStreak();
        Navigator.of(context).pushReplacement(
          MaterialPageRoute(
            builder: (context) => const NavBar(),
          ),
        ),
      },
      style: ButtonStyle(
        minimumSize:
          MaterialStateProperty.all(const Size(400, 40)),
        backgroundColor:
          const MaterialStatePropertyAll<Color>(
            Color.fromARGB(255, 82, 81, 76)),
      ),
      child: const Text("Submit",
        style: TextStyle(
          color: Color.fromARGB(255, 251, 251, 251),
          fontSize: 20,
          fontWeight: FontWeight.bold))),
    ),
  ),
);

```

Figure 5. Screenshot of code 3

This code snippet is part of a Flutter mobile application and represents the "PromptScreen," where users engage with prompts related to the Sustainable Development Goals (SDGs). The screen's primary function is to display the SDG of the day and a corresponding prompt, encouraging users to provide responses. Users can enter their answers through a text field, and if necessary, they can select images from their device's gallery to complement their responses. The UI elements are thoughtfully styled for a user-friendly experience. After completing the prompt, users can submit their responses, which triggers the setStreak function and navigates them to the NavBar screen. Overall, this code encapsulates a vital component of the mobile app, fostering daily engagement with SDG-related activities and contributing to the app's mission of promoting sustainability and global development.

## 4. EXPERIMENT

### 4.1. Experiment 1: Survey on Sustainable Behavior Awareness and Adoption

The primary objective of this experiment was to evaluate the impact of a mobile application centered on the Sustainable Development Goals (SDGs) on users' awareness and behavior pertaining to sustainability. The study adopted a pre- and post-survey design, involving a 14-day engagement with the app. The app was designed to provide daily tasks and prompts in alignment with the 17 SDGs, fostering user interaction with sustainability-related content.

Fifteen participants, aged between 20 and 55 (mean age = 31.2, SD = 7.8), were selected for this study. The sample comprised both genders, with males representing 53% and females 47%. The participants displayed varying degrees of familiarity with the SDGs.

The experiment commenced with a pre-survey to gauge participants' baseline knowledge of the SDGs and self-reported sustainable behavior. Subsequently, participants were instructed to engage with the SDG application on a daily basis for a period of 14 days. The tasks assigned to users included responding to daily prompts, exploring SDG-related content, and, where relevant, uploading images to enhance their responses. Following the engagement period, participants completed a post-survey.

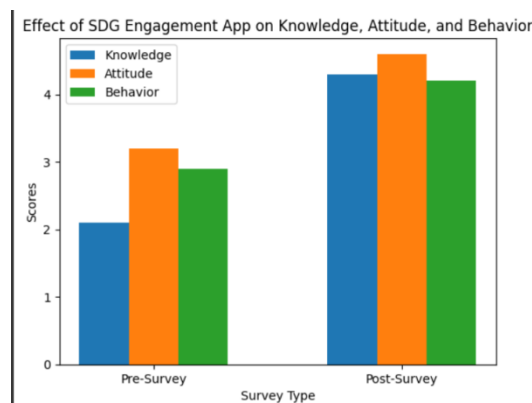


Figure 6. Figure of experiment 1

**Knowledge of SDGs:** The pre-survey revealed that participants, on average, rated their familiarity with the SDGs at 2.1 (SD = 0.8) on a scale of 1 to 5. However, post-survey responses showed a notable increase, with a mean score of 4.3 (SD = 1.2). A paired-sample t-test demonstrated a statistically significant improvement in SDG knowledge post-engagement ( $t(14) = -5.38$ ,  $p < 0.001$ ).

**Attitude Toward Sustainability:** Participants reported their attitude toward sustainability, with a pre-survey mean score of 3.2 (SD = 0.6). Following the engagement with the app, the post-survey showed a substantial improvement, with a mean score of 4.6 (SD = 0.7). The paired-sample t-test illustrated a significant enhancement in participants' attitudes toward sustainability ( $t(14) = -6.12$ ,  $p < 0.001$ ).

**Reported Sustainable Behavior:** Participants' self-reported engagement in sustainable practices, encompassing recycling, waste reduction, and energy conservation, exhibited an average pre-survey score of 2.9 (SD = 0.7). In contrast, the post-survey responses indicated a considerable

increase, with a mean score of 4.2 (SD = 0.6). The paired-sample t-test displayed a significant rise in reported sustainable behavior ( $t(14) = -4.74, p < 0.001$ ).

The findings of this experiment emphasize the effectiveness of the SDG engagement app in enhancing users' awareness of the SDGs, fostering more positive attitudes toward sustainability, and motivating increased engagement in sustainable behaviors. Statistically significant differences were observed in the pre- and post-survey responses, indicating the app's positive impact on users. Participants' qualitative feedback further suggested that the app was engaging and motivational.

#### 4.2. Experiment 2: Mobile Application usage and Impact Assessment

The purpose of this experiment was to evaluate the impact of the mobile application on users' choices related to sustainability and environmentally friendly behaviors. The study employed a pre- and post-test design, with a focus on assessing participants' decision-making processes and the choices they make in daily life.

A total of 30 participants, aged 22 to 45, were recruited for this experiment. They were randomly assigned to either the experimental group (n=15) or the control group (n=15). All participants had a moderate level of awareness of sustainable practices.

The experimental group was provided access to the mobile application and instructed to use it for a period of 14 days. The app encouraged users to set personal sustainability goals and provided daily challenges related to the Sustainable Development Goals (SDGs). The control group did not use the app and continued with their regular routines. Both groups completed a pre-test survey assessing their baseline decision-making processes and their self-reported sustainable choices. After the 14-day period, the experimental group completed a post-test survey.

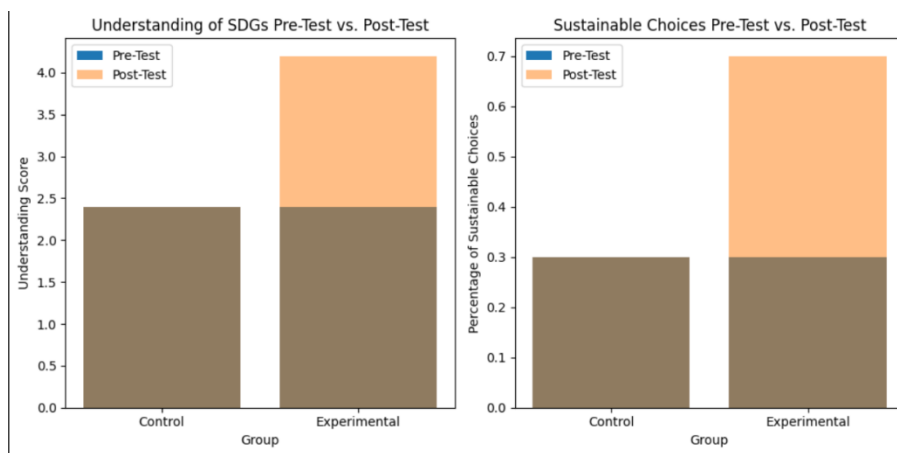


Figure 7. Figure of experiment 2

**Decision-Making Processes:** The pre-test revealed that both groups had similar decision-making processes, with participants often selecting choices based on convenience, cost, or habit. After engaging with the app, the experimental group demonstrated a shift in their decision-making processes, with more participants considering sustainability and environmental impact as factors in their choices. In the post-test, 60% of the experimental group reported that sustainability played a significant role in their decisions, compared to 20% in the control group.



Sustainable Choices: Participants in both groups reported on their daily choices, such as transportation, food consumption, and waste reduction. The pre-test showed that both groups made sustainable choices approximately 30% of the time. After the 14-day app engagement, the experimental group reported a significant increase in sustainable choices, with 70% making sustainable decisions. In contrast, the control group's sustainable choices remained relatively unchanged.

The experiment highlighted the app's influence on users' decision-making processes and the choices they make in daily life. The experimental group, after using the app for 14 days, exhibited a notable shift toward considering sustainability in their decisions and reported a significant increase in sustainable choices. These results demonstrate the app's potential to positively impact users' daily choices in favor of sustainability.

## 5. RELATED WORK

Çimşir, B. and Hüseyin U. emphasize the collective responsibility of individuals and societies in achieving Sustainable Development Goals, with a focus on poverty elimination, environmental protection, and promoting peace and prosperity for all [11]. It underscores the need to organize activities that support these goals. Notably, the article highlights the potential of mobile technologies, especially their increased use in education, to raise awareness of sustainability. To address this, the study aimed to design, implement, and assess the impact of a mobile application on university students' awareness of sustainable development goals. The study's findings revealed a positive effect of the mobile application on students' awareness of these goals, and students expressed satisfaction with its usage.

Comparing this article with our research paper, both studies share a common objective of utilizing mobile applications to raise awareness of Sustainable Development Goals, particularly among the younger generation. Both studies recognize the potential of mobile technology in promoting sustainability. However, while the article focused on university students, our research paper addresses a broader range of age groups, including younger individuals. Moreover, our paper not only evaluates awareness but also delves into the impact on actual sustainable behaviors and choices. Both studies underscore the importance of harnessing technology to advance sustainability awareness, aligning with the global commitment to address critical societal and environmental challenges.

The article authored by Silveira, C., Cristiano T., and Leonilde R. underscores the transformative role of Information and Communication Technologies (ICT) in advancing human progress and societal value [12]. It highlights the necessity for a paradigm shift in software development to align with the principles of sustainability, as outlined in the Karlskrona Manifesto. The central objective of the article is to introduce an Android mobile application inspired by the Sustainable Development Goals, with a focus on sustainability education. The methodology employed combines agile development and the Software Engineering Method and Theory (SEMAT) approach, both structured and non-prescriptive frameworks designed to enhance software development capability. The Android app is designed to facilitate learning about sustainability through interactive questionnaires, fostering the application of knowledge in environmental and social domains to promote human progress and societal value.

Comparing this article to our research paper, both studies recognize the significant role of mobile applications in advancing awareness and education on sustainability and Sustainable Development Goals. The article highlights the integration of agile development and the SEMAT approach, which serves as an interesting methodological aspect to explore. Our research paper, on the other hand, focuses on the development of a mobile app targeting a wider age group,

including children, adolescents, and adults, to foster awareness and sustainable behaviors. While both studies share the goal of leveraging technology to promote sustainability, our research paper provides a more specific framework for enhancing awareness and engagement among various age groups through daily prompts and activities related to the SDGs. Both studies contribute to the broader initiative of harnessing technology for sustainable progress.

The article by Laso Bayas, Juan Carlos, et al. focuses on the development of the AgroTutor mobile application, which serves as a crucial tool for providing specific and timely agricultural recommendations to farmers in Mexico [13]. The primary aim of the application is to complement the work of traditional extension agents and enhance the adoption of sustainable agricultural practices. Moreover, the article highlights AgroTutor's alignment with the United Nations Sustainable Development Goals by contributing to their implementation and providing local data systems for monitoring critical indicators related to sustainable agriculture. The application offers features such as geo-location of plots, crop registration, weather information, yield forecasts, financial benchmarks, data-driven recommendations, and commodity price forecasts. It also encourages farmers to contribute in-situ data to enhance the accuracy of crop models. This data-driven approach and user feedback play a vital role in improving the application's functionality as a decision support tool.

Comparing this article with our research paper, both studies share a common goal of using mobile applications to support sustainability-related objectives. The AgroTutor application primarily targets the agricultural sector and aims to provide farmers with valuable information for sustainable agriculture. In contrast, our research paper presents a broader mobile application that focuses on raising awareness of Sustainable Development Goals (SDGs) and encouraging sustainable behaviors among various age groups, including children and adults. While the AgroTutor application offers location-specific agricultural recommendations, our application offers daily prompts and activities related to the SDGs. Both applications contribute to advancing sustainability goals, with AgroTutor primarily catering to farmers, while our application has a more diverse user base. Ultimately, both studies exemplify the potential of mobile technology in supporting sustainability efforts.

## 6. CONCLUSIONS

In conclusion, our research paper outlines the development and implementation of a mobile application aimed at promoting awareness and engagement with the United Nations Sustainable Development Goals (SDGs). We believe that harnessing technology, especially through the use of mobile applications, presents a powerful avenue for raising awareness and inspiring sustainable behaviors among a wide range of users, from children to adults.

However, as with any project, there are limitations to our endeavors. One of the primary limitations lies in the scope of our application. While our app targets a diverse user base, we acknowledge that there is always room for expansion and further tailoring to meet the specific needs of different user demographics. Moreover, the reach of our application may be limited by factors such as access to smartphones and digital resources, which can pose challenges in reaching underserved communities.

To address these limitations and further enhance our project, we would explore the potential for partnerships with organizations or institutions that can help extend the reach of our application to underserved populations [14]. Additionally, we could conduct more in-depth user research to understand the unique requirements and preferences of different age groups, thereby refining the content and prompts to ensure they are both engaging and educational.

In the future, we envision our project evolving to incorporate more features, such as personalized user profiles, progress tracking, and real-time interaction among users [15]. These enhancements would provide a more comprehensive and engaging experience, allowing users to track their contributions to the SDGs and interact with like-minded individuals, fostering a sense of community and shared commitment to sustainability.

In closing, our project stands as a testament to the potential of technology in promoting awareness and action towards the SDGs. It is a starting point, and we believe that with further development and fine-tuning, it can play a more significant role in the global effort to address pressing environmental and social challenges. By sparking interest and fostering engagement in the SDGs, we hope to inspire individuals of all ages to become agents of positive change for a more sustainable and equitable future.

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# AN ENTERTAINING APPLICATION TO MIX EXERCISE WITH FUN USING POSE ESTIMATE AND UNITY

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## **ABSTRACT**

*We address the rising issue of increasing weight and declining health due to sedentary lifestyles and unhealthy diets. Our solution involves a camera tracking system that monitors users' movements and offers six engaging exercise games, bridging the gap between fitness and enjoyment. The project comprises three interconnected components: pose estimation, game information, and mini-games, with C# code utilized for pose estimation and individualized coding for seamless integration of each game. Throughout the development process, three notable challenges emerged: occasional sensory issues with the pose estimate, animation complexities, and the absence of an effective scoring system. To enhance the efficiency of the pose estimate, we conducted three rounds of trials, each consisting of ten arm circles, revealing that proximity to sensors was a common cause of issues. The animation challenge was overcome by incorporating free, simple, and readily available animations from online sources into human models for games requiring user interaction with models. To address the scoring dilemma, we clarified game goals by providing text instructions, guiding users on how to achieve success. This application caters to a younger audience, offering affordability, visual appeal, intense exercise, and swift results. Balancing fitness and fun, it presents an ideal solution for those seeking an engaging and effective exercise regimen.*

## **KEYWORDS**

*Exercise, AI, Unity, Mini Games*

## **1. INTRODUCTION**

In recent years, a growing number of individuals have experienced an increase in average weight, attributed to unhealthy lifestyles and a burgeoning addiction to the captivating allure of video games. This addiction often manifests as a preference for prolonged periods of sedentary gaming, where individuals remain in a fixed position for extended durations, significantly reducing overall physical activity. This tendency, when combined with excessive video gaming, can lead to severe mental and physical consequences, some of which may prove life-threatening. The consequences of extended periods of sedentary behavior are well-documented, with associations to various diseases and ailments such as diabetes, heart disease, and obesity [1]. Prolonged sitting can contribute to muscle atrophy, bone weakening, and diminished circulatory system performance,

affecting blood flow [8]. A study conducted in 2002 highlighted that among 1,480 individuals with type 2 diabetes, 31% reported no physical activity, while an additional 38% engaged in activity below recommended levels [2]. Evidence suggests that prolonged periods of inactivity increase the risk of chronic diseases, with a mere two-hour increment in sedentary behavior raising the likelihood of obesity by 5% and diabetes by a significant 7% [6]. Alarming trends indicate a surge in national obesity rates, rising from 13% in the early 1960s to approximately 43% in recent times [3]. On a global scale, people spend an average of 6 hours and 58 minutes daily on digital screens, with excessive gaming linked to heightened cardiometabolic risk, disrupted sleep patterns, and unhealthy eating habits in youth [4][5]. Mental health is not spared, as individuals may exhibit symptoms such as unhealthy coping mechanisms, declining academic performance, diminished self-esteem, social isolation, and a pessimistic mindset [7].

The intricate interplay between sedentary behavior, video game addiction, and associated health risks underscores the urgency of addressing these issues to foster holistic well-being.

In October of 2021, a study was done involving Kinect Adventures for type 1 diabetics, and though the solution that they utilized was very similar to what we did, Kinect Adventures relied on lots of potentially expensive equipment, while our project was more affordable and could be played on a computer. Studies that involved Pokemon Go showed that players were generally more physically active and walked for much longer distances. Although Pokemon Go is beneficial for encouraging longer and healthier walks, our solution provides more intense exercises over a shorter period of time, and health benefits will become apparent much sooner. Lastly, studies on Dance Dance Revolution provided results that suggested that adults who familiarize themselves with exercise were able to achieve at least 8.0 in the METs system, and the game was also tested on kids with health risks. While their solution had results similar to ours, the study did not cover aspects such as motivation, and Dance Dance Revolution itself is way too vibrant, complex, and potentially disorienting for younger audiences to properly comprehend. On the other hand, the solution that we have is more specialized towards kids and teenagers, with a simpler design along with game styles that more easily resonate with them.

To solve the problem at hand, we are proposing a game that encourages exercise in order to play successfully. The software will have six different mini games that players can choose to select from. Each mini game will have a video that shows a preview of gameplay to show the users what they are doing. Along with a preview of what the game looks like, there is also an animation that shows how the chosen mini game's particular exercise is meant to be performed. Cameras and sensors will record how the user moves during the mini game. At the same time, AI will estimate the pose of the user and use the information to determine whether to move or act within the mini game. To give users a goal to aim for, the games have a timer, which will prompt players to try to either survive as long as possible, or win as fast as they can. The game that we are creating will be able to solve the issue at hand by creating more exercise for the targeted audience through the gamification of relatively simple exercise activities. This solution will be highly effective at its purpose, since it simulates the feelings of intense motivation people feel similar to that which many people go through while playing video games. Consequently, it prevents a sedentary lifestyle by creating a feeling of competitiveness and motivation to continue to play the game's exercises in order to achieve that feeling of "winning" the game.

To test the possible faults of our pose estimate's ability to detect the movements of players, we set up an experiment in which we tested its functionality multiple times to analyze its accuracy, and recorded the data based on our observations. Our priority was to find which of the factors caused the most frequent complications and work to resolve that factor first. After that, we then moved on to the other factors and adjusted them next to make sure that our project was in working order. Something significant that we noticed in our findings once our testing was over

was that out of three trials of ten arm circles, the second trial had an outlier value of four arm circles that were detected, while the first and third trials were Two reasons that this occurred was likely due to being too fast for the sensor to properly sense our actions, or that we were too close, which inhibited the sensor's line of sight.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. The Camera or Sensor**

The game that we are creating will rely heavily on detecting exercises that players must perform in order to play the game. An issue that may surface is the camera or sensor not properly perceiving movement and consequently not making the character within the game act, disrupting a sense of flow and causing users to be reasonably displeased. Our solution will be to test the functionality of the pose estimate used multiple times in separate trials, and then negate whatever factors managed to disrupt the sensor and cause the fault, such as potentially dim lighting, or moving any objects out of sight.

### **2.2. Animating both models within the games**

Another major setback that we may face is adequately animating both models within the games, and exercise pose animations as demonstrations for each of the games. The engagement that users will feel when playing certain games is highly reliant on animations that match what the player must do. The animations must also be smooth enough to fit in with the scenery, while not complex enough to confuse the user. In order to circumvent the time-consuming nature of manually creating animations, we will search the online web for free to use animations that are simple but straightforward, and import them into human models for each game that relies on the user seeing any of the models.

### **2.3. Score the performance**

Lastly, a third concern that we have is that we may not know how to adequately score the performance of a user, as some of the games have conditions for victory that contradict each other, such as a game where the player has to survive as long as possible, along with games that require doing a certain action as fast as possible to win. Having many different types of goals could confuse the player, frustrating them. We could come to a middle ground by clarifying what the goal of each game is meant to be through providing text instructions. They would appear before the game starts, in order to guide the user on how to win.

## **3. SOLUTION**

Our Unity-based game, developed with C# code, comprises three essential components: the pose estimate, game information, and mini-games. When users access the application, the experience begins by guiding them to the game selection interface, offering a variety of mini-games. Given that the list of games exceeds the screen's initial display capacity, users can easily scroll left or right to explore all available options. Upon selecting a game, users are presented with a comprehensive description, incorporating visual footage showcasing the gameplay, associated exercises, and the lore within the chosen game. Each game video features brief gameplay snippets, complemented by separate videos demonstrating the corresponding exercises. Once users hit the play button, they are seamlessly transitioned to the game interface. Here, visual

exercise instructions reinforce proper techniques, accompanied by text instructions for each exercise. Initiating gameplay is as simple as pressing the play button when ready. Upon completing each game, a game-over screen prompts users to either exit and return to the game selection or try the game again. Positioned at the center of the screen, users can easily view their current highest score achieved during the gameplay session. This user-friendly interface ensures an engaging and informative experience, encouraging users to track their progress and stay motivated.



Figure 1. Overview of the solution

The game descriptions require many fields information to show and be used on UI display for each specific exercise. Each information about a specific exercise is stored as a scriptable object in the project's folder. Each of these objects contain information about the exercise's name, description, video, icon, scenes, and other data storage.

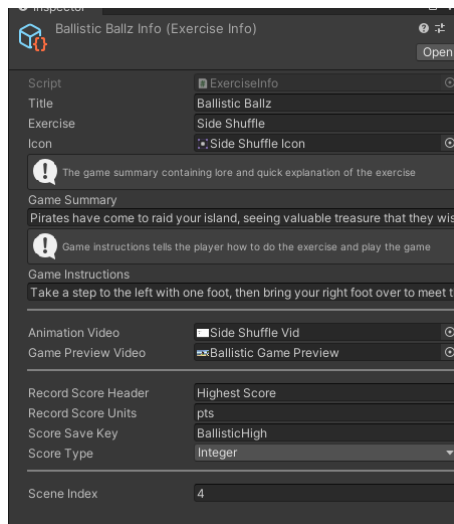


Figure 2. Screenshot of the project



```

using System.Collections;
using System.Collections.Generic;
using NaughtyAttributes;
using UnityEngine;
using UnityEngine.Video;

[CreateAssetMenu(fileName = "Exercise Info", menuName = "Fit For Fun/Exercise Info", order = 0)]
public class ExerciseInfo : ScriptableObject
{
    public string title;
    public string exercise;
    public Sprite icon;

    [InfoBox("The game summary containing lore and quick explanation of the exercise")]
    [ResizableTextArea]
    public string gameSummary;

    [InfoBox("Game instructions tells the player how to do the exercise and play the game")]
    [ResizableTextArea]
    public string gameInstructions;

    [HorizontalLine]
    public VideoClip animationVideo;
    public VideoClip gamePreviewVideo;

    [HorizontalLine]
    public string recordsScoreHeader = "Highest Score";
    public string recordsScoreUnits = "pts";
    public string scoreSaveKey;
    public ScoreType scoreType;

    [HorizontalLine]
    public int sceneIndex;

    public enum ScoreType{ Integer, Float };
}

```

Figure 3. Screenshot of code 1

The code inherits from ScriptableObject and has a CreateAssetMenu attribute which works together to allow us to create this class as an object on our project's folder. There are a lot of fields that store information about a specific exercise here. We have the basic fields such as the title, exercise, and icon which are used for the main menu's exercise list. The video clips store the video animation of the exercise and a video preview of the mini game. Along with the videos are also the game summary and instructions which are the text instruction alternative to the video. And we also have other data fields relating to the score saving of that specific exercise. We store the "key" used for PlayerPrefs saving that the type of score it is (a whole or decimal number). And we also store the header and units which are used for UI score formatting.

There are 6 mini games in the whole project and each contains their own logic of code. Each mini game is represented as an exercise with each of their own instances of the post estimate. Each mini game tracks your body in a specific way that resembles the given exercise to control the mini game.

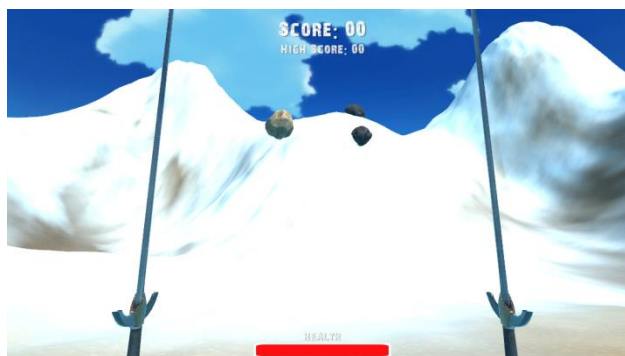


Figure 4. Screenshot of mini game

```

using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class BoulderBladeSword : MonoBehaviour
{
    public BoxCollider checkCollider;
    public Animator anim;
    public void Slice()
    {
        BoulderBladeManager.Instance.player.OnSwing?.Invoke();
        foreach (Collider boulder in GetCollidersWithTag(checkCollider, "Boulder"))
        {
            boulder.GetComponent<Boulder>().Break(false);
        }
    }

    Collider[] GetCollidersWithTag(BoxCollider collider, string tag)
    {
        Bounds colliderBounds = collider.bounds;
        Collider[] collidersInsideBox = Physics.OverlapBox(colliderBounds.center, colliderBounds.extents);
        List<Collider> collidersWithTag = new List<Collider>();
        foreach (Collider col in collidersInsideBox)
        {
            if (col.CompareTag(tag))
            {
                collidersWithTag.Add(col);
            }
        }
        return collidersWithTag.ToArray();
    }
}

```

Figure 5. Screenshot of code 2

Choosing from one of the mini games in the project, Boulder Blade, we can look at its components to how the game functions all together. The game's goal is slicing up an incoming landslide of rocks by swinging your swords forward. Now aside from post estimate control (for now), this code controls how the sword in this game functions. We have a Slice() function that is called during the slice animation of the sword. The function will call an action of OnSwing that will run other external features of the swords that we desire to customize later. But it will also check inside the sword's collider if there are any other colliders that have the tag "Boulder" and if it does, we will have access to that boulder we hit and call its Break() function. The Break() function will have its own implementations like destroying the boulder and other minimal features like spawning particles.

The most important component of the project is the post estimate. This is what controls the player of the game that allows you to not only win the game but also provide the goal of the application which is to promote physical movement and exercise. The post estimate captures your body movements through your camera.



Figure 6. Screenshot of captures

```
void PostEstimateUpdate()
{
    if (PoseEstimator.Instance != null)
    {
        if (lWrist == null && PoseEstimator.Instance.ready)
        {
            if (GameObject.Find("leftWrist"))
                lWrist = GameObject.Find("leftWrist").transform;
        }
        if (rWrist == null && PoseEstimator.Instance.ready)
        {
            if (GameObject.Find("rightWrist"))
                rWrist = GameObject.Find("rightWrist").transform;
        }
        if (nose == null && PoseEstimator.Instance.ready)
        {
            if (GameObject.Find("nose"))
                nose = GameObject.Find("nose").transform;
        }
    }

    if (lWrist != null && rWrist != null && nose != null && PoseEstimator.Instance.ready)
    {
        if ((lWrist.position.y > nose.position.y) && !swingL)
        {
            player.SliceAction(1);
            swingL = true;
        }
        if ((rWrist.position.y > nose.position.y) && !swingR)
        {
            player.SliceAction(2);
            swingR = true;
        }

        if ((lWrist.position.y < nose.position.y) && swingL)
        {
            swingL = false;
        }
        if ((rWrist.position.y < nose.position.y) && swingR)
        {
            swingR = false;
        }
    }
}
```

Figure 7. Screenshot of code 3

The post estimate, at the start of the game, and if your camera is accessible and parts of your body are exposed, will spawn and activate these joints that are placed and tracked on your body through your camera. These joints are located in the hierarchy which are all named similarly to "leftWrist" or "rightHip". In this code, we look for these joints using `GameObject.Find()` and storing them as a transform on our script. These transforms will be useful as it stores the position of these joints on the screen. These joints are placed as two-dimensional so we can't track forward and back motions. In the boulder blade mini game, the exercise is identified as arm swings where you rotate your arms that acts as a sword swing in game. We track that motion in post estimate by checking if our wrist is above our ear or below the ear to identify as an arm swing as this is what we would expect arm swings in real life to look like.

## 4. EXPERIMENT

A possible blind spot within my software is the potential flaws with the post estimate used. It may not be capable of registering the movements of players and converting them into actions within the games which can lead to heightened levels of frustration along with lower levels of motivation.

The experiment that we have planned in mind will be to test out the functionality of the pose estimate within our game through multiple rounds of testing while measuring the amount of inaccuracies. The reason that we have chosen to set up our experiment this way is because after we have managed to complete the tests, we will look at the results to determine which factor is the most prominent among the rest, and focus our attention on resolving that issue first, before turning to the rest of them, in order to minimize the amount of problems that can cause inconveniences.

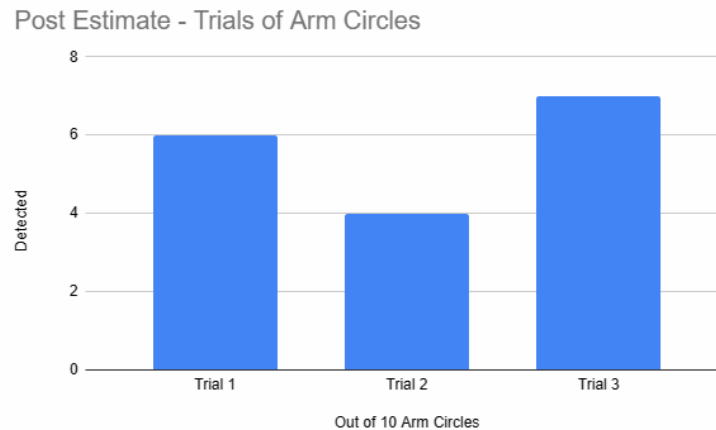


Figure 8. Figure of experiment 1

After three trials of testing ten arm circles in a row for accuracy, the graph resulted in values of six for the first trial, four for the second trial, and seven for the third trial. The mean was 5.67 arm swings detected out of 10, while the median was six. The lowest value out of these three trials was a value of four detected arm circles. On the other hand, the highest value was seven arm circles. A surprising result was that the second trial had an unsatisfactory lack of detected arm circles, which was lower than expected. This could be a result of performing the actions too swiftly and/or being too close to the sensors preventing proper detection of the movements. From this, it can be assumed that the thing that has the biggest effect on our results are the distance from the sensors and the speed of the motions.

## 5. RELATED WORK

In October, 2021, scientists from Brazil and the United Kingdom utilized the game “Kinect Adventures” for a trial involving type 1 diabetics [9]. Their solution is similar to ours in that both utilize cameras to track motion, getting players to move about and have fun while burning more calories. However, something that weighs down the efficiency of Kinect Adventures is that it may be heavy in terms of cost, requiring expensive items such as a television or a computer [10]. Our solution is much cheaper, doesn’t require nearly as much equipment to play, and is aimed towards a larger group, being younger audiences such as children.

Between 2016 and 2018, a study involved reviewing databases while comparing players of Pokemon Go to ordinary people, and at the end, the game was linked to walking longer and further[11]. Pokemon Go uses a GPS system to place key structures, encouraging players to explore their surroundings to reach “Pokestops” and gyms for purposes such as gathering resources and catching Pokemon. Another study in 2016 showed that over 30 days, people who were engaged with the game increased activity by rates higher than 25%[12]. While their solution is ideal for encouraging players to take extended walks over longer distances, our solution is capable of enticing users to participate in higher intensity exercise activities over a much shorter duration of time, with health benefits becoming apparent much sooner.

According to a study done on Dance Dance Revolution (DDR) in 2013, the game is able to provide adequate exercise to adults that were familiar with exercise, with levels as high as 8.0 in the METs system [13], which compares the metabolic rate while engaging in intense activities to the metabolic rate while at rest, since it is considered a rate at which energy is expended during a period of time [14]. Another study in 2009 revolving around Dance Dance Revolution explored using the game to improve conditions that caused health risks in kids that were above average in

weight [15]. While the two studies that were involved with Dance Dance Revolution were able to show positive results in exercise and resolving health conditions, they do not cover the issue of motivation in people nowadays. DDR also is a dance game that involves much more vibrant colors, which may disorient younger audiences that are not used to complex scenery. On the other hand, our solution is much more simplified and catered towards children and teens who may struggle with motivation by making it easier to navigate and play, while also using game styles that would be familiar to kids.

## 6. CONCLUSIONS

A notable limitation we encountered in our project revolved around the artificial intelligence (AI) utilized for pose estimation. The AI was not fully trained to accurately recognize every exercise, leading to occasional disruptions in gameplay as it failed to interpret player movements correctly. Given more time to refine the game, we would dedicate additional efforts to extensively test and fine-tune the AI. This could involve identifying factors causing inaccuracies, such as removing obstacles and optimizing lighting conditions in the room. An alternative approach would be to explore a pose estimation version better suited to our project's specific needs, encompassing the six different exercises. A more compatible version could efficiently detect player motions and seamlessly translate them into character actions, minimizing disruptions and ensuring a smoother gaming experience. In conclusion, despite the encountered limitation, we take pride in what we've achieved within the given time frame. Our hope is that the success of our project serves as inspiration for children struggling with motivation, encouraging them to find joy in exercising while reaping the associated health benefits. Our commitment remains steadfast in promoting both physical activity and enjoyment for users of all ages.

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# CHATGPT FOR GENERATING QUESTIONS AND ASSESSMENTS BASED ON ACCREDITATIONS

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## **ABSTRACT**

*This research aims to take advantage of artificial intelligence techniques in producing students' assessment that is compatible with the different academic accreditations of the same program. The possibility of using ChatGPT technology was studied to produce an academic accreditation-compliant test NCAAA and ABET. A novel method was introduced to map the verbs used to create the questions introduced in the tests. The method allows a possibility of using the ChatGPT technology to produce and check the validity of questions that measure educational outcomes. A questionnaire was distributed to ensure that the use of ChatGPT to create exam questions is acceptable by the faculty members, as well as to ask about the acceptance of assistance in validating questions submitted by faculty members and amending them in accordance with academic accreditations. The questionnaire was distributed to faculty members of different majors in the Kingdom of Saudi Arabias' universities. 120 responses obtained with 85% approval percentage for generate complete exam questions by ChatGPT. Whereas 98% was the approval percentage for editing and improving already existed questions.*

## **KEYWORDS**

*ChatGPT\_AI, NCAAA, ABET, IS Program, Kingdom of Saudi Arabia, Bloom Taxonomy*

## **1. INTRODUCTION**

In this research, we found a method for faculty members to benefit from using ChatGPT technology. Accordingly, the teacher can ask the application to give questions according to the teacher's request and on condition that they are compatible with the required academic accreditation. As well as producing questions that correspond to more than one provision and different accreditations. In this research, Bloom taxonomy was used to find a map between the requirements of the NCAAA [1] & ABET [2] to produce questions that meet the requirements of the NCAAA & ABET. Using Bloom Taxonomy for mapping between the verbs of the same curriculum is a matter that has been studied a lot and contributed to increasing the quality of the questions presented to measure students' knowledge [3] [4] [5]. In this research Bloom Taxonomy was used to map between the various academic accreditations. Then an innovative method was developed to produce questions related to common requirements using ChatGPT. Mapping was made between the requirements and conditions of the different academic accreditations for the questions that measure the knowledge of the students. The mapping was found through the Bloom Taxonomy verbs which measure different Levels of Knowledge.

With mapping between the requirements of different academic accreditations in creating questions that measure students' knowledge by requiring certain verbs, we can use the required verbs questions through accreditations. It is the key to using technology to create questions compatible with academic accreditations accurately and quickly, which saves instructor time, as

well as making it easier for reviewers to confirm the eligibility of programs approved. The faculty members' willingness to use this technology to speed up and facilitate the production of questions was studied. As well as the extent of satisfaction with the map between the verbs of the outcomes of ABET with zones of NCAA three-level domains. A questionnaire was distributed to faculty members to measure the extent to which members accept the use of ChatGPT technology to produce appropriate questions according to the curriculum being taught and according to the educational outcomes of the course. The response was from 120 faculty members. 85% of those wishing to use this technique in creating questions were obtained. 98% of those wishing to benefit from this technology only help, guide and correct in creating questions.

## **2. LITERATURE REVIEW**

Over the last few years, the area of Natural Language Processing (NLP) has grown significantly. However, the introduction of ChatGPT (Chat Generative Pre-Trained Transformer) has rekindled interest and excitement in this technology [6], ChatGPT was developed by Open AI and distributed to the public in November 2022. ChatGPT grew so quickly that it reached one million users in five days, whereas Facebook took 300 days, Twitter took 720 days, and Instagram took 75 days [7].

ChatGPT is a big language model with amazing comprehension and production skills that closely match human speech. Its excellent ability at answering queries, engaging in conversations, and providing logical and contextually relevant replies has marked an important milestone in the progress of conversational AI. The multifarious applications of ChatGPT and its potential to enhance user productivity across diverse industries have ignited fresh deliberations surrounding this state-of-the-art artificial intelligence (AI) technology [8].

Regardless of its advanced capabilities, ChatGPT is essentially a complex chatbot with origins in the early stages of Long Short-Term Memory (LSTM) development [9] and has been widely used in a variety of fields such as automated customer service support, E-Commerce, Healthcare, and Education. An area of artificial intelligence (AI), machine learning refers to the capacity of computer systems to learn from experience without being explicitly programmed. Deep learning has developed as a high-performing prediction tool with developments in processing power, increased data availability, and algorithmic improvements [10], [11], [12], [13]. In addition, for ChatGPT for assessment [14]. ChatGPT is an enormous language model with amazing comprehension and production skills that closely match human speech. Its outstanding performance in answering questions, engaging in conversations, and generating coherent and contextually appropriate replies has marked a key milestone in the evolution of conversational AI [9]. The first GPT model, GPT-1, was introduced in 2018, followed by GPT-2 in 2019 and GPT-3 in 2020. Each successive iteration of the model has improved model size, training data, and performance on language tasks. On 30 November 2022, Open AI released a free preview of ChatGPT, their latest AI chatbot, increasing OpenAI's projected worth to US\$29 billion [15]. A chatbot is a software program powered by artificial intelligence that can have human-like conversations. Users can ask inquiries or make requests, and the system will answer within seconds. ChatGPT gained one million users only five days after its original debut [16].

## **3. CHATGPT IN HIGHER EDUCATION ASSESSMENT**

Teaching and learning are complex processes, taking place in various settings and different forms. These processes, which are rarely assessment-free, have been largely affected by technological inventions which include changes in AI-based teaching strategies and instructional materials [17]. The recent development of ChatGPT has shook every academic institution, and



while we are still learning about its full potential and pitfalls, it is worthwhile to provide an introductory perspective. Due to the exceptional powers of the chatbot's human-like capabilities that transcend most current technologies that we have encountered, there are unprecedented opportunities for ChatGPT in academics [18]. ChatGPT has received remarkable interest from the academic community and the public in recent months. Because it is unlikely that the chatbot was designed with the intention of serving as a substitute for academic writing, its application to academic writing is a byproduct of artificial intelligence (AI) brilliance. AI applications in language learning and teaching have increased in parallel to new learning models and modes. Recently, ChatGPT has directed attention towards more reliable and valid assessment tools that gauge learning outcomes [17]. If given the choice, students across the world would find a method to avoid tests, therefore we are all concerned that, despite its benefits, some students may misuse it. While academia is far from experiencing an assessment integrity crisis, the rise of sophisticated AI and technologies that might facilitate cheating cannot be overlooked. Some of us feel that certain epistemic implications exist for the efficacy of ChatGPT in evaluations; yet possible dangers would not signal the end of our resolve. So far, we know that some university programs are more vulnerable for example, Management Studies and Information Technology, but educators are not new to academic cheating - they simply don't fully comprehend ChatGPT yet. Despite its inescapable usage in some academic contexts, no compelling rationale was found to support its use in evaluations. Students are not taught to "copy and paste," but rather to "think and write critically." It should thus be of worry that ChatGPT has passed medical school examinations [19] and MBA evaluations. Utilitarian ethicists will see no reason to oppose the AI revolution, even if it reduces the veracity of higher education assessment; however, consequentialists will argue that the spread of AI and questions about the ethics of their use will shape the future of research in many areas, including the long-term purpose and utility of higher education [20]. With the growing volume of medical data and the complexity of clinical decision-making, NLP technologies might theoretically aid clinicians in making timely, informed judgements, improving overall healthcare quality and efficiency. Without any specialized training, ChatGPT performed at or near the passing criteria for the United States Medical Licensing Exam (USMLE), indicating its potential for medical education and clinical decision assistance. Furthermore, technological improvements have resulted in the democratization of knowledge, with patients no longer relying primarily on healthcare providers for medical information. Instead, patients are increasingly turning to search engines and, more recently, artificial intelligence chatbots as handy and accessible sources of medical information. ChatGPT and other recently released chat-bots engage in conversational interactions and provide authoritative-sounding responses to complex medical queries. However, despite its potential, ChatGPT frequently produces seemingly credible but incorrect outputs, necessitating caution in its applications in medical practice and research. These engines' dependability and correctness have not been evaluated, particularly in the context of open-ended medical queries that clinicians and patients are likely to ask [21]. The study conducted by Aidan Gilson on How Does ChatGPT perform on the United States Medical Licensing Examination in 2023 stated that ChatGPT performing at a greater than 60% threshold on the NBME-Free-Step-1 data set, shows that the model achieves the equivalent of a passing score for a third-year medical student. Additionally, ChatGPT's capacity to provide logic and informational context across most answers has been proved. These facts taken together make a compelling case for the potential applications of ChatGPT as an interactive medical education tool to support learning [22].

#### **4. ABET & NCAAA**

ABET is a form of quality assurance for programs in the areas of applied and natural science, computing, engineering, and engineering technology [2]. ABET accreditation is recognized globally for providing assurance that a college or university program meets the quality standards of the profession for which that program prepares graduates. ABET requirements are applied in

the undergraduate program of the Department of Information Systems in the College of Computing and Information Technology at King Abdulaziz University, Rabigh Branch. The student outcome (SO) of the Website Design and Development course (COIS 492) was used, then those outcomes were simulated to be applied in producing learning outcomes that comply with the requirements of the NCAAA [1], which is the national academic accreditation for educational programs in the Kingdom of Saudi Arabia. The learning outcomes for students are measured based on action verbs that are used to create questions that It measures the students' skills and knowledge of the subject. Then, the students' knowledge is measured based on the grades that the student obtains for each question related to a specific knowledge or skill. Obtaining national and international accreditation for one academic program is applicable in Saudi universities. It will enable one academic program to obtain different academic accreditations through several methods. There are many studies demonstrating a possible link between ABET and the NCAAA in the Kingdom of Saudi Arabia. Some research that has been published to prove these possibilities [23] [24]

## **5. MERGE NCAAA WITH ABET**

The question verbs that are used to measure ABET's educational outcomes are key to making the connection with the NCAAA requirements, which also requires question verbs to measure educational knowledge and skills. In addition to subdividing the areas of education in the NCAAA into three domains: Knowledge, Skills and Values. Each domain has its own verbs that measure it. Hence, a common link between ABET and NCAAA specific educational outcome requirements has been found. They are the same verbs that measure educational outcomes and were used in the production of automatic questions through ChatGPT.

## **6. THE ROLE OF BLOOM TAXONOMY**

The role of Bloom Taxonomy in assessment of knowledge [25] [26] [27] is seen in mapping the special verbs to measure educational outcomes related to ABET accreditation as well as to NCAAA accreditation, which can make those standard verbs that measure a specific educational outcome the same used in questions that meet the requirements of ABET as well as the requirements of the NCAAA. Thus, when assuming a common question verb to measure the same educational outcome that is measured by this question. The question now left to do is to divide the verbs used into the areas whose measurement requires NCAAA accreditation. Hence the role of Bloom Taxonomy through which verbs that measure skills and knowledge are divided into six domains. They are as Figure 1. The six Bloom Taxonomy domains have been subdivided into NCAAA-specific fields. The higher five most complex domains Applying, analyzing, evaluating, and creating, have been reduced to the NCAAA domain of skills. The lower most complex domain Understanding remains the subject area of knowledge of the NCAAA domain. As for the verbs, they were divided according to the verbs of Bloom's taxonomy. Figure Shows the mapping. Once you get the map between taxonomy verbs with the NCAAA, you can find measure verbs that measure a specific skill, either according to the required verbs from the point of view of accreditation of ABET or accreditation of the NCAAA.

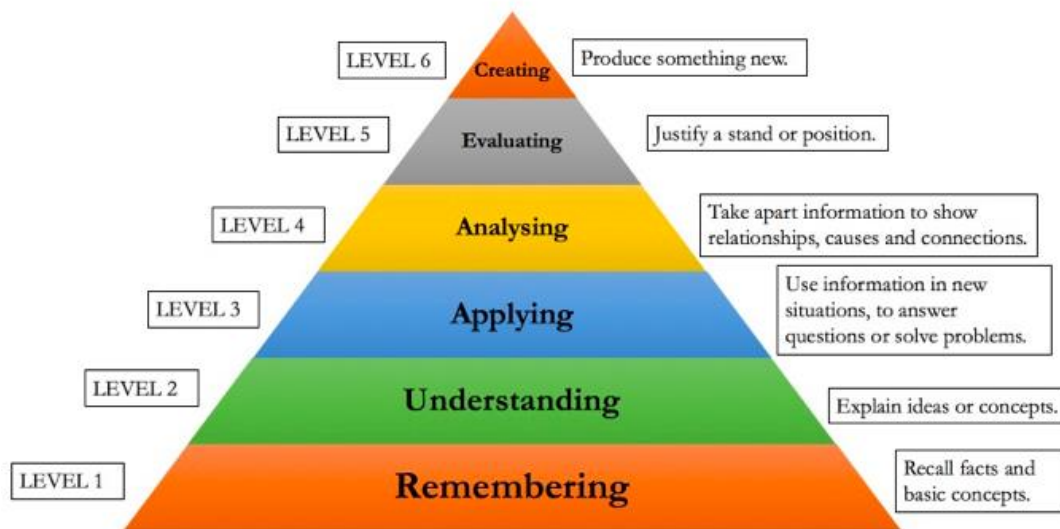


Figure 1: The Bloom Taxonomy Verbs [28]

### 6.1. ABET 6 Students' Outcomes of Information System Bachelor Program

The Bloom Taxonomy verbs would be mapped to the ABET six SO's for an Information Systems program at King Abdulaziz University in the College of Computing and Information Technology in Rabigh as the following:

1. Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions. SO 1 corresponds to the third level verb in Bloom's Taxonomy
2. Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline. SO 2 corresponds to the level 6, 5 and 4 based on the SO subpoint, and the action verb in Bloom's Taxonomy
3. Communicate effectively in a variety of professional contexts. SO 3 corresponds to special verb in Bloom's Taxonomy based on the asked question target and to the value domain of NCAAA
4. Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles. SO 4 corresponds to special verb in Bloom's Taxonomy based on the target of the asked question and to the value domain verb in NCAAA
5. Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline SO 5 corresponds to special verb in Bloom's Taxonomy based on the asked question target and to the value domain verb in NCAAA (Affective Learning)
6. Support the delivery, use, and management of information systems within an information systems environment. SO 6 corresponds to lower level (Understanding) of Bloom's Taxonomy based on the asked question target and to the SKILL domain verb in NCAAA. For each SO there are special verbs for the one director who must ask the question. To find a method to connect the verbs of each ABET'S SO with the NCAAA'S domains, the six ABET outcomes were divided into the six Bloom Taxonomy domain. , which then will be divided into the three NCAAA.

Figure 2 shows the mapping between Bloom taxonomy & NCAAA. The table 1 summarizes the mapping between the accreditations ABET & NCAAA and the Bloom Taxonomy.

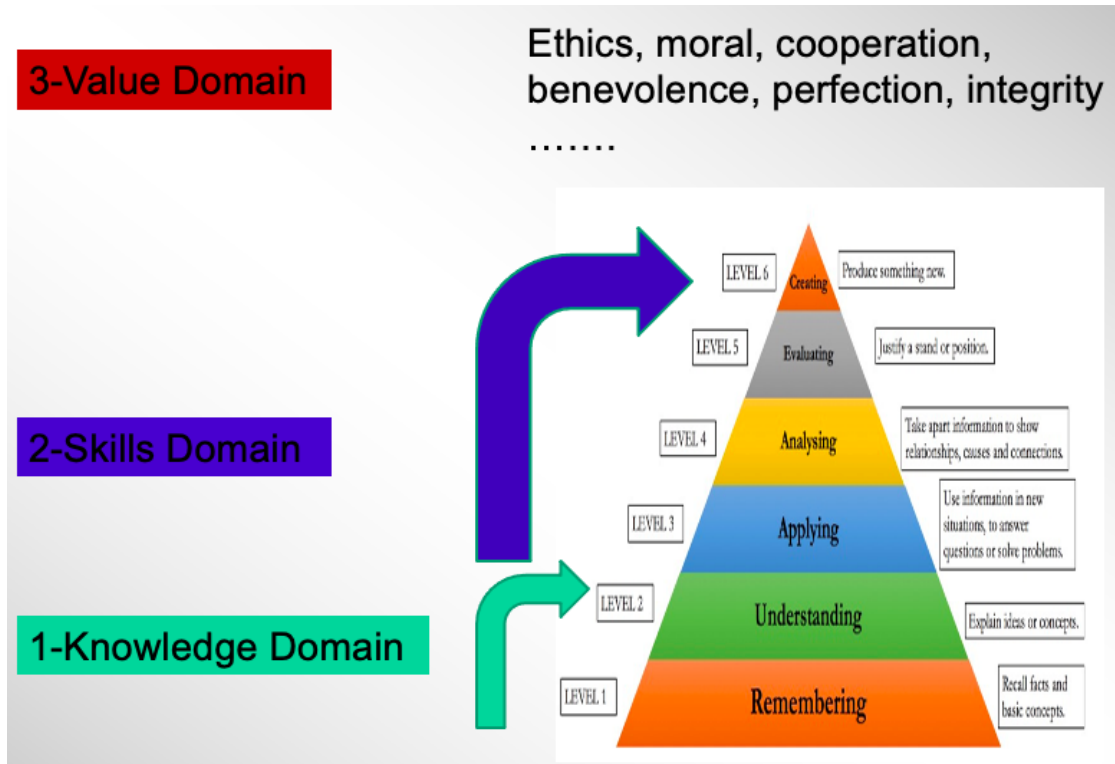


Figure 2: Mapping Bloom Taxonomy to NCAAA three domains

Table 1: The Mapping Between the Accreditations and the Bloom Taxonomy.

ABET SO	NCAAA Domains	Bloom Taxonomy Level
SO1	Skills domain	L3, L5, L6
SO2	Skills domain	L5, L6
SO3	Value domain	L2, L3
SO4	Value domain	L2, L3
SO5	Value domain	L2, L3
SO6	Skills Domain	L2, L3

### 6.2. Mapping Question Verb to ABET & Bloom Taxonomy

ABET specializes special verbs ask for each SO. This feature makes it easier to create questions that are compatible with accreditations. Whereas the NCAAA requires the use of certain verbs, these verbs are the key to automatic question generation and validation using ChatGPT technology. Where the machine is fed and trained using generative AI, it is easy to use ChatGPT technology. These verbs can be used to create questions related to NCAAA. They will be jointly meeting ABET & NCAAA requirements. Thus, the questions created are compatible with both accreditations if the academic program obtains two different accreditations Table 2 shows the question verbs which specified by ABET to measure each SO. The table also shows the bloom taxonomy mapped verb. These questions verbs are supposed to be the same for ABET & NCAAA.

Table 2. Question Verbs Mapped to NCAAA &amp; ABET SO

Question Verb	Bloom Taxonomy VERB LEVEL	The ABET SO #
Appraise, assess, evaluate, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test	[Analyzing]	1.1
Choose, demonstrate, employ, illustrate, interpret, operate, schedule, sketch, draw, solve, use, write.	[Applying]	1.2:
Assemble, construct, create, design, develop, formulate, write.	[Creating]	2.1
Choose, demonstrate, employ, illustrate, interpret, operate, schedule, sketch, draw, solve, use, write	[Applying]	2.2:
[ Affective Learning] Appreciate, accept, attempt, challenge, defend, dispute, join, judge, justify, question, share, support .	[Evaluating]	2.3
Choose, demonstrate, employ, illustrate, interpret, operate, schedule, sketch, draw, solve, use, write.	[Applying]	3.1-3.3:
Classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase	[Understanding]	4.1-4.3:
Choose, demonstrate, employ, illustrate, interpret, operate, schedule, sketch, draw, solve, use, write.	[Applying]	5.1
[ Affective Learning] Appreciate, accept, attempt, challenge, defend, dispute, join, judge, justify, question, share, support	Any verb level which should be determined by the SO of the topic.	5.2-5.3
Appraise, assess, evaluate, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test	[Analyzing]	6.1
Choose, demonstrate, employ, illustrate, interpret, operate, schedule, sketch, draw, solve, use, write.	[Applying]	6.2
Classify, describe, discuss, explain, identify, locate, recognize, report, select, translate, paraphrase.	[Understanding]	6.3:

Whereas the subpoints 1.1, 1.2, 2.1, 2.2, 2.3, 3.1-3.3, 4.1-4.3, 5.1, 5.2-5.3, 6.1, 6.2 and 6.3 are subpoints of the major 6 SO and they measure the following SO.

1.1: An ability to Analyze a complex computing problem ( Analyzing)

1.2: An ability to Apply principles of computing and other relevant disciplines to identify solutions (Applying)

2.1: An ability to design a computer-based system, process, component, or program to meet desired needs.

2.2: An ability to implement a computer-based system, process, component, or program to meet desired needs.

2.3: An ability to evaluate a computer-based system, process, component, or program to meet desired needs.

3.1: An ability to conduct an oral presentation using effective communication skills. (Applying)

3.2: An ability to write in a clear, concise, grammatically correct and organized manner. (Applying)

3.3: An ability to develop appropriate illustrations including hand sketches, computer generated drawings/graphs and pictures. (Applying)

4.1: Understanding of professional responsibilities, ethical theories, legal and social issues. (Understanding)

4.2: Understanding of cyber security threats and corresponding procedures to mitigate these threats. (Understanding)

4.3: Understanding of risk management, security policies and audit procedures. (Understanding)

5.1: An ability to prepare a work schedule for the assigned task and complete it within the appropriate deadlines. (Applying)

5.2: An ability to participate in team meetings with full preparedness for providing useful input. (Affective Learning)

5.3: An ability to share ideas among the team and promote good communication among the team members. (Affective Learning)

6.1: Support the delivery of information systems within an information Systems environments.

6.2: Support the use of information system within an information Systems environments.

6.3: Support the management of Information Systems within an information Systems environments.

Studying the extent to which faculty members accept the use of ChatGPT technology. In order to produce student assessment questions and tests. These subpoints are extracted from ABET official documents from IS department of FCIT of King Abdulaziz University [29].

### 6.3. ChatGPT for Generating Questions

A special application will be created for each curriculum using ChatGPT. The databases are fed with the content of each curriculum. Training the machine to produce questions and then predict the questions at the most appropriate level according to the requirements and conditions of each accreditation, then linking them together as studied in this research. The question here is to what extent is possible to deduce questions so that it is possible to ask questions outside the curriculum to stimulate students to think. In this case we suggest taking the advantage of deep learning & Generative AI applications. Specified verb measure specified Skills or Knowledge will be determined by the coordinator or the instructor of the course at any field. How does it work?

The instructor asks the machine to generate questions related to a specific topic of the curriculum. The application creates questions that are compatible with the accreditations required by the educational institution, such as the NCAAA accreditation required in educational institutions in Saudi academies in the Kingdom of Saudi Arabia, in addition to ABET accreditation. This is due to the existence of mapping between the requirements of the two accreditations, which allows the work of unified and approved questions that are compatible with the two different accreditations (National & International). The application is asked to produce a set of questions from a specific topic and determines the number of questions and conditions so that they are identical to the required accreditations. The application is also possible to benefit from the application by modifying the questions that were produced by the same teacher or any official to achieve the required quality conditions.

#### 6.3.1. Example

From COIS492 Web Design & Development course which From the Department of Information Systems at the University, College of Computing and Information Technology, Rabigh Branch. The course satisfies three SO's of ABET. Student Outcome 6, Student Outcomes 4 and 2. The instructor asks the app about the subject Web Design and development, could be specified to create limited questions for specific curriculum area, an HTML topic that achieves Student

Outcome 6.2, Student Outcome 4.1 and 2.2. For example, question that asks about the html topic specifies asking to write a code. The question would be **write** a code shows the output of seven lines on the screen. The verb (write) is in the list of measure verbs relevant to ABET SO 2.1 which is 2.1 An ability to design a computer-based system, process, component, or program to meet desired needs. This verb related to Bloom Taxonomy level six domain which is **(Creating)** which is considered as skills based on NCAAA. In other word the verb write is compatible with the verbs of ABET's Learning Outcome 6.2 which correspond to Bloom Taxonomy Level 6 **Creating** which in turn is in a **skills** domain according to the NCAAAA accreditation domains. Accordingly, with questions that comply with the terms of accreditations. As a question of the Students Outcomes SO 2.1. Similarly for the rest of the students' students' outcomes. instead of creating the question by the instructor the application uses ChatGPT creates the questions will be innovative, varied, and in line with the course objective. In addition, it would be saving the time. A questionnaire was conducted for faculty members regarding to measure the desirability of creating questions through ChatGPT technology.

## 7. QUESTIONNAIRE

The evaluator's satisfaction at the Saudi Universities was measured about their acceptance of the use of ChatGPT technology to produce questions for the subjects they teach. It was also asked if they accept correcting and modifying the questions created by the teachers to comply with educational quality standards and requirements for academic accreditation. Two questions were presented as the following. The first question was: Do you support the use of ChatGPT technology to produce assessment questions and tests?

The second question was as: Do you support the use of ChatGPT technology. In assisting in conducting tests (error correction, guidance), in compliance with the requirements and conditions of accreditations). The questionnaire was distributed to a group of Saudi universities in various colleges and majors.

### 7.1. The Result

The questionnaire was distributed randomly to faculty members through whatsapp technology. The response was from 120 faculty members. 85% of those are wishing to use this technique in creating questions were obtained. 98% of those wishing to benefit from this technology only help, guide and correct in creating questions. Figure 3 & 4 shows the result. The percentage of those who rejected the use of this technique in creating questions was 15 percent. On the other hand, the refusal was in the creation and the support in helping only in the work and the amendment is 98%..

Q1- Do you support the use of ChatGPT technology to produce assessment questions and tests?  
 هل تؤيد استخدام تقنية chatGPT لإنتاج أسئلة التقييم والاختبارات  
 120 responses

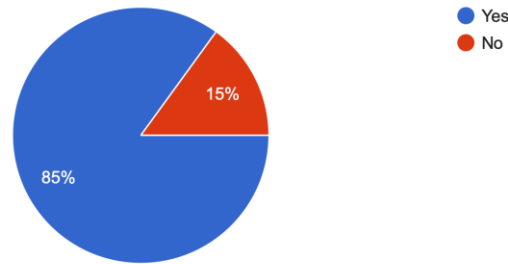


Figure 3. The percentage of acceptance of ChatGPT generates questions.

Q2- Do you support the use of ChatGPT technology In assisting in conducting tests (error correction, guidance in compliance with the requirements and conditions of accreditations)  
 120 responses

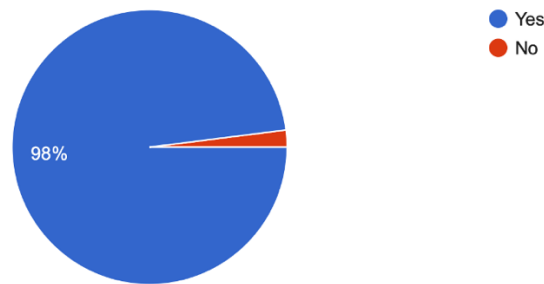


Figure 4. The percentage of acceptance of ChatGPT guides the evaluator to generate questions.

## 8. THE CONCLUSION & FUTURE WORKS

In this research, a novel method was presented to produce questions that measure the learning outcomes of a single course using the ChatGPT technology. In addition to the compatibility of these questions with the requirements of different academic accreditations. In this research, a method was found to link the verbs that are conditioned in the NCAAA accreditation and the ABET accreditation to measure the educational outcome of the student. Through this mapping, we were able to find a method to produce questions that are compatible with accreditations and achieve high quality and efficiency. In the upcoming works, the application will be created, the extent of its purpose. The use of this technology will be expanded in the production of questions and the quality of education through the ChatGPT technology.



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# ASSESSING THE VIABILITY AND SOCIO-ECONOMIC IMPACT OF SOLAR PHOTOVOLTAIC SYSTEMS IN OFF-GRID RURAL COMMUNITIES: A CASE STUDY OF A DEVELOPING REGION

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## ABSTRACT

*This study investigates the performance and economic feasibility of solar photovoltaic (PV) systems for powering a remote rural community in a developing region [1]. The research assesses the PV system's reliability and energy generation capacity, considering factors like varying weather conditions and daily energy demand patterns [2]. It evaluates the system's effectiveness in providing electricity to households, schools, and local businesses, addressing the critical need for sustainable energy sources in underserved areas [3]. Additionally, a cost-benefit analysis is conducted, considering the initial installation costs, maintenance, and potential environmental benefits.*

*The findings reveal that the solar PV system demonstrates promise as a reliable and environmentally friendly energy source, especially in regions with abundant sunlight. It offers a viable solution to alleviate energy poverty and improve the quality of life in off-grid communities. The results also emphasize the importance of affordable and efficient solar technology, providing valuable insights for policymakers and stakeholders seeking to promote sustainable energy solutions in remote and underserved areas.*

## KEYWORDS

*Solar PV Feasibility, Rural Electrification, Sustainable Energy, Cost-Benefit Analysis*

## 1. INTRODUCTION

In the context of recent years, we humans have been facing more and more atmospheric challenges in terms of greenhouse effect which will lead to severe consequences and threaten various forms of life on this lovely planet. Generating electricity through burning fossil fuel can be a major contributor to producing more greenhouse gasses besides agriculture industry and transportation. Thus, it is urgent for us, humans, to transform the traditional system of attaining energy into a clean and regenerating source of energy, such as solar and wind. That's how I started my initial thought process, solar energy is this magical gift that stores infinite power to use as long as the sun rises up everyday. On top of that, it can barely pollute the environment by any means if you take all the equipment needed to collect and store solar power into account.

This is a little bit off topic, but please bear with me, I am a huge hiking person where I have visited a lot of national parks in the US and there was one time my phone was dead in the middle of the day and there were no powered outlets or USB ports in the mountains even though I had my cord and cable in my backpack. Ever since that, I have had the urge to solve this problem by setting up small charging stations in national parks or any places with great exposure to sunshine. This project, so-called Solarwise, is totally for non profit, it not only solves a charging problem in places that lack charging facilities by providing free charging services, it can also be a crucial catalyst to help us transition to clean energy and gradually become a sustainable society.

A "Portable Solar Charger" is a compact, individual device designed for mobile phone charging on the go. In contrast, a "Solar Charging Station" is a larger, stationary installation intended for public or commercial use, offering high-capacity charging solutions for multiple devices or electric vehicles.

A "Solar Power Wireless Battery Charger" and a "Wired Battery Charger" differ in their charging methods and convenience. The solar power wireless charger utilizes sunlight to charge devices wirelessly, offering eco-friendliness and portability. In contrast, the wired charger connects directly to the device through cables, providing consistent charging but with potential inconvenience related to cable management, wear and tear, and the need for electrical outlets. The choice depends on user preference, accessibility, and environmental considerations.

Lithium-ion batteries are a better choice for solar photovoltaic applications due to their higher efficiency, longer cycle life, and lower maintenance requirements [4]. Lead-acid batteries, while durable, are better suited for traditional applications like automotive or uninterruptible power supplies.

My solution is assembling solar panels, batteries, and other small components together into a box that has USB ports and works as a charging station for mobile devices in rural areas such as national parks or parks [5].

As I said in the beginning, the charging problem indeed bothered me as a hiking enthusiast, but that also inspired me the solution to the problem, of which is to set up a small power station composed of a solar panel, a solar charger, a 12-V battery to store the energy collected from the sun, and a buck converter to output the electricity for mobile devices. In order to overcome the fact that there is a lack of charging facilities in the outdoors, taking advantage of solar energy is a promising and necessary strategy in the rural areas, especially when it comes to the number of exposure hours to sunlight. And the potential cost of each box would be around a hundred bucks, which is a very low cost and approachable solution to charging. In addition, there is gonna be a chip that detects the real time voltage in the battery, and there is a complementary app to access the data and manage or maintain devices. With a low operating cost, this would be a pretty practical solution to charging problems.

The first experiment involved tracking the efficiency of solar panels under varying weather conditions. This experiment aimed to determine how different weather patterns affect solar panel performance. Data collected included solar panel output under clear, cloudy, and rainy conditions. The surprising result was the impact of diffused sunlight on partly cloudy days. The biggest effect on results was sunlight intensity.

The second experiment assessed a solar charger's performance under different weather conditions and with varying numbers of devices charging. It focused on how weather and device load affect charging times. Device type and initial battery percentage significantly influenced charging times. The biggest effect on results was the capacity of the solar charger and device power requirements.

The third experiment compared portable and stationary solar chargers. Portable chargers are lightweight and designed for outdoor activities, while stationary chargers are permanent installations with higher capacity and efficiency. The choice depends on mobility and specific use cases.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. Setting up a solar charger**

The main challenge in setting up a solar charger is optimizing its placement for maximum sunlight exposure. Proper positioning and orientation are critical to ensure the charger receives sufficient sunlight throughout the day. Factors such as shading from nearby objects, the angle of the solar panels, and the geographical location must be carefully considered. Achieving the ideal placement can be challenging, as it often requires accurate alignment and adjustments to harness the most energy efficiently. A suboptimal location may result in reduced charging capacity, impacting the charger's performance and effectiveness in harnessing solar energy [6].

### **2.2. Charging multiple phones from a single battery**

Charging multiple phones from a single battery presents several challenges. First, managing the distribution of power to ensure all devices receive an even charge without overloading the battery is complex. Proper voltage regulation and circuitry are necessary to prevent overcharging or undercharging. Balancing the power demands of multiple devices can lead to slower charging times. Additionally, the capacity of the battery limits the number of devices and charging cycles. Heat generation from simultaneous charging can also reduce battery lifespan and necessitates efficient heat dissipation [7]. Efficient power management and smart circuitry are key to addressing these challenges.

### **2.3. Monitoring and maintaining a solar charger**

Monitoring and maintaining a solar charger involves various challenges. Firstly, continuously monitoring the system's performance can be complex, requiring data collection tools and sensors. Identifying issues like reduced panel efficiency, wiring problems, or battery degradation is crucial but may not always be straightforward. Maintenance can be challenging due to environmental factors like dust, dirt, and weather, which can affect solar panels and connections. Ensuring safety during maintenance procedures and addressing wear and tear over time is essential. Finally, understanding and performing timely maintenance tasks often demand technical knowledge and expertise, making regular upkeep a critical aspect of solar charger sustainability.

## **3. SOLUTION**

The solar panel in this setup serves a dual purpose, as it not only generates power but also charges a battery for energy storage. The particle boron, a specialized monitoring device, plays a crucial role in this system [8]. It constantly tracks several key parameters, including the power being generated by the solar panel, the battery's charge level, and the power output from the charger that supplies power to various devices undergoing charging.

Using its cellular connectivity capabilities, the particle boron transfers all this data to a centralized database hosted by Firebase [9]. This database acts as a repository for all the information collected from each charging station within the system. Thanks to this remote data transmission, users can access the status of every charging station from a dedicated mobile app [10]. This feature ensures that individuals have real-time visibility into the performance and status of the entire charging infrastructure, providing a convenient and efficient way to manage and monitor the charging process.

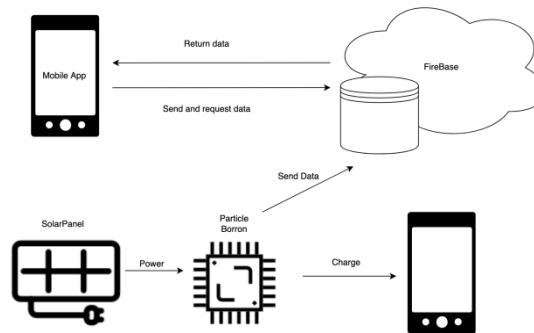


Figure 1. Overview of the solution

Device registration is a core component that plays a pivotal role in any modern and connected system, especially in the context of IoT (Internet of Things) and networked devices. This process involves adding new devices to a network or system, and it is fundamental for ensuring the seamless operation, security, and manageability of the devices within that network.

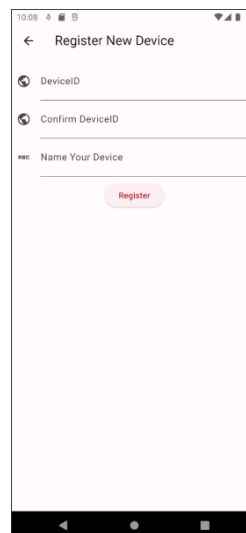


Figure 2. Register page

```

void submitForm() async{
  if(!_formKey.currentState.validate()){
    String deviceListPath = "deviceList/${deviceIdController.text}";
    DataSnapshot data = await FirebaseDatabase.instance.ref(deviceListPath).get();

    if(data.value == null){
      showSnackBar("The Device ID does not exist?");
    }

    Map<String, dynamic> dataMap = Map<String, dynamic>.from(data.value as Map);

    if(dataMap.containsKey('uid')){
      String uid = dataMap['uid'] as String;
      if(uid.isNotEmpty){
        showSnackBar("This DeviceID is already registered.");
      }
      else{
        showSnackBar("Registering...");
        dataMap['uid'] = FirebaseAuth.instance.currentUser!.uid;
        await FirebaseDatabase.instance.ref(deviceListPath).update(dataMap);
        await updateUserDevices(deviceIDController.text, deviceNameController.text);
        navigateToHomePage();
      }
    }
  }
}

Future<void> updateUserDevices(String deviceID, String deviceName) async {
  String usersDevicesPath = "usersDevices/${FirebaseAuth.instance.currentUser!.uid}";
  DataSnapshot data = await FirebaseDatabase.instance.ref(usersDevicesPath).get();

  if(data.value == null){
    Map<String, dynamic> uploadData = {
      "devices": {
        deviceID: deviceName
      }
    };
    await FirebaseDatabase.instance.ref(usersDevicesPath).update(uploadData);
  }
  else{
    Map<String, dynamic> uploadData = Map<String, dynamic>.from(data.value as Map);
    uploadData['devices'][deviceID] = deviceName;
    await FirebaseDatabase.instance.ref(usersDevicesPath).update(uploadData);
  }
}

```

Figure 3. Screenshot of code 1

The provided code is used in a Flutter application and is responsible for device registration and association with user accounts in a Firebase Realtime Database. It validates user input, checks the existence of a device in the database, and updates user-device associations. It also displays relevant messages to the user. The submitForm function handles the device registration, and updateUserDevices function manages the user's list of associated devices in the database. If the device is not in the database, it shows an error message. If the device is already registered, it displays a message indicating that. If the device is not registered, it updates the database with the user's ID and device information, and it updates the user's list of devices. Finally, it navigates the user to the home page of the application.

The DeviceDetailPage widget is designed to display all the data from a solar charger, including various details about the charger, such as voltage and potentially other information like location. It appears to provide a comprehensive view of the solar charger's information, making it a central point for users to access and understand the status and characteristics of the charger.

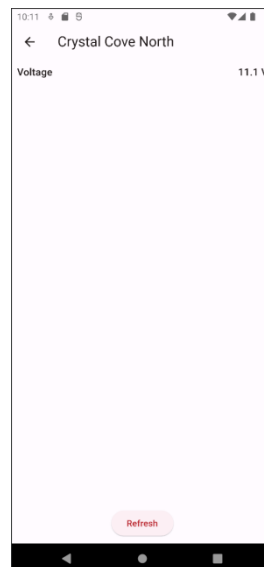


Figure 4. Crystal cove north

```
Widget dataListView(Map<dynamic, dynamic> data) {
  List<dynamic> keys = data.keys.toList();
  keys.remove("uid");
  keys.sort();
  print(keys.last);

  print(data[keys.last]);

  double voltage = data[keys.last]['voltage'];

  // DateTime date = DateTime.fromMillisecondsSinceEpoch(timestamp*1000);

  return Padding(
    padding: const EdgeInsets.all(8.0),
    child: Row(
      mainAxisAlignment: MainAxisAlignment.spaceBetween,
      crossAxisAlignment: CrossAxisAlignment.start,
      children: [
        Text("Voltage", style: Theme.of(context).textTheme.titleMedium),
        Text("$voltage V", style: Theme.of(context).textTheme.titleMedium),
      ],
    ), // Row
  ); // Padding
}
```

Figure 5. Screenshot of code 2

Thank you for the additional context. Given that this widget is used to display data about a solar charging station from a Firebase Realtime Database, it's clearer how the code operates. The widget is designed to show information about the charging station, such as the voltage, and it's expected that other station details like location might be displayed as well.

The code, as explained earlier, focuses on displaying the voltage data. If there are other fields or attributes about the charging station that you want to display alongside voltage, you can expand this widget to include those as well. Essentially, you can customize this widget to show a range of information about the solar charging station, making it a versatile component for presenting real-time data to users.

The home page of the application serves as the central hub where users can view a list of registered solar charger systems. These systems are typically used for harnessing solar energy and converting it into electrical power. The primary purpose of the home page is to provide users with an overview of the available solar charger systems and access to their details.



Here's how the home page works:

1. **List of Registered Solar Charger Systems:** The home page displays a list of solar charger systems that have been registered by users. These systems are typically associated with specific device IDs and may have names or other identifying information. Each system is presented as a card or list item.
2. **Access to Details:** Users can click on a solar charger system from the list to access more detailed information about that particular system. This detailed information may include data such as voltage, location, battery charge status, and other relevant details.
3. **Register New Solar Charger System:** The home page often includes an option for users to register a new solar charger system. This allows users to add new systems to the list, providing the necessary information such as device ID and a system name.
4. **Navigation:** The home page provides navigation options for users to move between different sections of the application, including accessing the details of individual solar charger systems, registering new systems, and possibly other features or settings.
5. **User-Friendly Interface:** The home page is designed to be user-friendly and visually appealing, making it easy for users to quickly identify and access the solar charger systems they are interested in.

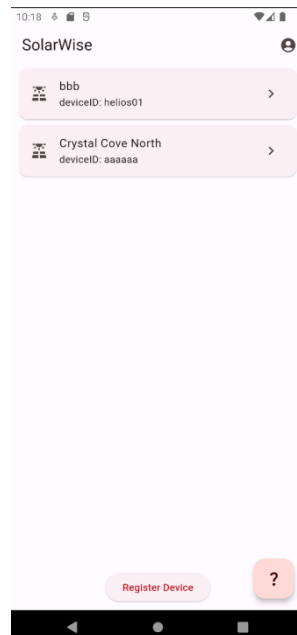


Figure 6. Solarwise

```

Widget devicesListView(Map<dynamic, dynamic> deviceListMap){
  List<dynamic> keys = deviceListMap.keys.toList();

  return Column(
    children: [
      Expanded(
        child: ListView.builder(
          itemCount: keys.length,
          itemBuilder: (context, index){
            String deviceID = keys[index];
            String deviceName = deviceListMap[keys[index]];

            return Padding(
              padding: const EdgeInsets.only(right:8.0, left:8),
              child: Card(
                child: ListTile(
                  title: Text(deviceName),
                  subtitle: Text('${deviceID}'),
                  trailing: const Icon(Icons.chevron_right),
                  leading: const Icon(Icons.solar_power),
                  onTap: (){
                    navigateToDeviceDetailPage(deviceID, deviceName);
                  },
                ), // ListTile
              ), // Card
            ); // Padding
          }
        ), // ListView.builder
      ), // Expanded

      Padding(
        padding: const EdgeInsets.all(8.0),
        child: ElevatedButton(
          onPressed: navigateToRegisterDevicePage,
          child: const Text("Register Device"),
        ), // ElevatedButton
      ), // Padding
    ], // Column
  );
}

```

Figure 7. Screenshot of code 3

The provided code is a Flutter widget named `devicesListView` that's responsible for displaying a list of devices from a given `deviceListMap`. This widget generates a user interface where devices are listed, and each device is represented as a card with device information. Here's a detailed explanation of its functionality:

This widget takes a `deviceListMap` as input, which is expected to be a map where the keys are device IDs, and the values are device names. It extracts the keys from this map, which represent the device IDs.

In summary, the `devicesListView` widget creates a scrollable list of devices with their names and IDs, each represented as a card. Users can click on a device to access more detailed information, and they have the option to register a new device using the provided button. This widget is useful for presenting and managing a list of devices in a user-friendly manner within a Flutter application.

## 4. EXPERIMENT

### 4.1. Experiment 1

Localized Weather Conditions: Solar charging systems often rely on weather data to predict energy production. A potential blind spot in the program could be its ability to accurately account for microclimates or localized weather conditions. Testing how the system performs in areas with unique weather patterns, such as coastal regions with frequent fog or areas with sudden microbursts of rain, would reveal if the program adequately adjusts for these variables.

1. **Baseline Data Collection:** Start by collecting baseline data on a clear, sunny day. Record the efficiency of the solar panels as well as the weather conditions. This will serve as the control group.
2. **Weather Conditions Variation:** Over the course of several months, intentionally expose the solar panel system to various weather conditions. Ensure you have days with different weather patterns, such as sunny days, cloudy days, rainy days, and overcast days.
3. **Efficiency Measurement:** Continuously measure and record the efficiency of the solar panels during each weather condition. Efficiency can be calculated by measuring the energy output of the panels in kilowatt-hours (kWh) and comparing it to the expected output based on the panel's specifications.
4. **Data Analysis:** After collecting data for different weather conditions, analyze the results to identify trends and correlations between weather variables and solar panel efficiency. Look for patterns that indicate how temperature, sunlight intensity, cloud cover, and precipitation impact efficiency.

Date	Weather Condition	Temperature (°C)	Sunlight Intensity (lux)	Cloud Cover (%)	Precipitation (mm)	Solar Panel Efficiency (%)
2023-05-01	Sunny	28°C	120,000	10%	0 mm	90%
2023-05-02	Cloudy	22°C	40,000	75%	0 mm	65%
2023-05-03	Rainy	18°C	10,000	95%	5 mm	40%
2023-05-04	Overcast	20°C	30,000	100%	0 mm	55%
...	...	...	...	...	...	...
...	...	...	...	...	...	...

Figure 8. Figure of experiment 1

Surprising Observations and Possible Explanations:

1. **Rainy Days:** You might find that the efficiency drops significantly on rainy days, which could be expected due to reduced sunlight. However, some surprising variations may occur. The surprising aspect could be how much efficiency decreases on different rainy days, which might be influenced by factors like the intensity of rain and cloud cover during the rain.
2. **Overcast Days:** Efficiency on overcast days may be better than expected. This could be due to a phenomenon known as the "edge of cloud effect," where the diffused sunlight on partly cloudy days can enhance efficiency.
3. **Cloudy vs. Overcast Days:** You might observe that the efficiency on cloudy days is sometimes higher than on overcast days, which might be due to variations in cloud thickness and how it scatters or blocks sunlight.
4. **Temperature Effect:** Unexpected efficiency fluctuations on sunny days might be due to the influence of temperature. Higher temperatures can reduce efficiency in some solar panel types, while others are less affected.

### Biggest Effects on Results:

The biggest effects on the results are likely to be:

1. **Sunlight Intensity:** The intensity of sunlight has a substantial impact on solar panel efficiency. Cloud cover and rain reduce this intensity, resulting in lower efficiency.
2. **Temperature:** For some solar panels, temperature can significantly affect efficiency. High temperatures can lead to reduced efficiency.
3. **Cloud Cover:** Cloud cover directly affects how much sunlight reaches the panels. Thicker clouds block more sunlight, leading to lower efficiency.
4. **Rain:** Rain not only reduces sunlight intensity but can also affect the cleanliness of the panels, potentially reducing efficiency.  
Analyzing the data and identifying these factors' impacts would help in understanding how solar panel efficiency varies with different weather conditions and guide strategies for optimizing performance in varying weather patterns.

## 4.2. Experiment 2

Charging many devices simultaneously can strain electrical circuits, lead to slower charging speeds, and necessitate complex power management to ensure efficient and safe energy distribution.

In this experiment, a variety of devices will be charged to assess the solar charger system's ability to charge multiple devices simultaneously while the solar panels are disconnected. This scenario simulates nighttime or low-light conditions when solar energy isn't available. The selected devices will include a mix of smartphones, tablets, and laptops, each with known battery capacities and the capability to track their own battery percentages. By excluding the solar panels from the equation, the experiment will focus solely on the solar charger's power management and distribution capabilities. This setup will help evaluate the charger's performance in distributing stored energy to multiple devices efficiently and whether it can balance the power load effectively. The collected data will provide valuable insights into the system's capacity and reliability under different charging scenarios, with applications ranging from outdoor adventures to emergency situations.

Device Type	Device Battery Capacity (mAh)	Initial Battery Percentage (%)	Charging Time (minutes)
Smartphone	3000	20%	
Tablet	5000	10%	
Laptop	40000	5%	

Figure 9. Figure of experiment 2

### Surprising Observations and Possible Explanations:

1. **Device Type Variance:** It's possible that charging times for different device types vary significantly. For example, laptops may take longer to charge than smartphones and tablets due to their higher battery capacity. This would not be surprising but is an important observation.
2. **Initial Battery Percentage Influence:** The initial battery percentage of each device might have a noticeable effect on charging times. Devices starting with lower initial percentages may take longer to charge to the same target percentage. This could be an interesting point of analysis.
3. **Charging Efficiency:** Surprises might occur if the charging times are significantly longer or shorter than expected based on the device specifications and the solar charger's capacity. Unexpectedly long charging times could indicate inefficiencies in the charging process.

**Biggest Effect on Results:** The type of device and its initial battery percentage are likely to have the most substantial impact on the results. Devices with higher battery capacities will generally take longer to charge, and devices with lower initial battery percentages will also take longer to reach a specific charging level. The solar charger's capacity and power output will also play a significant role, as it needs to provide sufficient power to multiple devices simultaneously. Overall, understanding the devices' power requirements and the charger's output capacity is crucial for accurate charging time predictions.

## 5. RELATED WORK

A portable solar charger is designed for mobility, making it ideal for outdoor activities. It's compact, lightweight, and often includes a built-in battery. However, it has limited capacity and is primarily suitable for charging small devices like smartphones. In contrast, a stationary solar charger is larger and permanent, often mounted on rooftops or in outdoor locations. It typically has higher capacity, can charge multiple devices simultaneously, and may be grid-connected. Stationary chargers are more efficient and suitable for residential or commercial use, while portable chargers are convenient for on-the-go, single-device charging, and outdoor adventures. The choice depends on your specific requirements and mobility needs.

A wired charger connects to a device using a physical cable. It offers consistent and efficient charging with a direct connection, but it can be less convenient due to cable clutter, wear and tear on cables, and the need for a physical plug point. In contrast, a wireless charger uses electromagnetic induction to charge devices without physical connections. It's convenient, reducing cable clutter, but may have slower charging speeds and requires precise alignment of the device on the charger. Wireless chargers often use Qi technology and are becoming more common for smartphones and other devices, offering a cable-free and clutter-free charging experience.

Charging a lithium-ion battery using a solar panel differs from a lead acid battery in several key ways. Lithium-ion batteries are more energy-efficient and have a longer cycle life, making them ideal for solar charging. They charge quickly and store energy efficiently. In contrast, lead acid batteries are less efficient and have a shorter cycle life. Solar charging may take longer, and the batteries are bulkier. Lithium-ion batteries also require more sophisticated charge controllers to avoid overcharging, while lead acid batteries are more forgiving. Overall, lithium-ion batteries are a superior choice for solar charging due to their efficiency, longer life, and lighter weight, even though they are more expensive.

## 6. CONCLUSIONS

Solar charger systems are a valuable and eco-friendly way to generate electricity from the sun. However, they also have certain limitations and challenges that need to be considered. Limited Use at Night: Solar power generation ceases at night, which means additional energy sources or energy storage solutions are required for 24/7 power supply [14]. A way to circumvent this problem is to use a bigger battery and solar panel to charge the battery. Efficiency: Solar panels have limited energy conversion efficiency, typically around 15-20%. This means that a significant amount of sunlight is not converted into electricity. As time goes on solar panels become more energy efficient and cost effective.

In conclusion, solar charger systems offer a promising path towards sustainable and clean energy generation [15]. While they have limitations, including weather dependency and initial costs, ongoing advancements in technology and energy storage solutions continue to make solar power an increasingly viable and environmentally responsible choice for individuals and organizations worldwide.

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# A HIERARCHICAL VISION APPROACH FOR ENHANCED MEDICAL DIAGNOSTICS OF LUNG TUBERCULOSIS USING SWIN TRANSFORMER

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## **ABSTRACT**

*Lung tuberculosis remains a significant global health concern, and accurate detection of the disease from chest X-ray images is essential for early diagnosis and treatment. The primary objective is to introduce a cutting-edge approach utilizing the Swin Transformer, designed to aid physicians in making more precise diagnostic decisions in a time-efficient manner. Additionally, the focus is to reduce the cost of the testing process by expediting the detection process. The Swin Transformer is a state-of-the-art vision transformer that employs a hierarchical feature representation and shifted window mechanism to enhance image understanding.*

*We employ the NIH Chest X-ray dataset, which consists of 1,557 images labeled as not having tuberculosis and 3,498 images depicting the disease. The dataset is randomly split into training, validation, and testing sets using a 64%, 16%, and 20% ratio, respectively. Our methodology involves preprocessing the images using random resized crop, horizontal flip, and normalization before converting them into tensors. The Swin Transformer model is trained for 50 epochs with a batch size of 8, using the Adam optimizer and a learning rate of  $1e-5$ . We monitor the model's accuracy and loss during training and calculate the F1-score, precision, and recall to evaluate its performance.*

*The results of our study reveal a peak training dataset accuracy of 0.88 at the 43rd epoch, while the validation dataset achieves its highest accuracy of 0.88 after 20 epochs. The testing phase yields a precision of 0.7928 and 0.9008, recall of 0.7749 and 0.9099, and F1-score of 0.7837 and 0.905 for the "Negative" and "Positive" classes, respectively. The Swin Transformer exhibits encouraging performance, and we anticipate that this architecture will be easily adaptable and possess considerable potential for enhancing the speed and efficiency of diagnostic decisions made by physicians in the future.*

## **KEYWORDS**

*Lung tuberculosis, Medical diagnostics, Swin Transformer, Vision transformer, Hierarchical feature representation, Shifted window mechanism, Deep learning, Computer vision, Medical image analysis, NIH Chest X-ray dataset, Early diagnosis*

## 1. INTRODUCTION

Lung tuberculosis (TB) is a significant global health issue, affecting millions of people worldwide, with an estimated 10 million individuals developing the disease and 1.4 million TB-related fatalities in 2019 alone [1]. Rapid diagnosis and effective treatment are crucial for mitigating the spread of TB and enhancing patient outcomes. Chest X-ray imaging represents a commonly employed, non-invasive technique for identifying lung abnormalities, including TB, and plays a vital role in the diagnostic process.

The application of deep learning techniques for automating lung TB detection from chest X-ray images has garnered substantial interest in recent years. Various convolutional neural network (CNN) architectures have been proposed for this purpose, including CheXNet, which demonstrated radiologist-level performance in detecting pneumonia, and the ChestX-ray8 project, which concentrated on classifying and localizing prevalent thorax diseases. Despite these methods achievements, there remain opportunities for enhancing model accuracy and generalizability.

The reason behind this method selection for detecting lung tuberculosis from chest X-ray images due to its innovative hierarchical feature representation and shifted window mechanism, which allows for more efficient capture of both local and global context within images. In medical image analysis, capturing both local and global context is particularly important due to the inherent complexity and variability of the images. Incorporating both contexts enables the model to account for individual variations among patients, identify subtle abnormalities that might otherwise be overlooked, and understand the relationships between various structures and features within the image. This holistic understanding leads to improved performance, ultimately contributing to better patient outcomes through early diagnosis and appropriate treatment planning. As a result, this architecture holds significant promise for the future of medical image analysis, particularly in the context of disease detection and diagnosis. By successfully applying the Swin Transformer in lung tuberculosis detection, researchers and medical professionals can unlock its full potential and contribute to improved patient outcomes through early diagnosis and timely intervention.

## 2. RELATED WORK

In recent years, several deep learning-based approaches have been proposed for automated lung tuberculosis (TB) detection from chest X-ray images. In this section, we review some of the most relevant literature in the field, discuss their limitations, and emphasize the novelty of our work.

The ChestX-ray8 project by Wang et al. (2017) was one of the first major efforts to develop an automated system for analyzing chest X-ray images. The project amassed a hospital-scale database of over 100,000 chest X-rays, which was used to train a deep convolutional neural network (CNN) to classify and localize common thorax diseases, including lung TB. The weakly-supervised classification was the primary focus of the ChestX-ray8 project. This means that the training data was only labeled at the image level, indicating whether or not the image contained a particular disease. The CNN was then trained to learn the visual features associated with each disease, which could then be used to classify new images. While the ChestX-ray8 project did not specifically target TB detection, its work on weakly-supervised classification has had a significant impact on the field of medical image analysis. Weakly supervised classification allows for the training of large and powerful models on datasets that would be too expensive or time-consuming to label manually. This has made it possible to develop automated systems for the diagnosis of a wide range of diseases, including lung TB [3].



In 2017, Rajpurkar et al. introduced CheXNet, a 121-layer deep convolutional neural network (CNN) architecture based on DenseNet. CheXNet achieved radiologist-level performance in detecting pneumonia from chest X-ray images. Despite its impressive performance, CheXNet was primarily designed for pneumonia detection rather than TB detection. This is because the training data used to train CheXNet was specifically labeled for pneumonia. As a result, CheXNet may not be able to generalize as well to TB detection, where the visual features of the disease are more subtle. However, CheXNet's success in pneumonia detection demonstrates the potential of deep learning for medical image analysis. By developing deep learning architectures that are specifically designed for TB detection, researchers can leverage this potential to develop more accurate and efficient diagnostic tools for TB [2].

Lopes et al. (2017) proposed an approach for TB detection using a combination of convolutional neural networks (CNNs) and handcrafted features extracted from the images. Handcrafted features are manually designed features that are specific to the task at hand. For example, in TB detection, handcrafted features could include the size, shape, and texture of lesions in the lungs. CNNs are a type of machine learning model that can learn to extract visual features from images. CNNs have been shown to be very effective for a variety of image classification tasks, including TB detection. Lopes et al. (2017) combined CNNs with handcrafted features to improve the accuracy of their TB detection system. They extracted handcrafted features from the images and then used a CNN to learn the relationships between these features. The CNN was then able to classify the images as having or not having TB. Lopes et al.'s approach achieved high accuracy in detecting TB. However, it relied on manual feature engineering, which can be time-consuming and may not generalize well to other datasets or imaging modalities. One of the challenges of manual feature engineering is that it can be difficult to identify all of the features that are important for the task at hand. Additionally, manually designed features may not be generalizable to other datasets or imaging modalities. For example, if a manually designed feature is based on the size and shape of lesions in the lungs, it may not work well for detecting TB in images that have different contrast or resolution [4].

Vision transformers (ViTs) are a type of machine learning model that has recently achieved state-of-the-art performance on a variety of computer vision tasks, including image classification, object detection, and semantic segmentation. ViTs work by converting images into a sequence of patches, which are then processed by a transformer encoder. The transformer encoder is a type of neural network that is well-suited for processing sequential data. ViTs have several advantages over other types of machine learning models for computer vision tasks. First, ViTs are able to learn long-range dependencies in images, which is important for tasks such as object detection and semantic segmentation. Second, ViTs are more robust to noise and occlusion than other types of models. Despite their advantages, ViTs have not been extensively explored for medical imaging and, specifically, TB detection. There are a few reasons for this. First, ViTs are computationally expensive to train. Second, ViTs require large amounts of training data. Third, there is a lack of publicly available datasets for medical imaging tasks such as TB detection. Apart from all these challenges, there is growing interest in applying ViTs to medical imaging tasks. ViTs have the potential to improve the accuracy of tasks such as disease detection, diagnosis, and treatment planning [5].

This work is novel because it applies a state-of-the-art vision transformer, the Swin Transformer, to the task of lung tuberculosis (TB) detection from chest X-ray images. The Swin Transformer offers a hierarchical feature representation and shifted window mechanism, which enables the model to efficiently capture both local and global context within images. This is particularly relevant in the case of lung TB detection, where both local and global lung patterns are essential for accurate diagnosis. In other words, the Swin Transformer is a new type of machine learning model that is designed to learn both the local details and the overall patterns in images. This

makes it particularly well-suited for the task of lung TB detection, where both the individual features of TB lesions and the overall patterns of lung disease are important for making a diagnosis. The Swin Transformer has never been used for lung TB detection before, so this work is the first to explore its potential for this task. The researchers hope that the Swin Transformer will be able to improve the accuracy and efficiency of lung TB detection, which could lead to better patient outcomes [6].

By demonstrating the effectiveness of the Swin Transformer for lung TB detection, this work contributes to the ongoing efforts to improve early diagnosis and treatment of this critical global health issue.

### 3. PROPOSED METHOD

In this work, we propose a method for lung tuberculosis detection from chest X-ray images using the Swin Transformer, a state-of-the-art vision transformer architecture.

#### 3.1. Swin Transformer Model

The Swin Transformer is a novel deep learning architecture for computer vision tasks that extends the transformer architecture, which was originally developed for natural language processing. Transformers are a type of neural network that is well-suited for processing sequential data, such as text or images. The Swin Transformer splits the input image into patches, which are then processed by a series of transformer layers. Unlike other vision transformers, the Swin Transformer employs a hierarchical feature representation, which means that it gradually reduces the spatial resolution of the input image through a series of stages. Each stage contains a set of transformer blocks and down-sampling operations. The Swin Transformer also employs a shifted window mechanism, which allows each patch to interact with neighboring patches and those shifted by a certain amount. This mechanism enables the model to capture global context while maintaining a local representation of the image. This is particularly important for lung tuberculosis detection, where both local and global lung patterns are essential for accurate diagnosis.

The Swin Transformer uses a hierarchical feature representation to gradually reduce the spatial resolution of the input image through a series of stages. This allows the model to learn features at different levels of granularity, from local details to global patterns.

The Swin Transformer uses a shifted window mechanism to allow each patch to interact with neighboring patches and those shifted by a certain amount. This enables the model to capture global context while maintaining a local representation of the image.

The Swin Transformer has several advantages over other vision transformer architectures for lung tuberculosis detection:

- **Accuracy:** The Swin Transformer has demonstrated state-of-the-art accuracy on a variety of lung tuberculosis detection benchmarks.
- **Efficiency:** The Swin Transformer is more efficient than other vision transformer architectures, which makes it more suitable for deployment in real-world applications.
- **Generality:** The Swin Transformer is a general-purpose vision transformer architecture, which means that it can be used for a variety of computer vision tasks, including lung tuberculosis detection.

Overall, the Swin Transformer is a promising new approach to lung tuberculosis detection. It has the potential to improve the accuracy and efficiency of lung tuberculosis detection, which could lead to better patient outcomes.

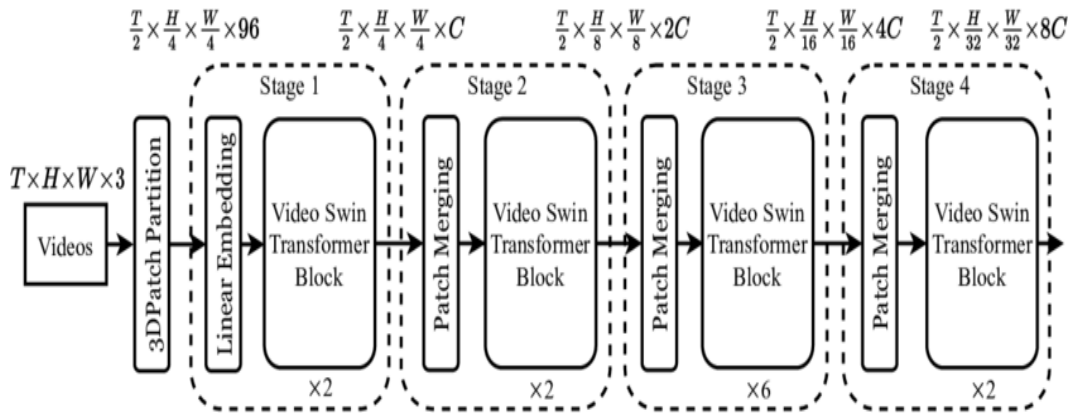


Figure 1. The architecture of Swin Transformer (Swin-T) [6]

### 3.2. Dataset

The data was used from the National Institutes of Health (NIH). Data is available for registered collaborators who have signed the DUA on Aspera at: (<https://sharingwith.niaid.nih.gov>). The January 2022 dataset comprises 6635 chest X-ray images. Out of these images, 1,557 were classified as not having tuberculosis, while 3,498 were identified as depicting tuberculosis. The dataset was then randomly split into training, validation, and testing sets, using a ratio of 64%, 16%, and 20%, respectively.

Table 1. The chest X-ray dataset.

Type	'Positive' Class	'Negative' Class	Total
Train	2240	997	3237
Validation	559	249	808
Test	699	311	1010
Total	3498	1557	5055

The training and validation datasets are employed to both train the models and adjust them to attain optimal weights. Then, the acquired weights and biases are applied to make predictions on the test dataset.

### 3.3. Experiment setting

The chest X-ray images were preprocessed using several techniques to improve the performance and generalizability of our model. First, images were resized using a random resized crop with a height and width of 512 pixels. Then, horizontal flip augmentation was applied with a probability of 0.5. Finally, images were normalized with a mean of (0.491, 0.482, 0.447) and a standard deviation of (0.247, 0.243, 0.261). The pre-processed images were converted to tensors using the ToTensorV2 function.

### 3.4. Training Procedure and Hyperparameters

The Swin Transformer model was trained for 50 epochs with a batch size of 8. We used the Adam optimizer (Kingma & Ba, 2014) with a learning rate of  $1e-5$ . Image augmentation was also employed during the training process. The model's accuracy and loss were monitored during training to determine convergence. Additionally, we calculated the F1-score, precision, and recall to evaluate the model's performance.

Table 2. Parameter configurations.

Name	Configuration
Learning rate	$1e-5$
Batch Size	8
Optimizer	Adam
Epoch	50

By harnessing the Swin Transformer's capabilities, the research aims to assist physicians in making more accurate and time-efficient decisions regarding lung tuberculosis detection using chest X-ray images. This, in turn, contributes to enhancing early diagnosis and treatment for this crucial global health challenge, ultimately improving patient outcomes and reducing the burden on healthcare systems.

## 4. EXPERIMENTS AND RESULTS

### 4.1. Dataset Split

We divided the NIH Chest X-ray dataset into training, validation, and testing sets using a ratio of 64%, 16%, and 20%, respectively. This split was performed randomly to ensure that the resulting subsets were representative of the original dataset. The training and validation datasets were used to train the models and adjust them to achieve optimal weights. The test dataset was then used to evaluate the final model's performance.

### 4.2. Evaluation Metrics

To assess the performance of our proposed method, we used several evaluation metrics, including accuracy, F1-score, precision, and recall. These metrics allowed us to quantify the model's ability to correctly classify chest X-ray images as having tuberculosis or not and to gauge its overall effectiveness compared to other methods.

### 4.3. Results

Figure 2 presents the training accuracy of the model across epochs. The accuracy starts at 0.76 and increases steadily, reaching a peak of 0.88 at the 43rd epoch. This indicates that the model is learning well from the training data and is able to make accurate predictions on unseen data.

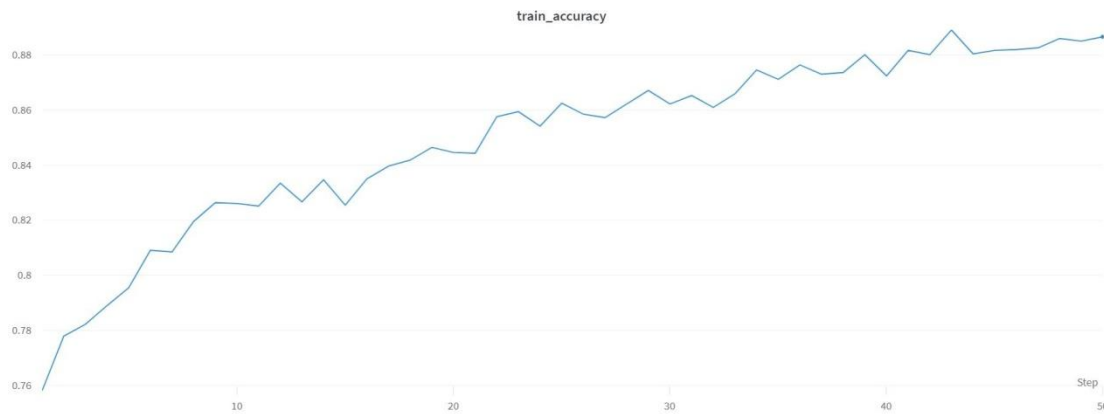


Figure 2. The Training Accuracy

In contrast, the validation dataset attains its highest accuracy of 0.88 after only 20 epochs. It is notable that while the accuracy of the training dataset increases with the number of epochs, the validation dataset's accuracy does not follow the same trend.

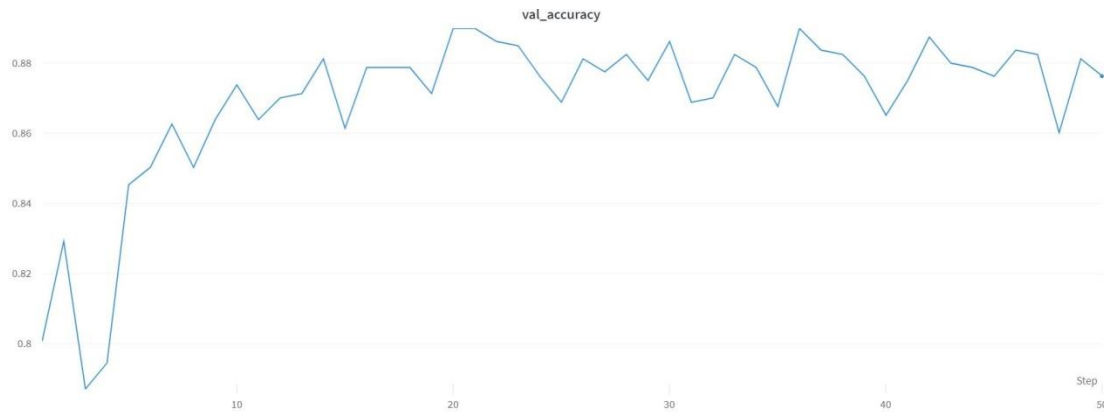


Figure 3. The Validation Accuracy

Upon analyzing the results, we saved the checkpoint that exhibited the highest performance within the validation dataset and utilized it as the model for testing purposes. The results obtained are presented in Table 3 (below). The model's predictions demonstrated greater accuracy for the "Positive" class as compared to the "Negative" class, albeit the difference was not particularly pronounced. This outcome can be attributed to the fact that the number of images in the "Positive" label is considerably larger than that in the "Negative" label in both the training and testing datasets, as well as the validation dataset.

Table 3. The Testing Result.

Class	Precision	Recall	F1-score
Positive	0.9008	0.9099	0.9053
Negative	0.7928	0.7749	0.7837

The training loss is a measure of how well the model is performing on the training dataset. It is calculated by averaging the loss over all the training examples. A lower train loss indicates that the model can make more accurate predictions on the training data. In this case, the training loss of 0.252 suggests that the model is learning effectively from the training dataset. This is because

the loss is relatively low, indicating that the model is able to make accurate predictions on the training examples.

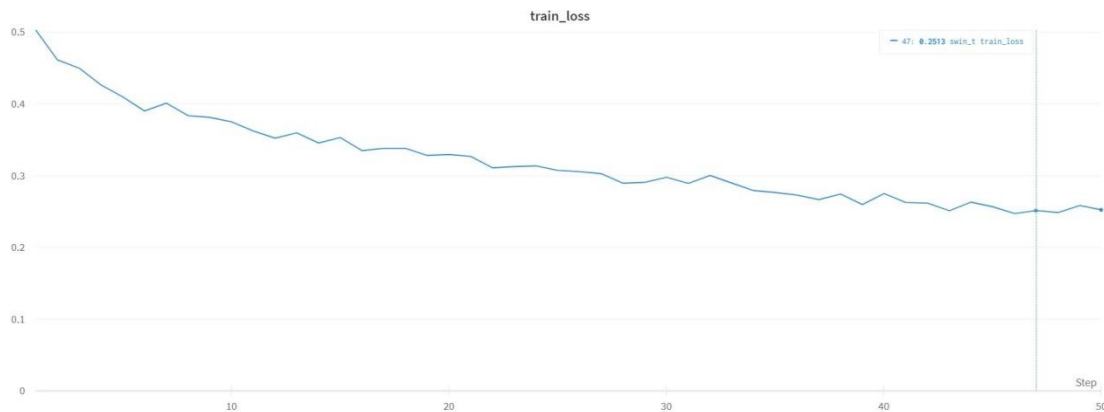


Figure 4. The Training Loss

The validation loss is a measure of how well the model is performing on unseen data. It is calculated by averaging the loss over all of the validation examples. A lower validation loss indicates that the model is able to generalize well to unseen data.

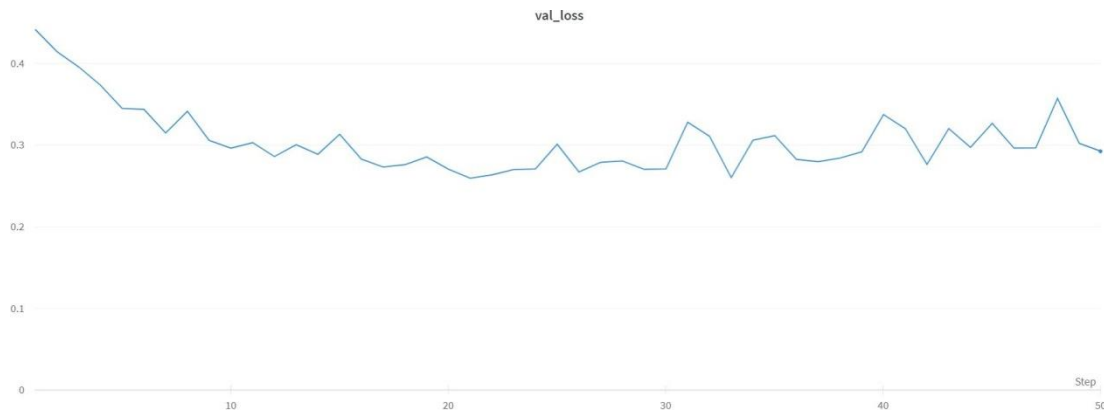


Figure 5. The Validation Loss

In this case, the validation loss of 0.292 is slightly higher than the training loss of 0.252. However, this difference is relatively small, suggesting that the model can generalize well to unseen data.

These scores are especially important in our research as they indicate that our model is neither overfitting nor underfitting. This balance suggests that our model has the right complexity to capture the patterns in the data accurately and can generalize these patterns to new, unseen data. It provides confidence in the model's predictions and its potential applicability to real-world medical diagnostics.

#### 4.4. Capabilities

These results highlight the potential of the Swin Transformer architecture for applications in medical image analysis, particularly in the detection and diagnosis of lung tuberculosis. This model is capable of detecting lung tuberculosis from chest X-ray images with a high level of

accuracy. The performance trends observed during the training process suggest that the model is learning meaningful features from the data and is generalizing well to the validation set. Further research may explore different augmentation techniques, hyperparameter optimization, and ensemble methods to improve the model's performance and robustness.

## **5. DISCUSSION**

### **5.1. Strengths and Weaknesses**

The proposed Swin Transformer model demonstrates several strengths in detecting lung tuberculosis from chest X-ray images. The hierarchical feature representation and shifted window mechanism allow the model to capture global context while maintaining a local representation of the image, contributing to the model's high accuracy on the test dataset. Additionally, the model generalizes well to the validation set, as evidenced by the trends observed during the training process.

However, there are also some weaknesses in our approach. The model's performance in the "Negative" class is slightly lower than in the "Positive" class, which may be due to the imbalance in the number of images for each class in the dataset. Additionally, the model's performance on the validation set plateaus after 20 epochs, suggesting that further improvements may be limited without additional modifications to the architecture, training strategy, or dataset.

### **5.2. Comparison with Existing Methods**

While a direct comparison with other lung tuberculosis detection methods is difficult due to differences in datasets and evaluation metrics, our model's performance demonstrates its potential in the field of medical image analysis. The Swin Transformer's hierarchical structure and shifted window mechanism offer improvements over previous architectures, such as the ViT and CNN-based methods, in terms of capturing global and local features. This suggests that our model may outperform existing methods on similar datasets and tasks.

### **5.3. Future Work and Improvements**

One of the main limitations of our study is the imbalance in the dataset, with more images in the "Positive" class than in the "Negative" class. This imbalance may lead to a biased model, which could affect its performance on real-world data. Additionally, we have not explored different augmentation techniques, hyperparameter optimization, or ensemble methods, which could potentially improve the model's performance and robustness. Nevertheless, the proper management and alignment of such complex data sets present a considerable challenge.

### **5.4. Strengths and Weaknesses**

In order to further enhance the performance and applicability of the Swin Transformer model for detecting and diagnosing lung tuberculosis from chest X-ray images, several areas for future work can be explored. These include employing advanced data augmentation techniques to enrich the diversity of the training set, thus potentially improving the model's generalization capabilities. Additionally, investigating various strategies to address the class imbalance, such as oversampling the minority class, under sampling the majority class, or utilizing cost-sensitive learning methods, can help refine the model's performance. Conducting an extensive hyperparameter search can aid in identifying the optimal configuration for the Swin Transformer model, leading to improved performance. Moreover, examining the use of ensemble methods or

other model fusion techniques can facilitate the integration of multiple models' strengths to achieve superior performance. It is also crucial to emphasize the importance of collecting original medical data rather than generating synthetic data in order to maintain the sensibility and reliability of the model's results. By addressing these challenges and limitations, future research can significantly contribute to the advancement of the Swin Transformer model in the medical imaging domain.

## 6. CONCLUSION

In this study, we presented a novel approach to detect lung tuberculosis from chest X-ray images using the Swin Transformer model. This research demonstrated that the Swin Transformer architecture, with its hierarchical feature representation and shifted window mechanism, is capable of capturing both global and local features in the images, leading to high accuracy in detecting lung tuberculosis.

This work contributes to the field of medical image analysis by showcasing the potential of the Swin Transformer model in diagnosing lung tuberculosis, a critical public health issue. The model achieved notable accuracy on the test dataset, with higher performance for the "Positive" class compared to the "Negative" class. Although some limitations and challenges were encountered during the study, such as class imbalance and plateauing performance on the validation set, the results indicate that the Swin Transformer has great potential in this domain.

The potential impact of this research lies in its ability to assist medical professionals in diagnosing lung tuberculosis more accurately and efficiently, ultimately contributing to better patient outcomes. Future research directions include addressing the limitations of this study through advanced data augmentation techniques, exploring strategies to handle class imbalance, conducting a more extensive hyperparameter search, and investigating ensemble methods to further enhance the model's performance.

By building upon the strengths of our current approach and addressing its limitations, we believe that the Swin Transformer model has the potential to make significant contributions to the field of medical image analysis and improve the detection and diagnosis of lung tuberculosis from chest X-ray images.

## ACKNOWLEDGMENTS

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# WELCOME TO ULTAKI: EXPLORING THE RELEVANCE OF LARGE LANGUAGE MODELS FOR ACCURATE BEHAVIORAL SIMULATION IN ENERGY TRANSITION

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## **ABSTRACT**

*The global focus on greenhouse gases reduction places a major role on electrification of systems. While replacing fossil fuels with clean electricity is extremely appealing, the non-negligible costs associated with extracting and transforming mineral resources into renewable energy production systems as well as their world-wide deployment must be considered. As such, this study presents a novel approach to integrating Large Language Models (LLMs) into energy demand simulation, addressing the complexities and variability of human behavior as well as its profound impact on energy systems. By leveraging LLMs to impersonate diverse characters with distinct psychological traits, we explore the plausibility of reactions, prompt sensitivity, and second-order dynamics through individual agent experiments. Furthermore, we introduce a framework for multi-agent scenario investigation, where a shared limited volume of energy triggers a traumatic event if the average environmental sensitivity drops below a specified threshold. A thorough result analysis and discussion concludes this work and sheds light on the relevance and current limitations of integrating modern language models both in complex systems and decision-making processes as well as more specific energy demand estimation the formulation of sustainable energy strategies.*

## **KEYWORDS**

*Large Language Models, Population Dynamics, Behavioral Simulation, Energy Transition.*

## **1. INTRODUCTION**

As the global community grapples with the urgent need to address climate issues [1], it is imperative to incorporate the necessary paradigm shift across all sectors of society. One critical aspect of this transition is the increasing utilization of renewable energy sources. However, these systems have faced considerable strain due to rising energy demand and their susceptibility to extreme climatic events. Moreover, the pursuit of increased production to meet this demand raises concerns regarding carbon emissions and potential constraints on planetary resources. Therefore, it is essential to consider the influence of population behavior on energy demand in order to effectively plan for the energy transition.

Anticipating and understanding population trends and dynamics plays a pivotal role in the planning process, especially in the context of islanded smart-grids powered by renewable

energy. Smart-grids have the strength of efficiently integrating

Project repository: [https://github.com/MoMeAKR/Ultaki\\_data](https://github.com/MoMeAKR/Ultaki_data)

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renewable energy sources, optimizing energy distribution, and promoting sustainability. However, they may face limitations in terms of the intermittent nature of renewable energy production, the challenges of balancing supply and demand, and vulnerabilities in the energy network infrastructure. As such, accurate modeling is essential to capture the significant impact of individual behavior on the overall performance of these self-contained energy systems. However, effectively capturing and modeling individual behavior poses significant challenges, as individuals exhibit diverse and context-dependent reactions to localized events that are often difficult to formalize using conventional modeling tools. Existing research offers behavioral modeling strategies that provide a macro-level approximation of societal trends, but they may lack the necessary accuracy and fidelity required to capture the intricate complexities of individual human behavior. Concretely, the limitations of simulation models based on simplifications and statistical views of sociology blurs the nuanced impact of specific events, policy decisions, or even interpersonal conversations on an individual's ecological sensitivity in islanded smart-grids fueled by renewable energy. Therefore, the development of suitable modeling approaches that can adequately represent and incorporate the variability of individual behavior remains a critical area of research in this domain.

Recent advancements in the field of natural language modeling have shown strong results in terms of generalization and the ability to handle diverse and complex downstream applications. In particular, this work builds upon the foundational concepts introduced in [2] to delve into the modeling of complex population dynamics at the individual level. By leveraging Large Language Models (LLMs) flexibility and adaptability, this research aims to show that capturing the nuanced behavior of individuals in response to local or global events is within technical reach.

Therefore, in stark contrast to conventional modeling methods, we present a series of experiments and configurations aimed at showcasing the potential of this fine-grained framework while also highlighting its current limitations. Specifically, we investigate various aspects of employing LLMs for behavioral simulation, including assessing the plausibility of responses given specific character-event combinations, examining prompt sensitivity, and incorporating higher-order dynamics. Finally, we implement these concepts within a multi-agent simulation framework, wherein a finite energy supply constraint prompts individual behaviors that can have far-reaching consequences, ultimately triggering shared traumatic events. These traumatic events encompass scenarios such as prolonged blackouts or energy restrictions, impacting every agent within the simulation. The objective is to observe and analyze the extent to which agents adapt their energy consumption in response to being informed of the energy depletion, thereby examining the behavioral dynamics and decision-making processes in the face of energy scarcity.

While significant further extensive testing, benchmarking and baseline comparison are necessary before practical implementation, our initial results demonstrate

satisfactory performance and exciting perspectives for the use of LLMs to enhance the accuracy and fidelity of behavioral simulation in energy transition scenarios and beyond.

## 2. RELATED WORKS

Population modeling serves as a vital tool for understanding the complex dynamics of populations, encompassing their interactions with the environment and responses to various drivers of change. It provides a comprehensive framework for simulating population behavior over time and evaluating the impacts of different scenarios and management strategies on factors such as population growth, distribution, and sustainability. The field of population modeling has dedicated significant research efforts to uncovering the underlying mechanisms that drive the responses and evolution of diverse populations. This includes studies on population growth [3], distribution patterns [4], species interactions [5], and the stability of populations [6].

While differential equation-based systems have been widely utilized across various domains [7, 8], research focusing on human communities has increasingly turned to social computing, despite the notable challenges it presents [9]. Notably, investigations into unsympathetic behaviors within social networks, specifically trolling, have been conducted by [10], who employed simulations and real-world data to explore the underlying mechanisms behind such conduct. Similarly, [11] undertook a comprehensive study on social networks, aiming to identify positive communities and propose strategies for enhancing the online experience. Taking a broader perspective, these studies are promising and have yielded valuable insights, they are hampered by labor-intensive social engineering processes [12, 13], manual analyses, and reliance on collected data, limiting their applicability in prospective scenarios, such as those implying human behavior in the scope of climate change and energy transition.

Alternatively, recent advancements in language models have shown promising results and impressive generalization capabilities. Furthermore, while not currently rigorously backed by formal theory [14, 15], empirical research [16] has demonstrated that meticulous crafting of input prompts can increase model performance, specifically in tasks involving reasoning and arithmetic [17, 18]. This observation highlights the effectiveness of these models when appropriately prompted, thus reinforcing their increasingly validity and reliability. In relation to the present nascent field of research, [19–21] have explored the application of LLMs in understanding human behavior [22] and social simulations. Moreover, [2] introduced a dense and multi-agent framework with a complex environment, highlighting emergent and plausible behavior, agents' short and long-term planning capabilities as well as adherence to initially defined characteristics, thanks to the concept of memory. These characteristics are particularly appealing as they suggest that these approaches could provide significant advantages over traditional population modeling methods in broader scopes. This work presents an attempt to extend such techniques to the domain of energy-related environmental policies and underscores the unique advantages and current limitations of LLMs.

## 3. THE ULTAKI APPROACH: CONTEXT AND BACKGROUND

As introduced, the training regimen of LLM and the immense volume to which they are exposed to provides them with an accurate yet very diverse representation of human psyche and behavior. As such, when adequately prompted, LLM are able to simulate responses of distinct individuals [2, 22]. Consequently, these approaches are likely to constitute strongly valuable tools for modelling complex configurations that can eventually involve complete

populations of agents and be applied to sensitive policies or landscapes where testing is unfeasible, unethical or too onerous.

In particular, this work focuses on social simulations and modelling in the scope of the transition towards renewable energy, which is likely to impact current habits and result in society exhibiting inertia or even plain resistance. Specifically, the following paragraphs describe an initial modelling framework and explore various scenarios to establish LLM suitability for this kind of modelling.

### **3.1. Characters and Memory**

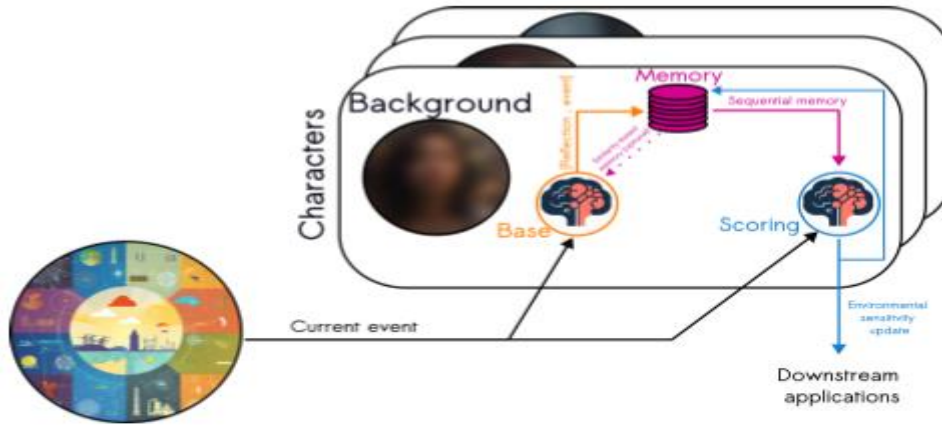
Using insights and practices introduced in [2], our proposed framework incorporates a persistent memory mechanism that maintains the state of the Large Language Model (LLM) in the form of a character. This memory framework enables the LLM to generate contextually appropriate responses based on the character's background and the events they have recently experienced. Additionally, we introduce the concept of an environmental sensitivity score, ranging from 0 to 10, which reflects individuals' level of concern regarding climate issues.

Concretely, as shown in Figure 1, in our experiments, each character aggregates a pair of LLM that are used for two specific tasks:

- The first model embeds the main psychological aspects and background story and is used to simulate the character reaction to a given event.
- The second model stores the first model output as a memory and is solely used to provide an update on the character own sensitivity score.

In this context, several kind of memories were defined and are used in the simulations presented below:

- **Sequential memory:** this memory is embedded in the scoring model and stores sequences of tuples containing the event, the associated thought and environmental sensitivity score. This memory has a maximum length and discards oldertuples once filled.
- **Similarity memory:** this memory is associated with the character agent has no durability limit. Following the sequential configuration, it stores tuples of events and associated thoughts and retrieves a predefined number of them based on cosine similarity between the tuple embeddings and the input request.



**Fig. 1.** The proposed framework relies on fine-grained population modelling through a social simulation that relies on a set of LLM dedicated to either providing plausible answer to a given event and computing character environmental sensitivity score updates

### 3.2. Prompting strategies

Prompts play a critical role in steering and guiding the output of language models to align with user expectations, as emphasized by numerous studies. In light of the contextual variations and diverse characters involved in this study and in order to ensure consistent and desirable model responses, intensive care has been dedicated in producing robust prompts. Consequently, the authors propose a template that can be formally described as follows:

$$p = p_i \circ p_c \circ p_m \circ p_a \circ p_e \quad (1)$$

Concretely, the proposed prompting strategy in this work involves the combination of various sources of information to construct a comprehensive final prompt:

- $p_i$  is an optional contextual prompt that provides an explanation of the environmental sensitivity score. It sets the stage for the subsequent prompts by establishing the relevant background information and is mainly used by the scoring agent
- $p_c$  is the prompt that defines the psychological traits of the character. It captures the main personality traits and provides indications regarding character reactions to given events
- $p_m$  represents the memory prompt and includes the character's recollection of recent or related events, shaping the decision-making process. It is optional for the base agent but mandatory and sequential for the scoring agent.
- $p_a$  is the anthropomorphic prompt, which prompts the model to consider itself as the character and exhibit plausible behavior given the defined cognitive traits
- Finally,  $p_e$  is the event prompt, setting the stage for the model to respond as the impersonated character

### 3.3. Usage in a Higher-Level Energy Simulation

Simulating a large number of highly diverse agents in complex and challenging scenarios is desirable as it provides a flexible way to explore prospective scenarios. However, rigorous evaluation of the reliability of long-horizon simulations using LLMs and the extent of divergence with observed human behavior remains complex. Nevertheless, this section

focuses on preliminary works on framework integration, which, as rapid increase in performance in state-of-the-art methods suggests, could be relevant. Due to current limitations and extensive costs associated with LLM usage, simulating a full population for a significant time horizon is currently beyond the realm of authors' accessibility. Instead, an extrapolation from a reduced panel of individuals that represent thinking clusters is proposed and could provide interesting insights into how the general population could react to global events while still preserving the fine-grained granularity required when considering renewable energies.

## 4. EXPERIMENTS

In order to demonstrate the relevance of LLM for behavioral modelling in the scope of energy transition, a set of experiments designed to evaluate empirical answer plausibility, prompting sensitivity as well as the impact of second order dynamics inclusion is proposed. Furthermore, a configuration integrating multiple agents in a shared simulation allowing the evaluation of traumatic events impact on a complex population is also detailed. Every experiment presented here has been done using Open AI's Chat GPT (gpt-turbo 3.5) and Open AI Embeddings for the second order dynamics.

Due to the substantial amount of text generated by each configuration, the authors have chosen to provide a condensed representation in the paper. While this presentation aims to capture and present the most valuable insights, readers are

encouraged to access the project repository for a more comprehensive view of the generated text.

### 4.1. Characters

Considering a broad scope of personalities and their answers to vastly different events that would be excessively complex to formally describe is crucial in establishing LLM relevance for future large populations modelling. In this scope, we introduce several characters inspired from the 2016 US election demographics [23]: designed to embed a wide horizon of sensibilities, this study include eight distinct personalities ranging from *evangelical republican* to *progressive democrat*. For each character, we prompt a LLM to generate a background story that contributes in anchoring them in a more grounded and relatable situation and plays a significant role in guiding their reaction to the events to which they are exposed to.

### 4.2. Events

Events constitute a crucial element of the proposed approach as they are supposed to elicit vastly dissimilar and contrasting reactions from a the spectrum of character introduced. Emulating the background story for individuals, the imaginary town of Ultaki, a small Rust Belt town is proposed as the common location for the involved figures. As such, a set of personal, local and global events is predefined offline by prompting a generative LLM in particular contexts, collated and drawn from during the testing phase. Specifically:

- Personal events are suggested by a hairdresser having conversation with his clients. For instance:
  - *"I'm really concerned about the recent break-ins in our neighborhood."*
  - *"It's been so hot lately"*



- Local events are proposed by a program manager at a local radio trying to both meet his audience as well as broaden its view and horizon. Local events include:
  - *"The Climate Crisis Hits Home: How Ultaki is Impacted by Climate Change"*
  - *"The role of education in Ultaki's future"*
  
- Finally, an imaginary editorial director in a newspaper covering international topics produces the global events by retrospectively reflecting on significant events in 2023.
  - *"The Afghanistan Withdrawal: Implications for the Region and Global Security"*
  - *"The Arctic Thaw: Consequences for the Environment, Geopolitics, and Indigenous Communities"*

### 4.3. Plausible Simulation of Individuals

As previously discussed, population modelling often adopts a coarse granularity approach to simulate group dynamics or employs simplified rules to represent roughly-defined individuals. However, work aims to showcase the capability of fine-grained modelling. To achieve this, we commence by evaluating the plausibility of reactions based on a combination of character traits and specific events. Subsequently, we assess prompt sensitivity, examining the influence of different prompts on the model's output. Furthermore, we explore the integration of higher order dynamics into the modelling framework. In this section, we adopt a comparative context where all agents experience the same sequence of events, allowing for meaningful inter-agent comparisons and analysis.

**Individual reactions to a sequence of events** Taking advantage of LLM ability to untangle knowledge and context and consequently recombine them when adequately prompted, this first experiment relies on the following agents, formally defined in Section 3.2:

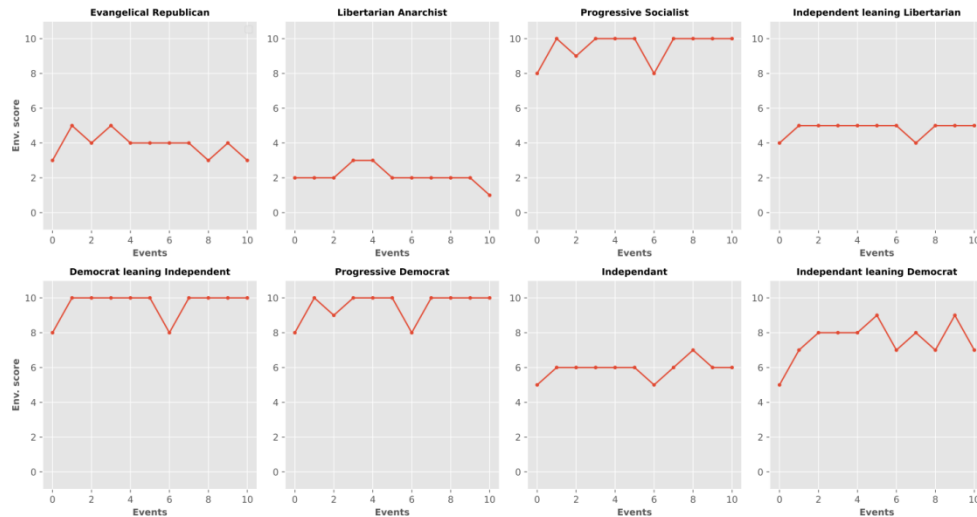
- Base agent:  $p_A = p_c \circ p_a \circ p_e$ . This agent does not use introduction nor similarity-based memory prompt
- The scoring agent directly implements Equation 1

In this context, the experiment proceeds by sequentially prompting each character with a shared set of ten events and recording both the agent reaction and its updated score. Figure 2 displays environmental sensitivity score evolution along time and the associated events and demonstrates that, even with a unique sequence of events, agents display an interesting diversity of trajectories along time.

For obvious reasons, an exhaustive review of all produced outputs is beyond the scope of this paper but a detailed view of reactions associated with several distinct events is provided in Figure 3. Specifically, in the hiking scenario, while the Independent leaning Libertarian character expresses enthusiasm for outdoor activities, it also mentions a desire to limit government intervention which contributes to lowering its environmental sensitivity score as computed by the scoring model. In contrast, the Progressive Socialist character insists on public land protection, thus underlining a representative initiative which is evaluated as a strongly positive increase in environmental sensitivity score. Interestingly, it appears that

characters have a tendency to underline their psychological traits in their answer as a way to justify the way they perceive the current event, as discussed in Section 5.

**Alternative score estimator** As suggested by the above results, plausible simulation of diverse human behaviors can be attained and can trigger likely reactions, in particular with an adapted structure that relies heavily on prompting strategies.



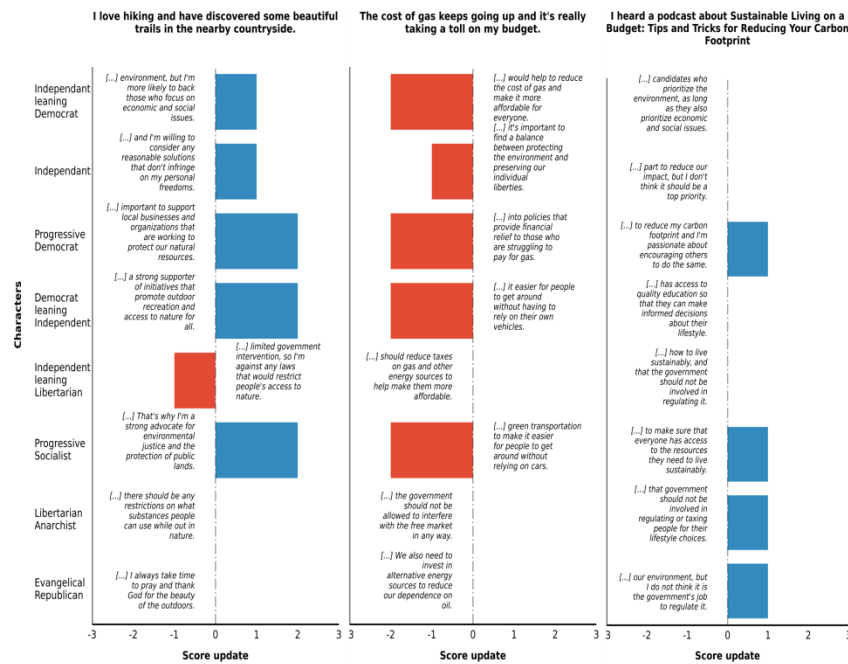
**Fig. 2.** Environmental sensitivity score evolution along a shared sequence of event for a set of distinct characters

In this context, prompt sensitivity and its impact on final results are important considerations in using Language Models (LLMs) in real-world applications. While careful attention was given to crafting prompts for agent reactions and memory, alternative prompt solutions could have been explored, such as the one presented in this section.

Concretely, this particular experiment replaces the self-evaluation in the memory component of an agent and instead introduces a third-party observer. Formally, the base agent is unchanged but for the scoring agent,  $p_a$ , the anthropomorphic prompt component, is altered to inform the model that it is now *a knowledgeable researcher in social science with profound insights into mechanisms likely to update behaviors and environmental beliefs*. Using the previously defined set of events, each character is thus prompted using the third-party observer and results are reported in Figure 4. As can be seen, global consistency is maintained during the trajectories but several configurations result in non-negligible spread between the two prompting strategies. As an insightful example, consider event 3 (*Tips on Sustainable Living on a Budget*) for the Libertarian Anarchist. When prompted, the character answers with the following:

[...] "I'm not sure I'm the best person to be giving advice on sustainable living.[...] I think that people should be free to make their own decisions about how to reduce their carbon footprint, and that government should not be involved in regulating or taxing people for their lifestyle choices."

In this specific example, while the character is visibly conscious of the need to reduce individual carbon footprint, which can be interpreted as a positive sign re-

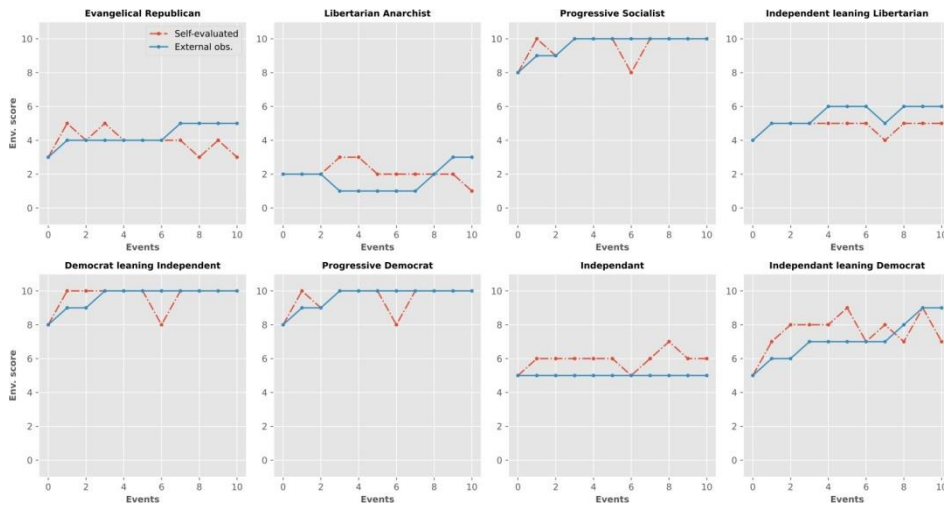


**Fig. 3.** Detailed overview of several event-induced scores updates for all characters and associated self-reflection

garding environmental sensitivity (contrasting with some agents expressing higher sensitivity towards financial or familial issues, for instance), it also suggests being against government intervention, consequently negatively affecting chances of larger-scale coordination. Given these elements, it is possible to argue both cases, depending on the weight associated to each aspect of the answer. In this view, it is interesting to notice that, in this case, self-evaluation returns higher scores than external observation.

Taking a broader perspective, while this type of effect can appear benign in these simplified simulations, it could have important effects if compounded at scale in constrained environments, such as islanded smart-grids connected to renewable energy sources and consequently requires adequate prompt calibration.

**Including second order dynamics** Previous works on traditional modelling population dynamics and its impact on islanded energy systems have contributed insightful dynamic models [24] but including second and higher order dynamics have proved challenging as it consequently becomes complex to foresee the effects of such trends within the models without extensive (and potentially costly) testing, resulting in significant probability to introduce non-negligible instabilities in the studied system of equations.



**Fig. 4.** Comparison of reference trajectory (red, dashed) with the alternative prompting strategies updates (blue, solid)

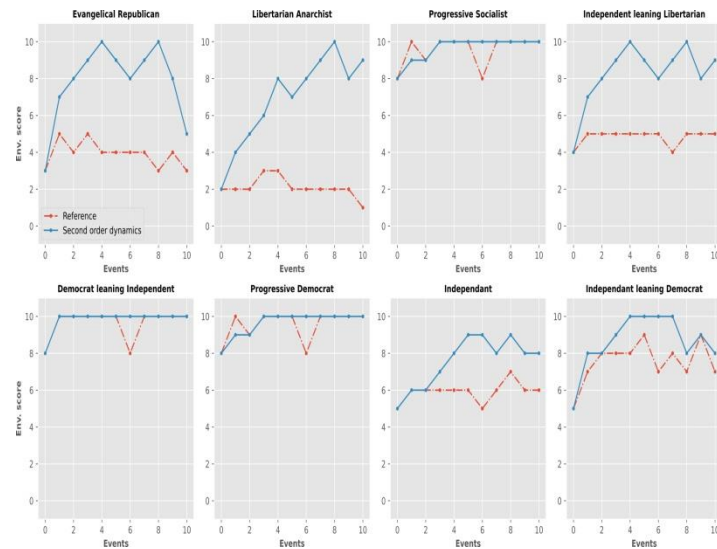
Nevertheless, this aspect can be explored in a novel and innovative manner by leveraging the capabilities of LLMs. Specifically, by incorporating a memory component in the agent initial stage, that is the one providing the answer to a given event, reactions to past events can be considered in the agent's response and consequently lead to the emergence of second-order dynamics.

Concretely, a configuration including second order dynamics is explored and its consistency evaluated against the reference initial approach. Formally, while the scoring agent is unchanged, the base agent incorporates a similarity-based memory that provides a set of past events and associated reflections for a given input, which are then added to the  $p_m$  prompt component. Memory retrieval relies on cosine similarity between sentence embedding that are computed for each new event and we present results for  $k = 2$  retrieved previous events, although additional values could be considered and explored.

The incorporation of second-order dynamics, brings about substantial modifications across various configurations, as depicted in Figure 5. These modifications frequently manifest as significant updates in the environmental sensitivity score, often towards higher values.

For instance, the first event presented to all characters is a simple personal thought: *"It's been very hot lately"*. This prompt results in the memory returning the following events:

- *I heard a podcast about Is Ultaki doing enough to combat climate change?*
- *I heard a podcast about The Climate Crisis Hits Home: How Ultaki is Impacted by Climate Change*



**Fig. 5.** Comparison of reference trajectory (red, dashed) with the second-order dynamics (SOD) driven prompting strategies updates (blue, solid). A strong increase in environmental sensitivity score can be observed in many SOD cases

By adding such events (and their associated reflection) to the base agent’s prompt, it is possible to observe much stronger environmentally conscious and concerned answer. Indeed, for the Independent leaning Libertarian character, the following reactions can be considered:

- Reference (base) answer: “[...] I think it’s important to take precautions to stay cool and hydrated. I also believe that it’s important to be mindful of our environment and to take steps to reduce our carbon footprint.”
- Second order dynamics answer: “I am concerned about the effects of climate change on our environment and the potential impacts it could have on our lives. I believe that the government should take action to reduce emissions and protect the environment,[...] I believe that the best way to address climate change is through incentives and regulations that encourage businesses to reduce their emissions and invest in renewable energy sources.”

In contrast to the base configuration, the answer generated by incorporating second-order dynamics tends to express greater concerns and evoke a stronger sense of urgency. This outcome subsequently leads to a significantly higher evaluation of environmental sensitivity by the scoring agent. Notably, when examining the overall pattern, it can be observed that the range of variations is narrower among characters who are already environmentally conscious. This observation suggests that the utilization of second-order dynamics may partially overshadow the underlying psychological traits, particularly in situations involving conflicting opinions.

#### 4.4. System Integration

As introduced in Section 3.3, this research ultimately aims at motivating LLM in large-scale social experiments. As a first step, an initial system integration demonstration is proposed in which, in contrast with previous single agent configurations, the impact of the average environmental sensitivity score of all agents participating can present a global effect.

In the proposed simulation, the process involves presenting individual agents with distinct events at each simulation step. The agents' reactions to these events are then used to assess their environmental sensitivity. The scores obtained from each agent's reaction are aggregated at each step. If the average score drops below a predetermined threshold, representing, for example, the minimum acceptable environmental sensitivity (assuming a correlation between environmental sensitivity and energy demand), a traumatic event is introduced into the agent's memory for a specified number of steps. It is important to note that traumatic events are forgotten after three steps in this particular study, although this parameter can be tuned. Concretely, traumatic events can include increased energy prices, energy restriction or even complete blackouts.

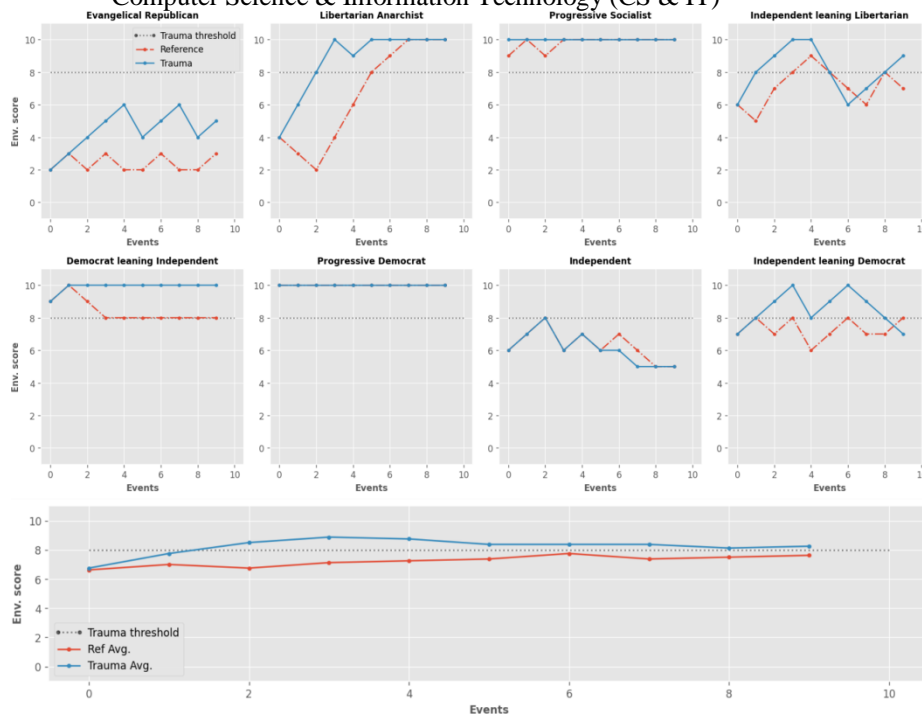
To examine the impact of this mechanism, Figure 6 compares the trajectories of agents experiencing the same sequence of events, with and without the inclusion of the trauma system. As can be seen, the average environmental sensitivity score quickly raises above the threshold value and consistently maintains a healthy level, in contrast with reference trajectory.

## 5. DISCUSSION

The results of the above experiments highlight the remarkable flexibility and capabilities of LLMs-driven agents in reacting to a wide range of events. The plausible and diverse responses generated by the LLMs underscore their potential for usage in large-scale social simulations, ultimately enabling fine-grained modeling of human behavior and its impact on energy systems.

However, the experimental approaches detailed in the previous sections underline need to acknowledge the limitations and challenges associated with the use of LLMs. Beyond the critical sensitivity to prompt structure, which, although representative of the variability human behavior, introduces numerous additional variables such as prompt components ordering or character incarnation, some model specific factors are to be considered.

Indeed, despite introducing a wide diversity of characters and background stories, it has proved challenging to elicit highly controversial or less elaborate opinions from the specific LLM model (GPT 3.5 turbo) used in this study. This limitation may be attributed to the RLHF fine-tuning technique employed during the model's development and that aims at preventing toxic or biased output. Exploring the



**Fig. 6.** Comparison of individual and averaged trajectories including trauma mechanism against reference baselines. The first two rows display individual environmental sensitivity evolution along events and demonstrate that the traumatic events do influence and generally increase the character environmental sensitivity score. Lower row shows the averaged evolution along time, demonstrating that the traumatic events configuration results in a more favorable energy demand.

results obtained with different LLM architectures could provide valuable insights into capturing a broader range of opinions and enhancing the diversity of responses generated by the models. Furthermore, we suggest that, considering the rapidly increasing context window length of LLM, superior model consistency with base character could be attained by including additional background elements that could ultimately partially overshadow the biases introduced by RLHF.

Taking a broader perspective, while the authors of this work strongly believe that this research provides interesting insights and exciting perspectives, it also underlines the need to invest collaborative efforts in designing adapted benchmarks and associated metrics for the extended spectrum of applications now accessible through this new paradigm.

## 6. CONCLUSION

Social computation and simulation of multi-agents systems are pivotal domains for preparing the energy transition effort by exploring prospective scenarios and effect of public policies on individuals. Taking advantage of the recent advances in Large Language Models (LLMs), this work demonstrates, through a series of diverse experiments, that the flexibility of this paradigm yields important benefits such as modelling responses to events that would otherwise be formally intractable and including higher order dynamics. These advantages extend to multi-agent simulations, allowing for the consideration of the impact of global events that arise from fine-grained local events and the unique reactions of individuals with distinct personalities. While the results of this study are promising and provide exciting research prospects, it is important to acknowledge the limitations, such as

prompt sensitivity and potential biases. Addressing these limitations through benchmarking, real-world calibration, and further research will contribute to the advancement of this field and enhance the practical applications of LLMs in energy transition efforts.

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# AXIOMATIC METHODOLOGY OF FORMALIZATION AS A WAY TO INTELLECTUAL ANALYSIS IN COMPUTER SCIENCE

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## ABSTRACT

*The report discusses the possibility of creating a universal mathematical formalization tool for the formalized solution of intellectual problems of cognition of both real processes and phenomena of the surrounding world and man-made processes. A path based solely on the tools of classical mathematics is proposed – the methodology of axiomatic modelling. At the same time, the problems that prevent obtaining an effective true solution to these problems by the proposed means today are described in order to eliminate them. The report is devoted to this topic. The proposed methodology is capable of carrying out semantic data analysis and solving intellectual problems, complementing the existing most modern methods of computer science with semantic accuracy, practical or experimental verification and formal proof of statements.*

## KEYWORDS

*Formalization, Axiomatic Modelling, Intellectual Analysis, Computer Science, Intellectual Task*

## 1. INTRODUCTION

Computer science, as it develops, captures all new areas of knowledge and takes on new functions. «We contend that understanding how data are acquired and processed into functional information will be instrumental in developing a richer understanding of complex evolving systems, and to building a general theory of life. A full examination of the role that information plays in various biotic and abiotic systems requires a more granular level of exploration» [1].

The understanding of the term "information" is also being improved. «The act of transforming data into a state that increases a system's survivability generates functional or semantic information» [1].

And yet, the key question of the subject of computer science - information, remains the question of its truth.

## 2. RELEVANCE

Researchers use top-end methods and language models to analyse the veracity of a particular information, achieving fantastic skill in this [2], in the absence of uniform, understandable for everyone and competently formulated capacious criteria for scientific evaluation of truth. It's no secret that the truth of the statement "this apple is delicious", although it will be approved by the

majority of respondents, but as a rule there is someone who will challenge this fact. At the household level, we could neglect the opinion of a small number of the most demanding respondents. But when it comes to complex tasks or large dimensions, accuracy requirements in particularly important scientific and practical tasks, such an error can cast doubt on the truth of the final result and the legitimacy of its further use [3]. This fact, as well as the rapid development of IT technologies, determined the relevance and the need to analyse our existing capabilities to create more advanced approaches to formalization. After all, formalization is exactly the proven tool that can reduce the cost of making intelligent decisions. The use of the results of modern studies of the human thinking process [4] for the correct formalization procedure determines the success of the proposed approach.

Unfortunately, with the exception of the scientific concept of "law" [5], today there are not only clearly defined and used scientific criteria for the truth of facts (evidence-based medicine is a pleasant exception), especially in formal sciences, although intuitive and social, directly or allegorically expressed assessments certainly exist. There are also no objective estimates of optimality for data handling methods. For example, mathematical science has more than 1,500 mathematical structures [6], before the appearance of modern structural structures adapted to the needs of AI and IT, and instructions or "passports" describing these structures and their capabilities: optimally solved problems, types of optimally processed data, restrictions, and so on, are traditionally absent. They are sometimes present in specific tasks, but when it comes to choosing a solution method and mathematical structure for a practical purpose, this choice is made more intuitively and often by specialists in various fields of knowledge, but not by mathematicians.

### 3. MATERIAL AND METHOD

In order to advance computer science towards the goal of creating universal artificial intelligence tools and their safety for humans, it is necessary to define each of the scientific concepts and tools used to operate with these concepts with precision.

The creation of a universal formalization methodology that is optimal in terms of resource costs, capable of carrying out data mining and solving intellectual tasks, is quite a feasible task [7], if at each step of its implementation one adheres to the principle of reliability of facts and scientifically justified legality of using tools for formal operation in this way. The solution to this strategic task can be found only in proven historical practice and well-studied scientific achievements, the legacy of centuries-old scientific observations concentrated in scientific laws and philosophical truths.

The physiological fact that a person can effectively reason only on the foreseeable amount of initial data [8] should have been a guide to the creation of this methodology, offering a convenient and simple formal language.

**The purpose of the report** is to identify the possibilities of creating a universal formalization methodology.

The genetic feature of the human thinking function is that the power of the creative component of this function is maximal when all the components of the studied law are in the field of view of this person [9]. Otherwise, this power decreases exponentially. James Clerk Maxwell [10], guided by this feature, worked on only one hundred symbols of the law, unlike Michael Faraday [11], who worked with a thousand pages of typewritten text of the same law. The modern statistical man remains in the Faraday situation. and he will never be able to repeat Maxwell's success in the same way that Faraday failed to do it. And this is because a person always reflects

on the context of the law located in his psyche, on a large number of pages of his own memory. Maxwell, on the other hand, previously created a formal language that allows describing a problem task with a number of symbols-identifiers of scientific categories smaller than a hundred, and then on the same categories created an ingenious law reflecting vital activity in all its subtleties for an infinite set of electromagnetic fields [12].

In principle, there can be no alternative to formal languages because of their property of automatically increasing by several orders of magnitude the semantic load per symbol of a language compared to natural language, which corresponds to an increase in the power of the creative component in the function of human thinking. Classical mathematics, as an arsenal of formal languages for describing stereotyped logical and numerical relations between variable physical quantities that functionally fully characterize the permissible states of material processes and phenomena, can provide such a universal formal language – the logic of predicates of the first order [13]. Provided that we have learned how to use it, in the most fundamental sense, covering the knowledge of all related fields of science [14].

**A formal language** is a mathematical model of operating functions with the meanings of one of the natural languages, for example, English [15].

The semantic elements in English are words. The symbolic codes of each of the words and their semantic load are recorded in explanatory and encyclopaedic dictionaries. The rules for the formation of correct meanings made up of words are defined in grammar.

There are no grammars similar to English grammar in formal (formulaic) languages. Moreover, there are no words fixed in dictionaries that carry elementary meanings. The statement of a specific task clearly and unambiguously formulates each of the meanings and its identifier, which are assigned to them as operands of this task.

The grammar of formal languages consists of two components [16]:

- the syntax of the language, i.e. the rules for the correct spelling of language formulas;
- language semantics, i.e. rules of correct interpretation:
- for the language of mathematical logic – the aspect of truth, or falsity, conveyed by the formula of compound meaning;
- for one of more than 1500 formal languages of classical mathematics – the aspect of matching the meanings of each of the operations in this formal language.

Classical mathematics is a product of the spiritual production of the highest mental function of human thinking [17] and contains more than 1,500 formal languages of description and methods for solving problematic functional problems for the processes and phenomena of the universe.

One of the most important features of the higher mental function of human thinking is the formulaic interpretation of **the functions of operating with meanings** when solving problematic functional tasks of analysing material dynamic systems. Here we will give another characteristic of each formal language, which significantly affects the effectiveness of operating with meanings.

Each of these formal languages has another name "mathematical structure" [18], since it is provided with stereotypical methods for solving problematic functional problems, the formulation of which is feasible exclusively in this language.

The data types of this language, as well as its types of operations and types of relationships between data, are properties of physical variables that functionally fully characterize all permissible states of the process under study, or phenomena in the universe. Of all mathematical structures, the mathematical structure called first-order predicate logic [19] is fantastically universal and, like no other, is designed to solve so-called intellectual problems, i.e. logical problems that do not have pre-known solution algorithms.

A mandatory requirement for the formulation of intellectual tasks in the language of first-order predicate logic is their presentation in the format of theorems formulated on the basis of material axioms, which are facts of full-scale experimentation with the processes and phenomena of the universe under study.

Science is a system of knowledge about the laws of life and the development of matter, society and thinking [20]. It is both a system of knowledge, and their spiritual production, and practical activity based on them.

This is a historically formed form of human activity aimed at cognition and transformation of objective reality. This is a spiritual production that results in purposefully selected and systematized facts, logically verified hypotheses, generalizing theories, fundamental and particular laws, as well as research methods [21]. Like any form of activity, science is improving, responding to new challenges and tasks.

The subject of science is the media of inanimate and living matter, their various forms and types of movement, their reflection in human consciousness. According to their subject, sciences are divided into natural-technical, studying the laws of nature and ways of its development and transformation, and social, studying various social phenomena and the laws of their development, as well as man himself as a social being [22]. Among the social sciences, a special place is occupied by a complex of philosophical disciplines that study the most general laws of the development of nature, society, and thinking [23].

In the natural sciences, one of the main methods of research is experiment, and in the social sciences – statistics. It is these concepts that can serve as a criterion for **the truth of a fact**, and should be explicitly taken into account in the structure of formal sciences.

General scientific logical methods of empirical data processing are: deterministic or probabilistic approach, induction, deduction, analysis, synthesis.

In each science, the empirical level differs, that is, the accumulated factual material - the results of observations and experiments, and the theoretical level, that is, the generalization of empirical material expressed in relevant theories, laws and principles; scientific assumptions based on facts, hypotheses that need further verification by experience [24]. The theoretical levels of individual sciences converge in the general theoretical, philosophical explanation of open principles and laws, in the formation of ideological and methodological aspects of scientific knowledge as a whole [21].

The spiritual products of science are true **informational reflections** - objective knowledge about the laws of vital activity and development of inanimate and living matter in the universe, about the studied matter of the universe. Therefore, the actions of science can be figuratively represented as the transmission of a light beam of the material medium under study, in the reflection of which (the light beam) the target information about this material medium is manifested. And this should also be implemented in intelligent modelling and formalization.

The objectivity of solutions to intellectual problems will be ensured if only **formal proofs** of theorems by the method of resolute inference act as proofs. The complexity of such a solution, subject to the principles outlined above and the proposed solution algorithms, will be the minimum possible.

First of all, thinking is the highest cognitive process. It represents the generation of new knowledge, an active form of creative reflection and transformation of reality by a person [25]. Thinking generates a result that does not exist either in reality itself or in the subject at this moment in time. It is this observation that requires special attention of physiologists, biologists, psychologists, representatives of all sciences about the functioning of human thinking for the most in-depth understanding of the algorithms of thinking and the functions of permissible operation with information received from the outside.

**The essential qualities of human thinking** are:

**logical** thinking is the ability to follow a strict sequence of reasoning, taking into account all the essential aspects in the object under study, all its possible relationships;

**evidence-based** thinking is the ability to use facts and patterns at the right moment, confirming the correctness of judgments and conclusions;

**critical** thinking is the ability to strictly evaluate the results of mental activity in order to discard incorrect judgments, conclusions and decisions (the ability to abandon the actions started if they contradict the requirements of the task) [26]. Today, this component is the least provided for in formal languages offered for use in AI sciences today.

#### 4. CONCLUSION

The movement towards intellectualization in the sciences of AI creation, along with the invention of new ways of processing various data using existing AI and LM methods, combines the study of the physiology of human thinking and a formal description of this process in order to increase its productivity.

The key issue in the problem of cognition of thinking is the generation of new knowledge by the brain on the basis of knowledge stored in its memory, requires further study and experimental confirmation of research results. The answer to this question about the possibilities and properties of thinking is the key to the creation of formalisms capable of intellectual analysis of information. Creation of a methodology for formal assessment of the truth of the information received – a universal algorithm of intellectual analysis and a methodology for solving intellectual problems.

We have already developed proposals for creating such a methodology [27] in the form of the author's axiomatic modelling methodology, but a lot of interdisciplinary work is required to effectively implement these proposals in the practice of artificial intelligence and in the theory of AI, LM and IT.

This work, despite numerous approbations of our proposals [7,14,27], will not be able to achieve maximum efficiency if it is not applied systematically. The simple procedure of using knowledge from various fields of science and practical life in each specific task, in the methodology of axiomatic modelling, generates a desire to use the entire complex of knowledge obtained today for the most accurate solution of each of the tasks. In turn, all the new knowledge used should not destroy the accuracy and reliability of the final result, i.e. must meet the accepted criteria of truth. This requirement also applies to the use of mathematical structures, as well as to each of the

permissible means of operation. Therefore, their critical assessment will certainly become a priority in the roadmap for creating universal artificial intelligence tools.

Mathematics, as the most important tool for cognition of reality, has repeatedly been criticized for its objectivity [28-30]. This article does not pursue this goal. It is the high role of mathematics in objective science that makes it the first to respond to the growing challenges and requirements for the accuracy of its tools, its compliance with our new, powerfully accumulating knowledge. Moreover, we would like to emphasize that the centuries-improving, precise apparatus of classical mathematics is capable of solving the most modern problems and responding to the most pressing challenges, confirming its perfection. We hope that the implementation of the axiomatic modelling methodology will demonstrate this.

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# FROM U-NET TO (U-NET) +, WHAT INNOVATIONS HAVE WE MADE FOR THE TREATMENT AND DISCOVERY OF BREAST CANCER?

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## **ABSTRACT**

*Artificial Intelligence (AI) has achieved remarkable performance in the field of medical image analysis, particularly in tasks such as object detection, segmentation, and classification. In this paper, we introduce a solution for automatic breast cancer diagnosis based on the U-Net architecture, which we call (U-Net)+. The novel (U-Net)+ is designed to handle both segmentation and classification tasks within a signal framework. We retained the original U-Net architecture due to its strong learning capabilities and its advantages in semantic segmentation. Notable, we incorporated fully connected layers into the bottleneck layers, serving as a multi-functional classifier for both initial diagnoses based on raw images and further diagnoses for segmented images. The (U-Net)+ model is trained using a joint loss function. We conducted the experiments on breast ultrasound images, demonstrating that the (U-Net) performs well in both classification and segmentation tasks.*

## **KEYWORDS**

*Breast Cancer; Automatic Diagnose; Classification; Semantic Segmentation; U-Net;*

## **1. INTRODUCTION**

At the beginning of 2020, I experienced the loss of a loved one to cancer for the first time. My aunt passed away after a two-year battle with breast cancer, and it was the first occasion I felt that cancer's proximity to my life. It was no longer a pathological concept in textbooks but a disease that could affect those around us, or even ourselves. Moreover, since 2022, I have been involved in advocating for affirmative action for Afghan women, including women's right to education and voice. During this journey, I learned that breast cancer is the most common cancer among Afghan women, especially in Kabul City. Using this fact as a starting point, I began to focus on events related to breast cancer. According to the World Health Organization (WHO) Global Female Breast Disease Questionnaire, more than 2.3 million women worldwide suffer from breast cancer every year. In more than 90% of countries, breast cancer is the first or second leading cause of female cancer death[1].

However, in some cases, breast cancer is detected only after symptoms appear, yet many women with breast cancer remain asymptomatic in the early stages. Early detection or diagnosis is important, as it

can significantly enhance survival rates and drastically reduce overall treatment costs[2]. Usually, the most direct and efficient method for detecting breast tumours is through medical imaging tests. The precision of this diagnosis relies on the physician's experiences and expertise in image analysis. This raises the question: can we develop a computer-aided system to assist doctors in achieving more accurate and efficient breast cancer diagnoses?

With the rapid development of AI technologies, they have been applied in medical image analysis, including image classification, target detection, image segmentation, and image retrieval, etc. These applications have achieved remarkable performances[3,4,5,6]. AI technologies were used to develop tools to assist doctors in detecting and segmenting tumours with lower possible errors. During my research, I explored various online resources and discovered U-Net as a deep-learning model that has shown great success in the field of medical image segmentation[7,8]. The availability of open-source code implementations and extensive academic research attracted me. I try my best to understand its details and implement it on breast cancer ultrasound images. Additionally, we designed an enhanced U-Net model and named it (U-Net)+, which is proficient in both segmentation and classification. The model offers the physicians the segmented tumour and automatic diagnosis results, categorizing them as normal, benign, or malignant. The main contributions of our work include:

1. We presented a comprehensive view of U-Net in an easily understandable manner. To understand it well, we likened U-Net to the process of seed growth for the contracting path and blossoming for the expansive path, where the skip connections can be thought of as the source of nourishment. In addition, we displayed the 2D convolution, and 2D transpose convolution operations, and introduced the concepts of encoder and decoder.
2. We designed a system that incorporates multiple functions, including classification and segmentation based on the U-Net architecture. We named it as (U-Net)+. We embedded a classifier that can classify the normal, benign, and malignant samples. It performs effectively on both ultrasound images and segmented images. During the training process, we employed Sigmoid and Softmax activation functions as per their respective tasks and also applied different weights in the total loss functions.

## **2. BACKGROUND**

### **2.1 Basic information about Breast Cancer**

Breast cancer is the most frequent cancer among women worldwide, accounting for 1 in 4 cancer cases. It occurs when the damaged cells grow in an uncontrolled way and a tumour is formed. This disease is typically categorized into four stages: the appearance of abnormal cells, pre-invasive and invasive cancer, and cancer spread. When breast cancer is detected and treated at an early stage, the chances of survival are significantly higher. Figure 1 illustrates the division of different stages and the corresponding survival rates.

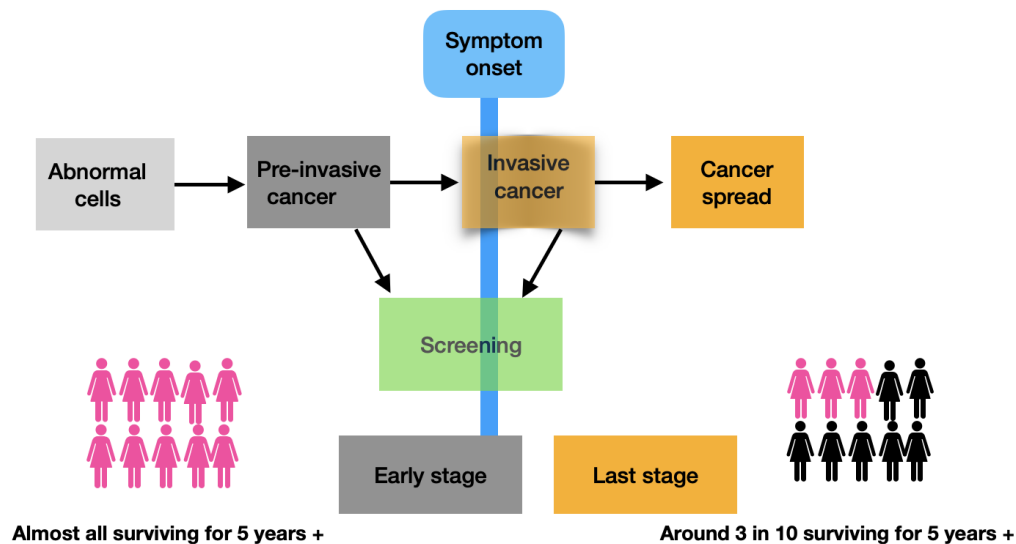


Figure 1. Breast Cancer Diagnosis Stages and Survival Rates

According to statistical data, we see that nearly all women survive breast cancer for 5 years or more if breast cancer is diagnosed at the early stage, but this rate decreases to approximately 3 in 10 women when the cancer is in its advanced stage[9]. However, early diagnosis can be challenging because many women with breast cancer don't exhibit symptoms in the initial stages. Therefore, regular breast cancer screening and precise medical imaging analysis are critical for preventing death. Currently, a range of medical imaging methods is employed, such as breast ultrasound, breast MRI, mammograms, newer and experimental Breast Imaging Tests, etc. In the next, advanced image analysis technologies gradually appeared to improve the accuracy of diagnosis.

## 2.2 AI in medical image analysis

Medical imaging plays an important role in disease diagnosis and surgical treatment. Through these images, doctors can locate tumours, segment specific areas, and make decisions regarding staging[10]. However, manual detection and segmentation processes are time-consuming and susceptible to various subjective and objective factors that include a physician's expertise, emotions, prejudice, and diagnostic methods, resulting in a relatively high rate of misdiagnosis. To understand and interpret images well, many computer-aided diagnosis (CAD) schemes have been developed. These schemes aim to assist doctors more efficiently and objectively, to achieve a higher diagnostic accuracy[11,12]. In recent years, AI has experienced rapid development, leading to its widespread applications in the medical field. At present, AI is employed in medical image processing, including image classification, target detection, image segmentation, and image retrieval.

To complete these tasks, extensive models have been developed, and deep learning models have been remarkably successful. As one of the most popular deep learning-based models, U-Net was proposed by Ronneberger et al in 2015, which is for Biomedical Image Segmentation[13]. It can capture both the context and the localisation feature. In our work, we'll train a smart U-Net called (U-Net)+ for breast cancer diagnosis.

## 3. BREAST CANCER DIAGNOSIS SYSTEM

We aim to design an intelligent system capable of performing both segmentation and classification for breast cancer diagnosis automatically, as illustrated in Figure 2. Usually, input samples in the form of ultrasound images are processed through the system. Firstly, the system provides an initial classification result as either normal, benign, or malignant. Then, the images are directed to the

semantic segmentation module, and based on the segmentation results, the system generates further and final diagnostic results. Next, we'll describe this process from an AI perspective. Enhanced segmentation is crucial, as it not only facilitates more accurate diagnoses but also plays a significant role in planning surgery and determining appropriate therapeutic strategies.

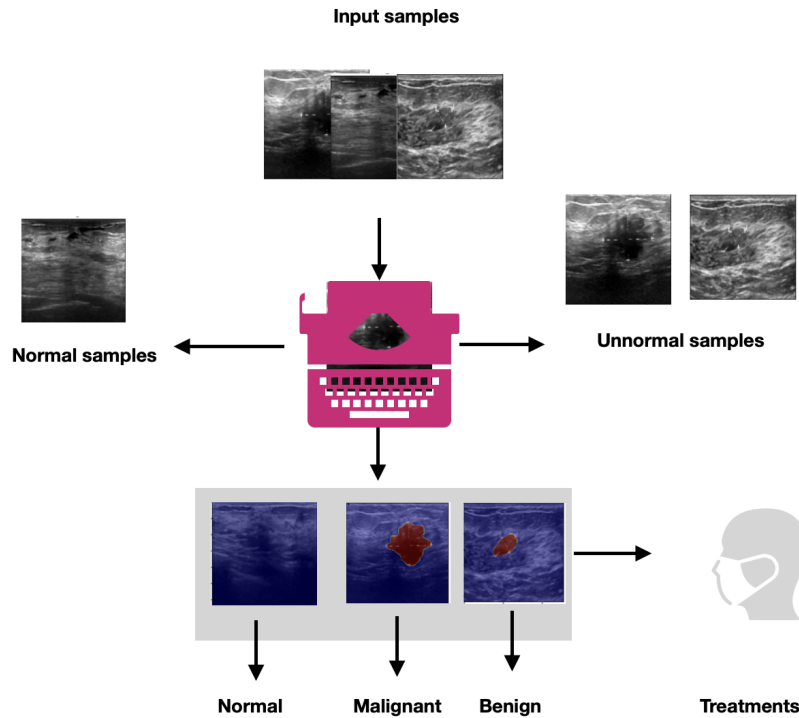


Figure 2. Breast Cancer Diagnose

First, we organised the dataset into three categories: normal, benign and malignant. The dataset includes ultrasound image sets  $X$  and their corresponding labels  $Y$ , 0 for benign, 1 for malignant, and 2 for normal. Consequently, we need to train a multi-class classifier  $C_1$ . The goal of the classifier  $C_1$  is to establish a rule for predicting the label  $Y_{pred}$  for a given sample in  $X$ , which can be represented as

$$C_1: X_{test} \rightarrow Y_{pred} \{0, 1, 2\} \quad (1)$$

Then the ultrasound images undergo processing in the semantic segmentation module, which is a technology that aims to categorise each pixel in an image which means each pixel is assigned to a specific class. Semantic segmentation can also be seen as a classifier to predict the categories for each pixel.

In our work, we defined the two categories in the breast cancer image, one is a normal pixel (such as tissue) and the other is abnormal pixels representing the tumour. Unlike the first classifier  $C_1$ , the labels generated by segmentation form a matrix of the same size as the image. In this matrix, 0 represents the background, and 1 denotes the tumour. The goal of semantic segmentation is to highlight the tumour's shape, edges, and positions while eliminating noise or interference.

$$S: X_i \in X \rightarrow M_i \{0,1\}, W_i \in M \quad (2)$$

We call the  $M$  mask image, which can be represented as  $M = S(X)$  semantic segmentation seems

like a labelling operator  $S$ .

Finally, the classifier is needed again to recognise the normal, malignant or benign samples based on the segmentation image  $M$ . Therefore, the diagnosis classifier is defined as

$$C_2: M_{test} \rightarrow Y_{pred} \{0, 1, 2\} \quad (3)$$

Our motivation is to design a smart U-Net system that can facilitate the diagnosis process. How to design this system and organise the relevant training data? We'll display our solution in section 4.

## 4. OUR SOLUTION: TRAIN A (U- NET)+

As we discussed in the previous section, we'd like to design a system that can perform both classification and semantic segmentation tasks. With the rapid development of neural networks, image recognition and segmentation achieved outperforming performance. In this section, we'll display our solution (U-Net)+.

### 4.1 U-Net introduction

U-Net is a popular deep-learning architecture for semantic segmentation. It has been widely applied in various medical image segmentation tasks, including brain tumour segmentation, lung segmentation, cell segmentation, etc. [14]. This architecture is based on U-shape type encoder-decoder networks with skip connections, which was named U-Net. Research has shown that U-Net has demonstrated successful results due to its representation learning capabilities and the ability to recover fine-grained details[15]. While existing U-Net has demonstrated powerful performance, they can only handle one task at a time. Figure 3 displays the U-Net and its corresponding analogies.

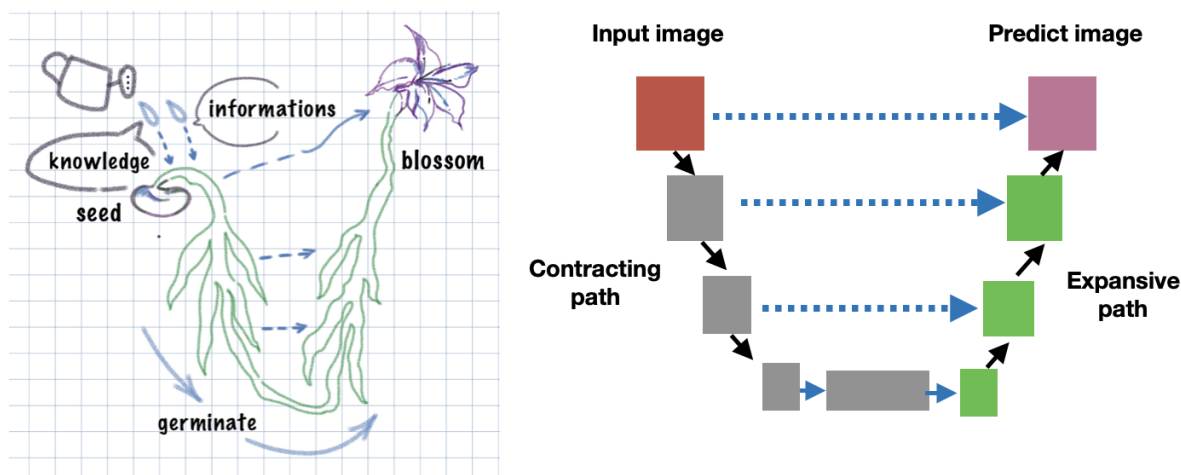


Figure. 3 U-Net architecture and its analogy

To understand the U-net architecture easily, an analogy has been drawn between its architecture and the growth process of a seed. The network's architecture comprises three parts: a contracting path (left side), a bottleneck layer (bottom), and an expansive path (right side). The contracting path seems like a seed was planted in the soil, where it takes root and absorbs the nutrients. In contrast, the expansive path mirrors the process of germination and growth, while the bottleneck layer acts as the bridge connecting these two paths. Moreover, the transfer of essential information between these paths is facilitated by the skip connections, which are analogous to the transport of nutrients.

In addition, there are two important concepts in this symmetrical architecture, encoder and decoder, where the left side takes root down to extract the nutrients just like an encoder and grows in an

expansive path that represents the function of a decoder. In the next section, we'll introduce them in detail.

### 4.2 The contracting path: absorb and extract the nutrients (learning features)

In this section, we are confronted with a challenging question: how to extract the essential features (resembling nutrients) required for our tasks? The answer is hidden in the contracting path, which is constructed by several encoder blocks. We explained them from a high school student's view, making them understandable to younger learners and inspiring their curiosity. Figure 3 shows the modules in the contracting path.

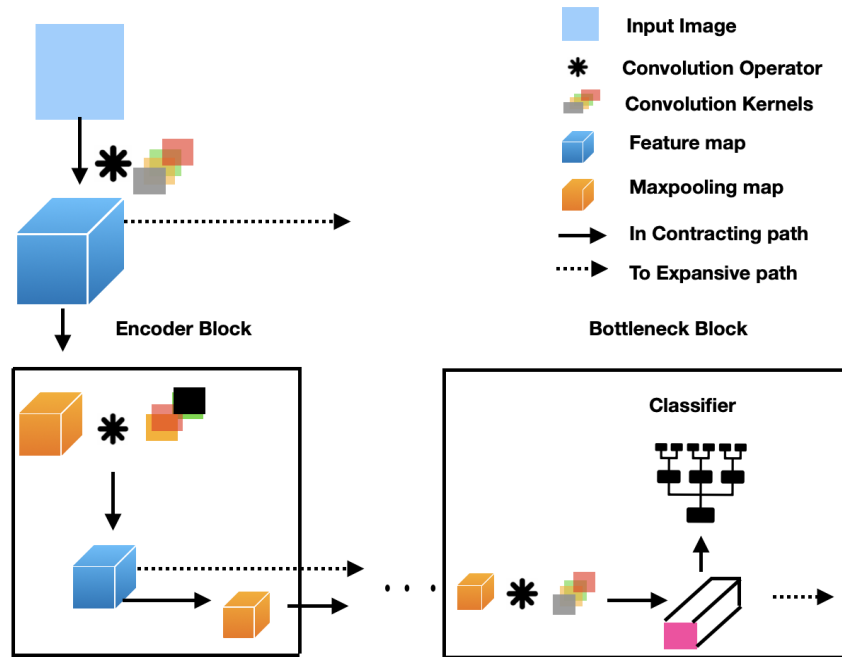


Figure. 4 Contracting Path and Bottleneck Block

First, let's introduce what the encoder in an AI algorithm is. Encoder is a terminology and an unfamiliar word for us. It serves as an operator that extracts the most significant features from the original data and represents it in a latent space. Consequently, the data was compressed after passing through each encoder block.

To provide a simpler analogy for the encoder, think of it as the process of transforming a seed into a root, with the essential nutrition being the hidden feature.

In our model, the encoder block comprises two components: 2D convolution and max-pooling operations. The 2D convolution is a technique in image processing that generates a feature map. While max-pooling can reduce the size/shape of the feature map. The 2D convolution equation is as follows:

$$F(m, n) = \sum_j \sum_k K(i, j) I(m - i)(n - j) \tag{4}$$

Where  $K$  is the kernel or filter, pass it over the image  $I$ . The indexes of rows and columns of the results feature map are marked with  $m$  and  $n$  respectively. In Figure 5, we show what are the operations in the encoder block, including 2D convolution, max pooling and related technologies.



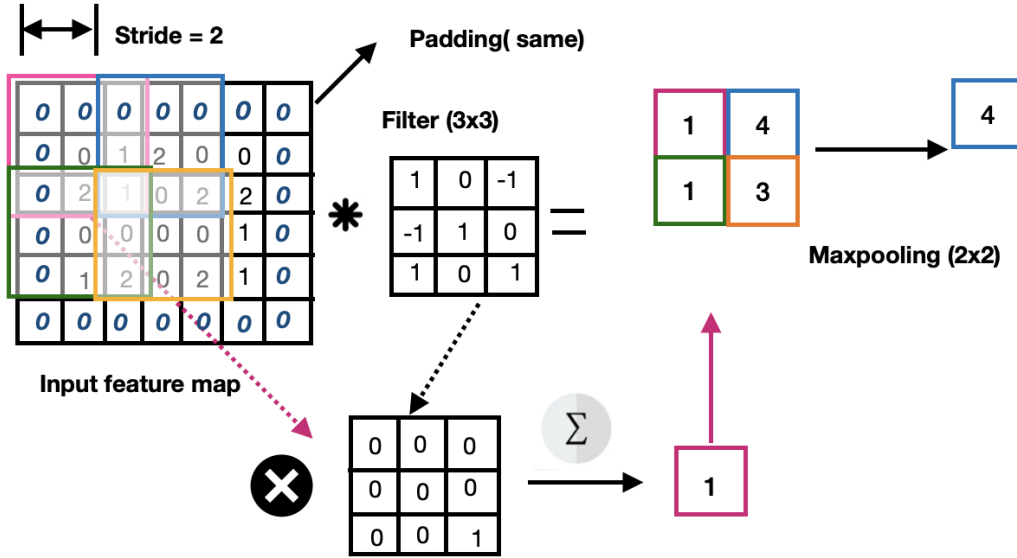


Figure 5. Operations in the encoder block

In Figure 5, we add a layer with the number “0” called padding, which is used to maintain the size of the original input. Then the filter  $K$  shaped as a 3 by 3 matrix performs an element-wise multiplication with the input image  $I$ . The values are summed to generate the feature map. This operation is achieved by sliding the filter over the input image, and the movement happens in steps known as strides. Finally, the max-pooling operation is employed to calculate the maximum value within each patch of the feature map. The purpose of max-pooling is to reduce the dimensionality of the feature map.

Therefore, there are two outputs for each encoder block, feature map and max pooling map. The max pooling map  $S_{map}^l$  will be the input of the next encoder block, and the feature map  $FC_{map}^l$  will be passed to the other side with a skip connection. We describe the  $l$ th encoder block as follows:

$$FC_{map}^l, S_{map}^l = Encoder(S_{map}^{l-1}) \quad (5)$$

$$FC_{map}^l = Conv2D(S_{map}^{l-1}, Filters^l) \quad (6)$$

$$S_{map}^l = Max Pooling(FC_{map}^l) \quad (7)$$

Then we'll introduce the bottleneck layer and skip connection, which are important parts of our (U-Net)+.

### 4.3 Bottleneck layer and skip connection: Connect and transport nutrients (features)

The bottleneck layer is located between the final encoder block of the contracting path and the first decoder block of the expansive path. It comprises a convolution layer with 1024 filters without max-pooling. To make class predictions, a fully connected layer and a softmax function need to be employed at this stage. Figure. 6 displays the details of this part.

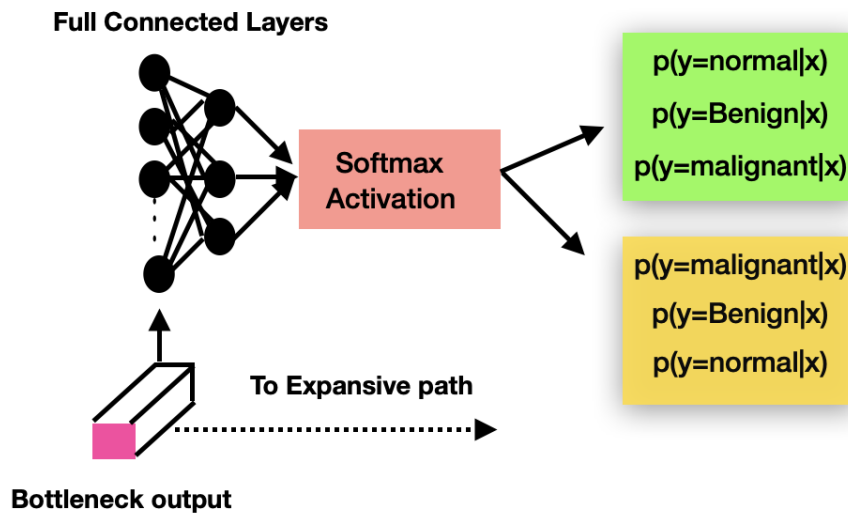


Figure 6. Details of Bottleneck layers in (U-Net)+

The output of the bottleneck layer serves as both the input for the expansive path and connects to a fully connected layer. The objective of the fully connected layer is to make class predictions. This layer takes an input that has been flattened into a vector and processes it through three dense layers. Then an activation function is applied before being sent to the output layer. It is described as follows:

$$\mathbf{y} = \mathbf{f}\left(\sum_{i=1} \mathbf{w}_i \mathbf{x}_i + \mathbf{b}\right) \quad (8)$$

Where  $\mathbf{w}$  is the weights and  $\mathbf{b}$  bias (a constant value),  $\mathbf{f}(\cdot)$  is the activation function. The choice of activation function depends on the type of classification problem. The “Sigmoid” for binary classification and “Softmax” for multi-class classification [16,17]. Here, the task is a multi-class classification for 3 categories, therefore, softmax is used. The final output vector’s size should correspond to the number of classes for prediction.

Another important element in the transfer of nutrients (features) is known as skip connection. We can imagine that the deep networks might “forget” or “lose” certain features as information passes through successive layers. To overcome this weakness, skip connections were introduced. Every decoder incorporates the feature map from its corresponding encoder, helping to preserve and reintroduce important features into the network.

#### 4.4 The expansive path: How to germinate and grow

In the expansive path, it takes the extracted features and reconstructs a segmentation mask. There are several Decoder blocks in the expansive path. In each decoder block, two fundamental operations are performed: transposed convolution and convolution. In addition, there is a bridge (skip connection) that connects the two paths and completes the flow of information. Specifically, the feature map from the contracting path is concatenated with the transposed map and they are passed through the other convolution together.

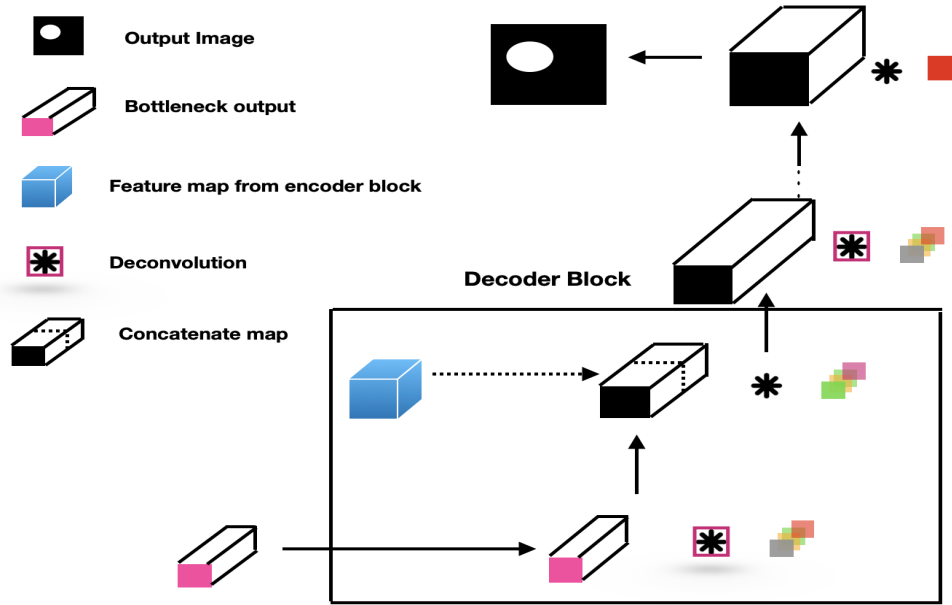


Figure 7. The expansive path

It consists of two 3x3 convolutions and a transposed convolution operation in each decoder block. We have already introduced the convolution in section 4.2. Here, we'll explain what's the transposed convolution, which is another kind of convolution, but in a backward direction. It aims to increase the dimensions of each element pixel in an image. Figure 8 displays the transposed convolution operation.

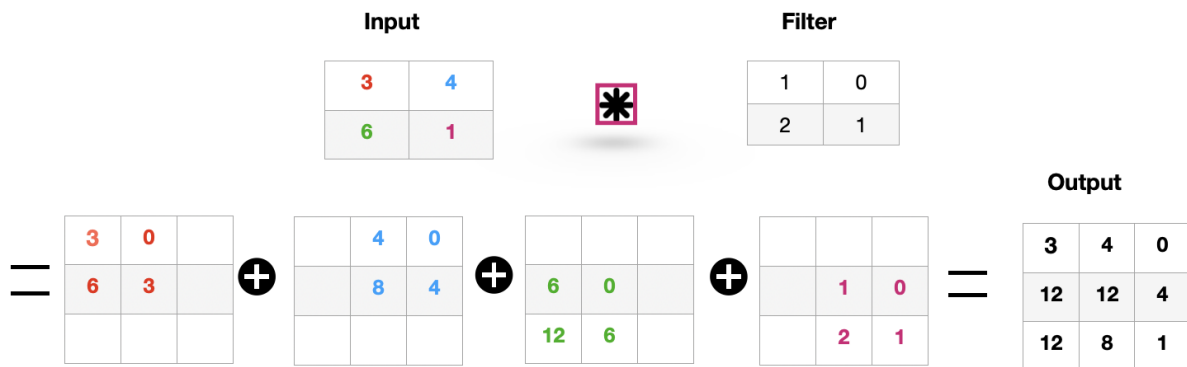


Figure 8. Transposed Convolution Example

We represent the  $l$ th decoder block as follows:

$$DT^l = Conv2DTranspose(D^{l-1}, Filters) \tag{9}$$

$$L^l = [FC_{map}^l, DT^l] \tag{10}$$

$$D^l = Conv2D(L^l, Filters) \tag{11}$$

Where  $FC_{map}^l$  is the feature map which connects to the  $l$ th layer in the decoder. At the final layer, there is a 2D Convolution with 1 filter and the activation function sigmoid, which can be seen as a binary classification for each pixel.

## 4.4 Training

The original U-Net architecture was modified in our solution by employing classifier networks to the bottleneck layer. Then, we'll discuss how to train the proposed (U-Net)+. Three loss functions are combined to train the model.

The first loss function is shown in equation (12) for the semantic segmentation. The input is the original breast cancer ultrasound image and the output is for the segmentation masks.

$$L_{seg} = - \sum_{i=1}^N \mathbf{y}_{true}^{(i)} \log \widehat{\mathbf{y}}_{pred}^{(i)} + (1 - \mathbf{y}_{true}^{(i)}) \log(1 - \widehat{\mathbf{y}}_{pred}^{(i)}) \quad (12)$$

Where  $\mathbf{y}^{(i)}$  is the  $i$ th sample's label, ( $\mathbf{y}^{(i)}=1$  if it's a tumour, and  $\mathbf{y}^{(i)}=0$  if it's background), and  $\widehat{\mathbf{y}}^{(i)} = P(\mathbf{y}^{(i)} = l|x)$ ,  $l = \{0, 1\}$ . The  $P(\mathbf{y} = l|x)$  can be computed by the pixel-wise sigmoid as follows:

$$P(\mathbf{y}^{(i)}) = 1 / (1 + \exp(-a_k(\mathbf{y}^{(i)}))) \quad (13)$$

$a_k(\mathbf{y}^{(i)})$  represents the activation in the feature channel  $k$  at the pixel position,  $P(\mathbf{y}^{(i)})$  and is the approximated maximum function.

The second loss function is for the classification of three categories, i.e. normal, benign and malignant. While the ultrasound images are the input and the output is their labels.

$$L_{UL} = \frac{1}{m} \sum_{i=1}^m \sum_{j=1}^C q(\mathbf{X}^{(ij)}) \log(q(\widehat{\mathbf{X}}^{(ij)})) \quad (14)$$

$$q(\widehat{\mathbf{Y}}^{(ij)} | \mathbf{x}_i) = \frac{e^{x_i}}{\sum_{j=1}^C e^{x_j}} \text{ for } j = 1, 2, \dots, C \quad (15)$$

In equation(14),  $m$  is the number of samples for the ultrasound image for training.  $C$  is the number of categories.  $\mathbf{X}$  is the ultrasound images. In equation (15), Where  $x_i$  is the output of the dense layers before the classifiers, which is decided by the input of the contracting path.

The third one is also used for the classification of the three categories while the input is the segmentations (masks) images denoted as  $\mathbf{S}$ . Also  $p(\widehat{\mathbf{S}}^{(ij)})$  can be computed in the equation (13). But the  $\mathbf{x}_i$  is derived from the input images  $S$ .

$$L_S = \frac{1}{n} \sum_{i=1}^n \sum_{j=1}^C p(\mathbf{S}^{(ij)}) \log(p(\widehat{\mathbf{S}}^{(ij)})) \quad (16)$$

Therefore, the total loss functions are

$$L = aL_{seg} + bL_{UL} + cL_S \quad (17)$$

During training, different weights  $a$ ,  $b$ ,  $c$  are set for the three loss functions.

## 5. EXPERIMENTS

### 5.1 Data introduction

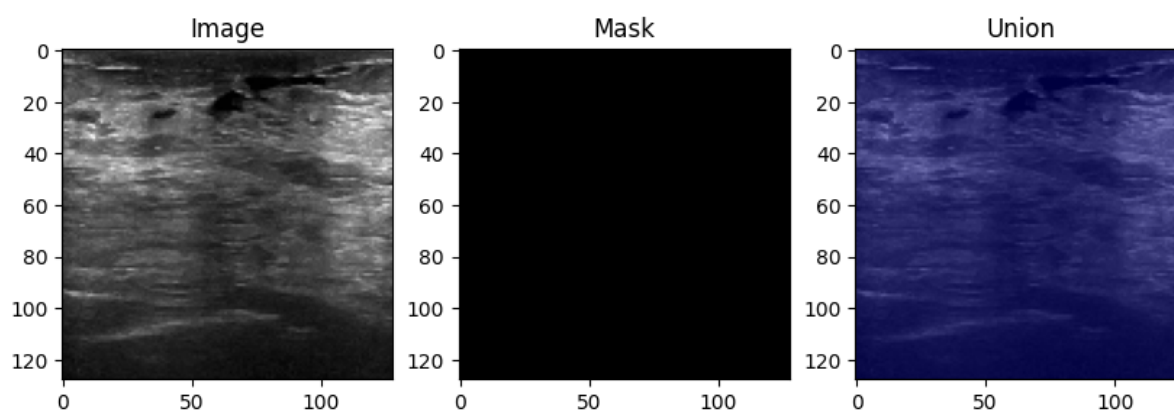
To prove the efficiency of our solution, we evaluated its performance on a public dataset of breast Ultrasound presented in [4]. The images are obtained through ultrasound scans, a safe and commonly used technique for breast cancer examination and early detection, especially when compared to other radiological imaging methods. This dataset was collected in 2018 including 780 images taken from women aged between 25 and 75. Among the 780 images, there were 600 female patients, and the images have an average size of 500x500 pixels, stored in PNG format.

These ultrasound images are categorized into three classes: normal, benign, and malignant, making

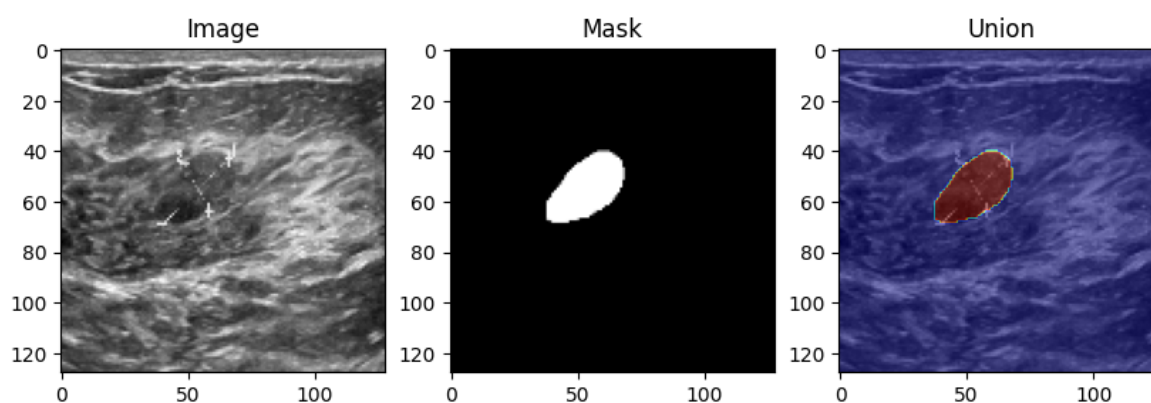
them suitable for classification and detection. In addition, corresponding masks are provided for the original images. In some cases, multiple masks are available, which may be due to the presence of multiple tumours in certain samples. Table 1 shows the distribution of these categories and Figure 9 displays a selection of sample images from the dataset.

Table 1. Dataset distribution according to categories

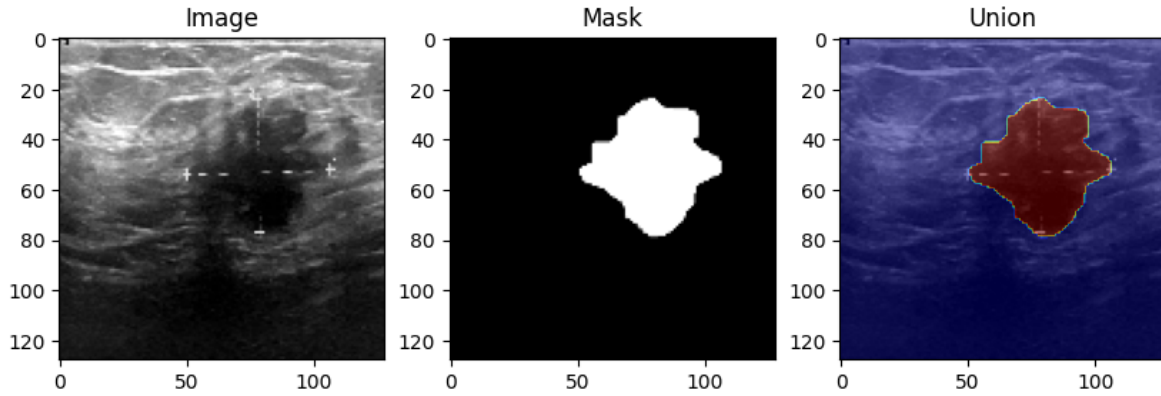
Category	Number of images	Number of masks
normal	133	133
Benign	437	454
malignant	210	211
Total	780	798



(a)Normal Class



(b)Benign Class



(c) Malignant Class

Figure 9. Some samples from the dataset

### 5.2 The Network settings in our experiments

We implemented an encoder-decoder network with a bottleneck layer as our fundamental architecture. The contracting path incorporates several encoder blocks to generate feature maps, with the bottleneck layers serving as input for the classifier. Moreover, the bottleneck layer also provides input to the expansive path. The settings and parameters for our (U-Net)+ are displayed in Table 2.

Table 2. The (U-Net)+ Settings

Parts	Contracting path	Bottleneck layer	Expansive path
Number of subblocks	4	1	4
filters	[64,128,256,512]	1024	[512,256,128,64]
Activation function	ReLU	Softmax	Sigmoid
parameters	Filters size(3,3) strides:2 Padding: same	----	Filters size (2,2) Strides =2 Padding: same
----	Optimizer: Adam; Loss: Binary_crossentropy; metrics: accuracy		

### 5.3 Performance of classification on ultrasound images

In this section, we evaluate the performance of the first classifier, which is designed to identify the three categories of ultrasound samples. Early detection serves as an important step in providing evidence for further diagnosis. This classifier can be seen as a rapid initial diagnostic tool. The training history and classification results (displayed with a confusion matrix) are shown in Figure 10.

A confusion matrix presents a table layout of the different outcomes between the true labels and the predicted ones. It helps to evaluate and visualise the classification performance easily.

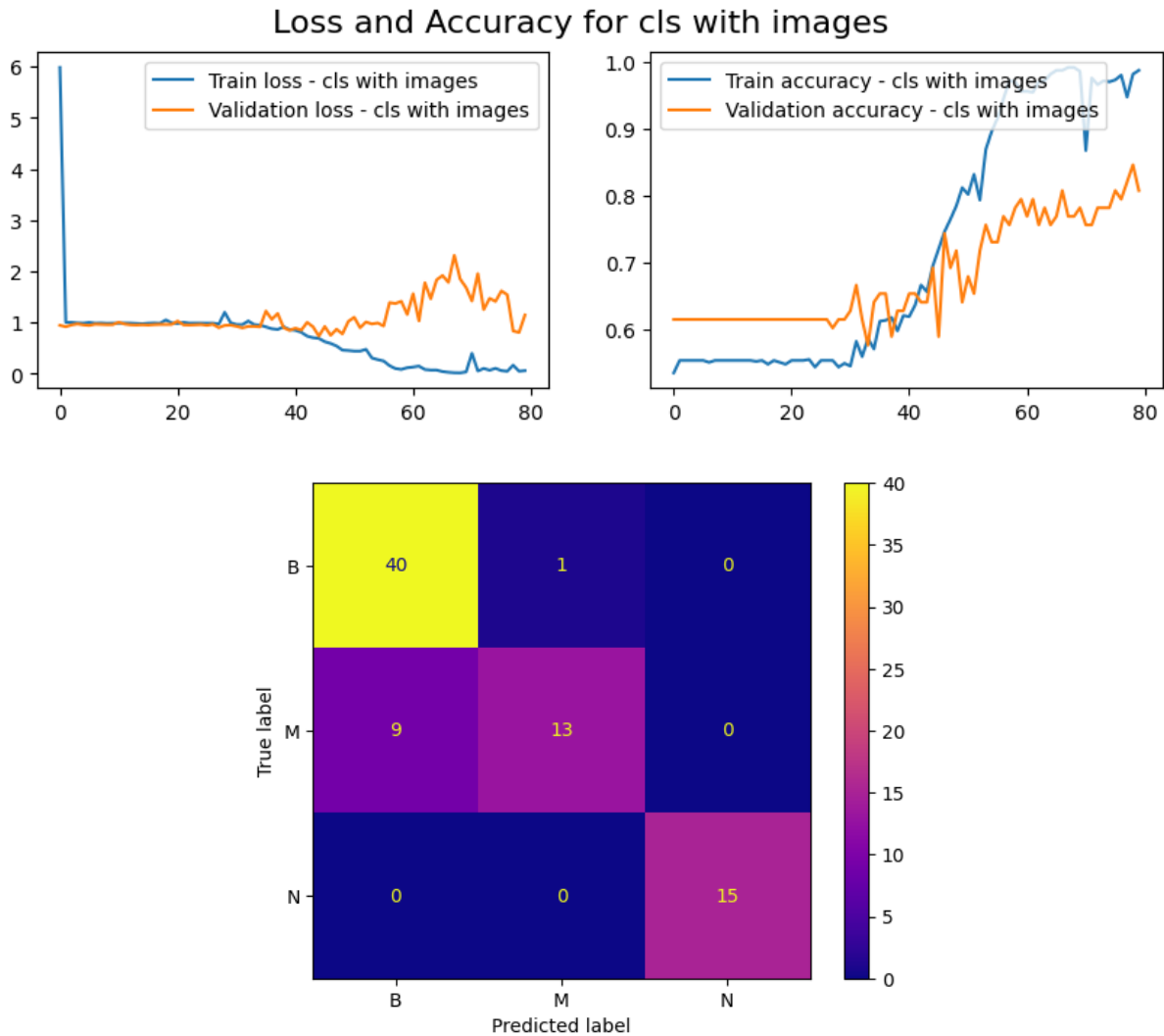


Figure. 10 The initial classification performance on Ultrasound images

From the training history lines in Figure 10, we observe that the loss consistently exhibits a decreasing trend, indicating that the model is learning and improving over epochs. However, it's important to acknowledge that, in the case of validation samples (depicted by the yellow line), the loss doesn't stabilize until around the 80th epoch. This implies that the model's performance on the validation set takes some time to reach a steady state. The classification accuracy for the ultrasound images exceeds 80% for the validation images, suggesting that the model is performing well. The confusion matrix displayed more details. For the samples labelled as "normal", the model correctly predicts all of them as "normal". This demonstrates the model's proficiency in identifying normal cases. In the case of samples labelled as "Benign", 40 samples are classified correctly, and there is one sample that is incorrectly recognized as "Malignant". When dealing with samples labelled as "Malignant", the model correctly identifies 13 of them as "Malignant". Unfortunately, 9 samples are classified as "Benign" incorrectly. It is very risky for further treatments.

#### 5.4 Performance of Semantic Segmentation

Semantic segmentation is a critical task in medical image analysis that aims to label each pixel in the image. This process is greatly helpful in aiding more accurate diagnoses and treatments for various medical conditions. In this section, we assess the segmentation performance both visually and quantitatively. Figure 11 displays the training history for the segmentation module and Figure 12

presents the visual segmentation results. Table Table 3 displays the quantitative results for the two categories. They are segmentation accuracy (ACC), Specificity (SP) and Sensitivity (SE) [18].

$$Se = \frac{TP}{TP+FN}$$

$$Sp = \frac{TN}{TN+FP}$$

$$Acc = \frac{TP+TN}{TP+FN+TN+FP}$$

Where TP, true positives, are the tumour pixels predicted correctly. FP(false positive), are the background pixels predicted as tumour pixels incorrectly. Therefore, TN (true negative) means the background pixels are predicted correctly, and FN (false negatives) are the pixels incorrectly predicted as background.

Table 3. Quantitative results for two categorical variables

Model	Se	Sp	Acc
Benign	0.927	0.997	0.992
Malignant	0.906	0.995	0.986
Benign+Malignant	0.920	0.997	0.990

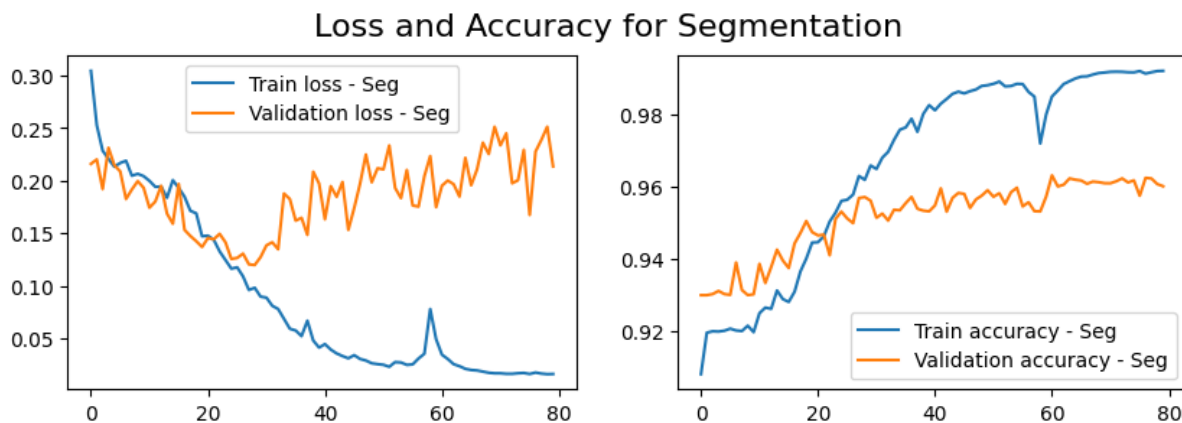


Figure. 11 Training history for the segmentation module

From the loss trends, we observe fluctuations in the validation loss when compared to the training loss, with a slight upward trend. However, it’s worth noting that the model’s accuracy remains consistently high, hovering around 96%. This accuracy stabilizes after the 20th epoch, indicating that the model has reached a stationary state in its learning process.

Our model displayed a good performance in the segmentation task as shown in Figure 12. It effectively preserves crucial information, including tumour shapes and edges, which serve as vital evidence for subsequent classification tasks. However, a classification error is shown in Figure 12, where a “Benign” case was incorrectly identified as “Malignant”. This misclassification may be attributed to irregular or non-smooth edges in the segmentation. To address this issue, extending the training could potentially lead to more accurate classifications.



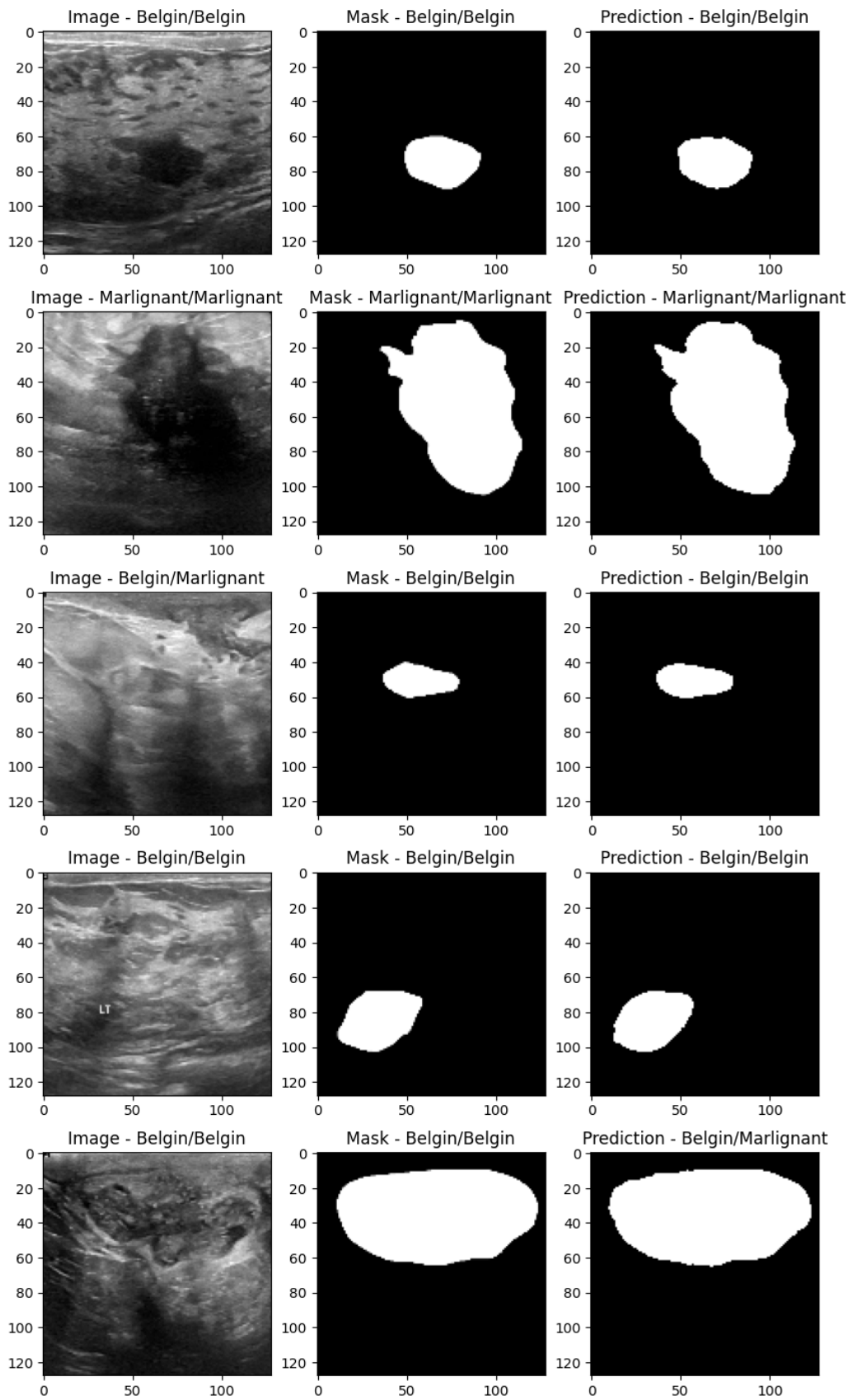


Figure 12. Segmentation and classification results

### 5.5 Performance of the second classifier on segmented images

We expect the classifier’s accuracy will be improved when applied to the segmentations, as the noise or disturbance is removed. Figure 13 displays the training history and presents the confusion matrix for the ACC.

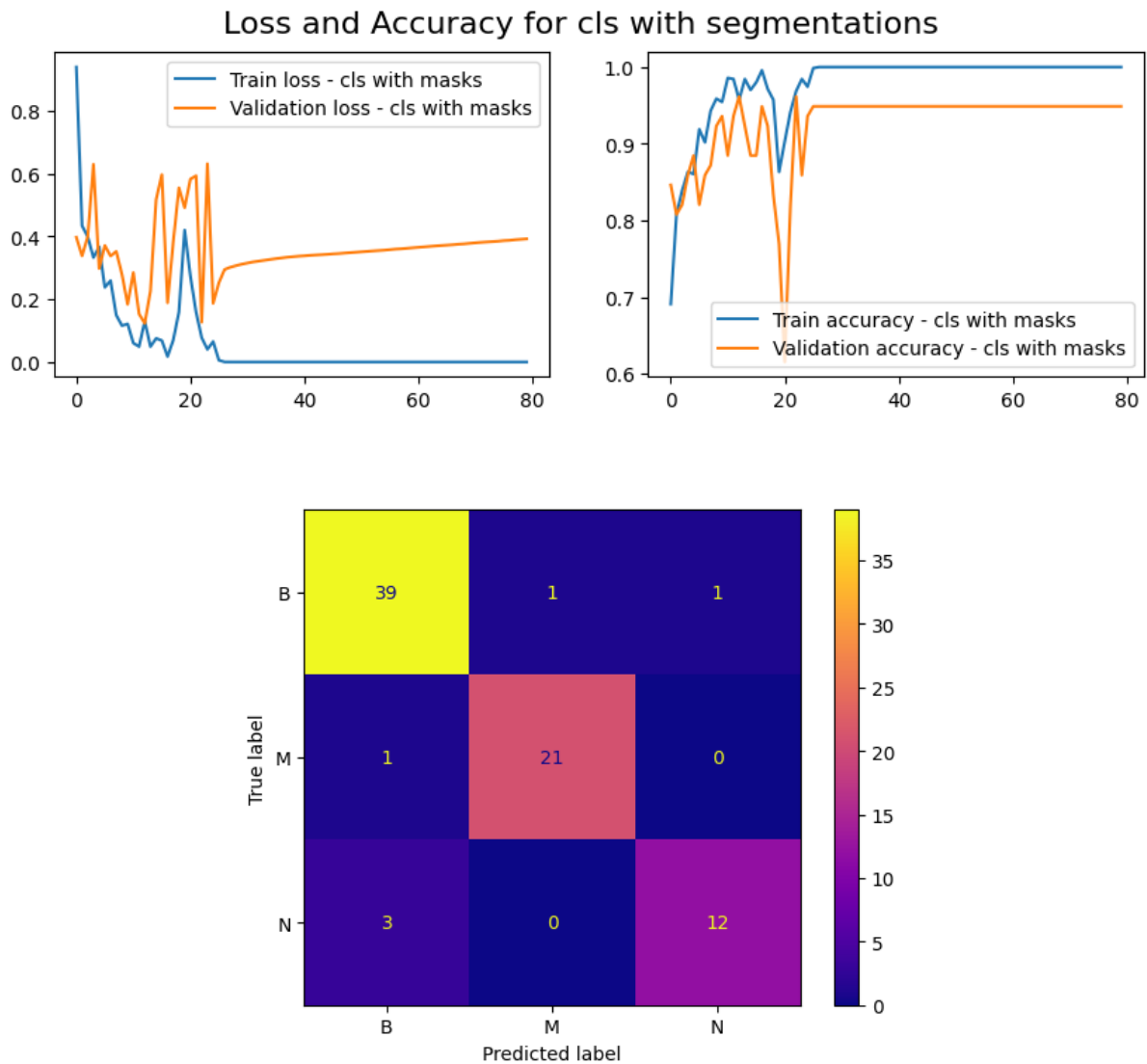


Figure 13. Classification performance based on segmentation images

Figure 13 shows that the convergence performance with notable stability observed in the loss and accuracy lines, reaching a stationary state around the 20th epoch. The classification accuracy stands at approximately 96%, representing an improvement over the initial classification. The confusion matrix provides a more detailed breakdown of the results. For samples labelled as “normal”, 12 of them were accurately predicted, and 3 were incorrectly classified as “benign”. This indicates that all 15 samples were diagnosed as “Normal”, and these misclassifications are unlikely to significantly impact further treatments.

In contrast, for samples labelled as “Malignant”, 21 were correctly predicted, and 1 was misclassified as “benign”. The accuracy for this category of samples is notably high at about 95.5%. However, the signal incorrect prediction could potentially lead to a delay in treatment. Comparing this classification to the initial assessment of ultrasound images, the error rate has significantly decreased substantial progress in the model’s accuracy and the potential to improve patient care.

## CONCLUSIONS

In this paper, we introduce a novel system, denoted as (U-Net)+, which has been trained to handle both classification and semantic segmentation tasks for breast cancer diagnosis. To understand the U-Net well, we draw an analogy between the U-Net architecture and the process of seed germination and growth, visually illustrating its key components. In our approach, we've made modifications to the original U-Net architecture by incorporating fully connected layers, thereby enabling it to perform classification tasks alongside segmentation. Our training process involves the use of three distinct loss functions, which are integrated into a total loss function. Experimental results validate the efficiency and effectiveness of our novel (U-Net)+ model.

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# THE AI TRANSFORMATION RISK MODEL: SOLUTIONS WHERE BENEFITS OUTWEIGH RISKS

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## **ABSTRACT**

*This paper summarizes the most cogent and recently-cited advantages and risks associated with Artificial Intelligence from an in-depth review of the literature. Then the authors synthesize the salient risk-related models currently being used in AI, technology and business-related scenarios. Lastly, in view of the most pressing issues and updated context of AI along with theories and models reviewed, the writers propose a new framework called “The AI Transformation Risk Model” to address the increasing fears and levels of risk. Using the model characteristics as a backdrop, the article emphasizes innovative solutions where benefits outweigh risks.*

## **KEYWORDS**

*Artificial Intelligence, Risk Benefit Models, AI Challenges, AI Advantages, Generative AI*

## **1. INTRODUCTION**

While AI offers many benefits in improving efficiency, accuracy, accessibility, pattern-recognition and creating higher-paid highly skilled technology-related jobs, sustainability and quality of life, it also presents risks including invading privacy, displacing jobs, creating bias, increasing fraud/deception and weaponizing of AI. As the costs and number of risks associated with AI rise, the ability both to assess those risks and to engage all-level workers in implementing controls will become the new competitive advantage [1].

This article addresses the risks of AI through the lens of benefit-risk analysis, based on relevant models and theories. From an analysis of the advantages and risks of AI and generative AI, this article reviews risk models and their characteristics to formulate a new paradigm for transforming AI risks into benefits. Lastly, innovative solutions based on the five dimensions of risks are elaborated to illustrate the transformational process where overall benefits outweigh the risks.

## **2. ADVANTAGES OF ARTIFICIAL INTELLIGENCE**

As far back as the industrial revolution, significant development in technical innovation has succeeded in transforming numerous manual tasks and processes that had been in existence for decades where humans had reached the limits of physical capacity. So it is no surprise that Artificial Intelligence (AI) offers this same transformative potential for the augmentation and

potential replacement of human tasks and activities within a wide range of industrial, intellectual and social applications [2]. If society and organizations managed the risks associated with the industrial revolution technologies, it is apparent that managing the challenges of AI is also within reach if leaders commit to vigilance, persistence and value-based decisions.

With new breakthroughs in algorithmic machine learning and autonomous decision-making coming at society with breakneck speed, leaders must learn how to take advantage of the new opportunities created by AI innovation and disruption while balancing the legal, political, ethical, and governance implications of these changes in both private and public sectors ranging from finance, healthcare, manufacturing, education and retail to supply chain/logistics, utility companies and governmental agencies[2]. With its ability to analyze vast amounts of data, identify patterns and provide accurate predictions, AI can help society to solve difficult problems like cybercrimes and AI can create a better world, which includes access to education, healthcare, and clean water, and fighting climate change, poverty and hunger. By harnessing the power of AI, society can accelerate the path towards a worldwide sustainable future (Iliescu & Bustos, 2022).

In fact, from a comprehensive analysis study, AI was found to be an enabler on 134 general targets (79%) across all of the Sustainable Development Goals (SDGs) set by the United Nations, which allows the world in general to overcome certain pressing worldwide problems. In the societal and environmental areas of challenges, AI can enhance the provision of food, health, water and energy services to the population, for instance. AI can create smart and low-carbon cities encompassing a range of interconnected technologies such as electric autonomous vehicles and smart appliances that enable demand response in the electricity sector and smart grids that match electrical demand to weather conditions [4]

By 2030, experts predict between 20 million to 50 million new AI-related jobs will be created globally (higher skill levels and ability to manage technology will be in high demand) and overall spending on technology could increase by more than 50 percent between 2015 and 2030 [5]. Studies have analyzed the societal, economic and organizational impact of this significant change, showing a changing jobs market that is predicted to focus humans on more creative and higher thinking skills in AI-support roles that pay more [6]. Generative AI is creating more types of jobs and leaders are already hiring more because of the generative AI surge[7].

Upwork Research Institute's new study surveying 1,400 U.S. business leaders—senior managers through C-suite level—confirms the positive job impact of AI. Although there may be variation in generative AI adoption of technologies such as ChatGPT and Midjourney across companies, two-thirds of top leaders agree that they will increase hiring as a result of generative AI [8]. Studies have identified the benefits of applying AI technologies to big data problems and the significant value of analytic insight and predictive capability for a number of scenarios (Rubik & Jabs, 2018). Health related studies, for example, show AI technologies can greatly support patient health-based diagnosis and predictive capability[9][10][11][12][13]. Economically, AI also promises to generate productivity gains [14]. In the legal and policy arena, the best cybersecurity solutions have AI and machine learning built into them, which creates dynamic protection that can consistently evolve to face ever-improving attacks and fraud threats that use automated scripts, such as account takeovers, credential stuffing, card fraud and fake account creation [15].

Although generative AI helps those who wish to radicalize people to create deep fake videos used online in social media, AI tools can also prevent it from succeeding. In November 2022, Intel released FakeCatcher, a cloud-based AI tool that it claims can accurately detect fake videos 96% of the time, using up to 72 different detection streams[16].

Retail and service-oriented organizations benefit from AI's ability to personalize the online experience through real-time, tailored product recommendations based on customers' purchase history, age, gender, geographic location, and other data points and continuously upgrades its capabilities by analyzing millions of customer-service interactions [17]. With the help of AI, companies can save time and resources and can create even more personalized experiences directly communicating with their customers, which will result in enhanced brand loyalty and lifetime relationships [17]. Item recommendation is instrumental for a content provider to grow its audience and evidence shows that automated recommendations account for 35% of sales on amazon.com, 50% of initial messages sent on match.com and 80% of streamed hours on netflix.com [18].

Big Data Analytics (BDA) develops the methodological analysis of large data structures tackling data volume, velocity, variety, veracity and value issues. BDA combined with AI has the potential to transform areas of manufacturing, health and business intelligence offering advanced insights within a predictive context [19][20][21]. Organizations are increasingly deploying data visualization tools and methods to make sense of their big data structures. Because the analysis and processing of complex heterogeneous data is problematic and human perception and cognition may be limited, organizations can extract significant value, understanding and vital management information from big data via intelligent AI-based visualization tools [22][13][23].

Advantages of AI span societal (SOC), economic (ECON), ethical (ETH), political/legal/policy (POL), environmental (ENV), data (DATA), technological (TECH) and organizational/managerial (ORG) arenas along with examples are shown in Table 1.

### 3. RISKS OF ARTIFICIAL INTELLIGENCE

The implementation of AI technologies can present significant challenges or risks for government and organizations as the scope and depth of potential applications increase and the use of AI becomes more mainstream. Although AI-based systems are increasingly being leveraged to provide value to organizations, individuals, and society, significant attendant risks have been identified recently.

[24] divided risks into two categories including 1) *Risks to fundamental rights*—flaws in the overall design of AI systems or biased data can lead to breaches in fundamental rights, including free speech, discrimination based on sex, race, religion, disability, age or sexual orientation, protection of personal data and private life and consumer protection; and 2) *Risks to safety and liability*—flaws in the design of AI technologies may present new safety risks for users related to the availability and quality of data or other problems stemming from AI and machine learning.

This research builds upon 8 AI challenge categories proposed in a public sector model, namely: 1) societal; 2) economic; 3) political, legal and policy; 4) environmental; 4) ethical; 5) data; 6) technological and implementation; and 8) organizational and managerial [13]. Public organization adoption of AI and data science presents numerous known challenges ranging from employee path dependency on embedded processes and norms, information silos, and a lack of resources, collaborative culture and technical capacities [25][26][27]. AI systems can have had some harmful side effects on communities, through effects on employment and inequality [28], privacy and safety—injury, property loss and workplace hazards [14] addictive behavior [29], fairness, bias and discrimination [30][31], human rights [12] and polarization, extremism, manipulative practices and conflict [32][33][34][18].

Table 1. Salient AI advantages by categories and examples

Categories	Examples
SOC	Worldwide productivity gains; Workers can choose what tasks they want to do; Societal increased well-being; Impact world sustainability goals of UN; Analytics and AI based predictions create better patient healthcare; Improve Customer/Organization Interface; Tackle world problems; Overcome Cultural barriers; Protect Human rights;
ECON	Increase higher-skill and higher-paying jobs; Create new job categories; Improve profitability; Optimize returns on investment;
POL	Detect deep fakes, propaganda, or spying on users; Fight cybercrimes and fraud; Stop weaponizing AI for harmful purposes; Add rules and accountability in the use of AI; Rely on European Union guidelines/rules for responsible AI
ENV	Address societal problems like climate change; Positively impact carbon footprint; Address resource scarcity;
(ETH	Build trust towards AI-based decision making; Increase explanation of decisions made by AI; improve processes relating to AI and human behavior, find balance in machine versus human value judgements; be vigilant in testing for bias/discrimination
DATA	Transform areas of manufacturing, health and business intelligence offering advanced insights within a predictive context; improve 5 V's of data; Increase transparency and reproducibility; Create reliable and sufficient data pools; Improve data integration and continuity; Create standards for data collection;
TECH	Fight adversarial attacks; Increase transparency and interpretability; Smart design of AI systems; Increase AI safety and security; gain value from big data; continue to innovate ways to decrease problems using unstructured data; integrate legacy and new systems through collaboration with vendors, governmental and educational institutions
ORG	More personalized customer experiences; Streamline repetitive and boring jobs; Use visualization to increase understanding of needs of the organizational system; Improve data sharing and collaboration; Increase AI talent through HR innovation in hiring and retraining; Create an AI-driven culture.

For example, researchers found race bias [35][36] and gender bias [37] for policing algorithms and bias against working-class and disadvantaged communities for educational assessments in the UK during COVID [38]. In addition, an AI algorithm created by Zillow was unable to accurately capture complex assessments such as estimating home values thus causing layoffs of 2,000 employees and a sell-off of its iBuying division [39]. Industry-friendly hackers also fooled Tesla's Autopilot AI program into merging into oncoming traffic and took control of the car using a video game controller [40].

To make matters worse, the high legal bar to prove either a disparate treatment or disparate impact cause of action under Title VII of the Civil Rights Act, coupled with the “black box” nature of many automated hiring systems makes the detection and redress of bias in such algorithmic systems very difficult [30].

In the intersection of privacy and human rights, AI used for target marketing/customer service may gather data that may include the user's private behaviors such as playing a certain game, smoking, watching porn or defaulting on loans)[18]. Concerns regarding online personalization range from recommendation algorithms isolating information seekers from differing viewpoints (filter bubble), radicalizing citizens' attitude towards controversial issues (polarization) or enabling malicious content [18]

Generative artificial intelligence (AI) has become widely popular, but its adoption by businesses comes with a degree of ethical risk [41]. With relatively modest amounts of data and computing power using generative AI, the average person can create a video of a world leader confessing to



illegal activity leading to a constitutional crisis, a military leader saying something racially insensitive leading to civil unrest in an area of military activity, or a corporate titan claiming that their profits are weak leading to global stock manipulation. These so called deep fakes pose a significant threat to our democracy, national security and society [32].

There are also practical issues over how accurate machine learning solutions actually are. The range of testing approaches available within machine learning is growing rapidly, and that is a good thing, but it is also driven by the evident limitations of the previous methods and the need to overcome those limitations [42].

Another important factor is the availability of suitable data. Although machine learning packages for Python and R can easily read all types of data from Excel to SQL and can perform natural language processing and process images, the speed with which machine learning solutions have been proposed has not kept pace with firms' abilities to suitably organise the internal data they have access to. Data is often held in separate silos across departments, perhaps on different systems, and perhaps with internal political and regulatory issues restricting the sharing of data. Important data might not even be recorded as data but rather kept as informal knowledge of the firm [42].

Estimates for work displacement due to automation highlight that up to a third of current work activities (between 400 million and 800 million jobs around the world) could be impacted by 2030 [5].

Another issue is the lack of skilled staff to implement these new technologies. A survey of the top 1000 firms in the United States found that their biggest concern in the implementation of AI was the readiness and ability of staff to understand and work with these new solutions [43]. Sixty-four percent of US executives and 70 percent of European leaders believe they will need to retrain, up-skill or replace a fourth of their workers due to advancing automation and digitization [44]. Please see Table 2 for a summary of salient AI risk examples by categories.

#### **4. MODELS AND THEORY**

Very few comprehensive models of AI risk are available today to help managers assess and mitigate the increasing risks they face. To address this void and in light of the ever-increasing depth and breadth of AI technology challenges, the researchers summarize existing related risk models and start with an historical empirically-based risk model dealing with the adoption of information technology projects. Since the risk of IT projects failing was very high in those days, [45] developed a model to predict project risk and delineate risk factors associated with organizational IT projects, which serves as a basis for a newly proposed AI risk framework.

The McFarlan Risk Model (MRM) provided a useful and measurable approach for the diagnosis and mitigation of IT project risks with three dimensions based on 'project size', 'project structure' and 'experience with technology'. For example, if there were high costs, large numbers and levels of staff needed, increased completion time to complete and impacted many different departments, then the risk was increased. If the user department needed to change a lot of procedures and structures to meet the project requirements and users were highly resistant to changes, the project was also considered higher risk. Lastly, if the team lacked the appropriate experience with the new technologies, the firm needed to hire more experts or use outside consultants and if the experts did not work in partnership with the company, the risks expanded exponentially [45].

These three dimensions were expanded in this research to include 'resources' (not just the size of a project but how many, how well and how long resources support AI implementation),

‘governance’ including guidelines and structural processes put in place (not just the project structure) and ‘expertise building’ or on-going capacity and commitment to train, retrain, upskill and encourage

Table 2. Salient AI risks by categories and examples

Categories	Examples
SOC	Customer/Organization Interface; World crises; Cultural barriers; Human rights; Country specific data profiles; Unrealistic expectations towards AI technology; Country specific organizational practices and insufficient knowledge on values and advantages of AI technologies.
ECON	Affordability of required computational expenses; High costs for customers; High cost and reduced profits for organizations; Wider divides in society leading to social upheaval
POL	Copyright issues; Embedded bias and discrimination by humans or technology; Injury; Governance of autonomous intelligence systems; Responsibility and accountability; reduced privacy/safety; National security threats from foreign-owned companies/governments collecting sensitive data, creating deep fakes, propaganda, or spying on users; Cybercrimes; Weaponizing AI for harmful purposes; Lack of rules and loss of accountability in the use of AI; Costly human resources still legally required to account for AI based decision; Lack of official industry standards of AI use and performance evaluation; difficult to redress bias legally.
ENV	Impact on carbon footprint, use of resources such as fossil fuels, water, electricity; impact on climate change and air quality
ETH	Lack of trust towards AI based decision making and unethical use of shared data. Responsibility and explanation of decision made by AI; processes relating to AI and human behavior, compatibility of machine versus human value judgement, moral dilemmas and AI discrimination
DATA	Lack of data to validate benefits of AI solutions; Format, quantity and quality of data; Transparency and reproducibility; Insufficient size of available data pool; Lack of data integration and continuity; Lack of standards of data collection;
TECH	Adversarial attacks; Lack of transparency and interpretability; Design of AI systems; AI safety; Specialization and expertise; Big data; Architecture issues and complexities in interpreting unstructured data; integrating legacy and new systems
ORG	Realism of AI; Better understanding of needs of the organizational system; Organizational resistance to data sharing and collaboration; Lack of inhouse and interdisciplinary AI talent; Threat of workforce layoffs and retraining; Lack of strategy for AI development; Embedded processes and norms; lack of resources; information silos

employee development (not just relying on the current experience of the workers or hiring outsiders).

In their Risk Assessment Framework on implementing enterprise resource planning projects, risks from ‘external engagement’, program management, work stream and work package levels across technical, operational, business and organizational categories were successfully mitigated using on-going risk controls [46].

The specific content of corporate governance guidelines and policies is an important variable to any risk mitigating model. Using a comparison between Belgium (weaker country guidelines) and Australia (stronger governance guidelines), researchers found significantly more developed risk management and internal control systems in Australian companies versus Belgian companies overall [47].

In addition to strong governance guidelines, impactful ‘governance’ also dictates that an entire risk management structure be in place. For example, the structure of risk control may include 4 phases of identifying, assessing, mitigating and monitoring risks [48] or 4 specific functions — govern, map, measure and manage — to help organizations address the risks of AI systems [49]. In this research, the ‘governance’ dimension of risk focuses on a broader range of AI policies, controls and structure. Using a comprehensive AI risk management system can maximize the benefits of AI technologies while reducing the likelihood of negative impacts to individuals, groups, communities, organizations and society” [49].

Companies that succeed in turning risks into results will create competitive advantage through more efficient deployment of scarce resources, better decision-making and reduced exposure to negative events. Leaders who apply a broad “risk lens” to their businesses will be most effective in transforming AI[50].

In a survey of 576 companies and a review of 2, 750 company/analyst reports, the researchers found that financial performance is highly correlated with the level of integration and coordination across risk, control and compliance functions. Effectively harnessing technology to support risk management is the greatest weakness or opportunity for most organizations [50].

To improve the predictive ability of McFarlan’s model, the Extended McFarlan Risk Model (EMRM) was developed to differentiate between project success and failure, adding an organizational ‘culture’ dimension [51]. The ‘culture’ attributes were quantitatively measured including users’ practices, users’ attitudes, company working practices, organizational policies such as information technology policy and data flow practices, internal and external communication practices in the organization, openness to change and cross-functional coordination. If the corporate culture was lacking, the implementation risk increased [51]. In this research the dimension of ‘culture’ was widened to encompass an ‘AI-driven culture’ with communication, work practices, policies, change management, innovation and cross-disciplines/perspectives which fully integrate AI throughout the firm for triple bottom line goals of profits, people and the planet[52].

The new risk model proposed is also based on the use of social cognitive theory which views people as active agents who can both influence and be influenced by their environment [53]. That is, people learn or are transformed by observing and interacting with others. For example, in her research, success in using cloud computer services was dependent on factors such as ‘external engagement’ with people who were using the technology and workers’ personal attitude towards risk and innovation [54].

The researchers propose a new dimension of ‘transformational collaboration’(not just ‘external engagement’ outside the firm) across boundaries such as disciplines, departments, divisions, firms, industries, societies and countries which emphasizes that a person’s attitude and collaboration with others who are using new technologies such as AI or those who have different backgrounds can help increase technology implementation success.

Combining this systematic literature analysis with related risk models and theory, this research adds value to the field of AI by synthesizing and creating an integrated model for managing risk designed particularly for AI adoption and implementation. Using [45] as a theoretical lens, the updated McFarlan model [46] for the context of culture and social cognition theory’s [53] contributions of personal attitude and engagement from previous risk research [46], the AI Transformation Risk Model proposes an innovative model that expands to 5 broader dimensions of ‘resources’ (RES), ‘governance’ (GOV), ‘expertise building’ (EXP), ‘AI driven culture’ (AI

CUL) and ‘transformational collaboration’ (TR COL) that has the potential to change AI risks into benefits as presented in Figure 1.

## 5. SOLUTIONS

Companies play a critical role in responsibly adopting AI and generative AI, and integrating these tools in ways that enhance, not diminish, the working experience of their employees and their customers. This comes back to ensuring the responsible use of AI in maintaining accuracy, safety, honesty, empowerment, and sustainability, while mitigating risks and eliminating biased outcomes. Corporate commitment should extend beyond immediate corporate interests, encompassing broader societal responsibilities and ethical AI practices as well [41].

Leaders remain in need of conceptual, technical and institutional mechanisms to assess how to achieve accountability for the harmful consequences of data-driven algorithmic systems—mechanisms that address both whom to hold accountable and how to hold them accountable [56].

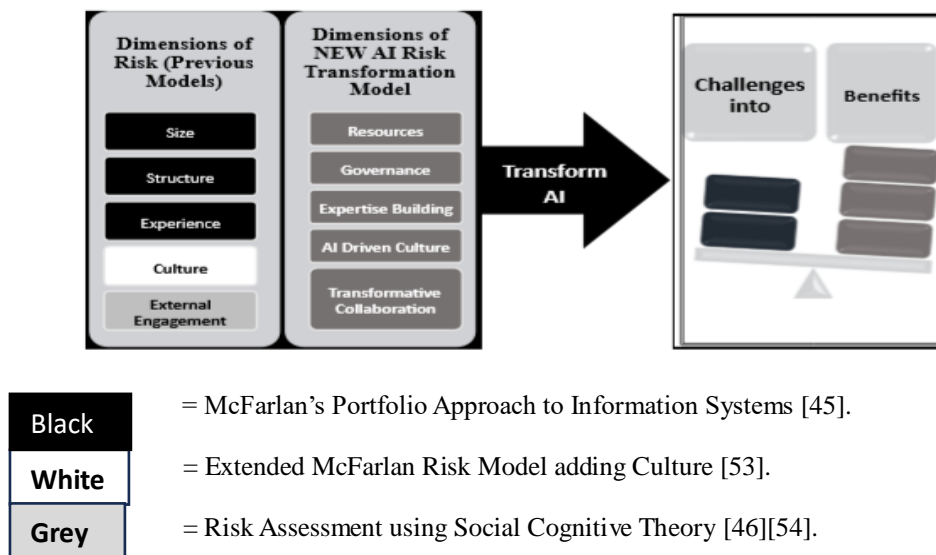


Figure 1. AI Risk Transformation Model: Transform AI challenges into benefits

In this section, the authors give examples of innovative solutions that can transform risks into benefits in each of the model’s 5 risk dimensions. Under the dimension of ‘resources’, innovative solutions such as developing policies to assure AI will be directed at ‘humanness’ and common good and building inclusive, decentralized intelligent digital networks ‘imbued with empathy’ will help leaders meet social and ethical responsibilities while using new AI technologies[57].

Another resource-related solution is to alter organizational, economic and political systems to better help humans ‘race with the robots’ and reorganize these systems toward the goal of expanding humans’ capacities and capabilities which will lead to stronger human/AI collaboration which in turn lowers the risk of compromising humans in the face of AI [57].

Beyond retraining, a range of resource policies can help, including unemployment insurance, public assistance in finding work and portable benefits that follow workers between jobs [5].

Increasing human/AI collaboration and human interventions in decision-making particularly in high risk situations like finance, healthcare and hiring practices will ensure trust, maintain transparency and decrease harms to people [41].

Under the ‘governance’ dimension, comprehensive AI lifecycle governance where policies and procedures are described and enforced during the design, development, deployment, and monitoring phases of an AI system lifecycle can increase transparency. AI factsheets are one example that captures model metadata across the AI lifecycle automatically, making enterprise validation and external regulation easier to monitor [58].

To increase fair and unbiased ‘governance’, create “an auditing imperative” for algorithmic hiring systems that mandates regular internal and external audits of automated systems, as well as detailed record-keeping for all job applications. There is precedent in other areas of law such as the Occupational Safety and Health Administration (OSHA) audits in labor law or the Sarbanes-Oxley Act audits in securities law, these steps ensure trust and confidence in AI- automated systems[30].

Other effective ‘governance’ solutions are to conduct your own bias, explainability and robustness assessments to protect privacy and harmful outputs and security assessments to help identify and decrease threats such as cybercrimes for the organization. Also prioritize the responsible use of AI and generative AI by ensuring it is accurate, safe, honest, empowering and sustainable by using “zero or first party data, keeping data fresh and well labeled, ensuring there’s a human in the loop, testing and re-testing and keeping feedback close” [41].

Base ‘governance’ on protecting society from harm and unwanted negative consequences for the firm by following stricter regulations, guidelines & certification standards such as those recommended by the European Union[24].

To increase the second dimension of ‘expertise building’, train or retrain workers in new fields such as digital forensics, cybercrime specialists, data analysts and AI governance specialists, use Protective Optimization Technologies (POTs) to both explore the effects that algorithms and optimization systems have on our society, and the design of countermeasures to contest their negative effects [59].

Widen educational opportunities to step into new AI jobs and learn new skills throughout the society (throughout the job and educational systems available or create new ones), build talent in technical competencies like AI engineering and enterprise architecture and empower people across the organization to work effectively with AI-infused processes[57].

These solutions collectively can: 1) create new jobs, tools and skills that help detect deep fakes, harmful patterns in the digital arena and make workers more productive; 2) bring structure and strategies to AI tool and skill use that actually help not harm society and 3) pairing more educational/training options with funding (grants, scholarships, internships) will increase the availability of skills throughout the organization and society and 4) increase firm efficiency and give workers opportunities to gain higher-skilled higher-paid jobs.

In the arena of creating an ‘AI driven culture’, use AI-based visualization tools [13][23],leverage open-source and user-provided data, be transparent when AI has created content using watermarks or in-app messages, cite the sources from where the model is creating content, explaining why the AI gave the response it did, highlighting uncertainty and creating guardrails, extend the commitment to using AI tools and technologies beyond immediate corporate interests,

helping meet broader societal responsibilities and ethical AI practices and prevent some sensitive and risk heavy tasks from being fully automated [41].

These innovative solutions for developing an ‘AI driven culture’ will have important benefits such as extracting significant insights from big data and allowing workers to understand the impact of AI directly, increasing transparency, accuracy and honesty about data uses and sources in the organization and broadly across societies, mitigating risks and eliminating biased outcomes while protecting sensitive data processes and uses [41].

In the final dimension of risk, ‘transformational collaboration’ solutions could entail: 1) working collaboratively to minimize the size of AI models[41], 2) collaborating with vendors and partners to create better data and train on models with large amounts of high-quality customer relationship management or other generated data; or 3) increasing collaboration and risk prevention and control discussions across departments, disciplines, companies, countries and societies to solve big complicated or wicked problems [57].

Working collaboratively can produce outstanding outcomes while lowering threats such as reducing the carbon footprint because less computation is required in smaller models, which means less energy (water and electricity) consumption from data centers and carbon emissions, higher quality data helps to maximize data accuracy, reliability and value, and working across boundaries and perspectives can facilitate the innovation of widely accepted approaches aimed at tackling wicked problems such as climate change or world health and improves risk control over complex human-digital networks worldwide[57]. Please see Table 3 for a sampling of innovative solutions in the five dimensions of risk that are poised to transform AI risks into benefits.

Table 3. Innovative sample solutions by risk dimensions transforming AI risks into benefits

Dimensions	Innovative Sample Solutions	Transforming AI Risks into Benefits
RES	<ul style="list-style-type: none"> <li>• Prioritize people by reorganizing organizational, economic and political systems towards the goal of expanding humans’ capacities and capabilities</li> <li>• Increase human/AI collaboration and human interventions particularly in high risk situations.</li> </ul>	<ul style="list-style-type: none"> <li>• Helps humans ‘race with the robots’ and staunches AI trends that would compromise human relevance</li> <li>• Improves trust and removes harms in finance, healthcare or hiring.</li> </ul>
GOV	<ul style="list-style-type: none"> <li>• Build comprehensive AI lifecycle governance where policies and procedures are described and enforced during the design, development, deployment, and monitoring of an AI system.</li> <li>• Create AI factsheets to capture AI metadata across the model lifecycle automatically,</li> <li>• Create “an auditing imperative” mandate for both internal and external audits of automated hiring systems</li> <li>• Keep and audit records of job applications.</li> <li>• Use AI tools for security and threat assessments</li> <li>• Conduct bias, explainability and robustness assessments</li> <li>• Base governance on protecting society from harm and unwanted negative</li> </ul>	<ul style="list-style-type: none"> <li>• Builds trust in AI through transparency</li> <li>• Facilitates enterprise validation or external regulation</li> <li>• Builds trust and confidence in decision making and has been used in other areas of law, such as Occupational Safety and Health Administration (OSHA) audits in labor law or the Sarbanes-Oxley Act audit requirements in securities law</li> <li>• Helps organizations identify vulnerabilities that may be exploited by bad actors such as cybercrimes</li> <li>• Protects privacy and harmful outputs</li> <li>• Self-regulation decreases risk of harms</li> </ul>

	<p>consequences for the firm by following stricter regulations, guidelines &amp; certification standards recommended by the European Union</p> <ul style="list-style-type: none"> <li>• Test and re-test and get feedback close to source</li> </ul>	<ul style="list-style-type: none"> <li>• Ensure data is high quality, accurate and has value</li> </ul>
EXP	<ul style="list-style-type: none"> <li>• Train or retrain workers in new fields such as digital forensics, cybercrime specialists, data analysts and AI governance specialists</li> <li>• Protective Optimization Technologies (POTs) systematizes the use of technologies as tools to both explore the effects that algorithms and optimization systems have on our society, and the design of countermeasures to contest their negative effects</li> <li>• Widen educational opportunities to step into new AI jobs and learn new skills</li> <li>• Building talent in technical competencies like AI engineering and enterprise architecture and training people across the organization to work effectively with AI-infused processes.</li> </ul>	<ul style="list-style-type: none"> <li>• New jobs, tools and skills can help detect deep fakes, harmful patterns in the digital arena and make workers more productive</li> <li>• Brings more structure and strategies to AI tool and skill use that actually help not harm society</li> <li>• More educational options along with funding (grants, scholarships, internships) will increase the availability of skills throughout the organization and society</li> <li>• Benefits the organization by increasing efficiency and gives workers higher skilled higher paid jobs</li> </ul>
AI CUL	<ul style="list-style-type: none"> <li>• Use AI-based visualization tools</li> <li>• Leverage open-source and user-provided data.</li> <li>• When autonomously delivering outputs, be transparent that an AI has created the content using watermarks on the content or through in-app messaging</li> <li>• Responsibly use AI in maintaining accuracy, safety, honesty, empowerment and sustainability by citing the sources from where the model is creating content, explaining why the AI gave the response it did, highlighting uncertainty and creating guardrails</li> <li>• Extend commitment beyond immediate corporate interests, encompassing broader societal responsibilities and ethical AI practices</li> <li>• Prevent some tasks from being fully automated</li> </ul>	<ul style="list-style-type: none"> <li>• Extracts significant value and key management information from big data</li> <li>• Ensures honesty about the use and sources of data</li> <li>• Increases transparency</li> <li>• Mitigates risks and eliminates biased outcomes.</li> <li>• Improves the accuracy of data by being transparent and in the organization and broadly across societies.</li> <li>• Human intervention may protect certain risky &amp; sensitive data processes and uses.</li> </ul>

TRAN COL	<ul style="list-style-type: none"> <li>• Work collaboratively to minimize the size of AI models</li> <li>• Collaborate with vendors and partners to create better data and train on models with large amounts of high-quality customer relationship management or other generated data.</li> <li>• Collaborate across departments, disciplines, companies, countries and societies to solve big complicated or wicked problems.</li> </ul>	<ul style="list-style-type: none"> <li>• Reduces carbon footprint because less computation is required, which means less energy consumption from data centers and carbon emissions</li> <li>• Maximizes data accuracy, reliability and value</li> <li>• Facilitates the innovation of widely accepted approaches aimed at tackling wicked problems and maintaining control over complex human-digital networks worldwide</li> </ul>
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## 6. CONCLUSIONS

This research has systematically reviewed the most salient advantages and risks of AI and generative AI in the current literature and categorized them by their impact on society. From this analysis, examples of these challenges and benefits are categorized into societal, economic, ethical political/legal/policy, environmental, data, technological and organizational/managerial arenas based on the research.

Next, relevant risk models and theories, based upon risk models in IT project management, cloud computing implementation, enterprise resource management and social cognitive theory applied from psychology were compared and synthesized into the context of AI resulting in the newly proposed “AI Risk Transformation Model.” The model presents a comprehensive framework tailored to handle the ever-increasing risks of the AI environment.

The ‘AI Risk Transformation Model’ adds to the research by expanding the previous categories of risks (such as ‘project size’ transforming into ‘resources’, ‘culture’ changing to ‘AI-driven culture’ and ‘external engagement’ widening to ‘transformational collaboration’ both internally and externally to the organization) in light of AI-related challenges found in the systematic review of the literature. Lastly, the research adds to the body of knowledge by presenting samples of pragmatic and innovative solutions in each of the AI and generative AI risk dimensions that highlight how risk transformation can occur in the context of the latest AI technologies.

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# AN ANALYSIS AND RESEARCH OF GROWTH FACTORS OF INTERNET CELEBRITY BOBA MILK TEA STORES USING MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

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## **ABSTRACT**

*The boba milk tea industry has emerged as a dynamic and competitive sector within the broader landscape of the food and beverage industry [1]. Characterized by its unique combination of tea, milk, and chewy tapioca pearls, boba milk tea has garnered a dedicated following of enthusiasts. To secure and expand their presence in this market, boba milk tea stores aspire to achieve the status of internet celebrities, attracting a widespread and loyal customer base [2].*

*This research paper delves into the intricate realm of boba milk tea store growth factors using Machine Learning and Artificial Intelligence [3]. The study is motivated by the recognition that the industry's success depends on understanding and harnessing a diverse array of factors, including customer sentiment, store location attributes, and effective marketing strategies [4]. Our methodology entails data collection and preprocessing from a variety of sources, encompassing customer reviews, sales records, geospatial data, and marketing data [5]. Through rigorous feature engineering and the application of advanced Machine Learning algorithms, including sentiment analysis, geospatial analysis, and personalized marketing models, we aim to uncover the key determinants of boba milk tea store success.*

*The results of our research offer actionable insights for both existing and aspiring boba milk tea store owners. Customer sentiment analysis reveals that customer reviews play a critical role in influencing store performance. Store location attributes, explored through geospatial analysis, indicate that proximity to target demographics, competitors, and high-traffic areas significantly impacts growth [6]. Furthermore, the effective deployment of personalized marketing strategies using Machine Learning techniques has been shown to enhance customer engagement and drive growth.*

*While our research provides valuable insights, it is essential to acknowledge certain limitations, such as data availability and the complexity of Machine Learning models. However, we are confident that this research contributes to the broader understanding of growth factors in the boba milk tea industry and can inspire further studies and practical applications.*

*As businesses in the boba milk tea industry navigate a landscape shaped by evolving consumer preferences, this research underscores the transformative potential of Machine Learning and Artificial Intelligence in achieving and maintaining internet celebrity status. Beyond its immediate application, the study provides a blueprint for leveraging technology, data, and industry expertise to thrive in the competitive landscape of modern retail.*

*This paper invites stakeholders within the boba milk tea industry and the broader retail and food and beverage sectors to embrace the power of data-driven decision-making, facilitating sustainable growth and success in the ever-evolving marketplace.*

## **KEYWORDS**

*Flutter, Web Scraping, Firebase Storage, Boba Milk tea*

## **1. INTRODUCTION**

Milk tea has emerged as a beverage of choice for many, especially among young adults. It's interesting to notice that a specific milk tea variety more favored in one store than another. This discrepancy can be attributed to various factors. For instance, the location of a milk tea store plays a pivotal role in determining its customer footfall and consequently, its pricing strategy. A store situated near a university is likely to enjoy higher popularity and perhaps higher prices, given the convenience it offers to students, as opposed to one located in a less frequented plaza. Moreover, the assortment of items a store provides, aside from the drinks, can also influence customer preferences.

Advertisement strategies employed by the stores further influence their popularity [7]. A store with a compelling marketing campaign might attract more customers, even if their prices are slightly higher. Understanding these nuances is not just crucial for customers looking for value, but also for shop owners aiming to optimize their offerings and pricing? For consumers, especially young adults with limited disposable incomes, consistently paying more for the same drink can strain their finances over time. For proprietors, understanding which drinks resonate with their clientele and which require refinement is paramount to ensuring sustained business growth. In the long run, this issue affects two primary groups. Young adults, who frequently patronize milk tea stores, may end up spending more than necessary due to a lack of price transparency. On the other hand, shop owners, aiming to keep their operations profitable, need to know customer preferences and pricing strategies of competitors.

For example, statistics might show that a particular flavor sees a 20% sales spike when promoted effectively or that stores near educational institutions have a 30% higher footfall. In essence, unraveling the complexities behind milk tea pricing and popularity benefits both consumers, particularly young adults with a penchant for the beverage, and shop owners aiming for sustained business success.

To help ease the problem of an oversaturated market of boba stores, a recommendation app is built to inform consumers about these stores. There are several ways to help solve the problems. For the users, it could help them save money and have a better experience when choosing the right milk tea stores to buy from. For milk tea shop owners, it enables them to know what is best to provide to the customers. In today's fast-paced digital era, people attach more importance to convenience. Each person has a cell phone today, and can open up an application and gather information they need in a few seconds. Moreover, users are able to know which store sells a specific drink, the price of the drink, and the rating of the store overall with a few clicks only through the app. In the past, people usually chose to ask friends to know if a milk tea store is good, and it took more time compared with the app. What's more, friends and family may not have experienced all the products of a store while the app can provide all the information about different stores in one search. Searching for the best milk tea by randomly trying out different stores can be both costly and time-intensive. However, the app allows users to know which store to go to for the best experience by knowing the popular drinks and the rating of each store.

## 2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

### 2.1. Ensuring Data Privacy and Security

Indeed, ensuring data privacy and security is a paramount challenge when developing an app that involves sensitive data like financial and customer information of boba milk tea stores. Here are some specific aspects and challenges related to data privacy and security:

**Data Encryption:** Implementing robust encryption mechanisms to protect data both in transit and at rest. This includes encrypting data stored in databases and ensuring secure data transmission [8].

**Access Control:** Managing access to the data is crucial. Implement role-based access control (RBAC) to restrict access only to authorized personnel and provide different levels of access as necessary [9].

**Authentication and Authorization:** Ensure strong authentication for users, and implement authorization mechanisms to determine what actions and data each user is allowed to access.

### 2.2. The Methods

**Complex Models:** Deep learning and other advanced machine learning models can be highly complex and difficult to interpret, making it challenging for stakeholders to grasp how they make decisions. **Black-Box Models:** Some AI models, like neural networks, are often considered "black boxes" because their internal workings are not readily understandable. **Trade-offs:** Making models more interpretable may involve trade-offs in terms of predictive accuracy. Simplifying a model to improve interpretability can result in reduced performance.

### 2.3. Verification

**User Identity Verification:** Verifying the identity of users reliably can be challenging. It's important to ensure that individuals accessing the app are who they claim to be.

**Multi-Factor Authentication (MFA):** While MFA enhances security, some users may find it cumbersome [15]. Balancing security with user convenience is a challenge.

**Password Management:** Users often struggle with password management, leading to weak or reused passwords. Educating users and implementing secure password policies is essential.

## 3. SOLUTION

A system overview for an application focused on the analysis and research of growth factors for Internet celebrity boba milk tea stores using Machine Learning and Artificial Intelligence might consist of various components. Here's a high-level overview of the system:

**User Interface (UI):** The user interface serves as the front end of the application, allowing users to interact with the system [14]. It should be user-friendly and intuitive, enabling users to input data, access reports, and receive recommendations. Users can include boba milk tea store owners and researchers.

**Data Collection and Integration:**

**Data Sources:** The system collects data from various sources, including publicly available data, user-provided data, and data from boba milk tea store owners. This data may include store information, sales data, customer reviews, and more.

**Data Integration:** Data from different sources is integrated and transformed into a consistent format for analysis. This might involve data cleansing, normalization, and enrichment.

**Machine Learning and AI Engine:**

**Data Analysis:** The AI and Machine Learning engine is responsible for processing and analyzing the integrated data. This includes identifying growth factors and trends based on historical and real-time data.

**Model Training:** Machine learning models are trained to make predictions and recommendations. This may include regression models, clustering algorithms, or deep learning models, depending on the specific use cases.

**Recommendation Engine:** The system generates recommendations for boba milk tea store owners based on the AI analysis. For instance, it could suggest marketing strategies, product improvements, or location expansion opportunities.

**Database and Data Storage:**

**Data Repository:** A database stores and manages all the data collected and processed by the system. It should be scalable and secure, supporting both structured and unstructured data.

**Security and Privacy:**

**User Authentication:** Users are required to authenticate themselves securely to access the system, protecting sensitive data.

**Data Encryption:** All data is encrypted in transit and at rest to ensure data privacy and security.

**Data Visualization:**

**Dashboard:** The system provides a visual dashboard that presents key insights and findings in a user-friendly format. Data visualizations like charts, graphs, and tables help users easily grasp the analysis results.

**Notifications and Reporting:**

**Alerts and Notifications:** Users may receive notifications based on real-time analysis, highlighting critical events or opportunities.

**Reporting:** The system generates comprehensive reports that can be downloaded or shared. These reports may include historical data, growth trends, and recommendations.

**User Management and Access Control:**

**Role-Based Access Control:** Different users have different roles and permissions, controlling what data and features they can access. Store owners might have access to their own store's data, while researchers may have broader access.

**Compliance and Regulations:**

The system ensures compliance with data privacy regulations (e.g., GDPR, CCPA) and any industry-specific regulations.



**Continuous Improvement:**

The system is designed to learn and adapt over time, continuously improving its recommendations and analysis as it processes more data and receives user feedback.

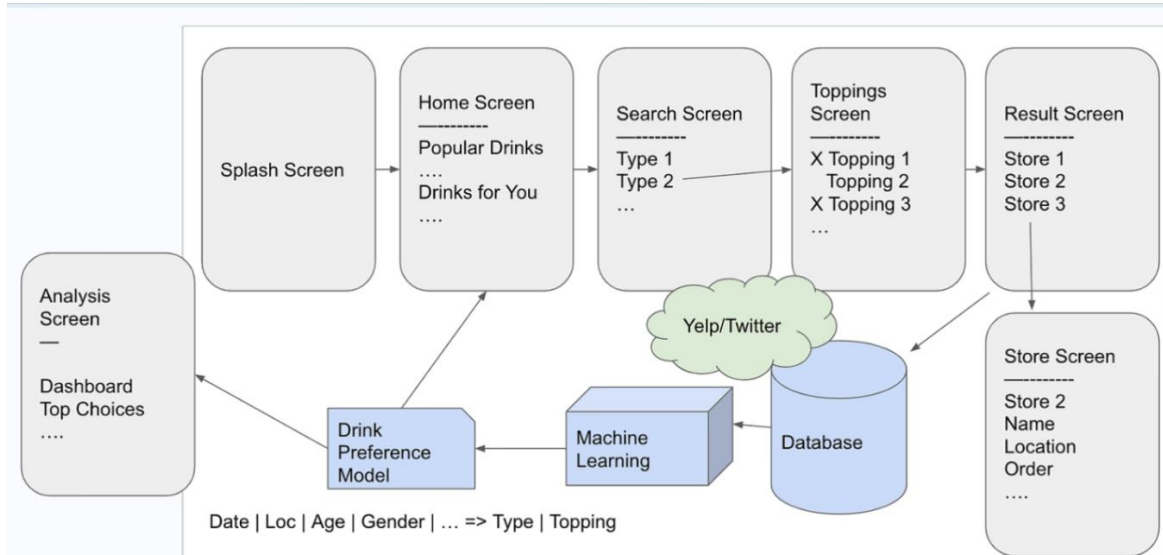


Figure 1. Overview of the solution

```
import 'dart:convert';
import 'package:flutter/material.dart';
import 'package:http/http.dart as http;

void main() {
  runApp(MyApp());
}

class MyApp extends StatefulWidget {
  @override
  _MyAppState createState() => _MyAppState();
}

class _MyAppState extends State<MyApp> {
  // Replace with your Twitter API keys and tokens
  final String apiKey = 'YOUR_API_KEY';
  final String apiSecret = 'YOUR_API_SECRET';
  final String accessToken = 'YOUR_ACCESS_TOKEN';
  final String accessSecret = 'YOUR_ACCESS_SECRET';

  Future<void> fetchTwitterTimeline() async {
    final url =
    Uri.parse('https://api.twitter.com/1.1/statuses/user_timeline.json?screen_name=twitteruserame');

    final response = await http.get(
      url,
      headers: {
        'Authorization': 'Bearer $accessToken',
      },
    );

    if (response.statusCode == 200) {
      final data = json.decode(response.body);
      print(data);
    } else {
      throw Exception('Failed to load Twitter timeline');
    }
  }
}
```

```

@override
Widget build(BuildContext context) {
  return MaterialApp(
    home: Scaffold(
      appBar: AppBar(
        title: Text('Twitter API Example'),
      ),
      body: Center(
        child: ElevatedButton(
          onPressed: () {
            fetchTwitterTimeline();
          },
          child: Text('Fetch Twitter Timeline'),
        ),
      ),
    ),
  );
}

```

Figure 2. Screenshot of the code

**Importing Libraries:**

We begin by importing the necessary Dart libraries for our Flutter application. These libraries include `dart:convert` for working with JSON data and `package:http/http.dart` for making HTTP requests.

**Defining the main Function:**

In the main function, we call `runApp` to start our Flutter application by creating an instance of The App.

**TheApp Widget:**

`MyApp` is a stateful widget that represents the main application. It extends `StatefulWidget`.

**State Class:**

`MyAppState` is the state class for `MyApp`. It extends `State<_MyApp>` and is where the main functionality of the application is implemented.

**API Keys and Tokens:**

The Twitter API keys and tokens are defined as class variables within `_MyAppState`. You need to replace these placeholders with your actual Twitter API credentials.

**fetchTwitterTimeline Function:**

The `fetchTwitterTimeline` function is an asynchronous method that sends a GET request to the Twitter API to retrieve a user's timeline. It is invoked when the "Fetch Twitter Timeline" button is pressed.

**HTTP GET Request:**

The `http.get` method is used to make a GET request to the Twitter API's `user_timeline` endpoint. The Twitter username to fetch the timeline for is specified in the URL.

**Request Headers:**

The Authorization header is set with the Twitter API's Bearer token authentication. This header is required for authenticating with the Twitter API.

**Response Handling:**

We check the HTTP response status code. If the status code is 200 (OK), we decode the JSON response using `json.decode` and print the data. In a real application, you would process and display this data as needed.

**Flutter UI:**

The build method defines the Flutter UI. It includes a simple app with an ElevatedButton labeled "Fetch Twitter Timeline." When this button is pressed, it triggers the fetchTwitterTimeline function.

**Replace with Your API Credentials:**

In the code, there are placeholders like 'YOUR\_API\_KEY', 'YOUR\_API\_SECRET', 'YOUR\_ACCESS\_TOKEN', 'YOUR\_ACCESS\_SECRET', and 'twitterusername'. Replace these with your actual Twitter API credentials and the Twitter username you want to fetch the timeline for.

**Error Handling and Optimization:**

This code provides a basic structure to demonstrate the HTTP request process. In a production application, you would add more robust error handling, ensure secure storage of API credentials, and possibly organize your code into separate files and classes for better maintainability.

Remember that when working with third-party APIs, it's essential to review the API's documentation to understand the available endpoints and their response structures. Additionally, you should implement proper error handling and security practices in your application.

```
import 'package:flutter/material.dart';
import 'package:firebase_auth/firebase_auth.dart';

void main() {
  runApp(MyApp());
}

class MyApp extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      home: LoginPage(),
    );
  }
}

class LoginPage extends StatefulWidget {
  @override
  _LoginPageState createState() => _LoginPageState();
}

class _LoginPageState extends State<LoginPage> {
  final FirebaseAuth _auth = FirebaseAuth.instance;
  final GlobalKey<FormState> _formKey = GlobalKey<FormState>();

  String _email = "";
  String _password = "";

  Future<void> _signIn() async {
    if (_formKey.currentState.validate()) {
      try {
        UserCredential userCredential = await _auth.signInWithEmailAndPassword(
          email: _email,
          password: _password,
        );
        // Successfully signed in, you can navigate to another page here.
        print("Signed in: ${userCredential.user.email}");
      } catch (e) {
        // Handle sign-in errors (e.g., wrong credentials)
        print("Sign-in error: $e");
      }
    }
  }
}
```

```

}

@override
Widget build(BuildContext context) {
  return Scaffold(
    appBar: AppBar(
      title: Text("Login Page"),
    ),
    body: Center(
      child: Padding(
        padding: const EdgeInsets.all(16.0),
        child: Form(
          key: _formKey,
          child: Column(
            mainAxisAlignment: MainAxisAlignment.center,
            children: <Widget>[
              TextFormField(
                decoration: InputDecoration(labelText: 'Email'),
                validator: (value) {
                  if (value.isEmpty) {
                    return 'Please enter your email.';
                  }
                  return null;
                },
                onChanged: (value) {
                  _email = value;
                },
              ),
              TextFormField(
                decoration: InputDecoration(labelText: 'Password'),
                obscureText: true,
                validator: (value) {
                  if (value.isEmpty) {
                    return 'Please enter your password.';
                  }
                  return null;
                },
                onChanged: (value) {
                  _password = value;
                },
              ),
              SizedBox(height: 16.0),
              ElevatedButton(
                onPressed: _signIn,
                child: Text("Sign In"),
              ),
            ],
          ),
        ),
      ),
    ),
  );
}

```

Figure 3. Screenshot of code 2

This source code is a basic example of a login system for a Flutter application using Firebase Authentication as the backend service. Let's break down the code and understand its functionality step by step:

#### Setting up the Flutter App [10]:

The Flutter app is set up in the main function, which calls `runApp` to start the app and displays the `MyApp` widget as the root widget.

#### MyApp Widget:

`MyApp` is a stateless widget that represents the entire application. It sets the initial route to the

#### LoginPage.

#### LoginPage Widget:

The `LoginPage` widget is a stateful widget where the core login functionality is implemented.

#### Firebase Authentication Configuration:

An instance of the Firebase Authentication service is created with `FirebaseAuth.instance`. To use this, you need to integrate Firebase into your Flutter project and configure it properly.

#### FormKey and Input Fields:

The `_formKey` is used to validate the form input fields. Two input fields are provided for email and password, and their values are stored in the `_email` and `_password` variables.

### \_signIn Function:

signIn is an asynchronous function that is called when the "Sign In" button is pressed. It validates the form fields using the `_formKey`.

If the validation is successful, it attempts to sign in the user using the `signInWithEmailAndPassword` method from Firebase Authentication.

Successful sign-ins are logged, and errors are caught and handled.

### Build Method for UI:

The build method defines the UI for the login page.

It includes a form with text input fields for email and password, as well as a "Sign In" button.

Input validation is performed, and any validation errors are displayed.

When the "Sign In" button is pressed, the `_signIn` function is called.

### Firebase Authentication Integration:

This code assumes that you have integrated Firebase into your project and configured it with the appropriate API keys and Firebase project settings. Make sure to follow Firebase setup documentation for Flutter.

### User Experience:

This code provides a basic login screen where users can enter their email and password to sign in. Successful sign-ins are logged, and errors are handled, but in a real-world application, you would typically navigate to other screens or perform additional actions upon successful login.

### Security and Error Handling:

Security and error handling are crucial aspects of any authentication system. In a production application, you should implement password reset, user registration, and secure error handling

```
import 'package:flutter/material.dart';

void main() {
  runApp(MyApp());
}

class MyApp extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      home: Scaffold(
        appBar: AppBar(
          title: Text('Search Bar Example'),
        ),
        body: SearchPage(),
      ),
    );
  }
}

class SearchPage extends StatefulWidget {
  @override
  _SearchPageState createState() => _SearchPageState();
}
```

```

class _SearchPageState extends State<SearchPage> {
  String _searchText = "";
  List<String> _dataList = [
    'Apple',
    'Banana',
    'Cherry',
    'Date',
    'Elderberry',
    'Fig',
    'Grape',
    'Honeydew',
    'Kiwi',
    'Lemon',
    'Mango',
    'Orange',
    'Pineapple',
    'Quince',
    'Raspberry',
    'Strawberry',
    'Tomato',
    'Ugli fruit',
    'Watermelon',
  ];

  List<String> _searchResults = [];

  void _performSearch(String searchText) {
    _searchResults.clear();
    if (searchText.isNotEmpty) {
      for (String item in _dataList) {
        if (item.toLowerCase().contains(searchText.toLowerCase())) {
          _searchResults.add(item);
        }
      }
    }
  }

  @override
  Widget build(BuildContext context) {
    return Column(
      children: [
        Padding(
          padding: const EdgeInsets.all(16.0),
          child: TextField(
            decoration: InputDecoration(
              labelText: 'Search',
              hintText: 'Search for a fruit',
              prefixIcon: Icon(Icons.search),
            ),
            onChanged: (text) {
              setState(() {
                _searchText = text;
                _performSearch(text);
              });
            },
          ),
        ),
        Expanded(
          child: ListView.builder(
            itemCount: _searchResults.length,
            itemBuilder: (context, index) {
              return ListTile(
                title:

```

Figure 4. Screenshot of game 3

The SearchPage widget is a stateful widget that contains the search bar and search results.

`_searchText` is a variable that holds the current search text entered by the user.

`_dataList` is a list of items to search within (in this case, a list of fruits).

`_searchResults` is a list that stores the search results based on the user's input.

The `_performSearch` function is called when the text in the search bar changes. It filters items from `_dataList` that contain the search text and stores them in `_searchResults`.

The user interface consists of a `TextField` for input and a `ListView.builder` to display the search results.

### 4. EXPERIMENT

Store Name	Location	Number of Reviews	Monthly Sales	Marketing Expenditure	Store Age	Online Presence	Competitor Count	Employee Count
Boba Bay	Los Angeles	250	18000	2000	2	Yes	5	4

Milk Tea City	New York	400	28000	2500	3	Yes	7	6
Sweet Delights	San Francisco	150	12000	1800	1	No	4	3
Tea Haven	San Diego	350	22000	2800	4	Yes	9	7
Boba Oasis	Houston	300	16000	2200	2	No	6	5
Bubble Bliss	Chicago	200	14000	1900	3	Yes	8	6
Sweet Serenity	Seattle	100	8000	1500	1	No	3	2

Happy Sips	Miami	450	30000	3000	5	Yes	10	8
Milk Magic	Orlando	350	20000	2100	2	No	7	6
Bubble World	Dallas	250	14000	1600	3	Yes	6	4
Taproot Time	Atlanta	350	22000	2700	2	Yes	6	5
Sweet Bubbles	Denver	280	18000	2300	3	No	5	4
Yummy Delights	Boston	180	11000	1700	1	Yes	4	3

Pearl Paradise	Phoenix	400	24000	2800	4	Yes	9	7
Boba Blend	Las Vegas	320	17000	2200	2	No	8	6
Sip 'n Savor	Philadelphia	280	13000	1900	3	Yes	7	5
Tea Temptations	Detroit	150	9000	1400	1	Yes	3	2
Bubble Burst	Minneapolis	390	26000	2900	4	No	6	5
Milky Way	Portland	220	14000	1800	2	Yes	5	4
Boba Bliss	San Antonio	280	17000	2100	3	No	6	5

Figure 5. Figure of experiment

The goal of these analyses is to identify patterns and factors that influence the growth and success of boba milk tea stores. The best predictive model for suggesting the best location depends on the specific dataset, the nature of the problem, and the available resources. It's often a good practice to try multiple models and select the one that performs best on our data. Based on the data table we have, the location and data set has the most related impact on the annual income.

## 5. RELATED WORK

Transmedia storytelling : business, aesthetics and production at the Jim Henson Company, Long, Geoffrey A [11]. Transmedia narratives use a combination of Barthesian hermeneutic codes, negative capability and migratory cues to guide audiences across multiple media platforms. This thesis examines complex narratives from comics, novels, films and video games, but draws upon the transmedia franchises built around Jim Henson's Labyrinth and The Dark Crystal to provide two primary case studies in how these techniques can be deployed with varying results. By paying close attention to staying in canon, building an open world, maintaining a consistent tone across extensions, carefully deciding when to begin building a transmedia franchise, addressing open questions while posing new ones, and looking for ways to help audiences keep track of how each extension relates to each other, transmedia storytellers can weave complex narratives that will prove rewarding to audiences, academics and producers alike.

The functional programming language ML has been undergoing a thorough redesign during the past year, and the module facility described here has been proposed as part of the revised language, now called Standard ML [12]. The design has three main goals: (1) to facilitate the structuring of large ML programs; (2) to support separate compilation and generic library units; and (3) to employ new ideas in the semantics of data types to extend the power of ML's polymorphic type system. It is based on concepts inherent in the structure of ML, primarily the notions of a declaration, its type signature, and the environment that it denotes.



## 6. CONCLUSIONS

In an era characterized by evolving consumer preferences and fierce competition in the food and beverage industry, the boba milk tea sector has risen to prominence as a beloved and distinctive category. As boba milk tea stores strive to secure their position as internet celebrities in this industry, our research has endeavored to shed light on the multifaceted landscape of growth factors using Machine Learning and Artificial Intelligence.

Our study has offered valuable insights into the determinants of success for boba milk tea stores. Through the application of advanced Machine Learning models and AI technologies, we have been able to delve deep into the intricacies of this dynamic sector [13]. The results are not only informative but also hold considerable practical relevance for stakeholders within the industry.

Key findings of our research highlight the significance of various factors. Customer sentiment, harnessed through sentiment analysis of customer reviews, has emerged as a fundamental influencer of store performance. The ability to discern and respond to customer preferences and feedback is instrumental in maintaining a strong and loyal customer base.

Moreover, the importance of location attributes cannot be overstated. Geospatial analysis has demonstrated that store proximity to target audiences, competitors, and high-traffic areas plays a pivotal role in determining store growth. Identifying optimal locations based on these attributes is vital for prospective and existing boba milk tea store owners.

Our study has also emphasized the pertinence of marketing strategies in the success of boba milk tea stores. Leveraging Machine Learning and AI for personalized marketing and customer segmentation has proven to be an effective approach to maximize marketing ROI and customer engagement.

While our research offers promising insights, it is important to acknowledge certain limitations. Data availability, particularly for customer reviews and geographic information, presents a challenge. Additionally, the complexity of Machine Learning models requires careful consideration when applying them to real-world settings.

As we conclude, the implications of our research extend beyond the boba milk tea sector. Our approach, centered on Machine Learning and AI, can be adapted and adopted in diverse retail and food and beverage contexts. The technologies harnessed in this study can empower businesses to make data-driven decisions, enhancing their strategies for growth and success.

In light of the findings and future research possibilities, we believe that the convergence of technology, data, and industry expertise will continue to shape the landscape of boba milk tea stores and other retail segments. As businesses strive to navigate this intricate landscape, the transformative potential of Machine Learning and AI offers a promising path forward in the pursuit of becoming internet celebrities in the world of boba milk tea.

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# DO YOU SPEAK BASQUENGLISH? ASSESSING LOW-RESOURCE MULTILINGUAL PROFICIENCY OF PRETRAINED LANGUAGE MODELS

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## **ABSTRACT**

*Multilingual language models' have democratized access to information and artificial intelligence (AI). Still, low-resource languages (LRL) remain underrepresented. This study compares the performance of GPT-4, LLaMa (7B), and PaLM 2 when asked to reproduce English-Basque code-switched outputs. The study uses code-switching as a test to argue for the multilingual capabilities of each model and compares and studies their cross-lingual understanding. All models were tested using 84 prompts (N = 252), with their responses subjected to qualitative and quantitative analysis. This study compares the naturalness of the outputs, code-switching competence (CSness), and the frequency of hallucinations. Results of pairwise comparisons show statistically significant differences in naturalness and the ability to produce grammatical code-switched output across models. This study underscores the critical role of linguistic representation in large language models (LLMs) and the necessity for improvement in handling LRLs.*

## **KEYWORDS**

*Basque, code-switching, low-resource languages, multilingual models*

## **1. INTRODUCTION**

Code-switching (CS) is the linguistic phenomenon that refers to alternating between two or more languages in a conversation. It usually arises within multilingual environments, where speakers are exposed to multiple languages. Several factors, such as the topic of conversation, the relationship between the interlocutors, and the interaction context, can influence language selection. This linguistic ability is a reflection of the speakers' cultural competence and cognitive flexibility. In this way, code-switching represents a complex, rule-governed use of language that provides rich insight into issues of identity, culture, and power.

Studies on bilingualism and code-switching have identified two related but distinct phenomena, code-switching (CS) and code-mixing (CM). Code-mixing involves the practice of mixing languages in a single sentence, whereas code-switching can occur either within or across sentence boundaries within a single discourse or constituent. Although these two phenomena are often used interchangeably, there are some subtle differences in their usage. Previous literature [1] [2] has differentiated code-switching from code-mixing, emphasizing that the former involves a more conscious and deliberate choice of language, while the latter is often more spontaneous and less planned. However, this study refers to code-switching and code-mixing

synonymously, taking both to refer to the practice of using more than one language within a single discourse or conversation. Understanding the nature of code-switching and code-mixing is important for researchers in the field of bilingualism, as well as for educators and policymakers who work with bilingual communities. By examining the patterns and contexts in which these practices occur, we can gain insight into the linguistic and cognitive processes that underlie bilingualism, as well as the social and cultural factors that shape language use.

Code-switching behavior has been studied differently depending on the age of the group looked at. Code-switching studies conducted in bilingual adults have analyzed grammatical and communicative functions [3] [4]. The complexity found in bilingual adults' code-switching attitudes revealed a sophisticated knowledge of the grammatical schemes of both languages and reflected the individuals' aptitude in using them appropriately. However, early research argued that code-switching revealed grammatical disorders caused by bilingual or multilingual language learning. From this point, language switching is considered a linguistic failure. Most studies pointing in this direction analyze what children's code-switching behavior suggests about their linguistic competency. Studies on kids' language alternation have postulated that bilingual children's mixing or switching of languages is provoked either by confusion or linguistic incompetency.

With multilingualism becoming common in today's world, there has been increasing interest in code-switching within natural language processing (NLP). This study focuses on the case of Basque and English code-switching to test the multilingual capabilities of models when dealing with low-resource languages (LRLs). The Basque language is a linguistically unique and low-resource language primarily spoken in the Basque Country, an autonomous region located in northern Spain, and to a lesser extent, in Navarre and some areas of southern France (Figure 1). These regions are the stronghold of the Basque language, which is noted for its distinct linguistic features, not related to any other known language. Despite its low number of native speakers (750,000) compared to global languages such as English, Basque has exhibited resilience and adaptability, largely due to active language revitalization efforts [5].

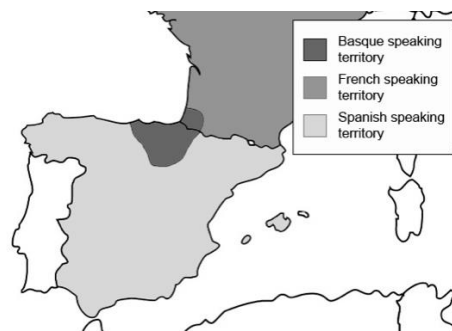


Figure 1. Map of Basque-speaking territory

In the evolution of language models, GPT-4 [6], LLaMa (7B) [7], and PaLM 2 [8], signify notable milestones. GPT-4, developed by OpenAI, is an enhanced version of its predecessor GPT-3.5, demonstrating remarkable capability in generating human-like text based on provided prompts. It harnesses the power of a transformer-based architecture and is trained on a diverse range of internet text. However, it also shares the limitations of its earlier iterations such as potential biases in the training data and lack of an understanding of factual correctness. LLaMa (7B) is the most lightweight model of LLaMa, developed by Meta's Fundamental AI Research (FAIR) team. This model distinguishes itself through its capacity to understand, learn, and adapt to different

languages and multimodal inputs, emphasizing linguistic diversity and inclusivity. It addresses some of the critiques of earlier monolingual-centric models and works towards reducing the digital language divide. Finally, PaLM 2 represents a paradigm shift towards procedural language models. It goes beyond the standard language model capabilities, demonstrating an understanding of procedural and sequential tasks. This ability to follow a sequence of instructions and generate logical, step-by-step explanations represents a significant advancement in the practical applications of language models [9].

## 2. PREVIOUS WORK

Literature on code-switching language modeling has underpinned the challenges that arise from the limited availability of large-scale code-switched data for training [10] [11]. Other code-switching language modeling studies have explored the use of recurrent neural network language models (RNNLM) and factored language models (FLM) for language modeling in code-switched speech [12]. These techniques integrated part-of-speech tags (POS) and language information (LID), significantly improving perplexity scores. Synthetic data augmentation has also been proposed as a solution to these limitations. [13] offer a sequence-to-sequence model that generates code-switching data by leveraging parallel mono-lingual translations from limited sources of code-switched data using a copy mechanism.

Some studies have focused on this problem in the context of automatic speech recognition (ASR). New methodologies to confront these limitations have consisted in introducing ASR-motivated evaluation setups that demonstrated to outperform generative language modeling [11]. Within the ASR framework, researchers have also proposed end-to-end (E2E) models to deal with intra-sentential CS [14], new datasets for ASR systems capable of identifying code-switching [15], and named entity recognition (NER) improvements in ASR through speech editing data augmentation [16].

This study proposes a different focus; it explores the utility of code-switching to evaluate the multilingual capabilities and cross-lingual understanding of language models. Drawing inspiration from [17], it analyzes the performance of three major models in handling low-resource-high-resource code-switching. Unlike previous studies that primarily focus on monolingual contexts, this research contributes to the field by simulating real-world language behaviour.

## 3. METHODOLOGY

### 3.1. Design

This study compares three of the most widely used text-generation models: GPT-4, LLaMa (7B), and PaLM 2. GPT-4 and PaLM 2 were selected due to their power and extensive capabilities; LLaMa (7B) was selected to compare the performance of models with lesser parameters. New currents in artificial intelligence and natural language processing may benefit from developing and deploying computationally light models.

The experiment consisted of 252 queries ( $N = 252$ ), 84 for each model ( $n = 84$ ). These were divided into groups of 6 ( $n = 6$ ) by topic. Topics include artificial intelligence, family, sports, language, weather, food, politics, news, economy, education, video games, music, traveling, and photography. Topics were selected with the objective of having a holistic view of the linguistic (or code-switching) capabilities of each model. Figures 2, 3, and 4 are some of the examples of the queries.

Prompt	Write an English and Basque code-mixed sentence about <b>Artificial Intelligence</b> .	
GPT-4	<b>Artificial Intelligence</b> -ak, edo AI-ak, gure bizitzan erabilgarriak diren teknologia berriak sortzen ditu, and they're transforming the way we live and work.	CSness: 3
LlaMa	I am sorry to say that I do not speak the language of this quiz, but I will try my best anyway... The <b>artificial intelligence</b> is really intelligent.	CSness: 0
PaLM 2	<b>Adimen Artifiziala (AI)</b> teknologia berria da, eta munduari eragin handia izango du.	CSness: 0

Due to the inability to use OpenAI's or Hugging Face's APIs, the study uses GPT-4 and PaLM 2 through their web interface. In the case of LLaMa, it was installed and used through Dalai, a library that allows running foundational language models. Prompts were queried manually for all the models.

Figure 2. Prompt example on artificial intelligence AI. Models' CSness score is shown on the right

Prompt	Imagine there are two English-Basque bilingual speakers talking to each other, can you imagine a brief conversation between them talking about <b>news</b> ?	
GPT-4	Speaker 1: Have you seen today's ' <b>egunkaria</b> '? It's really 'nahasia' - chaotic, isn't it? Speaker 2: Bai, I agree. There's so much 'aldaketa' - change happening everywhere. It's hard to keep up. Speaker 1: True. 'Baina', as they say, change is the only constant, 'ezta'? Speaker 2: That's right. 'Gure mundua' - our world is always evolving. We just need to adapt and stay <b>informed</b> .	CSness: 1
LlaMa	There's a new building being built in town and we think it will be ready by the end of summer. :)	CSness: 0
PaLM 2	A: Did you hear about the <b>news</b> ? B: What news? A: The one about the new <b>Basque</b> president. B: Oh, yeah, I saw that. It's pretty exciting. A: I know, right? I can't wait to see what they do. B: Me too. I think they're going to do a great job. A: I hope so. We need someone who will fight for our rights. B: Me too. We're strong together.	CSness: 0

Figure 3. Prompt example on news

Prompt	Imitate the speaking style of a person who can speak English and Basque in one sentence about <b>photography</b>	
GPT-4	Every <b>argazkia</b> I take is a reflection of how I see the mundua, the world, in that particular moment.	CSness: 2
LlaMa	You are at a dinner party, talking to someone you don't know very well yet but have just met over coffee or champagne cocktail hour. You want them interested enough by the end of this casual conversation that they invite themselves on your next hiking adventure in Basque Country!	CSness: 0
PaLM 2	I love <b>taking pictures</b> , edo argazkiak ateratzea, of the beautiful Basque Country.	CSness: 3

Figure 4. Prompt example on photography

### 3.2. Evaluation

Results were evaluated from a qualitative and quantitative perspective. The qualitative analysis provided tools for judging the naturalness, code-switching ability, and hallucinations from a

human perspective. After annotation, quantitative analysis provided the necessary tools to judge the statistical significance of the results obtained.

Through naturalness, the study measured the coherence, grammatically, and fluency of the outputs. Every answer was given a naturalness score ranging from 0 (not natural) to 10 (very natural). Even if naturalness judged three aspects, coherence (i.e., responding to the prompt) was the minimum requirement to obtain the minimum score of 1.

The models' ability to produce code-switching was measured by code-switchness (CSness). Each code-mixed answer was given a score from 0 to 3. 0 score meant no code-switching –or code-mixing–; answers were given just in English. Those outputs with loanwords from Basque (e.g., *sirimiri*, *aupa*) were given a score of 1. Cases in which switching consisted of single, isolated tokens, such as cases in context L1\_L1, were also given 1. The study provided a score of 2 to the generated code-switched text that showed the ability to go beyond the loanwords but that stayed in the domain of the topic queried (e.g., photography is great, *argazkiak ateratzea gustatzen zait*). Finally, a score of 3 was provided to the answers that showed code-switching abilities that went beyond the domain of the topic queried about (e.g., Sports are a good way of staying healthy *baita lagunekin momentu onak partekatzeko era bat*).

In artificial intelligence, hallucination refers to the creation of outputs that seem plausible but are either untrue or irrelevant to the given context. These outputs can arise from the AI model's inherent biases, lack of real-world knowledge, or training data constraints. Hallucinations were evaluated across groups to compare the linguistic performance of the three chosen models. This study classified hallucinations according to qualitative criteria as follows:

- **Out-of-Switch Language (OOS):** Out-of- speech (OOS) hallucinations happened when the output included keywords or phrases in a language that was not mentioned in the query. Most OOS hallucinations included languages that are geographically close to Basque (Spanish and French).
- **Linguistic Hallucination:** Linguistic hallucinations are ungrammatical responses. Some of the outputs included odd semantics, redundant syntax, or made-up lexicon.
- **Unexpected Output:** Unexpected output hallucinations included the outputs in which the model provided information that was not included in the prompt. This category also included those responses that did not answer the original query or that were produced by the comprehensive failures of the model.
- **Translation:** Translation hallucinations occurred when the model conceived code-switching as a direct translation of statements. This category also included outputs in which the model inserted translations in the form of clarification.

### 3.3. Exclusion Criteria

Exclusion criteria were applied to the outputs of the prompts. It was found that when models misinterpreted queries, they provided answers that followed similar patterns. These patterns included explanatory add-ons that were excluded to evaluate the code-switchness (CSness) of the output. Some examples are shown in Table 1.

Other analysis criteria included the evaluation of non-sensical outputs. To keep the analysis consistent, those outputs were considered hallucinations (classified as non-expected output) and

got 0 score on code-switchness. There was not any case that showed high code-switchness and non-sensical outputs. Similarly, structures connoting clarification (often between quotation marks or dashes) were not included in code-switch or code-mixing for this study, thus they got 0 code-switchness.

In outputs where two or more degrees of code-switchness (CSness) were found the output got the highest-ranked degree. This criterion was used mainly in answers to queries consisting of recreating a code-switched conversation. These outputs usually showed a variety of code-switches, which required a consistent evaluation across queries and models. In the same line, outputs that showed direct translation were given a score of 1 in CSness due to their lack of code-switching complexity.

Model	Query	Original	After Exclusion Criteria
GPT-4	Code-mixing refers to a phenomenon of combining two or more languages in a single sentence. Can you generate a code-mixed English-Basque sentence about food?	Sure, here's a code-mixed sentence: "This paella is delicious, oso gozoa da!"	This paella is delicious, oso gozoa da!
LlaMa (7B)	Write an English and Basque code-mixed sentence about sports.	In Euskara bat (basketball) is called gorri da or jaiusko da, depending on where it's being played/who plays in it...	In Euskara bat is called gorri da or jaiusko da, depending on where it's being played/who plays in it...
PaLM 2	Code-mixing refers to a phenomenon of combining two or more languages in a single sentence. Can you generate a code-mixed English-Basque sentence about politics?	I'm so excited to vote for the new Basque president! Eta irabazi behar du!	I'm so excited to vote for the new Basque president! Eta irabazi behar du!

Table 1. Examples of the exclusion criteria per model

## 4. RESULTS

### 4.1. General Overview

The study analyzed three categories to judge the multilingual capabilities of each model in the case of English-Basque code-switching. After annotation, the descriptive features of the results from the prompts are described in Tables 2, 3, and 4.

GPT-4													
Hallucinations					Code-switching					Naturalness			
Total	T	LH	OOS	UO	Switches	Total (CSness)	<i>M</i>	<i>mo</i>	<i>stdev</i>	Total	<i>M</i>	<i>mo</i>	<i>stdev</i>
<b>36</b>	15	14	3	4	<b>69</b>	<b>127</b>	1.51	1	1.07	<b>518</b>	<b>6.17</b>	6	2.01

Table 2. Descriptive analysis of the results for the data obtained from GPT-4

LlaMa (7B)													
Hallucinations					Code-switching					Naturalness			
Total	T	LH	OOS	UO	Switches	Total (CSness)	<i>M</i>	<i>mo</i>	<i>stdev</i>	Total	<i>M</i>	<i>mo</i>	<i>stdev</i>
<b>46</b>	1	8	5	30	<b>2</b>	<b>4</b>	0.05	0	0.34	<b>393</b>	<b>4.68</b>	0	3.03

Table 3. Descriptive analysis of the results for the data obtained from LlaMa (7B)

PaLM 2													
Hallucinations					Code-switching					Naturalness			
Total	T	LH	OOS	UO	Switches	Total (CSness)	<i>M</i>	<i>mo</i>	<i>stdev</i>	Total	<i>M</i>	<i>mo</i>	<i>stdev</i>
<b>42</b>	36	2	2	2	<b>11</b>	<b>21</b>	0.25	0	0.73	<b>513</b>	<b>6.11</b>	5	2.32



Table 4. Descriptive analysis of the results for the data obtained from PaLM 2

Figure 5 provides a general overview of the metrics under analysis. Total scores were summed and normalized to compare the three models equally. The initial landscape pointed out that GPT-4 was the model with the most code-switches produced (CS total) in Basque-English or vice-versa (0.69). PaLM 2 was significantly behind its direct opponent (0.11) and LLaMa (7B) was the model that least code-switches produced (0.02). This meant that GPT-4 was able to produce code-switches for the 82% of the prompts, PaLM 2 for the 11%, and LLaMa for the 2%. GPT-4 was also the model that showed fewer total hallucinations (0.36), followed by PaLM 2 (0.42), while LLaMa (7B) showed the highest number of hallucinations (0.46). As for naturalness, both PaLM 2 and GPT-4 were paired (0.518 and 0.513, respectively); LLaMa (7B) obtained 0.39.

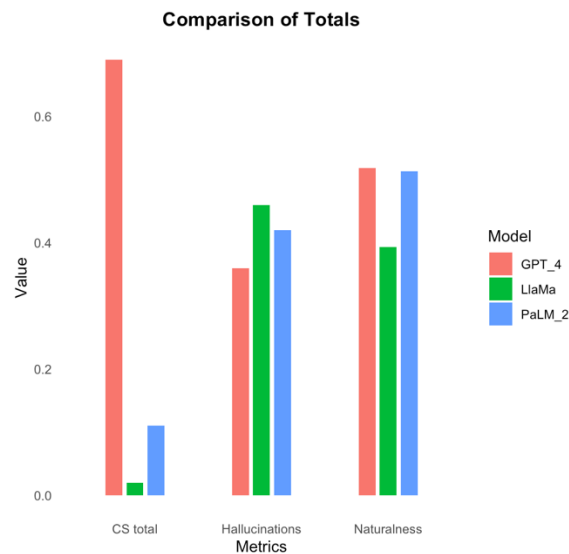


Figure 5. Totals of code-switched answers (CS total), hallucinations, and naturalness

## 4.2. Code Switchness

Code-switchness (CSness) measured the quality of the switches produced. It was hypothesized that the data did not follow a normal distribution. To have a closer insight, the Shapiro-Wilk test was used to assess the normality of the data distribution for the CSness of the models. The study assumed a significance level of  $p = 0.05$ . The results indicated a significant deviation from normality for all three models: GPT-4 ( $W = 0.858$ ,  $p = 0.0001$ ), LLaMa (7B) ( $W = 0.123$ ,  $p = 0.0002$ ), and PaLM 2 ( $W = 0.386$ ,  $p = 0.0002$ ). To test the homogeneity of variances among the three models a Brown-Forsythe test was performed. The F statistic was 7.126 (numerator  $df = 2$ , denominator  $df = 138.16$ ), with a  $p$ -value of 0.0002, indicating a significant difference in variances among the three models. The assumptions of normality and homogeneity of variance, which are prerequisites for parametric statistical tests, were violated in this case. This was taken into account at the time of considering further statistical analyses that compare the CSness of the models.

The Kolmogorov-Smirnov test measures the extent to which two data samples are drawn from the same distribution. In this context, it was used to determine whether the distributions of CSness scores from each pair of models were similar. GPT-4 and LLaMa ( $p < 0.05$ ), LLaMa and PaLM 2 ( $p = 0.017$ ), and GPT-4 and PaLM ( $p < 0.05$ ) indicated that the pairs did not have the same distribution. The Wilcoxon rank sum test with continuity correction pointed out in the same

direction: GPT-4 and LLaMa ( $p < 0.05$ ), LLaMa and PaLM 2 ( $p = 0.009$ ), and GPT-4 and PaLM 2 ( $p < 0.05$ ) statistically differed in the distributions of their CSness scores.

The results of the code-switching ability in English-Basque were tested to gain insight into the statistical significance of the differences between models. In line with the previous data exploration, a pairwise comparison through the Wilcoxon rank sum test with continuity correction was performed. In addition, to control Type I errors, the Bonferroni  $p$ -value adjustment method was applied. Results are shown in Figure 6.

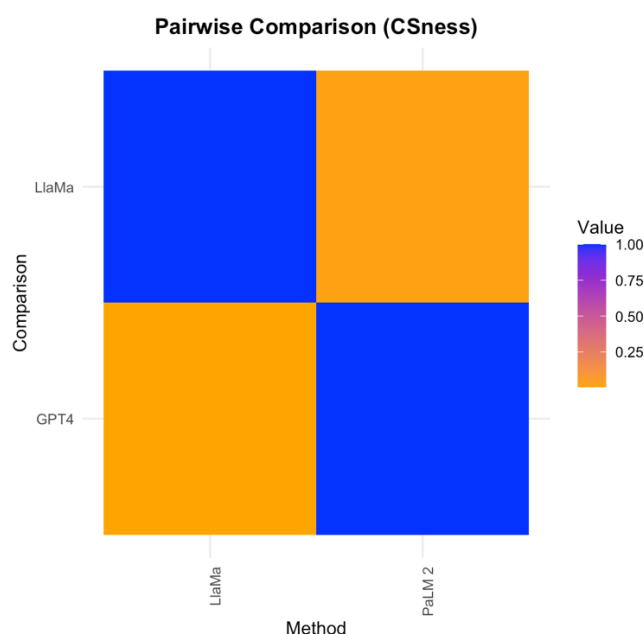


Figure 6. Comparison of CSness shown across models

The comparison between GPT-4 and LLaMa indicated a statistically significant difference in the code-switching ability of both models ( $p = 0.0047$ ). For GPT-4 and PaLM 2 the  $p$ -value was 1, therefore, their code-switching abilities in the case under study did not show a meaningful statistical difference. Finally, LLaMa and PaLM 2 indicated a statistically significant difference in English-Basque code-switching performance ( $p = 0.0215$ ). In conclusion, GPT-4 differed significantly in terms of code-switching ability from LLaMa but not from PaLM 2, its direct competitor. LLaMa and PaLM 2 also showed significantly different code-switching abilities.

### 4.3. Naturalness

For naturalness, the same procedure as for CSness was followed. The Shapiro-Wilk test indicated a significant deviation from normality for all three models: GPT-4 ( $W = 0.949$ ,  $p = 0.002$ ), LLaMa (7B) ( $W = 0.924$ ,  $p = 0.0001$ ), and PaLM 2 ( $W = 0.943$ ,  $p = 0.001$ ). To test the homogeneity of variances among the three models a Brown-Forsythe test was performed. The F statistic was 7.823 (numerator  $df = 2$ , denominator  $df = 161.99$ ), with a  $p$ -value of 0.0005, indicating a significant difference in variances among the three models. The assumptions of normality and homogeneity of variance were also violated in this case.

The Kolmogorov-Smirnov indicated that GPT-4 and LLaMa ( $p = 0.001$ ) and LLaMa and PaLM 2 ( $p = 0.029$ ) did not have the same distribution. In contrast, GPT-4 and PaLM ( $p = 0.329$ ), suggested that their distributions of naturalness scores were similar. The Wilcoxon rank sum test

with continuity correction pointed out in the same direction: GPT-4 and LLaMa ( $p = 0.0015$ ) and LLaMa and PaLM 2 ( $p = 0.007$ ) statistically differed in the distributions of their naturalness scores. By contrast, GPT-4 and PaLM 2 ( $p = 0.522$ ) indicated no significant difference.

Based on both the Kolmogorov-Smirnov test and Wilcoxon rank sum test, GPT-4 and LLaMa (7B), as well as LLaMa and PaLM 2, generated text with different degrees of naturalness when code-switching in English and Basque. However, GPT-4 and PaLM 2 produced text with comparable naturalness in the same context of code-switching. GPT-4 is the model that most robustness showed, as indicated by its range (Figure 7).

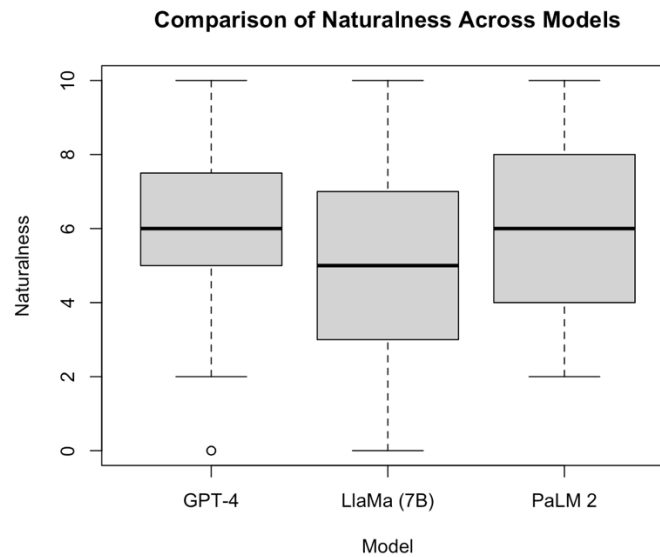


Figure 7. Comparison of naturalness shown across models

A pairwise comparison through the Wilcoxon rank sum test with continuity correction was performed (with Bonferroni  $p$ -value adjustment method). The comparison between GPT-4 and LLaMa yielded a  $p$ -value that was effectively zero ( $< 2e - 16$ ). It suggested a statistically significant difference in the naturalness of the text produced by these two models. Similarly, the comparison between GPT-4 and PaLM 2 was also close to zero ( $4.1e - 16$ ), indicating a statistically significant difference. The comparison between LLaMa and PaLM 2 yielded  $p = 0.029$ , which was less than the significance value ( $p = 0.05$ ), again suggesting a statistically significant difference in the naturalness of the text produced. In conclusion, each pair of language models had significantly different levels of naturalness. The results are shown in Figure 8.

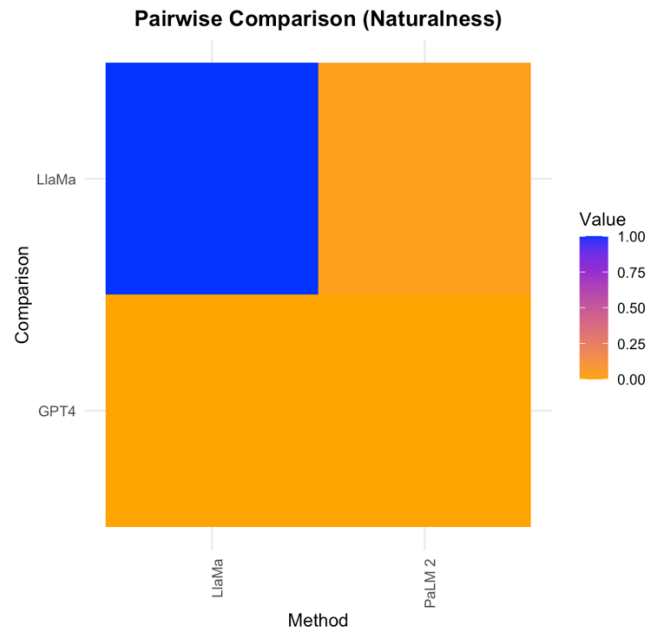


Figure 8. Comparison of naturalness shown across models

#### 4.4. Hallucinations

Models varied when analyzing the types of hallucinations shown. This study analyzed the types of hallucination prominent in each of the models. This study sought to have an insight into the cross-lingual understanding based on the amount and type of hallucinations shown by each of the models. Results are shown in Figure 9.

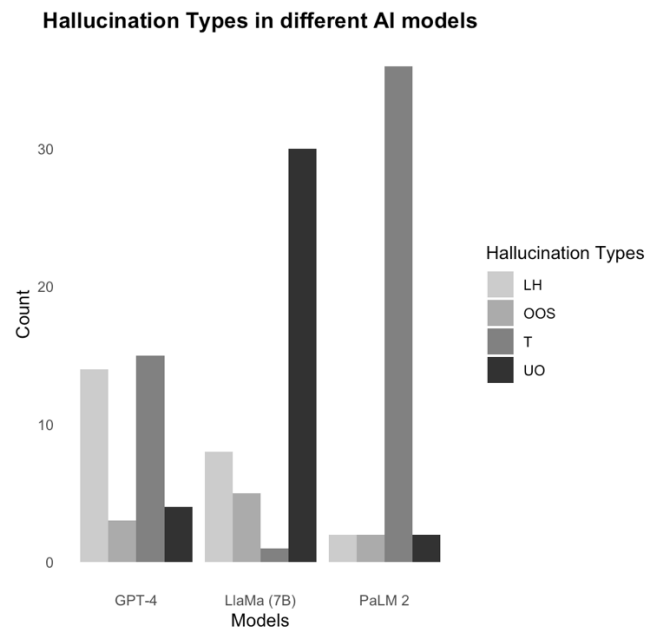


Figure 9. Types of hallucination by model. The study differentiates linguistic hallucination (LH), out-of-switch (OOS), translations (T), and unexpected output (UO). These are defined in Evaluation (3.2)

GPT-4 showed a tendency to produce hallucinations that mix the languages prompted (Basque and English) with others that keep a geographical and political relation (Spanish and French). It was observed that for prompts such as ‘Imitate the speaking style of a person who can speak English and Basque in one sentence about sports’, GPT-4 provided answers such as ‘*kirolak* (Basque) are really great for *gure osasuna* (Basque), and they help build *camaradería* (Spanish)’. Furthermore, it was observed that the model amplified some stereotypes through the Basque cuisine (e.g., excellent idea! *Sagardoa eta pintxos*), or that it mixed it with typical Spanish dishes (e.g., this *paella* is delicious, *oso gozoa da!*).

In GPT-4 linguistic hallucinations were also prominent. Many of them were vocabulary related, such as incorrect lexicon (e.g., *Gaurko eguraldia oso beroa da*, I think I will go for a *\*txotxongilo / izozki!*). Still, the most interesting linguistic hallucination was that GPT-4 generated odd syntactic constructions that merged Basque syntax and the English lexicon. Basque is characterized by having the determiner connected to the noun: the *-a* in *etxea* is equivalent to the English determiner *the*. GPT-4 generated instances such as *familya*, where it used the Basque determiner *-a* with the English word *family*.

LlaMa (7B) showed the highest number of hallucinations. Of those, unexpected outputs were the most significant. Most of the time, LlaMa was not capable of generating coherent responses that answered the prompts. When able to produce a switch, while the English text was correct, the part in Basque was rarely grammatical or coherent (e.g.,<sup>?</sup> *\*Euskara eta engelialan irektatu gaurken duzuko diren ondoren dira*. Language is a mixture of Spanish and<sup>?</sup> *\*Euskarian*.). This pointed out in the direction of a lack of sufficient training in low-resource languages such as Basque. It has to be said that LlaMa (7B) is a lightweight model; its lack of parameters could be one of the reasons to its poor performance.

PaLM 2 showed a tendency to produce switches that were direct translations of parts that were mentioned previously in the same sentence (e.g., *Hau da nire kirol gogokoena: eskubaloia*. This is my favorite sport: handball.). These cases were not considered code-switching in this study. Most of the translation hallucinations followed a similar scheme, where the translated part was between parenthesis or after a comma.

## 5. DISCUSSION

The evaluation of the Basque and English code-switching capabilities of GPT-4, LlaMa (7B), and PaLM 2 has shed light on the significant disparities among these models, particularly in terms of language-specific adaptations and their capability to generate answers in low-resourced languages. The experiments underline the broad-spectrum challenges of deploying large language models (LLMs) and the constraints that come into play, particularly in low-resourced languages and code-mixing scenarios.

The study shows that multilingual training does not necessarily lead to code-switching ability. The inability to create code-switched outputs of models such as PaLM 2 shows that, in many multilingual models, code-mixing is not recognized as an essential component. In fact, both PaLM 2 and LlaMa (7B) seem to misunderstand code-switching, interpreting it as simply a translation or random combination of two or more languages. Researchers must take code-mixing into account as an integral part of many linguistic repertoires around the world. By building LLMs that include code-mixing, NLP researchers can capture the dynamic elements of many languages more accurately while also helping to improve users’ understanding of cultural aspects embedded in dialogues. Through these considerations, new models will be able to provide a true multilingualism that goes beyond syntax and semantics.

A crucial theme that emerged during the analysis was the need for increased transparency in machine learning research. Specifically, this study emphasizes the need for a thorough and understandable disclosure of the methodologies used to train these models. A comprehensive knowledge of the learning strategies employed by these LLMs, including their dataset and hyperparameter details, would significantly aid researchers in discerning the reasons behind the performance disparities observed. This study shows that GPT-4 outperforms its direct opponent, PaLM 2, and the lightweight model, LLaMa (7B). However, in the absence of transparency, we cannot confidently identify why the models show these performances.

## 6. CONCLUSION

This study found that GPT-4 was the model that best reflected cross-lingual understanding. It was capable of combining two languages through natural code-mixing utterances, to the point of understanding the grammar of Basque. This was shown in the addition of the Basque determiner *-a* to the English word *family* (*family[a]*).

A salient observation drawn from this study was the unique positioning of GPT-4 in the realm of low-resourced text generation. GPT's adaptability to work with low-resourced languages, such as Basque, was distinctly superior to PaLM 2 and LLaMa (7B). It is hypothesized that this observation could be attributed to its built-in design or its training process. While PaLM 2 and LLaMa (7B) showed reasonable performances in data-rich languages like English, their performance dwindled in the context of Basque, emphasizing the intrinsic issues when it comes to generating low-resource language text.

Low-resource languages are still left behind in natural language processing (NLP). The difficulties of high-parameter models such as PaLM 2 reflect the lack of attention on LRLs. Research on how to improve low-resource data augmentation could bring significant benefits to LLMs to be deployed.

## 7. LIMITATIONS

### 7.1. Data Availability

This study provided the first Basque-English AI-generated code-switched dataset. This study showed statistical significance in the experiments performed. However, future studies focusing on Basque code-switching may benefit from increasing the data available.

### 7.2. Annotators

This study only used a single Basque native annotator, speaker of the neutral and Biscayan variants. No other candidate was proficient in the targeted low-resource language. Future studies may benefit from the annotation of several native speakers to further validate results.

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# THE EVOLUTION OF VANET NETWORKS: A REVIEW OF EMERGING TRENDS IN ARTIFICIAL INTELLIGENCE AND SOFTWARE-DEFINED NETWORKS

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## ABSTRACT

*The use of vehicular ad hoc networks (Vanet) has become increasingly important in today's world due to their ability to enhance driving safety and vehicular traffic efficiency. This article will discuss artificial intelligence techniques used in Vanet, including machine learning, deep learning, and swarm intelligence techniques. Furthermore, we will examine the routing challenges within Vanet, including issues like communication link disruptions, obstacles, and varying vehicle speeds. Lastly, we will explore the implementation of software-defined networks (SDN) in Vanet, encompassing SDN protocols and architectures.*

## KEYWORDS

*Vehicular communications, routing, artificial intelligence, software-defined networks & Vanet.*

## 1. INTRODUCTION

Vehicular ad hoc networks (Vanet) have become an emerging and promising technology to improve safety and efficiency in road transport. Vanet networks are based on wireless communication between vehicles and/or between vehicles and road infrastructure, enabling a wide range of applications such as accident prevention, traffic management, and route optimization as shown in Figure 1. However, the use of Vanet also poses significant technical challenges, such as communication link disruption, selection of message forwarding nodes, and vehicle speed, among others.

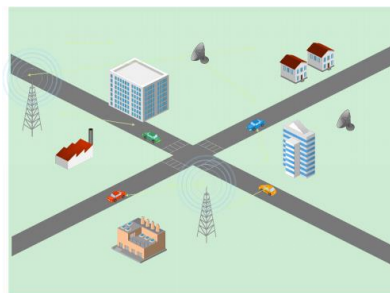


Figure 1. Vanet Network Source: Authors.

This article aims to provide an overview of the artificial intelligence techniques used in Vanet, including machine learning, deep learning, and swarm intelligence techniques. In addition, the challenges of routing in Vanet will be discussed and software-defined networks (SDN) will be presented as a solution to address these challenges. SDN protocols, SDN controllers, and SDN architectures will be described, analyzing the advantages and disadvantages of their application in Vanet.

For the preparation of this article, a systematic review of literature was conducted on various databases, including IEEE Explore, Science Direct, and Scopus. The following search equations were used: (Vanet OR "vehicular ad-hoc network") AND ("intelligent transportation systems" OR ITS) AND routing, Vanet AND ("artificial intelligence techniques" OR "AI techniques"), Vanet AND ("machine learning techniques" OR "ML techniques"), Vanet AND ("deep learning techniques" OR "DL techniques"), Vanet AND ("swarm intelligence techniques" OR "SI techniques") and Vanet AND ("Software-defined networking" OR "SDN") to identify relevant articles. Studies that met inclusion criteria, such as relevance to the research topic and quality of content, were carefully selected. From the literature review, the main technical challenges and proposed solutions in the field of Vanet were identified, with a particular focus on the application of artificial intelligence techniques and software-defined networks.

## **2. ROUTING IN VEHICULAR AD HOC NETWORKS (VANET)**

Routing is one of the challenges in Vanet, as vehicles move quickly and the network topology is constantly changing. The objective of routing is to send a message from the source to the destination through a suitable path in the network. However, in Vanet, messages can be interrupted due to lack of connectivity because of obstacles such as houses, buildings, or trees, or even due to the speed of vehicles. Furthermore, selecting the appropriate nodes to forward the messages is critical as some vehicles might have better connectivity than others.

Therefore, to address these routing challenges in Vanet, various routing techniques and protocols have been proposed. In [1], reliable routing protocols, like the improved genetic algorithm and lion optimization routing protocol, are suggested for selecting the best and optimal route. These routing protocols consider the movement and direction of vehicles, access points, and mobility, making them more efficient and reliable compared to traditional routing protocols. And in [2], traffic congestion is addressed and a cooperative and distributed information exchange mechanism is proposed to minimize communication redundancy and control the communication cost in Vanet. This method uses the travel time information measured by the vehicles and is sent through multi-hop communications to calculate the shortest routes. While in [3], the importance of security in the routing layer in IoT networks, including Vanet networks, is discussed. Different solutions for secure routing in IoT networks have been proposed, such as cryptography-based methods and trust-based mechanisms. Moreover, the reliability analysis of nodes is important to select reliable nodes for data transmission and deal with untrustworthy vehicles in Vanet.

Besides the aforementioned routing techniques and protocols, in [4], the challenges in disseminating warning messages in Vanet are specifically addressed. The authors propose a Traffic Warning Message Dissemination System (TWMDS) based on Vanet using a Reverse Routing Protocol (RRP). The RRP restricts the diffusion range of messages, specifies forwarding and receiving nodes, and reduces unnecessary communication overhead.

## 2.1. Communication Link Interruption

The communication link is a critical factor in Vanet, and its interruption can have a significant impact on the efficiency and safety of the network. The decentralized detection scheme proposed in [5] is an effective way to ensure the link quality, vehicle mobility, and behaviors, while the comprehensive resource in [6] thoroughly addresses security concerns in Vanet and offers practical solutions, such as authentication schemes and artificial intelligence techniques. In general, these studies are valuable resources to ensure the reliability and safety of Vanets.

The mentioned studies emphasize the importance of reliable communication in Vanet and propose solutions to address issues such as selfish nodes and malicious attacks.

## 2.2. Obstacles

The importance of reliable communication in vehicular networks and the potential problems arising from communication link interruption are addressed. Various studies presenting different solutions to improve network performance and minimize driving risks due to obstacles are included.

In [7], a collision prediction system for Vanet called QCP-SD is proposed, which uses a flexible Q-learning algorithm and aids in the dissemination of safety messages through the cloud. QCP-SD considers various factors to predict collision risk and is designed to predict vehicular accidents with high accuracy and disseminate safety messages timely to endangered drivers. On the other hand, in [8], the OPBRP routing protocol for Vanet is presented, which uses mobility prediction to avoid radio obstacles and enhance packet delivery reliability. The protocol employs predictive greedy forwarding and perimeter strategies to improve performance and reduce energy consumption. Simulation tests show that OPBRP outperforms other routing protocols in terms of PDR and E2E delay.

## 2.3. Message Forwarding Node Selection

In [9], a Q-learning and fuzzy logic-based hierarchical routing algorithm (QFHR) is presented that uses reinforcement learning techniques and fuzzy logic to find the most suitable route among different intersections in the network. This paper also presents a reinforcement learning-based routing protocol for clustered EV-Vanet. The results show that QFHR outperforms other approaches in terms of packet delivery rate, end-to-end delay, hop count, and routing overhead. While in [10], a multi-path route switching protocol for intelligent transportation systems is proposed that utilizes the Wiedemann car-following model. The protocol predicts future connectivity of multiple routes and dynamically switches between them based on the requested quality of service and the adopted switching criterion. The proposed LDD-based route switching protocol outperforms other criteria in ensuring packet delivery rate and average total end-to-end delay of packets. Moreover, this paper discusses the efficiency of position-based routing protocols for safety applications and the need for traffic prediction systems.

Both works present innovative solutions to improve the efficiency of vehicular ad hoc networks and intelligent transportation systems. They also provide a rigorous evaluation of their performance and discuss the strengths and weaknesses of related works in the field of fuzzy routing and multi-path route switching protocols.

## **2.4. Vehicle Speed**

In [11], an overview of research on reliable routing protocols for Vanet is provided, evaluating the performance of topology-based routing protocols in high-density dynamic systems of vehicles. Researchers conclude that DSR and AODV are the most efficient routing protocols for Vanet and suggest further research to ensure location privacy and explore other routing protocols with more performance metrics.

On the other hand, in [12], the Internet of Vehicles (IoV) is discussed and its potential to reduce traffic congestion and improve traffic flow through real-time communication between vehicles and other devices. The paper also highlights the importance of security and privacy in the IoV network and the potential use of artificial intelligence and machine learning.

In summary, these two papers offer an overview of reliable routing protocols for Vanet and of the IoV and their potential applications in the field of Vanets.

## **3. ARTIFICIAL INTELLIGENCE TECHNIQUES IN VANET: A MACHINE LEARNING, DEEP LEARNING, AND SWARM INTELLIGENCE APPROACH**

Vanets have sparked great interest in recent years due to their potential to improve traffic safety and the performance of communications between vehicles and between vehicles and infrastructures. However, due to the dynamic nature of Vanets, effective congestion control protocols are essential to ensure reliable and efficient data transmission.

In this context, one of the most promising techniques to improve the performance of congestion control protocols in Vanet is artificial intelligence. In [13], the Adaptive Congestion-aware Routing Protocol (ACARP) was introduced, which uses artificial intelligence to detect congestion and establish safe routes for data transmission. The work also presents an evaluation of the performance of ACARP in comparison to other congestion control protocols in Vanet. The results show that ACARP outperforms other protocols in terms of performance, Packet Delivery Ratio (PDR), and CO2 emissions reduction. Moreover, ACARP performs consistently under different mobility variations, making it an attractive option for implementation in Vanet. The evaluation results suggest that artificial intelligence could be a key ingredient in the future development of congestion control solutions in Vanet.

### **3.1. Machine Learning**

In [14], the authors propose a cloud-oriented model that uses machine learning algorithms for cooperative routing, secure data sharing, and traffic pattern analysis. The model aims to improve the reliability and safety of Intelligent Transport Systems (ITS) for the development of smart cities. Whereas in [15], a reinforcement learning-based protocol for routing in Vanet networks is presented. The protocol uses multi-agent reinforcement learning (MARL) to enable agents to solve routing optimization problems in a distributed way. The proposed protocol adapts to dynamic changes by applying a dynamic model (fuzzy system) and learning new events. In [16], the challenges and opportunities of using big data in Vanet networks are discussed. The paper presents a machine learning-assisted approach to efficiently support and process big data in Vanet under a security protocol using 5G technology. The paper also reviews existing routing protocols and proposes new routing information systems that employ machine learning technology to predict vehicle movements and select appropriate routing paths.

In [17], they provide an overview of several misbehavior detection schemes for Vanet. The schemes are classified based on different criteria such as architecture, approach, node-centric, and

data-centric. The paper describes various specific misbehavior detection schemes, including CAMDS, CA-DC-MDS, AECFV intrusion detection system, and MA-CIDS. On the other hand, in [18], they present ECRDP, an efficient clustering routing approach for Vanet that uses a new clustering algorithm based on Density Peaks Clustering (DPC) and Particle Swarm Optimization (PSO). The proposed scheme uses the advantages of both algorithms to group vehicles in an urban scenario. The paper also discusses the importance of group stability in Vanet and the use of machine learning for routing.

In [19], they discuss Vanet, their advantages and disadvantages, such as dynamic behavior, which requires an effective and efficient routing protocol to transmit data effectively. The paper proposes a hybrid detection method that uses machine learning and public safety techniques to enhance safety in transport systems. And in [20], they focus on using machine learning to predict the connection duration between two vehicles in a Vanet. Multiple features are proposed and different machine learning algorithms are examined to determine the best prediction method. The authors also discuss the implementation issues and challenges associated with implementing this type of system in Vanet.

In [21], they focus on the problem of detecting Sybil attacks in Vanet and examine various methods for doing so. A new method called SDTC is proposed that uses a movement matrix and an Extreme Learning Machine (ELM) to evaluate the mobility of actual vehicle nodes and detect Sybil nodes. The SDTC method aims to be fast, scalable, and low complexity while ensuring the security, integrity, and privacy of Vanet. And in [22], they cover various aspects of research in Intelligent Transportation Systems (ITS) and Vanet. It delves into Vanet applications, which can be categorized into road safety and traffic management. The paper emphasizes the importance of cellular Vehicle-to-Everything (C-V2X) technology and also proposes a new machine learning detector for RSU that can handle stealthy and brute-force DDoS attacks.

In [23], they focus on the use of machine learning in Vanet, particularly in its applicability to security and communication networks. A methodology for vehicular machine learning is presented, and various models and systematic techniques are reviewed. They also discuss a game theory-based approach for selecting the cluster leader and a stateless Vanet routing protocol called "geoSVR". In general, the paper explores the potential of machine learning and game theory to improve the social features, efficiency, and safety of transportation systems through Vanet. Whereas in [24], they focus on enhancing the efficiency and performance of Vanet through different approaches. One of these approaches is the use of a hybrid metaheuristic algorithm that incorporates machine learning techniques such as SVM, Naive Bayes, ANN, and Decision Tree to reduce latency. A comparative analysis between the HFSA-VANET and CRSM-VANET methods was carried out and it was found that the former achieved an 81% decrease in energy consumption, a 33% reduction in delay, and an 8% increase in throughput when using 80 nodes.

These papers present different techniques and machine learning approaches to enhance the performance, reliability, and safety of Vanet networks in the context of Intelligent Transportation Systems and smart cities.

### **3.2. Deep Learning**

In [25], they propose a novel system for detecting and mitigating attacks in vehicular ad-hoc networks using a weight-optimized deep neural network and an improved particle swarm optimization algorithm. The system extracts features related to traffic flow and vehicle position, detects attacks, and uses a mitigation process based on BAIT. The proposed system outperforms

existing techniques in terms of certain performance measures. The paper highlights the importance of road safety in Vanet communication and the decentralized nature of the network.

On the other hand, in [26], they describe a model for network traffic prediction that takes into account road traffic parameters. The proposed RF-GRU-NTP model combines machine learning and deep learning algorithms to predict network traffic flow considering road traffic parameters. The paper also provides an overview of recurrent neural networks (RNN) and their applications in deep learning. Additionally, the work compares different algorithms for predicting network and road traffic, and it was found that the RF algorithm was the best for both types of traffic prediction. As for [27], it proposes the use of a Q-learning deep learning approach and a centralized SDN control mechanism to address the negative influences of malicious nodes in Vanet. The proposed SD-TDQL framework improves data forwarding performance, link quality, and communication security of connected vehicles. A trust model is designed to assess neighbor behavior, and the expected transmission count (ETC) is used to characterize vehicle-to-vehicle communication link quality. Simulation results show that the proposed scheme significantly improves network performance. In [28], they discuss a hybrid relay selection technique that combines deep learning and reinforcement learning to improve diffusion in vehicular networks. The technique uses an artificial neural network to classify forwarding nodes and a Viterbi algorithm as a reinforcement tool to refine the classification. The proposed technique is tested using a grid map scenario with various traffic densities and compared with other parameter-based diffusion techniques. The results show that the proposed technique outperforms other techniques in terms of increasing success rate, saving retransmissions, and other parameters.

In [29], they present a deep learning technique based on convolutional neural networks (CNN) for the detection and recognition of pedestrians in urban environments using LiDAR sensors and RGB cameras. The proposed technique aims to detect and classify pedestrians in real-time in complex urban environments. The proposed neural network model uses a cascade structure to extract spatial and temporal features from the input data. The model is trained and evaluated using a dataset of pedestrians collected in a real urban environment. The results show that the proposed technique surpasses other deep learning methods in terms of detection accuracy and speed. And in [30], they present a deep learning technique based on convolutional neural networks (CNN) for traffic sign recognition using images from vehicle-mounted cameras. The proposed technique aims to detect and recognize traffic signs in real-time, which can be useful for driver assistance systems and autonomous vehicles. The proposed neural network model uses a cascade structure to extract spatial and temporal features from the input data. The model is trained and evaluated using a traffic sign dataset collected in a real urban environment. The results show that the proposed technique outperforms other deep learning methods in terms of traffic sign recognition accuracy and speed.

### 3.3. Swarm Intelligence

In [31], they present a collaborative communication scheme that uses drones to assist in vehicular ad-hoc networks. The problem is modeled as a multi-modal optimization problem, and a swarm-based optimization algorithm called Multimodal Nomad Algorithm is presented. The proposed scheme was compared with similar counterparts and demonstrated to outperform its competitors in terms of the number of hops, packet delivery ratio, and performance. The work highlights the importance of considering available UAVs when optimizing the location of drones. Whereas in [32], they propose an approach to maximize coverage in vehicular communication networks using Internet of Drones (IoD) nodes based on the locations of ground vehicles. An enhanced version of Particle Swarm Optimization (PSO) is used to optimize the deployment of IoD nodes. This approach is compared with two other schemes: one without IoD and another with a fixed IoD deployment. Simulation results show that the proposed approach achieves better coverage

and signal quality, and is able to adapt to vehicle movements. This work concludes by highlighting the importance of considering available UAVs when optimizing the location of drones. And in [33], they discuss various routing protocols for vehicular ad-hoc networks and propose a routing protocol based on hybrid genetic and firefly algorithms (HGFA) to overcome the limitations of these protocols in different traffic scenarios for vehicular ad-hoc networks. The proposed system model integrates genetic features with the firefly algorithm to optimize routing in vehicle-to-vehicle communication networks.

On the other hand, in [34] they propose a protocol called PSStreaming that addresses three challenging problems in video streaming in vehicular ad-hoc networks: load balancing, short-term mobility prediction, and efficient data caching. The protocol uses a particle swarm optimization algorithm to solve the load balancing problem, formulates short-term mobility predictions to react to vehicle mobility immediately, and performs efficient caching to store video data content on the calculated route until communication is completed. In [35], they describe a new clustering algorithm, called CAMONET, for vehicular ad-hoc networks. The algorithm uses the Moth and Flame Optimization (MFO) to generate optimized clusters for efficient transmission. The results of the experiments show that CAMONET provides results close to optimal, making it an efficient method for vehicular clustering. And in [36], it focuses on the challenge of ensuring safety in vehicular ad-hoc networks. Vehicular ad-hoc networks are used to improve safety and communication between vehicles, but they also face security threats due to the wireless and open nature of the network. The article discusses several common attacks in vehicular ad-hoc networks, such as denial of service (DoS), location spoofing, and message flooding attacks. Then, an overview of the proposed security schemes is presented and the limitations of each are highlighted.

#### **4. SOFTWARE-DEFINED NETWORKING (SDN) IN VEHICULAR AD-HOC NETWORKS: PROTOCOLS AND ARCHITECTURES**

Software-Defined Networking (SDN) technology has emerged as a promising solution to improve efficiency and security in vehicular ad-hoc networks. SDN separates the control plane from the data plane and allows a centralized controller to manage the network based on global information. In recent years, several SDN protocols and architectures have been proposed for vehicular ad-hoc networks that address issues such as security, reliability, and communication efficiency.

In [37], they propose a routing protocol based on MGM (Modified Gossiping Mesh) that applies network coding to entertainment and confidential messages to improve reliability and security. Additionally, a secure and reliable data broadcasting framework based on NC-enabled SDN is presented. In [38], they talk about how the use of blockchain and SDN in Intelligent Transportation Systems (ITS) can improve the vehicular ad-hoc network. A trust-based model is presented to limit malicious activities and ensure efficient network performance. In [39], they address the vulnerability of vehicular ad-hoc networks to cyber-attacks and propose a collaborative Intrusion Detection System (IDS) based on SDN and deep learning. Whereas in [40], they discuss an Adaptive Link State Perception (ALPS) scheme for software-defined vehicular ad-hoc networks. And in [41], they worked on the integration of blockchain and SDN in Intelligent Transportation Systems appears to be an interesting solution to ensure trust and improve the performance of vehicular networks. The simulation performed shows promising results in terms of efficiency and security in the network while in [42], they propose the safe routing protocol SURFER based on SDN and blockchain appears to be an innovative and effective solution for the Internet of Vehicles. The results of the simulations indicate that

SURFER outperformed other routing protocols in terms of latency, packet delivery, and network overhead, which is a great advancement for network management in this area.

#### 4.1. Sdn Architectures

The presented papers address different aspects of SDN architectures for vehicular ad-hoc networks. In [43], they focus on detecting DDoS attacks in vehicular ad-hoc networks, proposing a detection model that uses SVM with an optimized RBF-SVM kernel. In [44], they propose a Q deep learning framework to improve the performance of data forwarding, link quality, and communication security of connected vehicles in vehicular ad-hoc networks. In [45], they address the concept of network "slicing" in the 5G architecture, which allows network operators to create multiple virtual networks for different types of services with different requirements. In [46], they propose a fog computing-enabled architecture for efficient data broadcasting in heterogeneous software-defined vehicular ad-hoc networks. While in [47], they present an adaptive data emission interval proposed for data broadcasting in Vehicle-to-Infrastructure (V2I) environments using Software-Defined Networking (SDN) architecture. And in [48], they propose an architecture called SEARCH for vehicle route planning in urban areas with high traffic congestion. The architecture uses technologies such as UAV, vehicular ad-hoc networks, 5G cellular systems, and SDN to collect real-time traffic information and plan faster routes. Simulations showed that the architecture is effective in saving driving time.

### 5. CONCLUSIONS

The systematic literature review conducted in this paper provides a deep understanding of recent advancements in Vanet and highlights the importance of ongoing research in this field to confront emerging challenges and harness the opportunities offered by new technologies. The application of artificial intelligence techniques in Vanet, such as machine learning, deep learning, and swarm intelligence, offer promising solutions to address the challenges of routing in Vanet networks, thus enhancing their efficiency and security. Whereas the use of SDN in Vanet also presents great potential to overcome technical obstacles, such as traffic management and communication link disruption, by implementing SDN protocols and SDN architectures.

Routing in Vanet is a challenge due to the dynamic nature of the network and the possibility of connectivity disruption due to obstacles and vehicle speed. To address these challenges, various routing techniques and protocols have been proposed, such as reliable routing protocols, the distributed and cooperative information exchange mechanism, and cryptography and trust-based methods. Moreover, artificial intelligence has shown to be a promising technique for improving the performance of congestion control protocols in Vanet. Together, these advancements suggest that continued research in this field can lead to even more effective solutions for routing and congestion control in Vanet.

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# AN EMPOWERING MOBILE AID APPLICATION TO HELP VISUALLY IMPAIRED PEOPLE NAVIGATE AND EXPLORE PLACES AROUND THEM USING LOCATION TRACKING AND TEXT DETECTION

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## **ABSTRACT**

*In Section 1, we provide a comprehensive overview of the research findings concerning the challenges encountered by visually impaired individuals, which significantly impact their daily lives, and discussing potential solutions to address their needs. Section 2 delves into the obstacles we encountered during the development of our application, along with the strategies we implemented to overcome them. In Section 3, the functionality of our application is outlined, focusing on how it addresses the issues highlighted in Section 1. This section also details the specific systems within our app, including the sources and packages utilized in their development. Section 4 presents an in-depth analysis of potential blind spots in our application, supported by data and graphical interpretations. This section also discusses the precision and accuracy of our findings. Section 5 involves a comparative study of alternative solutions that address similar problems as our application, highlighting the distinct features and advantages of our approach. Finally, Section 6 summarizes the limitations of our current application and outlines planned enhancements to address these shortcomings in future updates, thereby improving the app's overall effectiveness.*

## **KEYWORDS**

*Blindness, Firebase, iOS, Android*

## **1. INTRODUCTION**

We aim to address the challenges visually impaired individuals face in daily life, including mental health, communication, navigation, and reading, to enhance their integration into various environments and connection with the broader world. The prevalence of blindness is escalating, surpassing the previous year's rates. In 1990, the global blind population stood at 31 million, with projections estimating a significant increase to 115 million by 2050. Notably, three Asian regions, comprising 51% of the global population, account for 62% of the worldwide blindness population [2]. Beyond the escalating numbers, the mental health issues affecting the visually impaired have not seen improvement. Individuals grappling with visual impairment commonly experience mental health challenges, including depression, nervousness, anxiety, stress, and, in some instances, even suicidal thoughts [4]. Research indicates that nearly one-third of the blind

exhibit mild depressive symptoms, while 10.7% to 45.2% report moderate-to-severe depressive symptoms [5]. These challenges intensify during social interactions, as blind individuals contend with anxiety arising from difficulties in perceiving nonverbal cues, adapting to unfamiliar environments, and self-consciousness about their visual impairment. Concerns about societal perceptions, negative reactions, and judgment contribute to heightened stress, severe anxiety, and, in extreme cases, suicidal tendencies. Living with blindness extends beyond visual impairment, encompassing unjust limitations in social and travel opportunities [6]. Communication hurdles arise from the inability to visualize conversations and interpret verbal cues relying on sight, leading to misinterpretations, heightened self-awareness, and social isolation. Moreover, barriers to safe navigation emerge due to inadequate accessibility features such as poorly placed signage, lack of wayfinding information, and absence of audio guidance [7]. Blind individuals face unjust obstacles impeding their autonomy, potentially exposing them to hazards. The impact is especially profound on those born blind, including children, young adult women, and older individuals. Young children, deprived of firsthand visual experiences, face challenges navigating the world independently. Those losing their sight soon after birth lack visual memories, potentially affecting their mental health. Young adults with vision loss are particularly vulnerable, lacking the experience and independence of older adults who have adapted to vision impairment [8]. Vision loss fundamentally influences behavior, introducing uncertainties about trust and relationships when visual cues are absent [9]. In conclusion, younger and less experienced visually impaired individuals face greater risks in traveling and navigating compared to others. Given that they cannot always rely on guidance from others, it is crucial to provide them with access to technology specifically designed to aid in overcoming these challenges, thereby enhancing their independence and safety.

One of the three solutions is to guide the visually impaired person to move around. This solution is to try to make it easier for visually impaired individuals to navigate around by telling them the amount of steps to reach the destination by voice message. This solution's shortcoming is that it can't tell the user whether there is an obstacle in front or not. Our applications can identify the obstacle that is in front of them and tell them what it is. Also can tell them they're surrounded by the environment. The second solution is to help blind people to navigate in indoor or outdoor scenarios. This solution is also trying to accomplish making the blind people travel around better by telling them if there is an obstacle detected or not by audio. The shortcoming of this solution is that it can't tell the environment around the user. Our application is combined with GPS with AI-powered scanning to make the user safely navigate around. The last solution is to provide location-specific audio insights. This solution is trying to accomplish auditory descriptions about the user's immediate environment. The shortcoming of this solution is that it can't help the scan texts. While our app can identify texts, signs, and menus and read aloud it to the user.

We are proposing an application designed for the visually impaired, enabling them to scan texts like menus, posters, and signs using the camera, and it also features GPS location and navigation functionalities. Our solution enables blind individuals to explore places by setting specific distance parameters and audibly present information about the place the user likes. Organized by distance range and then by categories such as stores, restaurants, hospitals, churches, and more. The GPS location/navigation helps blind individuals understand the places available to them. App reads aloud information about a location, including opening hours, popular dishes, distance, prices, and more. This would be a more holistic solution than other methods as it combines GPS with AI-powered scanning to provide both distant location awareness and immediate environment understanding for the blind. AI scanning can help blind people scan objects in front of them, such as poles, people, objects, etc. It will help them navigate better. AI scanning can also define objects such as plants, buttons on remote controls, lamps, and various objects in people's homes, restaurants, and shopping malls. As we developed the app, we continued to refine its features, putting ourselves in the shoes of a blind person: "What would we

need if we were them?" This empathy-driven approach led us to introduce real-time scanning to prevent accidents. We are continually working to improve the app to ensure maximum convenience and usefulness for blind users. " So we made a plan. While blind people navigate, they can use the scan feature to tell them what's ahead so they don't trip over it. In this way, we continue to transform the application into an application that is more convenient for blind people to use.

In Section 4, our focus revolves around rigorously testing the connectivity between the server, data sources, and our application, specifically within predefined distance ranges to ensure optimal performance. Experiment A is designed to assess the accuracy of data reception and transmission between our app and the server. Given the potential challenges arising from the use of two different sources, variations in connection quality are anticipated. To conduct Experiment A, we initiate our simulator, set a close distance range, and patiently observe as shops for each category emerge. Subsequently, we meticulously verify if all the anticipated shops are accurately displayed. The noteworthy outcome of Experiment A underscores its reliability, with an impressive 90% accuracy out of 100%. In Experiment B, our objective is to ascertain whether all the shops within the user-set distance range are appropriately displayed. To facilitate a comprehensive examination, we initiate this experiment with a short distance range, making it more manageable for testing purposes. We systematically inspect the displayed results to identify any discrepancies, ensuring that only relevant shops are showcased. The salient finding from Experiment B is the absence of inaccuracies in the displayed information within the specified distance range, reaffirming the precision and reliability of our application. These meticulous experiments not only validate the robustness of our server connections but also affirm the accuracy of information retrieval and display within designated distance parameters, ensuring the seamless functionality of our application.

## **2. CHALLENGES**

In order to build the project, a few challenges have been identified as follows.

### **2.1. Gathering Information**

Our primary challenge lies in accurately and reliably collecting data from various locations around the user. The accuracy of the data and the reliability of its source could lead to potential issues that require our attention. For example, if users are in an area where our information is not accessible, then our app may become ineffective for them because it relies heavily on location-specific data. For the accuracy of the data we could solve it by using the information from Google and Yelp, that provides a large amount of precise information, which can greatly enhance our dataset.

### **2.2. Scanning Feature**

Our second major challenge involves enhancing the scanning feature of our application, which is crucial for text recognition and interpretation. This feature is vital for assisting blind users, acting as a 'second eye' by converting visual information into a format they can understand. Without the ability to read aloud the text captured by the camera, the feature would be ineffective. To resolve this issue, we could use a Flutter package called "google mlkit text recognition". This package could help interpret whatever text and signs the user takes a picture of.

### **2.3. Identify a Wide Range of Objects**

The third challenge we are addressing revolves around enhancing the camera's capabilities to identify a diverse array of objects. By seamlessly integrating cutting-edge computer vision and machine learning technologies, our aim is to empower the camera with real-time recognition capabilities for a wide spectrum of common objects. This task presents significant complexity due to the imperative of achieving high accuracy levels, set at a minimum threshold of 30%. Challenges are further compounded by variations in environmental conditions and the need for extensive and unbiased training datasets. In our pursuit of resolving this intricate challenge, we are exploring the utilization of a Flutter PyTorch package. This package serves as a powerful tool for running model classifications, enhancing the camera's ability to discern and categorize a multitude of distinct objects. Additionally, we are implementing object model detection, incorporating bounding box prediction methodologies. This multi-faceted approach is poised to not only elevate the accuracy of object recognition but also enhance the adaptability of the system to diverse and dynamic real-world scenarios. In essence, our strategy involves leveraging state-of-the-art technologies within the Flutter PyTorch package, coupled with innovative object model detection techniques, to navigate the intricacies of achieving accurate and real-time identification of a broad spectrum of objects under varying conditions.

## **3. METHOD ANALYSIS**

The application is intricately structured around three key components: a robust text recognition system, an intuitive explore nearby destinations system, and an efficient object recognition system. Upon launching the application and navigating to the home screen, users are presented with two distinctive options: "Scanning Feature" and "Context Screen." Within the "Context Screen," users encounter a sophisticated distance range system complemented by diverse categories such as restaurants, shops, hospitals, churches, banks, and more. Utilizing the 'speech to text' and 'text to speech' Flutter packages, the application facilitates seamless voice interaction. The 'text to speech' package enables the app to audibly convey information to users.

To personalize their experience, users can express preferences through a long press on the home page, leading them to the context screen where they can dynamically adjust their preferred distance range. Google API then populates places based on the specified range, providing users with basic information about each destination, which is read aloud. Users have the option to delve deeper into details about a particular place by responding affirmatively with a simple 'yes.' The home screen also features a distinctive "Scanning Feature" that encompasses both text and object recognition capabilities. The text scanner leverages Google's MLKit Text Recognition, swiftly interpreting scanned content. Simultaneously, object recognition employs Flutter's Py Torch for model classifications, identifying a myriad of objects in the user's surroundings. The application efficiently harnesses Flutter's 'camera package' to access the camera, capturing desired text or objects with precision. This comprehensive design ensures a user-friendly experience, offering advanced functionalities in both voice-enabled exploration of nearby destinations and the versatile scanning feature for text and object recognition.



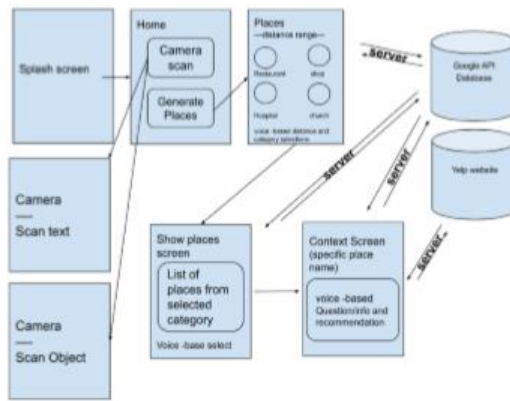


Figure 1. Overview of the solution

One of the central components in this application is the location generation system. Within the app, users define a distance parameter, prompting our server to source location data from both 'Google API' and 'Yelp' within the specified range. This system operates through a Python Flask server interfacing with the 'Google API' and 'Yelp', facilitating data requests and processing the returned results."



Figure 2. Screenshot of the project 1

```

100  func processSpeech() {
101  msg.Printf("Received %s\n", speech);
102  if (s.empty()) {
103      msg.Printf("Did you select %s, %s? Please respond yes or no!",
104              speech, name);
105      return;
106  }
107  // Get the user's choice
108  if (speech.find("more") != "") {
109      // User wants to know more information
110      // Call the getMoreInfo function
111      getMoreInfo();
112  } else if (speech.find("no") != "") {
113      // User does not want more information
114      // Call the getExtraInfo function
115      getExtraInfo();
116  }
117  }
118  }

```

```

119  Future<void> getMoreInfo() async {
120  http
121  .POST
122  // CHANGI LINK!!!!
123  .url("http://localhost:8080/stock?api_key=${apiKey}&place=${place}&size=${size}")
124  .then((response) {
125      if (response.statusCode == 200) {
126          Map<String, dynamic> result = json.decode(response.body);
127          print(result);
128          String text = "";
129          getStats();
130          infoMap.addAll(result);
131      }
132      result.forEach((key, value) {
133          if (key != "name") {
134              text += " $key: ";
135              text += value;
136          }
137      });
138      text += "\n Do you want to know more information, respond yes or no.";
139      info += text;
140      tts.speak(text);
141  });
142  }

```

```

143  Future<void> getExtraInfo() async {
144  Map data = {
145      "place_name": infoMap["name"],
146      "place_address": infoMap["address"]
147  };
148  http
149  .POST
150  // CHANGI LINK!!!!
151  .url("http://localhost:8080/stock?api_key=${apiKey}&place=${place}&size=${size}")
152  .headers: <String, String>{
153      "Content-Type": "application/json; charset=UTF-8",
154  },
155  .body: json.encode(data),
156  .then((response) {
157      if (response.statusCode == 200) {
158          Map<String, dynamic> result = json.decode(response.body);
159          print(result);
160          String text = "";
161          getStats();
162          infoMap.addAll(result);
163      }
164      result.forEach((key, value) {
165          text += " $key: ";
166          text += value;
167      });
168      info += text;
169      tts.speak(text);
170  });
171  }

```

Figure 3. Screenshot of code 1

To ensure users receive comprehensive information based on their selections, we employ a tiered process. Initially, we deploy a process speech, acting as an intuitive touchpoint to authenticate and affirm users' decisions. The decision that like 'do you want to know more information'. Once their choices are acknowledged, and the user showcases curiosity for further details, we seamlessly activate the get More Info function. This particular function by communicating with our dedicated Python server, which subsequently extracts data from Google API. Desire even more in-depth details following that, we've provisioned the get Extra Info function. Upon invocation, this function sends specific queries to our server, which dives deep into Yelp's vast database to extract data. This ensures that users are presented with a rich tapestry of detailed information, catering to their varied and evolving requirements.

Another component that we established is “The Text Recognition System”. This system allows the users to scan text on menus, signs, books, etc. In order to make this system, we used “google mlkit text recognition” This package could help interpret whatever text, signs, and books the user takes pictures of.



Figure 4. Screenshot of project 2

```
Future<void> _scanImage() async {
  if (_cameraController == null) return;

  final navigator = Navigator.of(context);

  try {
    final pictureFile = await _cameraController.takePicture();

    final file = File(pictureFile.path);

    final inputImage = InputImage.fromFile(file);
    final recognizedText = await textRecognizer.processImage(inputImage);

    await navigator.push(
      MaterialPageRoute(
        builder: (BuildContext context) =>
          ResultScreen(text: recognizedText.text),
      ), // MaterialPageRoute
    );
  } catch (e) {
    ScaffoldMessenger.of(context).showSnackBar(
      SnackBar(
        content: Text('An error occurred when scanning text'),
      ), // SnackBar
    );
  }
}
```

Figure 5. Screenshot of code 2

The code sample shows that we have used many different functions, packages and files. We used the processImage() function from google mlkit text recognition package to process the captured text in the image. The Text Recognition System runs when the user taps on the bottom of the screen to capture a picture of the text. The screen will have instructions on how to use the text recognition system, for example, double tap on the bottom to go back to home. All of the introduction will be audio and text. The system will try to capture, process, and generate text results based on the image taken, but if it fails, it will pop up an error message: “An error occurred when scanning text”. After the user takes the picture, the system will take time to load first, then it will pop up a result screen (which contains the audio read aloud and text display). The third component that we established is “The Object Recognition System”. This system allows us to define objects with the camera feature. We are using flutter pytorch to run model classification. And have an object model detection that uses bounding box prediction. These things allow our camera object-defined feature to work properly.



Figure 6. Screenshot of project 3

```
//load your model
Future loadModel() async {
  String pathObjectDetectionModel = "assets/models/yolov5_tiny.onnx";
  try {
    _objectModel = await FlutterPytorch.loadObjectDetectionModel(
      pathObjectDetectionModel, 80, 640, 640,
      labelPath: "assets/labels/labels_objectDetection_Coco.txt");
  } catch (e) {
    if (e is PlatformException) {
      print("only supported for android, Error is $e");
    } else {
      print("Error is $e");
    }
  }
}
}
```

```
if (_objectModel != null) {
  List<ResultObjectDetection> objDetect = await _objectModel!
    .getImagePredictionFromBytesList(
      cameraImage.pixels.map((e) => e.bytes).toList(),
      cameraImage.width,
      cameraImage.height,
      minimumScore: 0.3,
      IOUthreshold: 0.3);

  print("data returned $objDetect");
  widget.resultsCallback(objDetect);
}
}
```

```
void resultsCallback(List<ResultObjectDetection?> results) {
  setState(() {
    this.results = results;
    Set objects = {};
    results.forEach((element) {
      print(element!.className);
      objects.add(element!.className);
      print({
        "rect": {
          "left": element?.rect.left,
          "top": element?.rect.top,
          "width": element?.rect.width,
          "height": element?.rect.height,
          "right": element?.rect.right,
          "bottom": element?.rect.bottom,
        },
      });
    });
    t2s.speak(objects.toString());
  });
}
```

Figure 7. Screenshot of code 3

In the first code sample, the camera's ability to recognize the model proves, using the YOLOv5 model. The YOLOv5 model is mostly used for creating the pre-trained model. Our application will attempt to load the pre-trained model. However, if this process was unsuccessful, it will promptly issue a detailed error message to alert the user. An IOS phone user will receive "only supported for android, Error is (the error)", an Android phone user will receive "Error is (the error)". For object labeling we use the "labels\_objectDetection\_Coco.txt" file located in the Labels folder. The second code sample is calculating the prediction of the object accuracy. Our application requires a minimum accuracy of 30% to reliably recognize an object. The third code sample receives data from calculator prediction, and visually shows by drawing boxes around the object that are detected. Additionally, the objects are then being organized into a set to notify the users about the identified items.

## 4. EXPERIMENT

### 4.1. Experiment 1

A blind spot in our program that we want to test out is the "Context Screen" that displays specific information about a place. It is important that this part of our program works well because this page is getting information from two places: Google API Database and Yelp Website. The accuracy of various aspects, including address, name, popular dishes, and opening hours, is paramount. We need the information all to match each other so the information about each location will be precise and accurate.

We will do the following steps to test our information accuracy. First, we are going to tap on the bottom portion of our app, then set up the distance limit. Next, choose a random category. After choosing the category, the system will say the amount of category is available within that range. Finally, after choosing a pacific location/place, the information about that place will pop up. If we want all of the information then we will say "yes" and all of the facts will pop up. (Because at first the app will only show the basic information.) After all of the data pops up then we can check our data with the data on Google API and Yelp website. The experiment is set up this way because setting up like this we can easily figure out the difference/errors between our app's data and their data.

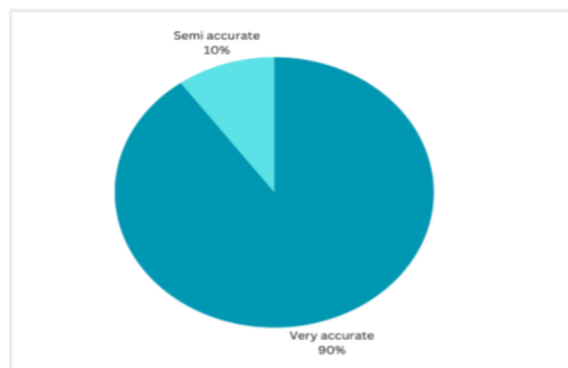


Figure 8. Figure of experiment 1

Our data accuracy ranges from a minimum of 10% to a maximum high of 90%. The reason why 90% is very accurate, because we are receiving data from google API and yelp website. They are both highly dependable platforms in the digital landscape. So, it stands the reason that the quality of data we receive from these trusted sources would be reliable, and as a result there will be less

chance of errors or unreliable data. And the reason why 10% is semi accurate is because the app may not always retrieve the information, this can be attributed to either occasional server disconnection with the app or with Google API and the Yelp website. We are confident in the data that we collected, because we understand how the server operates: it will either get accurate information from the database or return nothing at all. It is reliant on established sources like Google API and Yelp and unexpected data is going to be highly unlikely.

## 4.2. Experiment 2

Another blind spot that we want to test out is the distance limit. Because we want the blind people to know how far they need to travel to reach their destination by walking or driving. The distance limit is important to our app because the maximum range needs to be set in order for places to generate and be read aloud for the user to choose from.

First, we will set a distance limit, then we will choose a category such as a restaurant, shop, hospital, or church. Next, check if there are any places in the results that are farther than the maximum range. Finally, we are going to check if there are any places that didn't pop up or aren't mentioned within the area when the app is reciting the information. We will also check if there are any other categories showing up that are not related to the category that we have chosen – for example, if we choose a shop, then restaurant, church, and hospital shouldn't be showing up. We did the experiment like this because we want to make sure when the blind people are using it, it won't have any false or missing information.

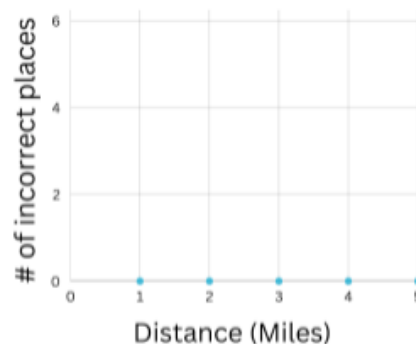


Figure 9. Figure of experiment 2

In this graph it doesn't have a minimum and maximum range. Because when we test the distance range it has an accuracy of 100%, no matter how far the distance is. For this system we also use the help of Google API, it helps us eliminate the shops that are out of the range. Google API is a very reliable source, we depend on it for this distance range system and the system that allows users explore places nearby.

## 5. RELATED WORK

The Lazarillo App, created by Luiz Fernando, is a georeferencing application that guides the visually impaired person to move around [10]. It automatically maps the routes traveled by the user and creates a graphical representation that can be used later. It provides guidance on the direction and the amount of remaining steps to reach the destination through voice messages [11]. The Lazarillo App by Luiz Fernando focuses more on navigation. While we provide users with an understanding of distant locales alongside an acute awareness of their immediate environment. By juxtaposing both, our innovative approach aims to furnish a comprehensive

navigational experience for the blind community.

Daniel Vera researchers propose a system based on this technology that helps blind people to navigate in indoors or outdoors scenarios. The prototype is portable assuring that can be used anytime and anywhere. The system is composed of wireless sensors that can be used in different parts of the body. The sensors detect an obstacle and inform the user with an audible warning providing a safety walk to the users [12]. As Daniel Vera's system is intended to be used for obstacle detection and safe navigation, while our method is more holistic, it combines GPS with AI-powered scanning to provide both distant location awareness and immediate environment understanding for the blind.

BlindSquare, crafted by Ilkka Pirttimaa, through the utilization of advanced GPS and map data, it efficiently delivers auditory descriptions about the user's immediate environment, it also can be paired with other navigation apps for turn-by-turn directions, BlindSquare's primary focus is to provide situational awareness. BlindSquare aims to enhance situational awareness, while its primary function is providing location-specific audio insights [13]. Our proposed application takes a more holistic approach. It seamlessly combines GPS navigation with cutting-edge AI scanning capabilities. This fusion not only aids in general navigation but also offers users a deep understanding of their immediate surroundings, bridging the gap between mere location information and comprehensive environmental awareness.

## 6. CONCLUSIONS

The core objective of this application is to empower visually impaired individuals by providing them with a tool to enhance their daily navigation and interaction with their surroundings. Despite the promising strides the app has made, it is evident that ongoing research and development efforts are imperative to elevate its performance across various intricate systems, specifically the text recognition, object recognition, and explore nearby destination functionalities. In the domain of text recognition, there is a clear need for heightened accuracy to precisely identify texts, ensure their correct sequencing, and seamlessly read them aloud for the user. The object recognition system, driven by artificial intelligence, requires enhancements to accurately identify objects and determine their proximity to the user. Simultaneously, the explore nearby destination system necessitates improvements in our app's server, fostering a more robust connection for efficient information transfer from sources like Google API and Yelp Website to the server and subsequently to our app [14]. One noteworthy limitation we currently face is in the realm of AI navigation, where further advancements are yet to be realized. Acknowledging this limitation is a crucial step toward transparency and sets the stage for potential future developments in this area. To address these challenges and propel the application forward, we are considering enhancements to the YOLOv5 model. This model, instrumental in creating a pre-trained model for our object recognition system, holds the potential for further refinement. Additionally, improvements in AI capabilities are on the horizon, aiming to enhance the accuracy of object calculations [15]. In summary, while the application has demonstrated notable progress, the commitment to continuous research and development remains paramount. The identified areas for improvement, encompassing text and object recognition, server connectivity, and AI navigation, underscore our dedication to providing a robust and effective tool for the visually impaired community.

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# ADVANCING WEB ACCESSIBILITY: A GUIDE TO TRANSITIONING DESIGN SYSTEMS FROM WCAG 2.0 TO WCAG 2.1

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## **ABSTRACT**

*This research focuses on the critical process of upgrading a Design System from Web Content Accessibility Guidelines (WCAG) 2.0 to WCAG 2.1, which is an essential step in enhancing web accessibility. It emphasizes the importance of staying up to date on increasing accessibility requirements, as well as the critical function of Design Systems in supporting inclusion in digital environments.*

*The article lays out a complete strategy for meeting WCAG 2.1 compliance. Assessment, strategic planning, implementation, and testing are all part of this strategy. The need for collaboration and user involvement is emphasized as critical strategies and best practices for a successful migration journey.*

*In addition, the article digs into migration barriers and discusses significant lessons acquired, offering a realistic view of the intricacies of this transforming road. Finally, it is a practical guide and a necessary resource for organizations committed to accessible and user-centered design. The document provides them with the knowledge and resources they need to navigate the changing world of web accessibility properly.*

## **KEYWORDS**

*Web accessibility, WCAG 2.0, WCAG 2.1, Design Systems, Web accessibility tools*

## **1. INTRODUCTION**

The WCAG (Web Content Accessibility Guidelines), established by the Web Accessibility Initiative (WAI) group under World Wide Web Consortium (W3C), serves as a globally recognized collection of guidelines and principles designed to make web content accessible to those with disabilities. This set of guidelines provides a structured approach to enhance the inclusivity and usability of digital content, including websites and web applications, for individuals with various disabilities, including visual, auditory, motor, and cognitive challenges. Web accessibility standards have become essential to government website compliance because they accord with equitable access, inclusion, and government agencies' legal responsibility to serve all residents [1], [2]. WCAG 2.1 significantly improves web accessibility requirements, expanding on the foundation established by WCAG 2.0. A critical component of the new criteria is that they address the changing landscape of digital interactions, with a particular emphasis on mobile accessibility. In today's world, when mobile devices are omnipresent, WCAG 2.1 recognizes this trend and provides criteria explicitly geared toward mobile platforms [3]. A significant success requirement, for example, is ensuring that all functionality can be accessed via

touch gestures recognizing the widespread use of touchscreens on smartphones and tablets. This is especially important in situations where individuals with motor disabilities rely primarily on touch-based interactions to navigate and interact with digital material.

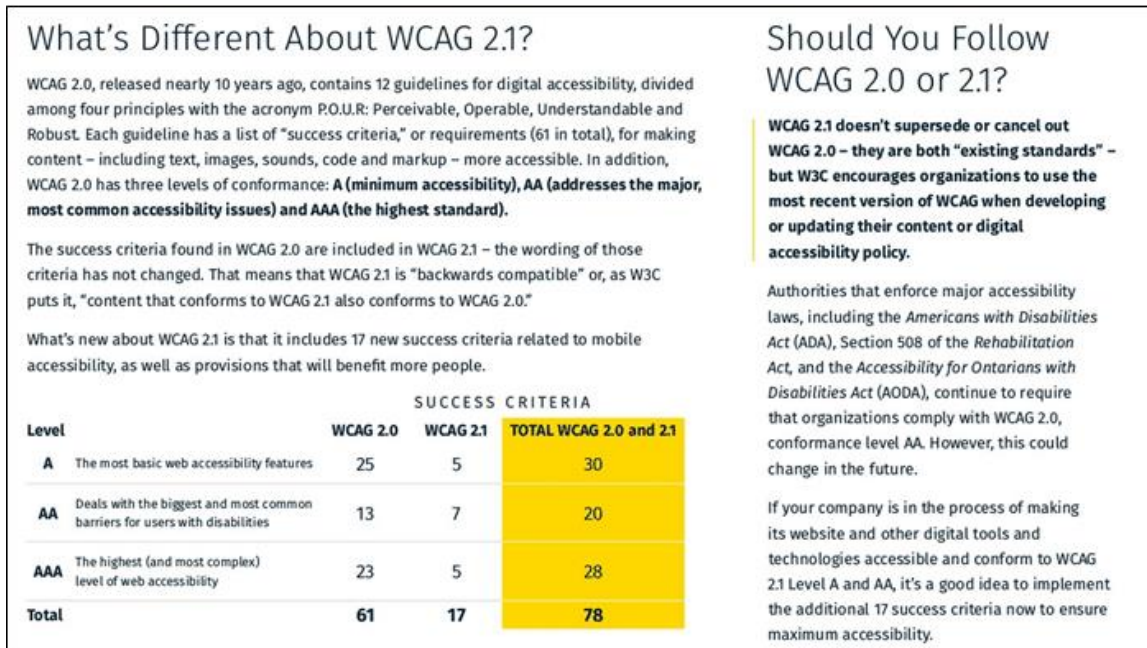


Figure 1: WCAG 2.1 scope and success criteria explained. Source: Adapted from [4]

Furthermore, WCAG 2.1 emphasizes the importance of delivering an inclusive experience for people with impaired vision [5]. New success criteria emphasize adjustable text spacing and contrast ratios in order to improve assistance for users with varied degrees of visual impairment. Consider the following scenario: a user with low vision visits a website on a desktop or mobile device [6]. The standards emphasize the necessity of ensuring that text is not just resizable but also adaptable in spacing, ensuring reading for people who need larger fonts or a unique visual presentation.

WCAG 2.1 also addresses cognitive and learning disabilities in depth. The new criteria emphasize developing a more cognitively accessible digital world, lowering possible barriers for people with various cognitive abilities. Consider the following scenario: a website with sophisticated terminology and extensive navigation [7]. The amended recommendations advocate for more straightforward language, predictable navigation, and fewer distractions, resulting in a more user-friendly experience for people with cognitive impairments [3]. Failure to comply with web accessibility regulations has resulted in litigation against governments and businesses [8]. Transitioning to WCAG 2.1 offers multiple benefits such as enhanced accessibility, a better user experience, adherence to legal standards, broader audience engagement, readiness for future developments, advantages in search engine optimization, ethical commitments, and a stronger position in the online marketplace [9]. It is a worthwhile investment promoting diversity while ensuring your digital information remains relevant and accessible in an ever-changing internet world. This research presents a clear roadmap for businesses and teams wanting to achieve WCAG 2.1 compliance by thoroughly examining the migration process. This roadmap includes assessing the accessibility status of the current Design System, understanding the subtleties of WCAG 2.1 standards, planning the migration, implementation, testing, and continuous compliance.

## **2. LITERATURE REVIEW**

The evolution of web accessibility standards from the Web Content Accessibility Guidelines (WCAG) 2.0 to WCAG marks a significant shift in designing inclusive digital experiences [6]. This literature review explores various scholarly works and industry practices that guide the transition of design systems to comply with the updated standards. Understanding WCAG 2.0 and its Limitations WCAG 2.0, established by the World Wide Web Consortium (W3C), has been the benchmark for web accessibility since its inception in 2008. It provided a comprehensive framework for making web content more accessible to people with disabilities [10]. However, research studies have pointed out its limitations, particularly in addressing the needs of users with cognitive disabilities and those relying on mobile devices. It emphasized the need for guidelines that evolve with technological advancements and also highlighted the gaps in WCAG 2.0 in catering to a broader range of disabilities [7].

### **2.1. The Emergence of WCAG 2.1**

In response to these limitations, WCAG 2.1 was introduced in 2018. This version extends WCAG 2.0 by adding 17 additional success criteria focused on improving accessibility for mobile users, people with low vision, and those with cognitive and learning disabilities [8]. Another research work provides an in-depth analysis of these new WCAG 2.1 criteria, demonstrating how they enhance the user experience for a wider audience [9].

### **2.2. Transition Challenges and Strategies**

The transition from WCAG 2.0 to 2.1 poses challenges for web developers and designers. They identified the need for updated training and awareness among professionals [11]. Similarly, a study conducted revealed the lack of preparedness in the industry for this transition, suggesting a need for comprehensive guidelines and tools to aid in the process [12].

### **2.3. Tools and Frameworks for WCAG 2.1 Compliance**

Several researchers have developed tools and frameworks to assist in the transition. For instance, the work on the WAI-Tools Project provides automated testing tools that help in evaluating WCAG 2.1 compliance [13]. Additionally, a design framework has been introduced that integrates WCAG 2.1 principles into the design process, making accessibility a foundational component of web development [14].

### **2.4. Case Studies and Best Practices**

Practical applications of WCAG 2.1 in real-world scenarios are crucial for understanding its impact. The study by [10] presents a case study of a university website's transition to WCAG 2.1, offering insights into best practices and challenges faced during the process [5]. Furthermore, [15] provided an analysis of how major corporations have adapted their design systems to comply with WCAG 2.1, highlighting the business benefits of accessibility.

## 2.5. Future Directions in Web Accessibility

Looking forward, studies like [16] discuss the future of web accessibility standards beyond WCAG 2.1. They emphasize the importance of continuous adaptation and the potential integration of emerging technologies like AI and machine learning in enhancing web accessibility.

In conclusion, the transition from WCAG 2.0 to WCAG 2.1 is a crucial step towards more inclusive web environments. The literature presents a comprehensive view of the challenges, strategies, and tools available for this transition. It also underscores the importance of ongoing research and development in the field of web accessibility to keep pace with technological advancements and the diverse needs of users.

## 3. IMPORTANCE OF DESIGN SYSTEMS

In the realm of web development, Design Systems have emerged as a fundamental framework, providing a structured approach to creating and managing digital products. These systems are not merely a collection of UI components and style guides; they represent a cohesive set of principles, patterns, and practices that guide the design and development process [6]. The importance of Design Systems lies in their ability to ensure consistency, improve efficiency, and foster collaboration among teams, ultimately leading to a more coherent user experience across various digital platforms.

A well-implemented Design System serves as a single source of truth for both designers and developers. It streamlines the design process by providing a library of reusable components and patterns [17]. This not only accelerates the development cycle but also ensures that the final product maintains visual and functional consistency [3]. By standardizing UI components, Design Systems reduce redundancy in the design process, allowing teams to focus on solving unique user problems rather than reinventing the wheel with each project. Moreover, Design Systems play a crucial role in enhancing the scalability of digital products [5]. As organizations grow and evolve, their digital products need to adapt without losing their core identity. Design Systems provide a flexible yet consistent framework that can accommodate new features and functionalities while maintaining the brand's visual language and user experience standards.

The strategic incorporation of Web Content Accessibility Guidelines (WCAG) 2.1 into Design Systems presents a significant advantage. WCAG 2.1 extends beyond the provisions of WCAG 2.0 by addressing a wider range of disabilities, including those related to vision, hearing, physical, speech, cognitive, language, learning, and neurological disabilities [16]. Integrating WCAG 2.1 directly into a Design System, as opposed to retrofitting accessibility into individual web applications, ensures that accessibility is not an afterthought but a foundational aspect of the design process.

This proactive approach to accessibility has several benefits. Firstly, it ensures that all components in the Design System are accessible from the outset, reducing the need for costly and time-consuming modifications later in the development process [10]. Secondly, it fosters an inclusive design philosophy, encouraging designers and developers to consider a diverse range of user needs and preferences from the beginning [12]. Through embedding WCAG 2.1 standards into the Design System, organizations can ensure compliance with legal requirements, thereby avoiding potential legal ramifications and enhancing their reputation as inclusive and socially responsible entities. In conclusion, Design Systems are indispensable in modern web development, offering a structured, efficient, and scalable approach to design and development.

The integration of WCAG 2.1 into these systems is not just a strategic advantage but a necessity in today's digital landscape, where accessibility and inclusivity are paramount [11]. By embracing this approach, organizations can create digital experiences that are not only aesthetically pleasing and consistent but also accessible to a broader audience, including those with disabilities.

#### **4. UNDERSTANDING WCAG GUIDELINES AND KEY CHANGES IN WCAG 2.1**

The Web Content Accessibility Guidelines (WCAG), established by the World Wide Web Consortium (W3C), serves as a globally recognized set of guidelines and principles designed to make web content accessible to those with disabilities. This set of guidelines provides a structured approach to enhance the inclusivity and usability of digital content, including websites and web applications, for individuals with various disabilities, including visual, auditory, motor, and cognitive challenges. Web accessibility standards have become essential to government website compliance because they accord with equitable access, inclusion, and government agencies' legal responsibility to serve all residents [1], [2]. Failure to comply with web accessibility regulations has resulted in litigation against governments and businesses [8]. WCAG 2.1 encompasses a mix of normative and informative guidelines [11], mirroring the structure found in WCAG 2.0, and it introduces an additional 17 success criteria aimed at advancing web accessibility [12]. Transitioning to WCAG 2.1 offers numerous benefits such as enhanced accessibility, an enriched user experience, adherence to legal standards, broader audience engagement, preparation for future requirements, advantages in search engine optimization, ethical considerations, and gaining a competitive edge in the online marketplace [9]. It is a worthwhile investment promoting diversity while ensuring your digital information remains relevant and accessible in an ever-changing internet world. This research presents a clear roadmap for businesses and teams wanting to achieve WCAG 2.1 compliance by thoroughly examining the migration process. The roadmap includes assessing the accessibility status of the current Design System, understanding the subtleties of WCAG 2.1 standards, planning the migration, implementation, testing, and continuous compliance.

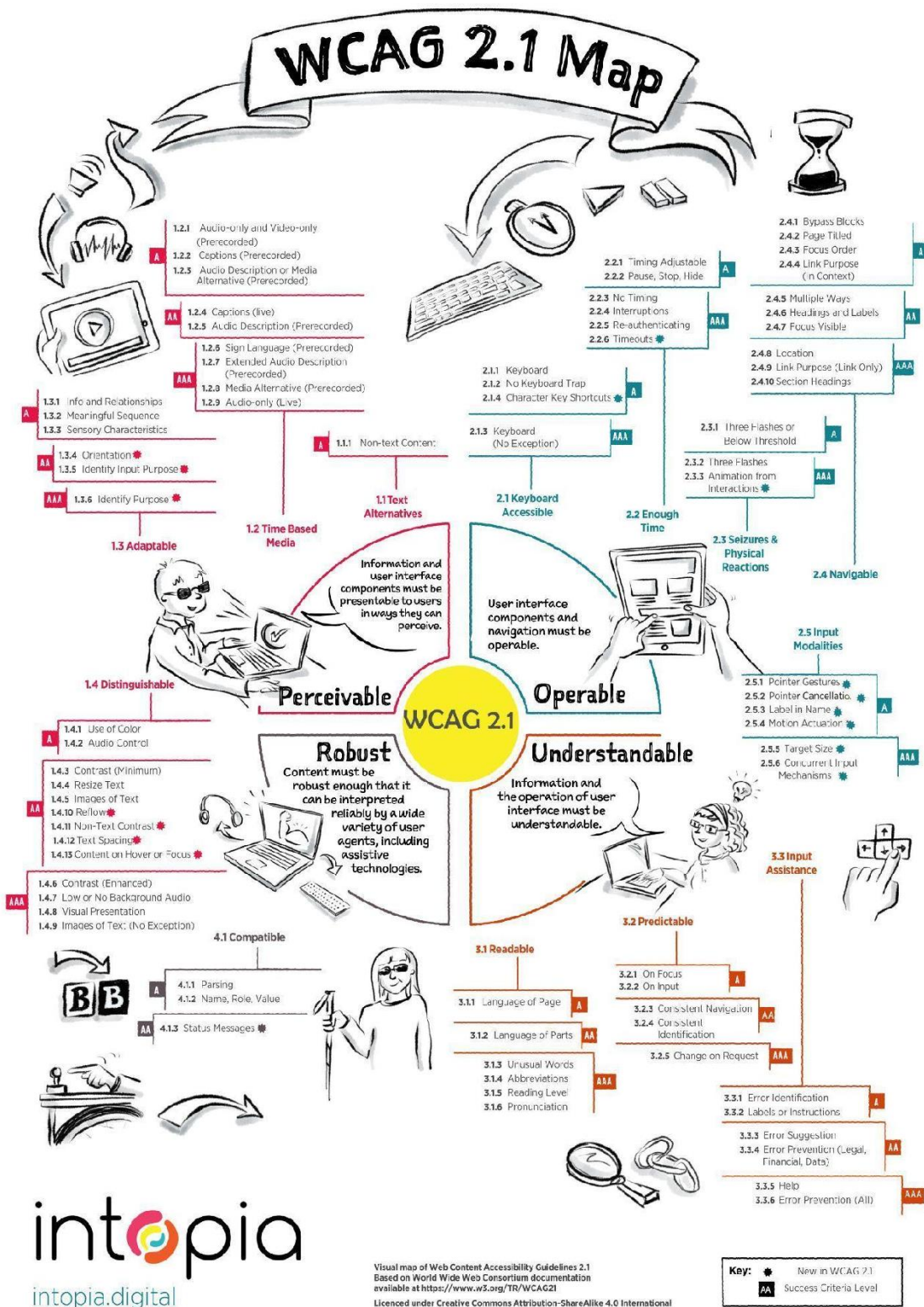


Figure 2: Key changes in WCAG 2.1. Source: Adapted from [13]

## **5. BENEFITS OF ADDING WCAG 2.1 SUPPORT IN DESIGN SYSTEMS**

In the evolving landscape of web development, the importance of accessibility cannot be overstated. The Web Content Accessibility Guidelines (WCAG) 2.1 represent a significant step forward in making web content more accessible to a wider range of people with disabilities [18]. Transitioning design systems from WCAG 2.0 to WCAG 2.1 is not just a compliance measure, but a strategic enhancement that brings numerous benefits.

### **5.1. Enhanced User Experience for a Broader Audience**

WCAG 2.1 extends the accessibility considerations of WCAG 2.0 by including additional criteria to cater to users with cognitive and learning disabilities, users with low vision, and users with disabilities on mobile devices [19]. By more usable and inclusive, thereby reaching a wider audience [20]. This inclusivity is not only a moral imperative but also expands the potential user base, which can be particularly beneficial for commercial websites.

### **5.2. Improved Compliance with Legal Standards**

Many countries are adopting stricter regulations regarding web accessibility. By aligning design systems with WCAG 2.1, organizations can ensure they are compliant with current and future legal requirements [21]. This proactive approach can prevent potential legal challenges related to accessibility, which can be costly and damaging to an organization's reputation.

### **5.3. Enhanced SEO and Online Visibility**

Search engines increasingly favor websites with higher accessibility standards. WCAG 2.1's focus on clarity, navigation, and responsiveness contributes to better SEO. Websites that adhere to these guidelines are likely to rank higher in search engine results, leading to increased visibility and traffic [6].

### **5.4. Future-Proofing Web Assets**

WCAG 2.1 is designed with future technologies in mind, including mobile and emerging assistive technologies. By forward-thinking approach ensures that web assets remain relevant and accessible as new technologies emerge.

### **5.5. Enhanced Brand Image and Corporate Social Responsibility**

Implementing WCAG 2.1 demonstrates an organization's commitment to diversity, equity, and inclusion [6]. This can enhance the brand's image and reputation, showing potential customers and partners that the organization values accessibility and inclusivity.

### **5.6. Reduced Maintenance and Development Costs**

In the long run, incorporating WCAG 2.1 into design systems can lead to reduced maintenance and development costs. Accessible design is often cleaner and more efficient, leading to faster load times and reduced bandwidth usage [6]. Additionally, accessible websites tend to be more robust and easier to maintain, with fewer compatibility issues across different browsers and devices.

In conclusion, the integration of WCAG 2.1 into design systems is not just about adhering to standards; it is a strategic decision that enhances user experience, ensures legal compliance, improves SEO, future-proofs web assets, boosts brand image, and can lead to cost savings. As the digital world becomes increasingly inclusive, the transition from WCAG 2.0 to WCAG 2.1 is a crucial step for any organization committed to providing equitable access to its digital content.

## 6. MIGRATING A DESIGN SYSTEM FROM WCAG 2.0 TO WCAG 2.1

Transitioning from WCAG 2.0 to WCAG 2.1 in your Design System guarantees accessibility for all users, encompassing individuals with disabilities. This migration process entails a systematic approach to aligning your design system with the most recent accessibility requirements. The first step is to assess your existing WCAG 2.0 compliance [11]. This entails thoroughly assessing your existing Design Systems to determine which components already meet WCAG 2.0 criteria and which areas need improvement. You will detect accessibility difficulties, semantic markup practices, and color contrast concerns through automated and manual testing across the Design System's components, template layouts, and demonstration examples [1]. Documenting these findings and developing a repair plan is critical to resolving WCAG 2.0 compliance issues.

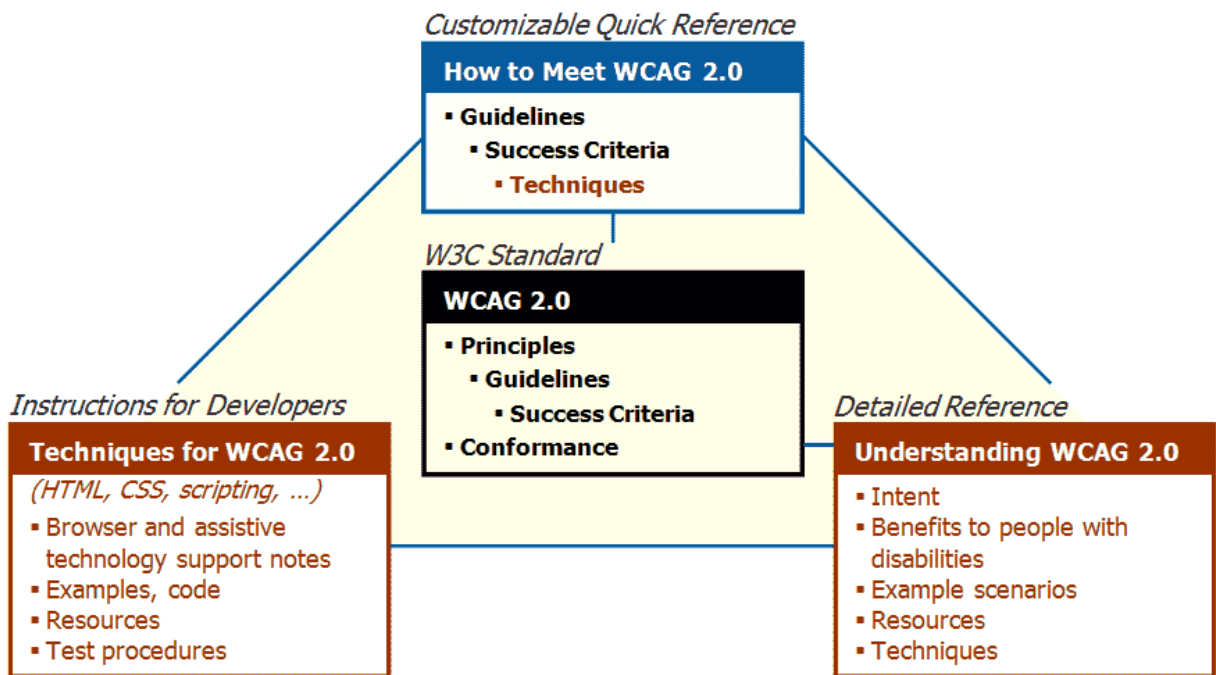


Figure 3: WCAG 2.0 migration - Quick Reference. Source: Adapted from [22]

When initiating the migration process, understanding the differences between WCAG 2.0 and WCAG 2.1 is essential. This information lays the groundwork for a smooth transition to the upgraded rules, ensuring you know the new success criteria, guidelines, and strategies provided in WCAG 2.1. The next step is to identify appropriate success criteria in WCAG 2.1 that are specific to your design system [21]. Because not all success criteria will have an immediate influence on your Design Systems, concentrate on those that will immediately impact the accessibility of your website or applications [14]. With a firm grasp of your starting point and the differences in the rules, it is essential to develop a complete migration strategy. This approach should encompass detailed methods, a timeline, designated roles and responsibilities for the migration process, and potential impacts on continuous design and development activities.



Several organizations have successfully transitioned from WCAG 2.0 to WCAG 2.1 by implementing effective tactics. Microsoft, for example, adopted a comprehensive effort to align its products, including Office 365 and Windows, with WCAG 2.1 criteria [21]. Microsoft promoted user interaction, doing extensive testing with people of varying abilities and incorporating comments to improve the accessibility of their products [19]. Another example is the BBC, which overhauled its design systems to meet WCAG 2.1 requirements. Prioritizing mobile accessibility and addressing cognitive disabilities through simplified language and navigation was part of the BBC's approach [5]. These examples highlight the significance of comprehensive assessment, strategic planning, and user participation in the migration process [6]. To ensure that their staff understood and supported the new standards, Microsoft and the BBC demonstrated proactive communication, transparent documentation, and regular training [21]. These real-world examples not only highlight successful transitions but also demonstrate the iterative nature of accessibility, urging firms to consider compliance as a journey rather than a one-time chore.

Prioritization is essential during your migration process. Prioritize accessibility improvements depending on their importance and urgency. Determine which situations require immediate attention and which can wait, allowing you to manage resources more effectively. As you progress, it is critical to review and update your accessibility rules and best practices documents [8]. Keeping your reference documents up to date can assist your design and development teams in keeping up with the current guidelines. The core of the migration process involves adopting the newly established success criteria set forth by WCAG 2.1 [11]. To achieve these revised accessibility standards, you must modify or add code, styles, and interaction patterns to your Design Systems [2]. The journey, however, continues after implementation. Conduct extensive accessibility testing to guarantee your Design Systems are entirely WCAG 2.1 compliant. This testing uses automated tools, manual evaluations, and assistive technology testing to identify and address any remaining issues.

Web accessibility is built on inclusivity; user testing and feedback are vital. Involve disabled persons in testing to obtain insights and feedback and fix any usability issues that may develop during this vital time. Provide training and awareness sessions on the new accessibility requirements set by WCAG 2.1 to empower your team for success [10]. It is critical for effective execution that your design and development teams grasp these requirements. Accessibility is a continuous effort. Create a procedure for continuing compliance that includes regular evaluations and changes to keep your Design Systems in line with WCAG 2.1 and future accessibility requirements. The importance of broad user participation in ensuring the success of the transition from WCAG 2.0 to WCAG 2.1 cannot be emphasized. Diverse user engagement gives a richness of viewpoints from a diverse range of skills, limitations, and user experiences [21]. This inclusivity serves as a litmus test for the efficacy of the modifications undertaken, allowing organizations to detect and address any accessibility hurdles that could otherwise go unnoticed [17]. Organizations obtain essential insights into the real-world usability of their digital assets by actively engaging users with varied needs, including those with visual, auditory, motor, and cognitive impairments. This user-centric approach not only adheres to essential accessibility standards but also develops a more empathic and responsive design attitude.

Furthermore, incorporating varied users in the testing phase helps to create a digital environment that caters to a larger audience [21]. It guarantees that the improvements implemented not only meet compliance criteria but also resonate with end users, resulting in a genuinely inclusive online experience. As a result, the depth and diversity of user involvement throughout the testing process are inextricably related to the migration's success.

Throughout this procedure, effective communication is critical. Changes and upgrades to your Design System should be communicated as it transitions to WCAG 2.1 compliance, engaging stakeholders to ensure everyone is informed and on board with the accessibility advances [12]. Maintain thorough documentation of the migration process and seek expert support from accessibility experts or organizations as needed [15]. Their advice can be invaluable in ensuring full WCAG 2.1 compliance and offering an inclusive user experience. Finally, remember to see WCAG 2.1 compliance as a critical step toward establishing a more accessible and inclusive digital world [6]. It acknowledges the commitment and hard work of your team in enhancing the accessibility of digital content for a wider audience.

## **7. THE ROLE OF MANUAL AND AUTOMATED TESTING IN THE MIGRATION PROCESS**

The significance of automated testing and manual audits in ensuring that Design Systems adhere to the most recent accessibility standards is critical when migrating from one set of accessibility guidelines to another, such as WCAG 2.0 to WCAG 2.1. Automated Scanning Tools are a helpful first step in the evaluation process. Organizations should proactively stay educated about developing rules as they anticipate future accessibility requirements such as WCAG 2.2 and WCAG 3.0 [6]. It is critical to embrace a culture of continual learning and adaptability [3]. Participating in pilot programs and early adoption activities for beta versions might provide valuable insights. Collaboration with user communities and the adoption of future technology, such as AI-powered accessibility solutions, will be critical [18]. Creating a structure for continuing accessibility reviews and encouraging a user-centric approach can help organizations move to and exceed forthcoming standards. This strategic vision not only assures compliance but also places enterprises at the forefront of providing inclusive digital experiences in a rapidly changing technology context. These tools are helpful for quickly finding common accessibility concerns in your Design System examples. Scanners excel at detecting flaws such as missing alt text for photos, incorrect markup structures, and text with insufficient contrast ratios [10]. They provide a rapid and systematic way to identify any issues with your Design System [5]. The W3C validation service, WebAIM Contrast Checker, Chrome Lighthouse, WAVE Web Accessibility Evaluation programs, and Accessibility Insights are well-known examples of automated scanning programs [14]. Utilizing these tools can accelerate the detection and resolution of simple difficulties. Manual testing, on the other hand, remains an essential component of the accessibility review process [1]. While automated technologies are beneficial, they may not detect all accessibility concerns. Human-led testing introduces a personal touch to the evaluation process, enabling a more detailed and subtle analysis [16]. It is critical to examine each design component in your Design System examples through the lens of accessibility during manual testing. This includes extensive testing with keyboard navigation, screen readers, and other assistive technology people with impairments use. Manual testing emphasizes key aspects such as proper management of focus, operability through keyboard input, and compatibility with screen readers. By doing extensive manual audits, you can uncover finer flaws that may not be detectable automatically.

## **8. CHALLENGES FACED IN WCAG 2.1 MIGRATION OF DESIGN SYSTEMS**

During the transition from WCAG 2.0 to WCAG 2.1, organizations may face a number of problems that must be carefully considered. One significant source of concern is the possible resource strain, both in terms of time and labor, that will be necessary for the complete evaluation and implementation of new success criteria. Furthermore, updating existing digital assets to match the revised requirements may provide technological challenges, particularly for sophisticated systems or outdated applications [19]. The organizational culture's resistance to

change may prevent the seamless adoption of WCAG 2.1 recommendations. Furthermore, ensuring that all team members have a thorough understanding of the new criteria may take time and effort [5]. Addressing these potential complaints necessitates a proactive approach that includes strong communication, resource planning, and ongoing training to promote a joint commitment to the long-term benefits of improved web accessibility [8]. Realistic expectations and a phased implementation strategy can reduce these issues, resulting in an easier transition and long-term compliance.

Organizations migrating from WCAG 2.0 to WCAG 2.1 may face a number of obstacles. One significant source of concern is the time and work required for a complete examination and implementation of new success criteria. Technological problems may occur, particularly for complicated systems or out-of-date applications, demanding extensive modifications to meet changed needs [17].

Furthermore, resistance to change within an organization's culture can inhibit the smooth implementation of WCAG2.1 recommendations. Another area for improvement is ensuring that all team members understand the complexities of the new criteria [7]. To address these difficulties, a proactive approach comprising excellent communication, resource planning, and continual training is required. Realistic expectations and a phased implementation strategy can allay fears, promoting a smoother transition and long-term compliance while respecting the nuanced challenges that companies may experience in their pursuit of improved web accessibility.

## **9. FUTURE WORK**

The research on migrating Design Systems from WCAG 2.0 to WCAG 2.1 provides essential insights into the changing landscape of web accessibility [14]. However, certain limits must be acknowledged. The paper focuses primarily on technical factors, potentially ignoring the socio-cultural components of accessibility. Future research could address the intersectionality of accessibility, considering varied user requirements and experiences beyond the mentioned disabilities [6].

Additionally, while the handbook promotes collaboration, more significant inquiry into efficient interdepartmental cooperation and communication tactics during relocation could boost its practical application. The study's ramifications extend beyond compliance to broader ethical problems in digital design [20]. A more extensive investigation of the societal impact of accessible design and the potential for encouraging innovation and creativity in the digital world is a path for future inquiry.

## **10. CONCLUSION**

Upgrading a Design System from Web Content Accessibility Guidelines (WCAG) 2.0 to WCAG 2.1 signifies a considerable commitment to encouraging diversity and user-centric design in the changing field of digital accessibility. As we conclude this study paper, it becomes evident that this transition represents more than merely a technological upgrade; it is a vital stride towards creating a digital environment that is both more accessible and equitable. The insights offered in this article emphasize that upgrading to WCAG 2.1 represents a transformative journey - one that closes the accessibility gap while also aligning with the larger objective of a universally inclusive digital world. It is critical to recognize that while this movement has its obstacles, it also opens up a world of potential. Furthermore, it positions companies and developers to effortlessly move to

future accessibility standards like WCAG 2.2 and WCAG 3.0, ensuring that digital experiences continue to improve in a way that benefits all users.

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# HARNESSING CUSTOMIZED BUILT-IN ELEMENTS: EMPOWERING COMPONENT-BASED SOFTWARE ENGINEERING AND DESIGN SYSTEMS WITH HTML5 WEB COMPONENTS

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## **ABSTRACT**

*Customized built-in elements in HTML5 significantly transform web development. These elements enable developers to create unique HTML components tailored with specific design and purpose. Customized built-in elements enable developers to address the unique needs of web applications more quickly, supporting consistent user interfaces and experiences across diverse digital platforms. This study investigates the role of these features in Component-Based Software Engineering (CBSE) and Design Systems, emphasizing the benefits of code modularity, reusability, and scalability in web development. Customized built-in elements enable developers to address the unique needs of web applications more quickly, supporting consistent user interfaces and experiences across diverse digital platforms. The paper also discusses the difficulties and concerns that must be addressed when creating customized built-in elements, such as browser compatibility, performance optimization, accessibility, security, styling, and interoperability. It emphasizes the importance of standardization, developer tooling, and community interaction in order to fully realize the potential of these features. Looking ahead, customized built-in elements have potential in a variety of applications, including the Internet of Things (IoT), e-commerce, and educational technologies. Their incorporation into Progressive Web Apps (PWAs) is expected to further improve web experiences. While obstacles remain, the article concludes that HTML5 customized built-in elements are a driver for web development innovation, allowing the production of efficient, adaptive, and user-centric web applications in an ever-changing digital context.*

## **KEYWORDS**

*Customized built-in elements, HTML5 Web Components, Component Based Software Engineering, Design Systems, Web UI development*

## **1. INTRODUCTION**

Web development is at the forefront of innovation and user-centric design in today's quickly expanding digital landscape. The advent of HTML5 customized built-in elements marks a watershed moment in the realm of web development. These elements, a subset of the Web Components standard, have the potential to transform software engineering, Design Systems, and user experience. Their ability to contain exact functionality, visual aesthetics, and interactive behaviors represents a new paradigm in web development, encouraging code modularity, reusability, and scalability. Customized built-in elements represent a significant change in the

world of web development. They allow developers to construct their own HTML components with unique features and behaviors that are similar to typical HTML elements such as `<div>` or `<p>` [6]. This adaptability is key to the ideas of Component-Based Software Engineering (CBSE), which enable developers to divide complicated applications into modular, granular components [10]. These components are intended to fit easily into the larger software ecosystem, promoting modularity, reusability, and maintainability.

Additionally, customized built-in elements have a revolutionary impact on Design Systems, which are critical in guaranteeing visual consistency and user experience across digital applications. These elements serve as the foundation for constructing user interface components by carefully adapting them to match an application's specific design language and brand identity. This personalization guarantees a consistent and visually appealing user interface across a wide range of digital products and platforms, improving brand coherence [9]. Cross-browser compatibility, speed optimization, accessibility, stylistic methods, and security are all factors to consider when implementing customized built-in elements. Attention to these details is critical for efficient integration into current online applications. In the future, they are set to revolutionize the field of web development across a diverse array of applications, including the Internet of Things (IoT), e-commerce platforms, and educational tech solutions [21]. Their interaction with Progressive Web Apps (PWAs) has the potential to improve web experiences even further. To realize their full potential, issues such as browser standardization, accessibility, security, developer tooling, and community participation must be addressed.

## 1.1. Objectives and Purpose

The following are the objectives and purpose of this paper:

Objectives:

- Investigate the importance of customized built-in elements in HTML5 Web Components.
- Emphasize their importance in Component-Based Software Engineering (CBSE) and Design Systems.
- Highlight the advantages that code modularity, reusability, and scalability provide in web development.
- Promote the broad usage of customized built-in elements to alter software engineering, improve design coherence, and improve user experience.

Purpose:

This paper's goal is to shed light on the transformative potential of customized built-in elements in current web development. When used successfully, these aspects have the potential to change software engineering and Design Systems. They improve code modularity, reusability, and scalability while adhering to CBSE principles. Furthermore, they ensure consistency and customization in the field of Design Systems, resulting in a unified and visually appealing user interface. This paper attempts to raise web development by addressing the expectations for efficiency and adaptability in digital solutions by pushing for the adoption of these aspects.

## 2. WEB COMPONENTS API AND CUSTOM ELEMENTS

### 2.1. Custom Elements in HTML5 Web Components

HTML5 Web Components feature a dynamic capability enabling developers to craft and establish their unique HTML elements, referred to as custom elements. These custom components provide a distinct and robust feature, allowing developers to encapsulate functionality, structure, and style similar to their well-known HTML equivalents, such as `<div>`



and <p>. Custom elements, at the heart of the Web Components standard, serve as a gateway to increasing HTML's vocabulary [4]. This enhancement streamlines the development of reusable and modular web application components [3]. The benefit of custom elements is their adaptability, which allows developers to easily define these elements using JavaScript . Once defined, these custom elements integrate smoothly into web pages, behaving exactly like any other HTML element [6].

```
JS 
// Create a class for the element
class MyCustomElement extends HTMLElement {
  static observedAttributes = ["color", "size"];

  constructor() {
    // Always call super first in constructor
    super();
  }

  connectedCallback() {
    console.log("Custom element added to page.");
  }

  disconnectedCallback() {
    console.log("Custom element removed from page.");
  }

  adoptedCallback() {
    console.log("Custom element moved to new page.");
  }

  attributeChangedCallback(name, oldValue, newValue) {
    console.log(`Attribute ${name} has changed.`);
  }
}

customElements.define("my-custom-element", MyCustomElement);
```

Figure 1: Example of MyCustomElement and lifecycle events using HTML5 custom elements API.  
Source: Adapted from [7]

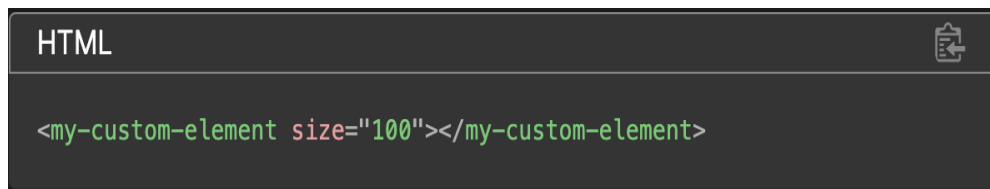
A screenshot of a code editor window titled "HTML". The editor displays the HTML declaration for a custom element: `<my-custom-element size="100"></my-custom-element>`. The text is color-coded: the opening and closing tags are green, and the attribute value "100" is red. A small icon of a document with a right-pointing arrow is visible in the top right corner of the editor window.

Figure 2: HTML declaration of MyCustomElement. Source: Adapted from [7]

In this case, we'll make a custom element called `<my-custom-element />`. This new custom element is defined in runtime using JavaScript. We established a class `MyCustomElement` that extends `HTMLElement`. If required, we can use `attachShadow` method to generate a shadow DOM within its constructor. We build a `<my-custom-element />` element and define its content and styling. Several lifecycle methods required to get access to the component are available as part of the API - `connectedCallback`, `disconnectedCallback`, `adoptedCallback` and `attributeChangedCallback`. Following that, the `customElements.define` method is used to register the custom element "my-custom-element" for use in HTML. After you've defined it, you can use `<my-custom-element></my-custom-element>` like any other HTML element. If you pass attributes - `size` and `color`, any change to these attribute values will trigger `attributeChangedCallback` and eventually log the attribute name in the browser console. This example implementation highlights the power of HTML5 Web Components' custom elements, which allow you to construct reusable and encapsulated components with their own behavior and appearance.

## 2.2. Customized Built-In Elements: Tailoring Web Components for Specific Needs

A distinct and highly specialized class of entities known as customized built-in elements develops from the vast geography of the Web Components API. They derive its semantic meaning from the base element which it is extending. These custom elements are painstakingly developed to meet individual web applications' precise and frequently sophisticated needs [8]. Developers have incredible control and accuracy when creating and improving these elements, adapting them to encompass precise functionality, visual aesthetics, and interactive behaviors [1]. Customized built-in elements are distinguished by their extensive feature sets, which include a wide range of properties, methods, and event-driven mechanisms. Each component in this system has been meticulously crafted to integrate seamlessly with the distinct architecture of a particular application [8]. This seamless integration is a cornerstone, increasing code modularity and reusability by enclosing complicated and multifarious functions into self-contained components [2].

In this example, we'll be creating a [customized built-in element](#) named `plastic-button`, which behaves like a normal button but gets fancy animation effects added whenever you click on it. We start by defining a class, just like before, although this time we extend `HTMLButtonElement` instead of `HTMLElement`:

```
class PlasticButton extends HTMLButtonElement {
  constructor() {
    super();

    this.addEventListener("click", () => {
      // Draw some fancy animation effects!
    });
  }
}
```

When defining our custom element, we have to also specify the `extends` option:

```
customElements.define("plastic-button", PlasticButton, { extends: "button" });
```

In general, the name of the element being extended cannot be determined simply by looking at what element interface it extends, as many elements share the same interface (such as `q` and `blockquote` both sharing `HTMLQuoteElement`).

To construct our [customized built-in element](#) from parsed HTML source text, we use the `is` attribute on a `button` element:

```
<button is="plastic-button">Click Me!</button>
```

Figure 3: Code example for Customized built-in element. Source: Adapted from [9]

### 3. ADVANTAGES OF CUSTOMIZED BUILT-IN ELEMENTS

HTML5's custom elements feature allows developers to specify and create their own HTML elements. These custom components, like built-in HTML elements (e.g., `<div>`, `<p>`), can encapsulate functionality, structure, and styling and are a cornerstone of the Web Components standard. They offer a robust method to expand the lexicon of HTML, simplifying the process of developing modular and reusable components for web applications. The beauty of custom elements is their JavaScript-based definition, allowing them seamlessly integrate into web pages like any other HTML element. The Web Components API adds a new category of customized built-in elements, representing a significant advancement in web development. These custom elements are painstakingly developed to meet individual web applications' distinct and nuanced needs [10]. Developers possess the distinct ability to design and precisely adjust these components.

Customized built-in elements are defined by their adaptability, frequently spanning a diverse set of attributes, methods, and events, all precisely crafted to integrate seamlessly with the architecture of a particular application [5]. These components act as foundational elements that promote reusability and the modular structure of code. They achieve this by encapsulating complex and specific functionalities within self-sufficient, readily deployable units. This transformational approach to web development improves software development productivity and develops a culture of modular, manageable, and scalable code [10].

The screenshot displays a web browser window with the URL `mdn.github.io/web-components-examples/word-count-web-component/`. The page title is "Word count rating widget". The content includes a "Sample heading" and two paragraphs of Lorem Ipsum text. Below the text, it says "Words: 212".

The browser's developer tools are open, showing the DOM tree on the left and the Properties panel on the right. The DOM tree shows the following structure:

```

<!DOCTYPE html>
<html>
  <head>
  </head>
  <body>
    <h1>Word count rating widget</h1>
    <article contenteditable>
      <h2>Sample heading</h2>
      <p></p>
      <p></p>
      <p is="word-count" == $0
        <#shadow-root (open)
          <span>Words: 212</span>
        </p>
      </article>
      <script src="main.js"></script>
    </body>
  </html>

```

The Properties panel shows the following attributes for the selected element:

```

accessKey: ""
align: ""
attributeStyleMap: StylePropertyMap {size: 0}
attributes: NamedNodeMap {0: is, is: is, length: 1}
autocapitalize: ""
autofocus: false
baseURI: "https://mdn.github.io/web-components-examples/word-count-web-component/"
childElementCount: 0
childNodes: NodeList []
children: HTMLCollection []
classList: DOMTokenList [value: '']
className: ""
clientHeight: 19
clientLeft: 0
clientTop: 0
clientWidth: 1134
contentEditable: "inherit"
dataset: DOMStringMap {}
dir: ""
draggable: false
elementTiming: ""
enterKeyHint: ""
hidden: false
id: ""
inert: false
innerHTML: ""
innerText: ""
inputMode: ""
isConnected: true
isContentEditable: true
lang: ""

```

Figure 4: Word count component implemented as a Customized built-in element.  
Source: Adapted from [11]

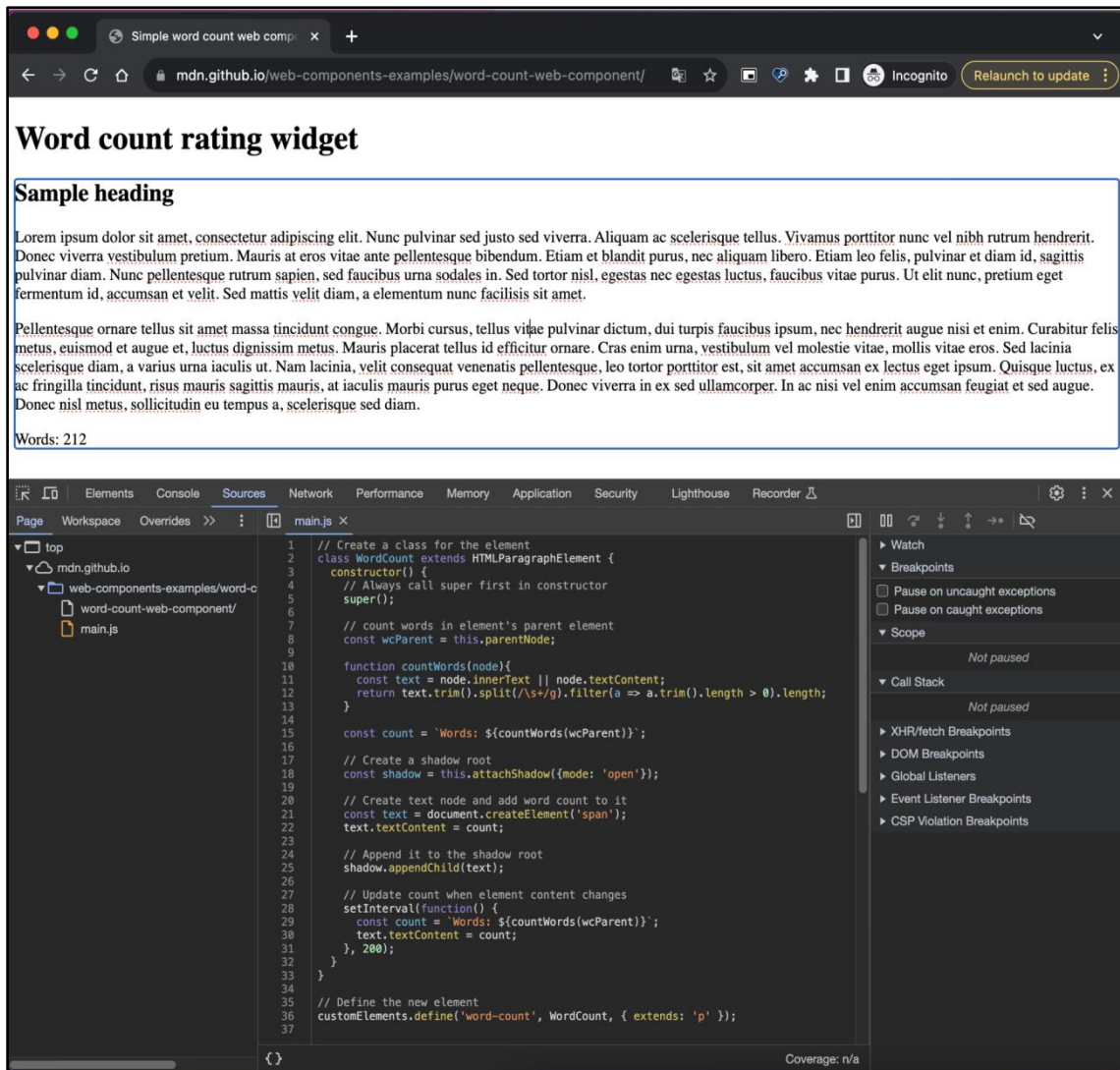


Figure 5: Source code for Word count component. Source: Adapted from [11]

Customized built-in elements are the foundations that allow developers to navigate the complex landscape of web application development with precision and grace, providing bespoke solutions to match the particular demands of any digital venture. For instance, `<p is="word-count" />` element can provide a consistent and feature-rich paragraph component with a word count feature which is consistent across different web applications, reducing the need for third-party libraries and ensuring a uniform look and feel. Similarly, a `<img is="user-avatar">` element implemented using customized built-in elements API can automatically fetch and display a user profile picture from a defined source, simplifying the process of user interface development. To conclude, customized built-in elements give developers the accuracy and flexibility they need to handle the unique needs of their digital projects, making web development more efficient and adaptable to a wide range of applications and industries.

## **4. APPLICATIONS OF CUSTOMIZED BUILT-IN CUSTOM ELEMENTS**

### **4.1. Elevating Component-Based Software Engineering (CBSE)**

Introducing customized built-in elements is disruptive in Component-Based Software Engineering (CBSE). These aspects are essential in systematically creating software components, allowing developers to break complex and multifaceted applications into more manageable, granular entities. Each of these components has been painstakingly designed to interact with the overall architecture and requirements of the software system [3]. Customized built-in elements prove to be the cornerstone in this process, infusing CBSE with a profound feeling of modularity, reusability, and maintainability [12]. Developers start on a quest to optimize the development process to unparalleled levels of efficiency by carefully utilizing these factors. The intrinsic compatibility of customized built-in parts with web application core architecture ensures that software components coexist healthily within the larger software ecosystem [6].

In real-world CBSE projects, customized built-in elements can be used to create complex data grids and interactive dashboards that are central to enterprise applications. Consider the case of an E-commerce company which has several dashboards in their online public shopping web application to represent latest sales and recent orders for the customer. Building new dashboards from scratch would come at an extremely high effort and cost. Customized built-in elements can address these challenges by allowing reusability of existing components in the Dashboards by migrating to customized built-in elements to provide a seamless and interactive user experience for data manipulation. However, developers face challenges such as ensuring the performance and security of these components. Custom elements help address these challenges by allowing encapsulation of functionality, which can lead to performance optimizations and better security through shadow DOM.

### **4.2. Design Systems Empowered by Customized Built-In Elements**

The adaptability of customized built-in pieces extends much beyond the limitations of Component-Based Software Engineering (CBSE). These aspects emerge as vital instruments with transformative potential within the vast area of web-based Design Systems [5]. Design frameworks, serving as repositories for recyclable web UI components, design principles, and established guidelines, are crucial in maintaining uniformity and consistency across various digital platforms and brand environments, thereby supporting design and user experience [4]. Within this framework, customized built-in elements stand tall as the foundation upon which many UI components manifest. These elements are used to precisely build buttons, input fields, navigation bars, and critical interface elements. What distinguishes them is the artistry of customization, which perfectly aligns each aspect with the application's distinctive design language and brand identity. This thorough alignment is the key to developing a coherent and visually appealing user interface that connects with the brand's character.

Organizations are prepared to start on a journey of frictionless consistency by seamlessly incorporating customized built-in elements into Design Systems [5]. They may easily transmit a consistent and visually pleasant user interface throughout the varied spectrum of their digital products and platforms using these elements as their base [12]. Consequently, individuals can traverse online environments experiencing both comfort and aesthetic appeal, due to the inventive brilliance of customized built-in elements. This marks the dawn of a novel phase in the evolution of Design Systems development. [3].

Consider a huge e-commerce company with many digital channels, such as a website, mobile app, and even voice-activated purchasing assistants. The company decides to establish a complete design system in order to maintain a uniform and visually appealing user experience across all of these platforms. This design system has components in the component library based on HTML5 customized built-in elements. The corporation can migrate their existing buttons in their application to the customized built-in element called 'SignUp' by adding just one attribute to their existing HTML5 buttons and importing the new design system library. This SignUp button has been precisely crafted to complement the company's brand identity and design language. It includes variables such as size, color, and shape, allowing developers to adjust button look based on platform constraints while maintaining brand consistency.

Here's how this example relates to Design Systems empowered by customized built-in elements:

- **Consistency:** The e-commerce company guarantees that buttons throughout its website, app, and voice-activated assistants have a uniform look and feel by leveraging customized built-in elements like `<button is="SignUp">Sign Up</button>`.
- **Alignment with Brand Identity:** Using the customization options in `<button is="SignUp">`, the organization may align each button with its individual brand identity, resulting in a consistent and visually appealing user interface.

Customized built-in elements, such as `<button is="SignUp">`, serve as modular building blocks within the design system. The same API can be used to generate a variety of UI components such as input fields, navigation bars, and other elements, enabling reusability and efficient design revisions. As a result, customized built-in elements enable the organization to create a unified design system that assures a coherent and visually appealing user experience across varied digital products and platforms while accommodating platform-specific requirements.

## **5. CONSIDERATIONS IN IMPLEMENTING CUSTOMIZED BUILT-IN ELEMENTS**

To effectively utilize HTML5 customized built-in elements, one must possess an in-depth knowledge of the technical intricacies and design elements involved in web development. These elements, while powerful, come with a set of considerations that developers must address to ensure their effective integration into web applications. Firstly, browser compatibility is a primary concern. While modern browsers have embraced the Web Components standard, discrepancies remain in how different browsers handle custom elements, necessitating the use of polyfills for unsupported features [13]. Developers must test their custom elements across a spectrum of browsers to guarantee consistent behavior and appearance [6].

Performance optimization is another critical consideration. Custom elements can introduce performance bottlenecks, particularly if they contain complex logic or are used extensively on a page. Developers should measure the impact of their elements on page load times and runtime performance, optimizing through techniques such as lazy loading and avoiding excessive DOM manipulation. Accessibility is a non-negotiable aspect of web development. Designing customized built-in elements should always consider accessibility, making sure they are functional and accessible for individuals with disabilities. This includes semantic structure, keyboard navigability, and ARIA roles where appropriate.

Styling customized elements requires a strategy that balances encapsulation with flexibility. While Shadow DOM provides style encapsulation, developers must also provide a means for consumers of the element to customize styles as needed, often through CSS custom properties or

slots. State management within custom elements must be handled with care to avoid tightly coupling the elements to a specific state management solution. Instead, elements should expose a clear API for state updates and changes. Security considerations are paramount, as custom elements can be susceptible to the same range of vulnerabilities as any web technology. Developers must sanitize content to prevent cross-site scripting (XSS) and ensure that any data bindings are secure.

Interoperability with other web components and frameworks is essential. Custom elements should be designed to work within different contexts and alongside other components, which may involve managing events and data flow between components. Testing customized built-in elements is as important as testing any other part of the application. Automated testing should cover the functionality of the element, its response to state changes, and its behavior under different conditions. Documentation is often overlooked but is critical for the adoption and maintenance of custom elements. Comprehensive documentation should cover the API, usage examples, and any quirks or limitations [5]. Lastly, lifecycle management is a technical consideration where developers must handle the creation, connection, disconnection, and attribute changes of custom elements with lifecycle callbacks provided by the Web Components API [12]. In summary, the implementation of HTML5 customized built-in elements requires careful consideration of cross-browser compatibility, performance, accessibility, styling, state management, security, interoperability, testing, documentation, and lifecycle management. Addressing these considerations is crucial for the successful integration of custom elements into modern web applications.

## **6. FUTURE OF CUSTOMIZED BUILT-IN CUSTOM ELEMENTS**

The horizon for customized built-in elements is expansive and promising, with the potential to revolutionize web development in profound ways. As we look to the future, several applications and challenges come into focus, heralding a new era of innovation and user-centric design. **Emerging Applications:** The future applications of customized built-in elements are diverse. Within the domain of the Internet of Things (IoT), these components act as the medium for intricate interactions between devices, facilitating user-friendly control interfaces and enhanced visualization of data [13]. In e-commerce, customized elements can provide unique shopping experiences with interactive and personalized components that enhance user engagement [14]. Educational technology can leverage these tools to develop interactive and adaptive learning settings tailored to each student's unique requirements [15].

**Integration with Progressive Web Apps (PWAs):** Customized built-in elements are set to play a significant role in the development of Progressive Web Apps (PWAs). They can be used to create app-like experiences within the browser, complete with offline capabilities and device-specific integrations [16]. This synergy will likely drive further adoption of PWAs as businesses seek to provide seamless experiences on both desktop and mobile [9].

## **7. CHALLENGES AND CONSIDERATIONS**

Despite the potential, there are challenges that need to be addressed. One of the primary concerns is the standardization across browsers. While major browsers support custom elements, there are inconsistencies in implementation that can lead to compatibility issues [17]. Performance optimization is another challenge, as the complexity of custom elements can impact load times and runtime efficiency [18].



**Enhancing Accessibility:** Accessibility will remain a critical challenge. When creating customized built-in components, it's essential to prioritize accessibility from the beginning. These components should adhere to the Web Content Accessibility Guidelines (WCAG) to ensure they are accessible and user-friendly for individuals with disabilities [19].

**Security Implications:** Security is another area of concern. Custom elements that handle data must be designed to prevent vulnerabilities such as cross-site scripting (XSS) and ensure data privacy [20].

**Tooling and Developer Experience:** Advancing the design of more advanced tools will be crucial for facilitating the creation and upkeep of customized built-in elements [5]. Integrated development environments (IDEs) and frameworks will need to evolve to provide better support for debugging and testing these components [21].

**Standardization and Community Engagement:** The evolution of web standards will continue to shape the future of customized built-in elements. Active engagement with the web standards community will be crucial to ensure that the development of custom elements aligns with the evolving needs of the web [22].

In conclusion, the future of customized built-in elements is bright but requires careful navigation of emerging technologies, standards, and user expectations. As the web continues to evolve, these elements will be at the forefront of creating more dynamic, efficient, and user-friendly web applications.

## **8. CONCLUSION**

HTML5 customized built-in elements represent a pivotal advancement in the realm of web development. They provide developers with a robust mechanism for crafting bespoke HTML components that possess specific functions and aesthetics. This approach significantly enhances modularity, reusability, and scalability within web applications, marking a new era in web development. This transformative technology has the potential to reshape both Component-Based Software Engineering (CBSE) and Design Systems, ensuring that software development becomes more efficient and design remains visually cohesive. By addressing the unique needs of web applications, customized built-in elements provide a path to a more streamlined and effective development process. Their adaptability allows for a high degree of customization and alignment with a brand's design language, fostering consistent user interfaces and experiences across various digital platforms. While the adoption of customized built-in elements brings immense promise, it also raises important considerations, such as browser compatibility, performance optimization, accessibility, security, and developer tooling. Addressing these issues is essential for the seamless and effective incorporation of these elements into web applications. Looking ahead, the future of customized built-in elements is bright, with potential applications in diverse fields and their integration into Progressive Web Apps (PWAs). However, ongoing efforts in standardization, accessibility, security, tooling, and community engagement will be crucial to unlock their full potential. In an ever-evolving digital landscape, HTML5 customized built-in elements serve as a beacon of innovation and a catalyst for enhanced web development practices. They empower developers to create efficient, adaptable, and user-centric web applications, ensuring that the web continues to evolve to meet the ever-growing expectations of digital consumers.

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# AI-BASED SECURITY ENHANCEMENT AND PERSONAL INFORMATION PROTECTION TECHNIQUES INHERITED FROM 6G NETWORKS

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## **ABSTRACT**

*As the realization of digital transformation expected with 5G networks has already begun and continue to evolve over this decade, the 6G communication era envisions how humans will interact with the digital virtual worlds beyond 2030. The security mechanisms designed for 5G using the concepts of SDN and NFV should be further improved to cater to the security demands in 6G networks. When 6G networks are harmonizing the concepts of SDN, NFV, and AI in an integrated environment to provide the necessary services, the system-level differences between 5G and 6G would introduce new security threats and privacy concerns. This paper aims to identify and systematically analyze new security threats and privacy concerns of 5G technologies inherited from 6G networks. The corresponding 6G-specific defenses will also be investigated.*

## **KEYWORDS**

*5G Networks, 6G Networks, Security and Privacy, Machine Learning.*

## **1. INTRODUCTION**

The 6G Networks(6G) communication era envisions how humans will interact with the digital virtual worlds beyond 2030. Future networks must possess novel technologies that enable the digital virtual worlds with connected intelligence, to address the communication and networking challenges beyond 2030. 6G rely on AI to enable fully autonomous networks[1]. In order to lead the 6G communication market, core technologies are being developed competitively, centering on the United States, Korea, China, Japan, and the European Union (EU). 6G technology aims to support services of up to 1Tbps (terabit per second, 1Tbps = 1000Gbps) by implementing a network that is about 50 times faster than the maximum speed of 5G networks (5G) of 20Gbps. In addition, the delay time, which is the reaction speed of the network, is 0.1 millisecond, which is one tenth of 5G, and has the characteristic of using the terahertz (THz) band.

Until now, various security issues have been continuously raised in 5G. Even in the future 6G network era, more intelligent and advanced technology development is expected for the development of technologies and tools related to security, trust, and privacy based on Artificial Intelligence(AI). Therefore, attacks on AI systems, especially Machine Learning (ML) systems, will catastrophic affect 6G networks. Such as poisoning attacks, data injection, data manipulation, logic corruption, model evasion, model inversion, model extraction, and

membership inference attacks are potential security threats against ML systems. The collection of more features allows AI systems to perform better. Attacks on collected data and the unintended use of private data lead to privacy issues as the data processing is usually not visible to the users[2].

AI-enabled security and privacy provision are core part of 6G systems. 6G achieves connected intelligence via AI-enabled functions, especially with ML systems that are subject to various threats. Specially, poisoning attacks influence the learning phase of a ML system, which lead the model to learn inaccurately. Multi-connectivity, mesh networks with tiny cells in 6G allow simultaneous communication for devices via multiple base stations[3]. Edge-based ML models could be used for dynamic detection of privacy-preserving routes, rank them, and allow devices to transfer data via privacy-preserving routes based on the ranking. federated learning keeps data in the users proximity compared to cloud-based learning to enhance data privacy and location privacy[3]. The 6G subnetwork level AI allows better privacy within the subnetwork and share only the learned intelligence outside to minimize privacy risks. Confining data within the network is suitable for applications like in-body networks. With the vast number of applications in 6G and the massive data collection to feed ML/DL models, users would prefer different privacy levels on different applications. AI-based service-oriented privacy-preserving policy updates are a potential way to enhance privacy in automated 6G networks[3].

Inspired by this need, this study aims to conduct a thorough study on the emerging security and privacy issues in 6G and on how to address these issues. First, 5G network softwareization is expected to continue with security issues in 6G along with functional and performance improvements. Therefore, research to solve these issues based on artificial intelligence is needed. Second, security issues related to SDN, NFV, MEC, etc., which seek to improve 5G functions and performance through software, are expected to become more intelligent and advanced in 6G. Therefore, even in 6G, it is required to develop a technology that can overcome security issues in this area. Third, in a 6G IoE edge AI environment where billions of heterogeneous IoT devices are hyper-connected, a security technology that can overcome advanced intelligent attacks against IoE edge AI with limited computing resources is required. In addition, it is required to develop technology that can prevent damage to large-capacity collected data and protect sensitive personal information.

The security mechanisms designed for 5G using the concepts of SDN and NFV should be further improved to cater to the security demands in 6G networks. When 6G are harmonizing the concepts of SDN, NFV, and AI in an integrated environment to provide the necessary services, the system-level differences between 5G and 6G would introduce new security threats and privacy concerns. In this paper, we aim to identify and systematically analyse new security threats and privacy concerns of 5G technologies inherited from 6G and the corresponding 6G specific defences will also be investigated.

The remainder of the article is organized as follows. In the next section, the background and research trends related to 6G security and privacy. In chapter 3, we addressed our research approaches regarding softwarization security issues of 5G technologies inherited to 6G network. And, we describes the AI-enabled illegal traffic detection approaches in 6G network. In chapter 4, we describes the conclusion of this paper and the direction of future research.

## 2. RESEARCH BACKGROUNDS

### 2.1. Backgrounds

As the realization of digital transformation expected with 5G has already begun and continue to evolve over this decade, the 6G communication era envisions how humans will interact with the digital virtual worlds beyond 2030. 6G technology is being developed closely related to AI in the fields of federated learning, IoE, compressive sensing, post-quantum computing, and intelligent security. In addition, the standardization of 6G technology is aimed at full-scale commercialization after 2028. Up to now, the core technology and details of 6G are in the beginning stage, but the US, China, Korea, Finland, and Japan are actively conducting future research in each expected part and detailed area. Beyond 2030 wireless applications will demand much higher data rates, extremely low end-to-end latency, extremely high end-to-end reliability. Moreover, 6G networks will comprise a collection of heterogeneous dense networks embedded with connected intelligence and utilize hyper-connected cloudification. Service provision for extreme requirements with complex 6G requires sophisticated security mechanisms. The security mechanisms designed for 5G using the concepts of SDN and NFV should be further improved to cater to the security demands in 6G [5,6,7].

The end-to-end automation of future networks demands proactive threats discovery, intelligent mitigation techniques, and self-sustaining networks in 6G. Hence, the end-to-end security design leveraging AI techniques is essential to autonomously identify and respond to potential threats based on network anomalies rather than cryptographic methods. Network softwarization technologies are still applicable for 6G systems, the security issues associated with SDN and NFV would remain in 6G. Additionally, MEC in 6G is subject to physical security threats, Distributed Denial of Service (DDoS), and man-in-the-middle attacks [8]. Potential attacks for network slicing are DoS attacks and data theft via compromised slices [9]. Attacks on network softwarization fail the 6G network from achieving the promised dynamicity and automation. 6G envisions the realization of the IoE, a collection of billions of heterogeneous devices. Key distribution and management functions are highly inefficient in such a massive network [10]. The resource constrained IoT devices cannot afford complicated cryptography to maintain strong security [11], making them a primary target of the attackers. These devices can be compromised and potentially used to initiate attacks. Data collection by hyper-connected IoE to serve 6G applications raises privacy issues. Data theft by exploiting resource constrained IoT devices will affect data privacy, location privacy, and identity privacy. The present security mechanisms based on asymmetric key cryptography are vulnerable against quantum computer-based attacks as the 6G era will mark the presence of quantum computers. Thus, the 5G communications enabled with public key cryptography may be no longer secure without quantum-safe cryptographic algorithms [12]. In 6G, which aims to implement autonomous networks based on AI, attacks on AI models are expected to have a serious impact. Therefore, defences against poisoning attacks, data injection, model evasion, model reversal, model extraction and member reasoning attacks, etc., would become increasingly important.

### 2.2. State-of-Art Related Works

Multilayered intrusion detection and prevention using deep reinforcement learning and Deep Neural Networks (DNN) is viable in SDN/NFV-enabled networks [13]. They effectively defend IP spoofing attack, flow table overloading attack, DDoS attack, control plane saturation attack, and host location hijacking attack compared to several conventional approaches. ML approaches, such as Decision Trees and Random Forest, are also proved useful for detecting DDoS attacks in SDN environments due to their short processing time and accuracy, respectively [14]. ML-based

adaptive security approaches are effective against attacks on SDN/NFV as the 6G networks expect dynamic placement of virtual functions ed network. Hence, rule-based detection systems are ineffective. On-device resource limitations, the difficulty of key management in massive scale heterogeneous networks, the vast amount of device data make the conventional authentication/authorization systems insufficient for adequately securing large-scale IoT. Anomaly-based intrusion detection systems detect malicious packets based on their behavior [15]. In 6G networks, learning based detection systems could utilize various features of the data as the input; therefore, they are suitable for detecting zero-day attacks. The use of communication link attributes and user behaviours with machine learning for authentication and authorization [16, 17] is a better approach for resource constrained devices. The sub-networks in 6G, which can be considered an expansion of local 5G networks beyond vertical domains, can benefit from learning-based security techniques within the sub-network and between different sub-networks. ML-based algorithms deployed at the perimeter can capture the behaviour of other sub-networks and detect malicious traffic. To avoid poor communication efficiency, a sub-network can share only the learned security intelligence with others [18]. Nevertheless, a dedicated sub-network can use the shared intelligence, feed it into its ML models, determine the malicious traffic of other networks, and apply dynamic policies.

### **2.3. Research Motivations and Objectives**

The security mechanisms designed for 5G using the concepts of SDN and NFV should be further improved to cater to the security demands in 6G. As 6G moves toward THz spectrum with much higher bandwidth, more densification and cloudification for a hyper connected world by joining billions of devices and nodes with global reach for terrestrial, ocean and space, automated security utilizing the concepts of security function softwarization and virtualization, and machine learning will be inevitable. To eliminate constraints in existing and evolving 5G networks security, security systems using the existing concepts of SDN and NFV must be further improved with embedding intelligence for dynamicity to match the needs of 6G security. In this vain, intelligent security functions in containerized VNF box will monitor traffic in 6G residing in gateways to scan the traffic using continuous deep learning on a packet/byte level and applying machine learning to enforce policies, detect, contain, mitigate, and prevent threats or active attacks. Security functions using container technology offers better utilization rates, less storage requirements, enhanced security, and faster reboot time. Containers will be grouped into Pods, each Pod consisting of multiple containers on a single machine, with security service functions and providing availability through scaling up or down. The advances in cloud computing such as edge and fog computing will be used to maintain and deploy security functions (security VNFs) in different network perimeters as the use arises through proactive decision-making using machine learning. Building on the concepts of SDN, global resource visibility and event monitoring, with synchronized network security policies among different stakeholders, and programmable APIs, network abstractions will be used to ensure end-to-end network security. 6G networks will harmonize the concepts of SDN, NFV, and AI in an integrated environment not only to provide the necessary service, but also to ensure end-to-end network security. Programmable interfaces on programmable forwarding plane will enable deploying softwarized security functions much like VNFs in any network perimeter or instance in a virtual environment using AI not only proactively discover threats, but also to initiate security function transfer from point-to-point throughout the network. Automated, zero touch and zero trust security where zero trust for all North-South (N-S outbound/inbound traffic from/to data center) and East-West (E-W form container to another) cloud traffic must be checked with AI based ML for threat detection, prevention, and containment where the network can be treated as a giant firewall that integrates the flowing security functions.



When 6G networks are harmonizing the concepts of SDN, NFV, and AI in an integrated environment to provide the necessary services, the system-level differences between 5G and 6G would introduce new security threats and privacy concerns. This paper aims to identify and systematically analyse these new security threats and privacy concerns. The corresponding 6G-specific defenses will also be investigated.

### **3. AI-BASED SECURITY ENHANCEMENT AND PERSONAL INFORMATION PROTECTION TECHNIQUES ON 5G NETWORKS**

#### **3.1. Security Issues of 5G Networks**

Network softwarization technologies in 5G such as SDN, NFV, Multi-access Edge Computing (MEC), and network slicing are still applicable for 6G systems. Thus, their security issues would remain in 6G. SDN related prominent security issues are attacks on SDN controller, attacks on northbound and southbound interfaces, inherent vulnerabilities of platforms used to deploy SDN controllers/applications. NFV related security issues are attacks targeting Virtual Machines (VM), Virtual Network Functions (VNF), hypervisor, VNF manager, NFV orchestrator. Due to the massively distributed nature of 6G systems, MEC in 6G is subjected to physical security threats, DDoS, man-in-the-middle attacks. Potential attacks for network slicing are DDoS attacks, information theft via compromised slices. Although 6G network architectures are not completely immunized from the above-mentioned attacks, the newly added ML/DL capabilities in 6G networks provide exciting new opportunities to detect and defend against these attacks. How to leverage the new ML/DL capabilities for security purposes is an important problem which is still under investigated.

In order to properly leverage the new ML/DL capabilities for security purposes, the data characteristics of the vulnerabilities and attacks inherited from 5G should be firstly studied. To this end, we examine attack vulnerability detection and defence techniques for ML/DL-based SDN. In this process, we study network attack detection and mitigation techniques for SDN based on ML such as decision trees and random forests, and detection and effective mitigation techniques for IP spoofing, flow table overload, and DDoS attacks based on deep reinforcement learning and DNN. And, ML/DL-based 6G network vulnerability detection and defence technology are considered to detect and prevent attacks expected in 6G networks. In particular, terminal devices such as hardware and software manipulation attacks, physical attacks that access physical devices, false data injection attacks that threaten moving data, data tampering attacks, man-in-the-middle attacks, and DDoS attacks develop attack detection and mitigation technology. Finally, through R-threat insight research that extracts relationships between security vulnerabilities, we develop attack detection and mitigation technologies by quickly and accurately checking threats and tracking them.

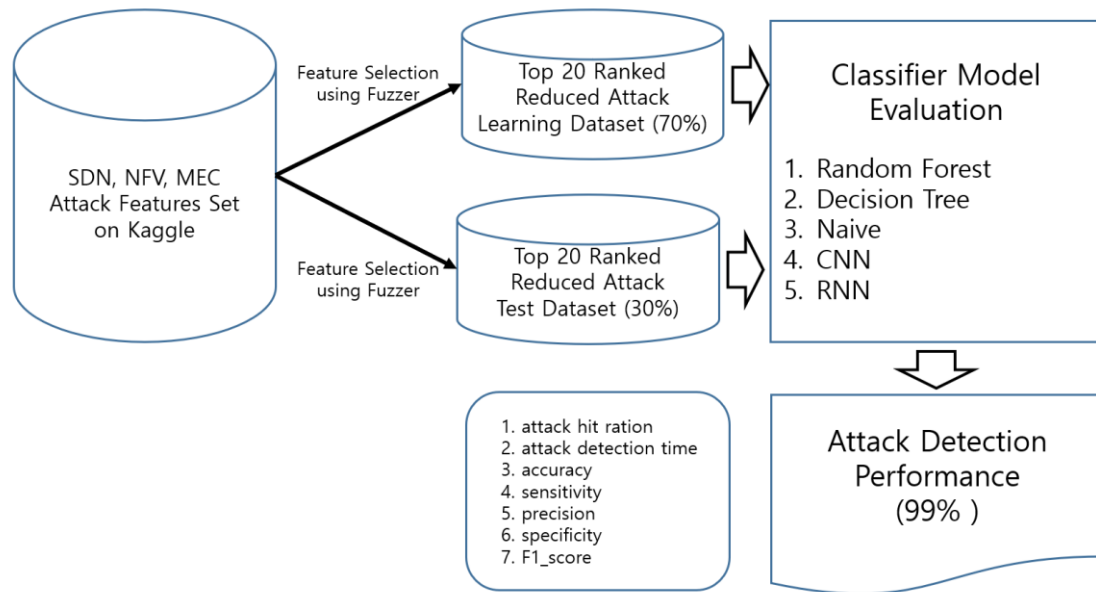


Figure 1. Structure of SDN, NFV, MEC Attack Detection Model

6G achieves connected intelligence via AI-enabled functions, especially with ML systems. We primarily utilized Kaggle to obtain reliable and diverse 6G threat data sets. For known attacks against 6G, fuzzing is used to identify each attack and collect the necessary data sets suitable for learning. In this way, the data can be automatically labeled by the fuzzer. Once the datasets are generated, we can train DNN models to detect attacks against 6G. In this way, we do not need to extract the features of such attacks. Through this, we could save a large amount of manual effort and increase the reliability and precision of the data. The DNN model completed through the proposed study is verified by applying it to the AI-enabled 6G smart factory sub-network and AI-enabled 6G i-transportation sub-network virtual environment. Through experiments, we evaluate effectiveness of the trained DNN models in detecting. In addition, we evaluated the model robustness against poisoning attacks, adversarial attacks, and relevant privacy threats. Finally, we quantitatively analyse the balance between the increased defense and performance degradation with our proposed mechanisms and model.

### 3.2. AI-enabled Detection of Illegal Traffic in 6G NETWORKS

6G envisions the realization of the Internet of Everything (IoE), a collection of billions of heterogeneous devices. The fundamental device security model relying on SIM cards is not a practical deployment for IoE in 6G, especially with the small form factor devices such as in-body sensors. Key distribution and management functions are highly inefficient in such a massive network. The resource-constrained IoT devices cannot afford complicated cryptography to maintain strong security, making them a primary target of the attackers. These devices can be compromised and potentially used to initiate attacks. Data theft by exploiting resource-constrained IoT devices will affect data privacy, location privacy, and identity privacy. When the attacker is using compromised devices to launch privacy and adversarial attacks, illegal traffic is in general unavoidable.

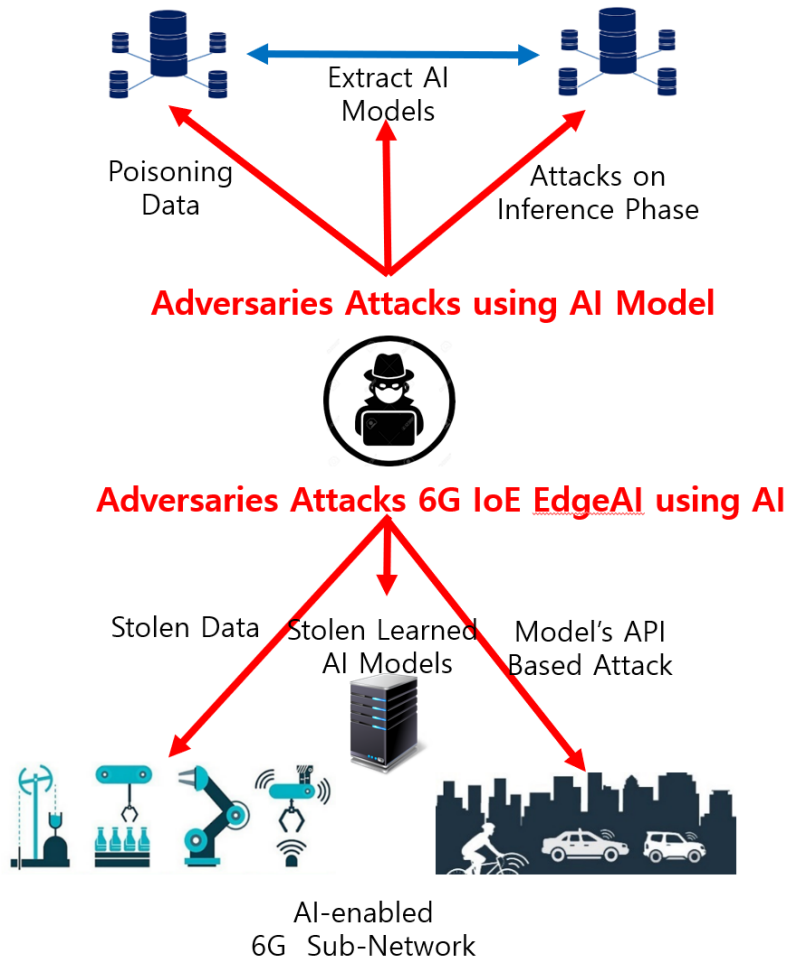


Figure 2. Structure of SDN, NFV, MEC Attack Detection Model

6G requires a massive amount of user data collected via billions of devices, and the users no longer foresee how external systems handle their data. For example, the 6G intelligent authentication systems depend on physical attributes and thus they may use private user data. Insecure IoT devices (ex: low powered sensors), which feed personal data to AI systems, are a major stepping stone for the attacker to launch attacks. Moreover, although edge-based federated learning preserves data privacy by imposing a physical control to maintain data closer to the user, the client ML/DL models being trained at the edge, could suffer from poisoning attacks launched from compromised IoT devices.

Compromised IoT devices feeding personal data to AI systems are a potential target for data theft. Model inversion attacks to retrieve the training data could also be a source for privacy violation. For known attacks against 6G privacy, fuzzing is basically used to identify each attack and collect the necessary data sets suitable for privacy learning. In particular, IoE EdgeAI-based federated learning preserves data privacy by imposing a physical control to maintain data closer to user. The data can be automatically labeled by the fuzzer. Once the datasets are generated, we can train DNN models to detect privacy attacks. In this way, we do not need to extract the features of such attacks. Through this, we could save a large amount of manual effort and increase the reliability and precision of the data we have obtained. The DNN models developed

through the proposed study will be verified by applying it to the AI enabled 6G smart factory sub-network and AI-enabled 6G transportation sub-network virtual environment built by the research team. Through experiments, we evaluate effectiveness of the trained DNN models in detecting the above-mentioned attacks. In addition, we will evaluate the models robustness against poisoning attacks and adversarial attacks.

#### 4. CONCLUSIONS

In this paper, we raised security and privacy issues inherited from 5G networks to 6G networks and presented a model to solve them. In addition, a method for detecting abnormal traffic expected in 6G networks based on ML/DL and a method for implementing it were presented. Currently, our proposed method has been implemented at the prototype level. In addition, noteworthy results can be confirmed through continuous experimental studies.

Currently, we are conducting various experiments. In this process, the maximum attack detection rate is 99%. For the objectivity and accuracy of the experiment, additional analysis studies are underway. In the future, we plan to derive more specific algorithm implementation, experimental results, and prove the experimental results through various simulations.

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# ON-PREMISE FILE SERVER VS CLOUD STORAGE WITH INCIDENT MANAGEMENT: A COMPARATIVE STUDY

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## **ABSTRACT**

*Many organizations are already shifting their infrastructure and applications to the cloud. Cloud technology is accessing and availing products and services over the internet. The maintenance of cloud technology is often managed by a cloud service provider. A comparison has been made between an existing technology, on-premise file servers, and virtualized file servers in the form of cloud storage to determine the advantages and disadvantages of each file-sharing system's performance. An architectural framework and a simulation of the new cloud storage architecture have been conducted to serve as file storage.*

*Finally, several users that are currently employing the existing on-premise file server technology have participated in user acceptance testing to try the cloud-based storage as a replacement for the file server. The test outcomes proved that end-users were able to execute their regular duties using cloud storage and that they favored it over their current file storage.*

## **KEYWORDS**

*Storage, Cloud, On-premise, Incident Management, Server, AWS*

## **1. INTRODUCTION**

In recent years, things have rapidly changed due to the global pandemic situation. Changes in information technology and computing systems need to be recognized by any organization and force them to move into the next generation of computing which is known as a paradigm shift [1]. Due to the recent COVID-19 pandemic, companies need to have a business continuity plan to continue delivering products and services despite the situation and the government announcement of a nationwide lockdown [2]. Employees are forced to continue working from home and sustain the expected deliverables. Companies went from fully occupied offices to skeletal staffing and later to a limited number of employees only reporting to the office physically. Employees have been migrated from desktops to laptops for the ability to work from home. Other physical devices that are essential for the company to function continuously, such as network switches, routers, access points, and servers, are all still sitting in the office and are accessed by the employees remotely.

One of the essential devices that the employees are required to access daily to perform day-to-day tasks is the file server. A file server, or a file-sharing system, is one of the key devices that support employees in saving and sharing important documents across the company. Various

documents such as images, PDF files, contracts, and client information are stored in a single repository for ease of access by the employees [3]. A file server also needs to be secured to protect confidential information stored within it. Since every employee is required to work remotely, a VPN connection is necessary to access the company resources. Even though the company finds it beneficial to access the company data in a single repository, even though these servers are physically available in the office, there are still some drawbacks experienced since the implementation of flexible working arrangements.

One of the technical drawbacks that the employees experience is that the connection is not stable. Employees experience latency and delay, especially when multiple users are accessing the server at the same time. Employees are unable to open the large files directly from the server, and the only workaround is to create a copy of the file from a local laptop to work on the file and put it back on the server once done. This causes a delay in doing daily work and too much of a hassle. If the employees will be working on hundreds of files, achieving the daily deliverable is a challenge. Another drawback is that due to the pandemic, the scalability of an on-premise server is limited and is often delayed.

If the storage capacity has been maximized, one of the solutions to resolve the problem is by upgrading the storage component, replacing the physical server, or migrating the server into a brand-new device, including the upgrade of software and hardware components which is very expensive. Based on the study, one of the major challenges for people working remotely mainly focuses on the technical issue [4].

Since there is limited staffing in most of the suppliers and vendors, upgrading the physical server was a challenge during the pandemic. Most of the suppliers receive materials from another supplier outside the country, and since the nearby borders were closed, materials needed were not delivered on time or not delivered at all. Maintaining the physical server would be a challenge as well for IT administrators and, at the same time, with vendors. A personal visit needs to be made in case they need to upgrade the hardware components. Most people did not risk their safety in traveling for work during the pandemic.

Alternatively, incident management is a way of handling incidents to avoid any disruption of a service provided by a system. An incident is a term used in the ITIL framework as any event that causes an interruption in service [5]. The main objective of incident management is to restore any interrupted service as quickly as possible and lessen the impact on the business. Incident management has different phases: incident detection, classification of incidents, investigation and diagnosis, resolution and recovery, and incident closure [6]. Incidents are prioritized based on urgency and business impact [5].

This study will focus on the comparison and benefits of both storage devices solving the technical challenges experienced by the employees of a company. The comparison can provide a solution to address the performance issues of the existing On-Prem storage approach. Automated incident management will also play an important role in achieving system reliability.

## **2. REVIEW ON RELATED LITERATURE**

Over the years, several studies have been conducted to improve the file-sharing system efficiently and effectively. Some of the considerations from previous research are cost-efficiency, time-efficiency, high performance, and can be easily managed by IT administrators. Different approaches and procedures were used in each study, but the best method only varies concerning the scenario or challenges they wanted to resolve.



A recent study proposed a new method of peer-to-peer transfer using client-to-client file transfer protocol (C2CFTP) which proves that the new method is more efficient in terms of direct and indirect transfer [7]. The objective of the study is to reduce the file transfer delay in client-server-client communication. The methods the researchers used to improve the file transfer between two clients are direct and indirect transfer. Different services are used to implement a direct transfer, such as file push, blocking channel, and file pull. Alternatively, file push and file pull services are used in the indirect transfer. The results have been measured statistically by comparing the speed of file transmission using the block/non-block method and the direct/indirect method. The system has seen that with the use of the proposed method, the average file transmission time has decreased by 54%. The study concluded that using the indirect and direct transfer method would efficiently increase the performance of file transmission with decreased time delay and is capable of transferring large amounts of data over the network.

A study about file servers and the task management function that works with a cloud services platform for cost reduction has been conducted by Namee K. [8]. The researcher found that using a cloud-based platform alone to run the websites would be too expensive. The purpose of the study is to implement a technique for a web application to function on a cloud-based platform with the help of an on-premise file server. The researchers used Microsoft Azure as the cloud-based platform to run the website, Trello as the web-based application that creates a list of tasks created by the user, a file server that is used to store the files (.html), Microsoft To-Do is another web-based application that enables users to create tasks, and last is the Microsoft Planning which is another web application that enables a user to create tasks. In web design, the users have the choice of which web application platforms to use (Trell, Microsoft To-Do, or Microsoft Planning). Results show that users can access the website successfully after authentication has been made on Azure AD.

Data storage in cloud computing is critical in handling data security in terms of confidentiality, integrity, and availability. The main objective is to discuss possible security issues presented in the cloud environment and techniques on how to secure the data. Based on the research, to protect confidentiality, data needs to be encrypted. Data stored on a public cloud can be easily attacked internally and externally. Data integrity can be protected by using digital signatures to avoid unauthorized modification of data to maintain accuracy. By using these two mechanisms, the researchers can ensure that the data will remain available to be accessed by authorized users anytime and anywhere. To address data security in the cloud, a service-level agreement between the customer and the service provider should include and highlight an agreement for the confidentiality, integrity, and availability of data.

Another approach to improving file systems was conducted in a study by Liu et al. [9], where a new storage architecture has been studied/implemented and called FSP with the creation of a system prototype called DashFS (file system as a process). The main objective of this study is to improve the performance of storage systems while maintaining data quality and integrity. Different system frameworks already existed but had performance issues. Existing frameworks often use kernels when communicating with different processes which causes slowness (100 microseconds). Some existing frameworks do not involve kernels or minimally use kernels, but there are some security challenges. Using DashFS, file system operations are being supported by minimizing crash consistency and using a simple data structure. The system also improves the performance by reducing latency by 43%.

Incident management is a tool used in a water treatment facility to track down any unplanned service interruption, such as equipment breakdown, groundwater issues, and other unknown events [10]. In a recent study, the researchers developed an internet-based incident management tool to enable the operations communication center to monitor, communicate, and document

operation-related activities to provide a better service. A workflow diagram has been created for the entire process of identifying, categorizing, resolving, and closing incidents. A prototype has been created using ASP.net, SQL database, and SMS API. Results were gathered through user acceptance testing (UAT) questionnaires, and it has been shown that end-users have supported the system proposed.

Industries are rapidly shifting into a new generation of digital transformation, adopting a holistic approach towards new business models, reconstructing architectural designs, and reforming the products and services to establish continuous growth and the need for continuous improvement in supplying service offerings to customers and an improved relationship with partners and suppliers [11]. As quoted by a Greek philosopher, “Nothing is constant but change” also applies to the world of technology. Shifting into a new infrastructure towards the cloud has proven beneficial in recent studies.

Although public cloud storage has received tremendous growth over the past years, organizations are facing higher risks in cyber-attacks such as denial-of-service (DDoS), man-in-the-middle, phishing, password attacks, and many more. Billions in company revenue may be affected once they encounter data breaches. In a study by Kolevski et al., [12] three top companies in the United States (i.e., Sony, Anthem Healthcare, and Equifax) faced the risk of a data breach.

Since the pandemic, more and more companies are facing the risks of cyber threats since most of them are exposed to a public internet connection. Based on the existing studies above, this paper describes some of the key differences, benefits, and risks between on-prem file storage and cloud storage.

### **3. METHODOLOGY**

In this study, an actual simulation of deployed cloud-based storage will be performed for a better understanding of the advantages to the organizations. The storage simulation has been divided into four phases. Phase one will focus on simulating the actual client workstations, on-premise servers, and secured cloud-based storage which is all connected to a single hosted domain, mittip.info. The storage has been configured in this phase to have auditable logs which will be used in phase two for reporting. An automated backup and backup retention policy are also set in this phase. This phase will achieve the scalability and fault tolerance of the system. Phase two is all about monitoring the health of the storage which will help the study achieve storage availability. Alarms are configured in this phase to set notifications when an anomaly has been detected. Messaging or sending communications or notifications is the focus of phase three. Topics and subscriptions are created so that notifications can be delivered through the desired communication channel. To ensure that any incidents that will occur in the system will be resolved as quickly as possible, the fourth phase will focus on incident management and help with incident logging, tracking, escalations, and resolutions.

The fifth and final phase of the experiment will focus on measuring the success of the system by conducting UAT. Multiple accounts have been created in AWS using the IAM tool. Individual testers will use each of the accounts to log in to the client workstation to test the connectivity and performance of the file server. Each account has been added to the Manila group which contains the security permissions of the cloud storage. Accounts that are created but are not members of the Manila group will not have access to the cloud storage. FSx cloud storage is mapped into the Manila group using a group policy object (GPO).

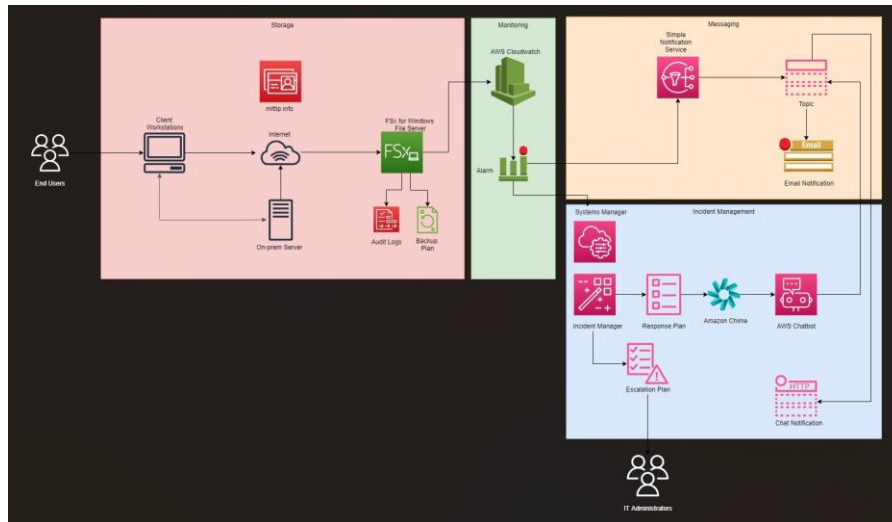


Figure 1. Proposed Cloud Storage Architecture

### 3.1. Storage Deployment

To address the main objective of the study, a public cloud storage deployment process has been used. The Mittip.info domain has been created to create necessary users and groups to verify the success of the study. Two elastic computing instances have been created to serve as a client and a server. The client machine will serve as a workstation while the server will be used to manage the active directory users and group policy objects which is necessary for automated mapping of the file share. FSx for Windows has been configured to serve as a file share with additional features of audit logs for enhanced security and a backup plan for data availability.

The steps below are taken in phase one:

1. A virtual private cloud (VPC) has been created in AWS to serve as a virtual network which will then be associated with other services that will be created. Subnet masks have been created in VPC to be allocated to the domain controllers, virtual machines, and file storage.
2. A domain has been created and hosted online to be used in this study. Once the domain has been hosted, it needs to be registered into the directory services offered by AWS, as shown in Figure 9. Upon creation of the domain, it needs to be associated with a VPC created in AWS.
3. Two virtual machines have been created using the EC2 services offered by AWS. One of the VMs has been created to serve as a client machine (Figure 12), and the other one has been created to serve as a physical server with additional configurations. Both VMs have been joined into the mittip.info domain.
4. Active directory accounts and group policy features are installed on the server which are both necessary to automate the mapping of the created file storage.
5. File system has been created using the FSx for Windows Server, allocating the virtual network and domain controller created earlier. An availability zone is set as well which will make the system fault-tolerant in a way that there are backup data centers in the region we have selected. KMS key ID is automatically enabled as an additional security feature that encrypts data at rest.
6. After creating the file system, it can now be attached to any devices connected to the mittip.info domain but using the command “net use \\<hostname>.<domain>\share.”

7. A user account and a security group have been created in Active Directory. The user account has been added as a member of the security group.
8. A GPO has been created and linked to the security group in the active directory. The GPO has been configured to map the file system created using the file path “\\<hostname>.<domain>\share.” The file path is set to be mapped as M:\ drive from the GPO and will be mapped automatically upon the user sign-in.
9. File access auditing is an automatically enabled feature of FSx that records the logs of the file system whenever changes occur. These audit logs can be viewed in CloudWatch with a visualization.

### 3.2. Monitoring Storage Health

Maintaining system availability, reliability, and performance is also essential. By monitoring the storage health with the help of CloudWatch, alarms and thresholds can be configured to prevent system downtime. CloudWatch offers metrics to determine the performance of Amazon services and help detect anomaly-based events which can be configured to create alarms based on the thresholds. Events can also be configured to clean up to a much more user-friendly notification.

The steps below are taken in phase two:

1. CloudWatch has been configured in this phase. The purpose of this service is to create alarms if an anomaly has been detected. Conditions and thresholds can be set to trigger the alarm and send notifications.
2. Additional alarms are configured to monitor the data being written in the storage account. It will help determine if the storage capacity allocated is nearly full or if there are too many hosts connected to the storage at the same time.

### 3.3. Messaging

Monitoring server health is not useful without notifying the concerned resources to fix any anomaly experienced by the system. Messaging plays an important role in notifying the resources needed to fix any issues encountered. Topics are created in SNS which can be used as a subscription to receive notifications by concerned individuals.

The steps below are taken in phase three:

1. A Simple Notification Service topic and subscription have been created in AWS to receive notifications created by the alarms. Notifications can be in the form of email and SMS.
2. Email notifications sent through Amazon are in JavaScript object notation (JSON) format, and it will be difficult for a non-technical person to understand. For the notifications to be more precise and understandable, A JSON cleanup has been set to indicate the input path and input template when triggered through CloudWatch Events.

### 3.4. Incident Management

To ensure the service remains uninterrupted or to bring back any uninterrupted service as quickly as possible, an automated incident management process has been created in AWS which is connected to alarms and thresholds set by CloudWatch. Incident management helps to prevent any serious incidents that may happen in the system. With the help of response, escalation, and engagement plans, necessary IT resources can help resolve issues in the system detected by CloudWatch. CloudWatch triggers the alarm which sends a signal to the systems manager in

creating an incident ticket. Once a ticket has been created, it will perform necessary actions such as a response plan which is responsible for sending a signal to SNS to send notifications to the ones who are subscribed to the topic. It will also trigger the escalation plan and engagement plan to gather the required individuals to resolve the issue.

The steps below are taken in the final phase:

1. A response plan has been created to automate the creation of critical tickets received through the CloudWatch Alarms. The automation was enabled in AWS Systems Manager. Incident tickets will be created automatically which can easily help identify the issue.
2. An escalation plan has been created as well to escalate an incident logged to the correct support group. Additional contacts can be added as needed; durations can be configured at the time of engagement between support staff. For the contacts to be included in an escalation plan, they need to be added to the list of contacts first.
3. A chat channel and engagement have also been created. The purpose of this chat channel is to engage the selected contacts to a channel in Amazon Chime to collaborate and provide a resolution to the incident.
4. An email will be sent to the contacts once they have been engaged with an acknowledgment code they need to enter once they open the incident ticket.
5. A chatbot has been created to easily provide reports to the engaged contact in Amazon Chime, from ticket creation to ticket resolution.

## **4. RESULTS**

A comparison between cloud storage and on-premises storage has been conducted to determine which of the storage solutions is better. Below are the key performance indicators used to measure each of the aspects discussed in the evaluation.

### **4.1. Costs and Maintenance**

To determine the comparison of costs and maintenance of on-premise servers, this study skimmed different compute provider websites and produced an estimate of the pricing based on their recent offers for extensive server requirements of medium to large enterprises.

Alternatively, Amazon has a pricing calculator based on a consumer consumption model which allows consumers to forecast the estimated monthly costs based on the specifications and resources or services availed. Shown in Table 1 are the data gathered.

Table 1. On-prem Total Cost in 5 Years

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Processor (Intel Xeon)	\$813.12	\$0.00	\$0.00	\$0.00	\$0.00
64 GB RAM	\$350.31	\$0.00	\$0.00	\$0.00	\$0.00
10 TB HDD	\$1,169.53	\$0.00	\$0.00	\$1,831.21	\$0.00
Electricity	\$9,652.61	\$9,652.61	\$9,652.61	\$9,652.61	\$9,652.61
Staffing (2 IT Staffs)	\$25,958.57	\$28,554.42	\$31,409.86	\$34,550.85	\$38,005.94
Throughput Capacity	\$1,375.71	\$1,375.71	\$1,375.71	\$1,375.71	\$1,375.71
Backup Storage	\$813.12	\$0.00	\$0.00	\$0.00	\$0.00
Data Transfer	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Operating System	\$5,797.42	\$0.00	\$0.00	\$0.00	\$0.00
Total Cost in 5 Years					\$224,395.95

Table 2. Cloud Total Cost in 5 Years

Item	Year 1	Year 2	Year 3	Year 4	Year 5
Processor (Intel Xeon)	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
64 GB RAM	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
10 TB HDD	\$1,445.77	\$1,445.77	\$1,445.77	\$1,445.77	\$1,445.77
Electricity	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Staffing (2 IT Staffs)	\$12,979.28	\$13,628.25	\$14,309.66	\$15,025.14	\$15,776.40
Throughput Capacity	\$5839.6	5839.6	\$5839.6	\$5839.6	\$5839.6
Backup Storage	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Data Transfer	\$271.16	\$271.16	\$271.16	\$271.16	\$271.16
Operating System	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Total Cost in 5 Years					\$109,501.38

The costs calculated in an on-premise server are based on the current market value and life cycle. For example, the current market value of a server processor is \$813.12 and has a life cycle of three to five years. After five years, it will no longer be supported and needs to be replaced. The same goes for the memory and hard drives. Electricity and throughput charges remain the same throughout the following years, although it is expected to increase or decrease depending on the economy. Two IT staff with a market value of \$12,979 per year accumulate 5% of their yearly salary. Backup storage has the same value as the server processor since both are servers. Since the server is located locally, data transfer will not accumulate extra charges. The newest server OS released by Microsoft costs \$5,797.42 and has a life cycle of 10 years.

Throughput capacity refers to the bandwidth speed for file transfers. The computation for on-premise is based on a known internet service provider in the Philippines with 200 MBps speed. Alternatively, cloud throughput capacity is determined on the initial setup of Amazon FsX which

is assessed per MBps. In this study, 200 MBps of throughput capacity only dedicated to FsX has been configured. The computation is shown below:

$$\begin{aligned}
 &1 \times 8 \text{ MBps per month} = 8.00 \text{ MBps per month} \\
 &\text{Max}(50, 8.00) = 50.00 \text{ MBps per month} \\
 &200.00 \text{ MBps of provisioned throughput} \times 2.479 \text{ USD per MBps-month} = 495.80 \\
 &495.80 \text{ USD} \times 12 \text{ months} = 5829.6 \text{ USD}
 \end{aligned}$$

Backup storage also requires upfront costs for on-premise servers since separate hardware equipment is needed for it to function as a backup server. Whereas Amazon already offers both automatic and user-initiated backup. Backup costs in AWS are determined through the hardware capacity configured. Data transfer is billed by “in” and “out” from Amazon by 0.12 USD per GB in. 200 GB of data per month would be 24 USD, unlike the on-premise in which data can be copied across different client machines or different servers on an infinite basis. The computation is shown in Tables 1 and 2.

#### 4.2. Throughput, IOPS, and Response Time

In evaluating the storage performance, three key aspects have been thoroughly analyzed: throughput, input/output per second (IOPS), and response time. Powershell is used as a benchmarking tool to assess the performance of each storage device. Powershell is a built-in command-line-based tool included on every Windows machine.

Throughput or data transfer is measured through megabytes per second. IOPS is the measurement of storage devices on how fast read and write are performed per thread. Last, response time is determined by how fast the system will respond to the requests and is usually measured in milliseconds (ms).

In testing the different aspects of the storage performance, two testing scenarios have been done: sequential operation testing and random operation testing. Sequential operation pertains to accessing locations in a non-stop manner and is usually connected to data files of larger sizes. Random operation pertains to a non-continuous manner that is connected to smaller data files. Figure 2 and 3 show the script that runs on both on-prem and cloud storage devices. The description of the parameters used on the testing script is shown in Table 3.

```
PS C:\temp\disk_perf_iops (1)> .\DiskPerformance.ps1 -TestFileName test.dat -TestFileSiz
eInGB 1 -TestFilepath D:\ -TestMode Get-LargeIO -FastMode True -RemoveTestFile True -Out
putFormat Out-GridView
```

Figure 2. Sequential Operation Testing Script

```
PS C:\temp\disk_perf_iops (1)> .\DiskPerformance.ps1 -TestFileName test.dat -TestFileSiz
eInGB 1 -TestFilepath D:\ -TestMode Get-SmallIO -FastMode True -RemoveTestFile True -Out
putFormat Out-GridView
```

Figure 3. Random Operation Testing Script

Table 3. Powershell Script Parameters

Parameters	Description
-TestFileName	Name of the file created by the script
-TestFileSizeInGB	File size of the test data
-TestFilepath	Location of the drive that needs to be tested
-TestMode	Get-LargeIO - For large data size (sequential) Get-SmallIO - For small data size (random)
-FastMode	Each test runs for 10 seconds
-RemoveTestFile	Remove the test file once the script has been completed
-OutputFormat	Format of the results that will be displayed

Sequential operation testing is determined by using 512 kb of data. The results are shown below:

Table 4. Sequential Operation Testing

MB/s	IOPS	Latency (ms)	Type	Target
102.9	205.8	4	sequential	D:\\test.dat
113.01	226.03	8	sequential	D:\\test.dat
116.22	232.45	12	sequential	D:\\test.dat
113.37	226.75	17	sequential	D:\\test.dat
111.83	223.66	21	sequential	D:\\test.dat

Table 5. Sequential Cloud Testing

MB/s	IOPS	Latency(ms)	Type	Target
1192.51	2385	0	sequential	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
1639.45	3278.9	0	sequential	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
2150.44	4300.9	0	sequential	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
2162.85	4325.7	0	sequential	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
1901.54	3803.1	0	sequential	\\amznfsx0ogpdjtx.mittip.info\share\test.dat

Throughput - Based on the results gathered, data transfer speed on the cloud increased gradually with every thread, while the on-prem throughput has an unstable speed. The first thread from the cloud is 168% faster than the first thread from on-premises. The average throughput of the first 5 threads in the cloud is 1809.39 MB/s which is 177% faster compared to on-prem only gives 111.47 MB/s.



IOPS - From the data gathered, the cloud's read/write operations have a speed of 2385 IOPS during the first thread compared to 205.8 IOPS in on-prem which is 168% faster. Compared to the throughput, IOPS is not increasing gradually per thread, but the speed is maintained on both devices. The average sequential IOPS for the cloud is 3618.72, and the average sequential IOPS for on-prem is 222.9. Cloud IOPS is 177% higher than on-prem.

Response time - based on the results indicated under latency ms, on-prem storage has a four-second delay in responding to the requests which gradually increases per thread. Alternatively, cloud storage maintains system responsiveness of a zero-second delay which is better than on-prem. The average response time of the cloud is zero, while the on-prem has 12.4ms which is 200% faster. The higher the response time is, the higher the latency is experienced. Random operation testing is determined by using an 8kb file size.

Table 6. Random On-prem Testing

MB/s	IOPS	Latency (ms)	Type	Target
110.91	14197.68	1	random	D:\\test.dat
112.77	14435.67	2	random	D:\\test.dat
105.93	13559.7	2	random	D:\\test.dat
105.47	13501.09	2	random	D:\\test.dat
109.16	13972.74	2	random	D:\\test.dat

Table 7. Random Cloud Testing

MB/s	IOPS	Latency (ms)	Type	Target
191.95	24570.45	0	random	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
175.75	22496.92	1	random	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
168.54	21573.96	1	random	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
178.61	22863.04	1	random	\\amznfsx0ogpdjtx.mittip.info\share\test.dat
166.43	21303.05	1	random	\\amznfsx0ogpdjtx.mittip.info\share\test.dat

Throughput - From the results of the data gathered, throughput can be seen with a stable transfer rate. Cloud has a transfer rate of 191.95 MB/s compared to 110.91 MB/s of on-prem during the first thread which is still 54% faster. The average transfer rate of cloud storage is 176.25 MB/s, and on-prem storage is 108.9 MB/s. The average throughput of the cloud is 47% faster than the on-prem's throughput.

IOPS - Both cloud and on-prem storage have a massive increase in random operation testing compared to sequential operation testing which is expected since the data size used in this testing

is much smaller. Cloud's IOPS during the first thread is 24570.45 compared to 14197.68 IOPS of on-prem which is 54% higher. The average cloud IOPS is 22561.48, while on-prem has only 13933.38. The average IOPS of the cloud is 47% faster than that of on-prem IOPS.

Response Time - Results from the data gathered in random operational testing show that the latency of on-prem gradually decreased compared to the sequential operation testing, while the cloud's response time has increased a bit but is still faster compared to on-prem. The latency experienced through the first 5 threads of on-prem ranges from 1-2ms, while on cloud, it ranges from 0-1ms. The average latency of the cloud is 0.8ms compared to 1.8ms of on-prem which is 77% higher.

### 4.3. Incident Management

Table 8. On-prem Incident Management (Manual)

Created	Date Closed	Engagement Time	MTBE
08/06/20 22 19:35	13/06/2022 21:00	10/06/2022 19:41	2 days, 00 hours, 05 minutes, and 56 seconds
12/06/20 22 12:55	17/06/2022 15:00	13/06/2022 13:11	1 day, 00 hours, 16 minutes, and 19 seconds
11/06/20 22 13:45	16/06/2022 16:00	12/06/2022 13:46	1 day, 00 hours, 00 minutes, and 34 seconds
07/06/20 22 22:40	21/06/2022 17:01	07/06/2022 23:21	0 day, 00 hours, 41 minutes, and 00 seconds
09/06/20 22 1:33	14/06/2022 4:00	10/06/2022 2:07	1 day, 00 hours, 33 minutes, and 24 seconds

Table 9. Cloud Incident Management

Created	Date Closed	Engagement Time	MTBE
17/03/2022 0:23	2022-03-18 00:26:40	17/03/2022 0:23	0 days, 00 hours, 0 minutes, and 0 seconds
07/06/2022 20:27	2022-06-07 20:41:34	07/06/2022 20:27	0 days, 00 hours, 0 minutes, and 1 seconds
08/06/2022 20:05	2022-06-08 20:09:41	08/06/2022 20:05	0 days, 0 hours, 0 minutes, and 1 seconds
08/06/2022 20:53	2022-06-08 20:58:40	08/06/2022 20:53	0 days, 0 hours, 0 minutes, and 1 seconds
17/06/2022 8:26	2022-06-17 08:27:31	17/06/2022 8:26	0 days, 0 hours, 0 minutes, and 11 seconds

Mean time between engagement (MTBE) is measured between the time the ticket has been lodged and the acknowledgment of the support team. Incident age is determined between the time of incident creation and the resolution. The results show that an automated incident management approach can help close the gap of manual engagement of necessary staff to address the issues of an incident.

#### **4.4. User Acceptance Testing**

To determine the success of the system, UAT has been implemented to gather feedback from existing users of file servers. Each of the users who participated has tested if they can perform their day-to-day tasks in the file server. The questions are basically to perform add, edit, transfer, and delete files on the cloud storage. They were also given a chance to rate the performance of the cloud storage to the existing file server they are using. The testing is categorized into two different areas: the client machine and the cloud storage.

The results from the testing validated that users could perform their day-to-day tasks using AWS, and they are rating it better than the current file server they are using.

### **5. CONCLUSION**

A comparison between cloud storage and the traditional on-premise file server has been made in this study. Different aspects of both storages have been thoroughly analyzed, including cost, maintenance, performance, and incident management. Since the cloud removes the upfront costs (CaPex) and only provides operational costs (OpEX), the results from cost and maintenance proved that the cloud offers a much more cost-efficient service compared to on-prem in the span of 5 years.

Performance data are gathered on two different kinds of testing: random operational testing and sequential operational testing. Throughput, IOPS, and response time are the performance counters measured which have been evaluated using a benchmarking tool. Based on the results of the testing, the cloud's throughput, IOPS, and response time are better compared to on-prem.

Automated incident tracking and manual incident tracking have been evaluated as well based on the actual incident tracking tool for on-prem and a simulated incident tracking tool in the cloud. The results show that by using an automated incident tracking tool, the engagement time between the system issue and the support can be lessened which can result in a faster resolution of issues. Last, testing based on end-users perspectives has been conducted to evaluate the cloud storage as a replacement for on-prem, where the users have concluded that the performance is better in the cloud.

Overall, given the results from the various aspects of thorough research and testing. Companies may find cloud storage beneficial compared to on-prem storage. It is more cost-efficient, easy to maintain, delivers better performance, provides enhanced availability with the help of automated incident management, and is user-friendly.

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## AUTHOR INDEX

<i>Afolabi</i>	29
<i>Akinwande</i>	29
<i>Alexander Jesser</i>	111
<i>Alexander Wu</i>	77
<i>Amelia Wu</i>	77
<i>Anne Yunsheng Zhang</i>	121
<i>Benjamin Jauvion</i>	123
<i>Bobby Nguyen</i>	63
<i>Byung-Suk Seo</i>	261
<i>Chao Qi</i>	53
<i>Chul-Long Kim</i>	261
<i>David Noever</i>	01
<i>Diane Fulton</i>	165
<i>Durojaiye</i>	29
<i>Emily X. Ding</i>	147
<i>Fabien Medard</i>	123
<i>Fuyi Xie</i>	181
<i>Hardik Shah</i>	233, 247
<i>Iñigo Parra</i>	195
<i>J. Mayowa</i>	29
<i>Jaymie Rae Medina</i>	127
<i>Jennalyn Mindoro</i>	127
<i>Jiajia Zhu</i>	53
<i>Jonathan Sahagun</i>	43
<i>Jun-Seop Lim</i>	261
<i>Jonathan Sahagun</i>	43
<i>K. Tobi</i>	29
<i>Kwang-Man Ko</i>	261
<i>Leonid Slovianov</i>	139
<i>Lewys Correa Sánchez</i>	209
<i>M. Olalekan</i>	29
<i>Megan Wei</i>	63
<i>Mehdi Mounsif</i>	123
<i>Miguel J. Espitia R</i>	209
<i>Minuo Qing</i>	147
<i>Moddwyn Andaya</i>	77
<i>Nate Haynes</i>	165
<i>O. Austine</i>	29
<i>Octavio José Salcedo Parra</i>	209
<i>Rania A Aboalela</i>	87

<i>Richard Fulton</i>	165
<i>Robert J. Hou</i>	147
<i>Samantha Elizabeth Miller Noever</i>	01
<i>Seong-Won Kim</i>	261
<i>Susan Kaplan</i>	165
<i>Syed Amir Hamza</i>	111
<i>T. Osariemen</i>	29
<i>T. Toyibat</i>	29
<i>Tianmu Li</i>	99
<i>Unuriode</i>	29
<i>Viktoria Kondratenko</i>	139
<i>Y. Babatunde</i>	29
<i>Yanbo Wang</i>	43
<i>Yiyao Zhang</i>	121
<i>Yu Sun</i>	121
<i>Yussuph</i>	29
<i>Yusuf</i>	29
<i>Zihao Luo</i>	181