A SMART ART-INSPIRED AUTOMATED STAGING DESIGN AND FURNITURE RECOMMENDATION SYSTEM USING ARTIFICIAL INTELLIGENCE AND DATA SCIENCE

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ABSTRACT

Designify is an innovative application that integrates artificial intelligence (AI) and augmented reality (AR) to revolutionize interior design [1]. The project leverages Google's Gemini AI model to provide users with personalized furniture recommendations based on room dimensions and layout, while the AR system allows for real-time visualization and interaction with virtual furniture [2]. Two key experiments were conducted to evaluate the system's effectiveness: the first tested the accuracy of the AI model across various room layouts, and the second measured the efficiency of user interactions within the AR environment [3]. The results showed that the AI performed well in standard room layouts but struggled with irregular spaces, while the AR system was intuitive for simpler tasks but required refinement for more complex interactions. These findings provide insights for improving both the AI's spatial reasoning and the AR gesture system, offering a strong foundation for future development and user-centered enhancements [4].

KEYWORDS

Augmented reality, Artificial Intelligence, Interior design, Furniture Recommendation, Flutter

1. INTRODUCTION

The process of designing interior spaces presents numerous challenges for individuals who lack access to professional designers or visual planning tools [5]. Many homeowners and renters struggle with choosing furniture that not only fits their space but also complements the overall design and functionality of their rooms. According to surveys, over a third of people report difficulties in visualizing how furniture will look once arranged in their homes. The absence of visual aids and interactive tools results in inefficient use of space, poor furniture selection, and dissatisfaction with the final layout.

This problem becomes even more pressing in urban environments where space is limited, and multifunctional furniture pieces are increasingly necessary. Without the ability to effectively plan, individuals often resort to trial-and-error methods, which can be costly and time-consuming. In a world that values efficiency, finding a modern, user-friendly solution to help individuals design their spaces has become crucial.

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The furniture industry, too, is impacted by this issue. With higher return rates due to buyer dissatisfaction, manufacturers and retailers incur additional costs. A 2021 study by Statista showed that online furniture return rates had increased by 15%, with the main reason being the discrepancy between expectation and reality. Consequently, the need for a tool that allows users to visualize their choices before purchasing can significantly benefit both consumers and the industry as a whole.

The three methodologies attempted to address the challenges of using augmented reality (AR) and artificial intelligence (AI) in interior design. Hui (2015) introduced a system for collaborative 3D model creation between designers and clients, but it relied on specialized hardware that limits accessibility [6]. Phan and Choo (2010) presented a more flexible AR system that allowed real-time interaction with virtual furniture, though it required external hardware for effective use. Finally, Patil (2018) developed an AR system that leveraged real-time tracking and 3D mapping algorithms to enhance precision but at the cost of added complexity in its setup. Our project improves on these works by focusing on mobile accessibility, removing the need for specialized hardware, and optimizing performance, making AR-driven interior design more intuitive and user-friendly.

Designify offers a modern, intuitive solution to these challenges by providing tailored furniture recommendations based on room dimensions, style preferences, and user interaction. By combining machine learning algorithms with augmented reality (AR), the app allows users to virtually place furniture in their rooms to see how the pieces will fit and look before making a decision [7].

The app leverages AI to analyze the dimensions and layout of a user's space, offering personalized suggestions for furniture that fits both stylistically and functionally. The AR capabilities further enhance the user experience by offering an interactive, realistic preview of how the selected furniture will appear in the actual space. This method effectively solves the visualization problem by allowing users to experiment with various layouts and designs without committing to a purchase. Compared to traditional methods or other design apps, Designify stands out by merging AI-driven recommendations with real-time AR, making it an efficient and innovative solution.

In this project, two experiments were conducted to assess the effectiveness of Designify's AI-driven furniture recommendations and AR interaction system.

The first experiment tested the accuracy of the Gemini AI model in recommending furniture for different room layouts. The experiment involved feeding the AI room images of various sizes and shapes—small, large, and irregular—and comparing its recommendations to those of professional designers. The most significant finding was that the AI performed well in standard room layouts, achieving 75-80% accuracy, but struggled with irregular spaces, achieving only 65% accuracy.

The second experiment evaluated user interaction efficiency with the AR system. Participants completed tasks such as adding, moving, scaling, and rotating furniture. The experiment revealed that users could quickly complete simpler tasks but faced challenges with scaling and rotating furniture, resulting in higher error rates. These results highlight the need for further refinement of the AI model for complex spaces and the AR system for advanced gesture control.

2. CHALLENGES

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

2.1. Developing A Comprehensive And Diverse Furniture Database

One significant challenge in building Designify is developing a comprehensive and diverse furniture database. The database must contain high-quality images of furniture from various brands, styles, and categories, each with detailed metadata such as dimensions, material, and color. Additionally, these furniture images need to be processed to remove the background so that they can be seamlessly integrated into the user's room through AR visualization.

To address this, the app could utilize automated background removal tools that employ deep learning techniques, such as U-Net or Mask R-CNN, to accurately separate the furniture from its background. Ensuring that the database remains up-to-date with new designs and trends is also a key factor. This can be managed by regularly updating the database with new product images, potentially through partnerships with furniture retailers. Maintaining high accuracy in background removal is essential to ensure a realistic and immersive experience for users when they visualize furniture in their rooms.

2.2. Providing Personalized And Relevant Furniture Recommendations

Providing personalized and relevant furniture recommendations is another challenge. The AI model must be trained to understand diverse design styles, user preferences, and spatial layouts. Since user preferences vary widely, it is critical to collect and analyze enough data to make accurate suggestions. The solution here involves continuously training the AI with user feedback and expanding the data set with various design styles, ensuring that the recommendations are both functional and aesthetically pleasing.

2.3. User experience

Rendering real-time AR models of furniture in a room can strain a mobile device's hardware, especially on older devices. To ensure smooth performance and a positive user experience, the app must optimize the rendering of 3D models while maintaining high visual fidelity. This can be achieved by using lightweight 3D models and efficient algorithms for real-time rendering, as well as by allowing users to adjust the rendering quality based on their device's performance capabilities.

3. SOLUTION

Designify's architecture comprises three core components: Firebase, Gemini AI, and AR Visualization. These components work together to provide users with a seamless experience, allowing them to scan their rooms, receive AI-driven furniture recommendations, and visualize the results in real-time using augmented reality.

Firebase for Data Management: Firebase plays a crucial role in storing and managing the furniture database, user data, and scanned room images [8]. The Firestore database holds furniture details such as dimensions, images, and styles, while Firebase Storage manages and serves images in real-time, ensuring that the app is always updated with the latest options.

Gemini AI for Furniture Recommendations: The Gemini 1.5 Flash model from Google's Generative AI suite is used to process room and furniture images, providing users with tailored furniture recommendations [9]. The model analyzes the room layout and images provided by the user and suggests the most suitable furniture items based on the room's dimensions and style preferences. This recommendation engine enables users to make well-informed design decisions, leveraging AI's ability to recognize patterns and optimize furniture placement.

AR Visualization for Real-Time Interaction: The augmented reality (AR) system allows users to interact with their virtual furniture choices in real time [10]. After receiving the AI-generated furniture recommendations, users can place, move, scale, and rotate the items within their scanned room environment. The AR system enables dynamic, intuitive interaction through gestures, offering a realistic preview of how the furniture will fit into their space.

The entire workflow begins with users scanning their room, followed by the AI providing recommendations, and ending with users placing virtual furniture in their real-world space through the AR interface. This system allows for a highly interactive and personalized design experience.

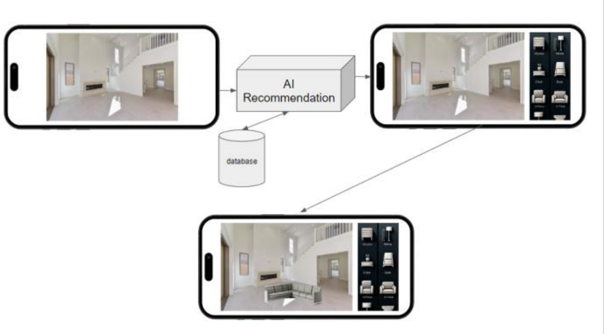

Figure 1. Overview of the solution

Designify's furniture database plays a critical role in storing and retrieving the extensive collection of furniture items, images, and related metadata. The system leverages Firebase Firestore to maintain a cloud-based, real-time collection of furniture data, while the Gemini system handles image processing, ensuring that the images are optimized for AR visualization.

The furniture database contains various items categorized by style, size, and material, ensuring that the AI recommendation engine can make tailored suggestions based on room dimensions and user preferences. The image processing workflow, managed by Gemini, ensures that the images are resized, converted to base64 format, and uploaded efficiently to Firebase Storage, allowing for fast retrieval and seamless AR integration.

```
from PIL import Image
import base64
import os
from glob import glob
from store_manager import Database

def resize_image(input_path, output_path, desired_size):
    with Image.open(input_path) as img:
        original_width, original_height = img.size
        ratio = min(desired_size[0] / original_width, desired_size[1] / original_height)
        new_width = int(original_width * ratio)
        new_height = int(original_height * ratio)
        img = img.resize((new_width, new_height), Image.Resampling.LANCZOS)
        img.save(output_path)

def png_to_base64(image_path):
    with open(image_path, "rb") as image_file:
        encoded_string = base64.b64encode(image_file.read()).decode('utf-8')
        return encoded_string

if __name__ == '__main__':
    db = Database()
    collection = 'interior_design'
    for file in glob('images/*'):
        timestamp = str(time.time()).replace('.', '')
        image_path = f'output/{timestamp}.png'
        resize_image(file, image_path, (200, 200))
        base64_string = png_to_base64(image_path)
        url = db.upload_file(f'{collection}/' + timestamp + '.png', image_path)
        db.update_firestore(collection, timestamp, {'image': url, 'base64': base64_string}
```

```
class FirestoreService {
  final FirebaseFirestore _db = FirebaseFirestore.instance;

  Stream<List<Map<String, dynamic>>> fetchImages(String collection) {
    return _db.collection(collection).snapshots().map((snapshot) {
      return snapshot.docs.map((doc) => doc.data()).toList();
    });
  }
}
```

Figure 2. Screenshot of code 1

The FirestoreService class in Dart allows the app to connect to Firestore and fetch furniture data in real time. It streams the data from a specific collection (in this case, likely the "furniture" or "interior_design" collection), where each document represents a piece of furniture, complete with its metadata and image URLs.

The Gemini system, written in Python, processes the images before they are stored in Firebase. It resizes the furniture images to ensure they are optimized for use in AR, reducing the file size while maintaining quality. The png_to_base64 function then converts the processed image into a base64 string, which is also stored in Firestore to ensure quick retrieval during real-time AR rendering. Finally, the image is uploaded to Firebase Storage, and the Firestore database is updated with both the image URL and the base64 string.

This component is essential to ensuring that Designify's AR environment runs smoothly and that the furniture database remains up-to-date, enabling users to access an extensive, real-time catalog of optimized furniture items for visualization in their rooms.

In Designify, the AI furniture recommendation system uses Google's Gemini 1.5 Flash model to analyze room images and provide tailored furniture suggestions [14]. This system processes the room scan (background image) and additional furniture images to generate a list of recommended items. The model intelligently analyzes the provided images and identifies furniture elements, returning a JSON object that maps the images to specific furniture types.

The AI model allows users to see personalized recommendations based on their room's scanned layout, which enhances their interior design experience by providing real-time suggestions on suitable furniture.

````
Future<void> getRecommendation() async {
  final model = gen_ai.GenerativeModel(model: "gemini-1.5-flash", apiKey: apiKey!);

  // Read the scanned room image
  final firstImage = await File(widget.imagePath!).readAsBytes();
  final imageParts = await _getImages();

  // Construct the prompt for the AI model
  String promptDescription =
      'Please provide a list of furniture identified in the images I have provided.'
      'The first image is the background, and the subsequent images (from index 0) are of
      'Return the list of furniture as a JSON object. The JSON should list the indices of

  final prompt = gen_ai.TextPart(promptDescription);

  // Call the AI model to generate the content based on the provided prompt and images
  final response = await model.generateContent([
    gen_ai.Content.multi([prompt, gen_ai.DataPart("image/jpeg", firstImage), ...imageParts
  ]);

  // Clean the response to parse the JSON
  String cleanResponse = response.text!.replaceAll('```json', '').replaceAll('```', '').tr
  Map<String, dynamic> info = jsonDecode(cleanResponse);
  List indexList = info["furniture"];

  // Set recommended furniture items based on the AI's response
  setState(() {
    _loading = false;
    _setRecommendedImages(indexList);
  });
}

// Set the recommended furniture images for display
_setRecommendedImages(List indexList) {
  for (var index in indexList) {
    recommendedFurniture.add(furnitureImageList[index]);
  }
}
````

```
// Fetch images from Firestore
Future<List<gen_ai.DataPart>> _getImages() async {
  List<gen_ai.DataPart> images = [];
  final FirestoreService firestoreService = FirestoreService();
  const String collection = "interior_design";
  final data = await firestoreService.fetchImages(collection).first;

  debugPrint("fetch images: " + data.length.toString());

  for (var image in data) {
    final Uint8List imageData = base64Decode(image["base64"]);
    furnitureImageList.add(image["image"]);
    images.add(gen_ai.DataPart("image/jpeg", imageData));
  }

  return images;
}
```

Figure 3. Screenshot of code 2

This code demonstrates how the Gemini AI model is used to generate furniture recommendations by analyzing room and furniture images. Here’s a breakdown of the process:
getRecommendation(): This function initiates the recommendation process by reading the scanned room image and fetching additional furniture images from Firestore. It constructs a prompt describing the task for the AI model, asking it to identify furniture in the images and return the results as a JSON object [15].

_getImages(): This function retrieves the images from Firestore, decoding the base64-encoded furniture images and adding them to a list. These images are then used as input for the Gemini AI model.

AI Model Call: The AI model (gemini-1.5-flash) processes the images and the prompt, returning a list of recommended furniture items, which are stored in the recommendedFurniture list for display in the UI.

By using the Gemini model, Designify ensures that users receive accurate and personalized furniture suggestions based on their room’s layout and style. This AI-powered recommendation system enhances the user experience, providing interactive and intelligent design assistance.

The AR visualization system in Designify allows users to interact with virtual furniture items in a scanned room using intuitive gestures such as tap, drag, pinch, and rotate. Users can dynamically place and manipulate furniture within their space, making the experience highly customizable and engaging.

Once a room image is scanned and displayed as a background, users can tap to add furniture, drag it around to change its position, pinch to resize, and rotate it to adjust its orientation. This seamless interaction enables users to visualize their room layouts more effectively, empowering them to design their spaces with ease.

Figure 4. Screenshot of the APP

```
Widget build(BuildContext context) {
  return Row(
    children: [
      Expanded(
        flex: 3,
        child: Stack(
          children: [
            // Displays the room image that the user has scanned
            Positioned.fill(
              child: Image.file(File(widget.imagePath!), fit: BoxFit.cover),
            ),
            // Loops through and places draggable furniture in the room
            ..._images.map((imageProps) {
              return Positioned(
                left: imageProps.x_position,
                top: imageProps.y_position,
                child: GestureDetector(
                  onTap: () {
                    _showDeleteDialogue(context, imageProps);
                  },
                  onScaleStart: (details) {
                    // Handling gesture events to move or resize furniture
                  },
                  child: imageProps.image,
                ),
              );
            }).toList(),
```

Figure 5. Screenshot of code 3

This code snippet represents the core of the AR visualization component in Designify. It allows users to drag and drop furniture images (provided by the AI recommendations) into the scanned room, which is displayed as a background image. The room's image is loaded using Image.file, and furniture images are placed on top using the Positioned widget. Users can interact with the placed furniture using gestures, such as tapping to delete or scaling to resize the items.

Each furniture item is stored in the _ImageProperties list, where its position and scale are tracked. The code ensures that users can arrange furniture realistically in the scanned room, providing a responsive and immersive design experience.

4. EXPERIMENT

4.1. Experiment 1

The primary aspect of Designify that requires rigorous testing is the accuracy of the Gemini AI in recommending furniture based on room scans and furniture images. The AI’s ability to suggest furniture that fits both the room’s dimensions and the user’s style preferences is critical for ensuring that the recommendations are practical and relevant. A potential blind spot in the AI recommendation system could be its understanding of spatial layout, particularly in rooms with unusual or non-standard layouts.

The experiment will evaluate the accuracy of the Gemini AI model's furniture recommendations by testing it on various room layouts, including small rooms, large open rooms, and irregularly shaped rooms. For each room type, a set of predefined furniture images will be provided, and the AI will generate a list of recommended items based on the room’s dimensions and layout.

The AI’s performance will be compared against furniture selections made by professional interior designers for the same rooms. The experiment will record the furniture recommendation accuracy by comparing how well the AI’s suggestions align with the designers' choices. The AI’s recommendations will be logged and categorized by accuracy for each room type.

To ensure robust testing, the room layouts will include a wide range of characteristics, such as compact spaces (small rooms), large open areas, and unconventional shapes (irregular rooms). This will help assess the AI’s ability to handle various real-world room configurations. The results of the

AI’s performance will be measured and analyzed for each room category to identify areas for improvement.

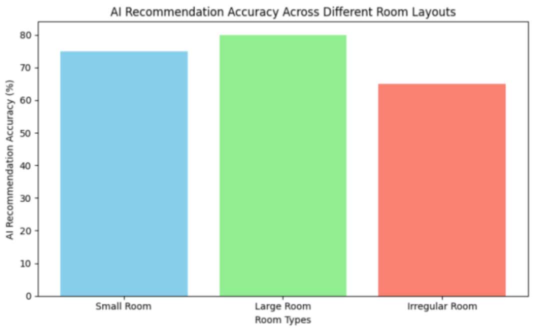

Figure 6. Figure of experiment 1

The analysis of the graph shows that the Gemini AI model performs well in standard room layouts but struggles with irregularly shaped rooms. In small rooms, the AI achieved an accuracy of 75%, indicating that while it handles confined spaces reasonably well, there is some room for improvement in selecting furniture that fits perfectly in tight spaces. In large rooms, the accuracy increased to 80%, reflecting the model's ability to recommend suitable furniture when there are fewer space constraints. The AI's performance is optimal in more flexible, open environments where it can make better recommendations without worrying about space limitations.

However, in irregularly shaped rooms, the accuracy drops to 65%, revealing a challenge for the AI in understanding non-standard layouts with corners or unusual dimensions. This suggests that the AI model could benefit from additional training data involving more complex room configurations to enhance its spatial reasoning. Overall, the model demonstrates solid accuracy across most room types, but improvements are needed to handle more intricate room designs effectively.

4.2. Experiment 2

This experiment was conducted to assess the efficiency of user interaction with the augmented reality (AR) system in Designify. The objective was to evaluate how quickly and accurately users could manipulate virtual furniture within a scanned room, using gestures such as dragging, scaling, and rotating. The experiment aimed to identify potential challenges users face when performing these tasks and measure task completion times, error rates, and user satisfaction.

Ten participants with varying levels of experience with AR interfaces were recruited to complete a set of predefined tasks in Designify’s AR environment.
The experiment involved four key tasks:
Adding a furniture item to the room.
Moving the furniture to a designated location within the room.
Scaling the furniture to a desired size.
Rotating the furniture to match a specific orientation.
Participants were asked to complete each task while their task completion time and errors were recorded. Errors included actions such as incorrectly placing or adjusting furniture. The experiment was conducted on a variety of devices, including iOS and Android smartphones, to ensure that the AR system performed consistently across different platforms. Upon completion of the tasks, participants provided feedback on their experience and rated the ease of interaction with the AR system on a scale from 1 to 5.

The graphs provide insights into the efficiency and accuracy of user interactions with Designify's AR system.

Task Completion Times: The bar chart indicates that simpler tasks such as adding and moving furniture had the shortest completion times, averaging 5 and 8 seconds respectively. These tasks involve basic gestures that are easier for users to perform. On the other hand, scaling and rotating furniture took significantly longer, with average times of 12 and 15 seconds. This suggests that users found these tasks more challenging, likely due to the precision required in multi-touch gestures for scaling and rotating objects.

Error Rates: The line chart highlights that the more complex the task, the higher the error rate. Adding and moving furniture resulted in very few errors, with an average of 1 and 2 errors per task. However, scaling and rotating tasks had higher error rates, with 3 and 5 errors respectively. This suggests that users struggled with the precision of these interactions, possibly needing to correct their actions multiple times to achieve the desired result.

Overall, the data show that the AR system performs well for simpler interactions but may require improvements in gesture handling for more complex tasks such as scaling and rotating. Optimizing the responsiveness and intuitiveness of these gestures could help reduce both task completion times and error rates, improving user satisfaction in future iterations of the app.

5. RELATED WORK

One effective approach to integrating AR in interior design was explored by Hui (2015), who proposed a system where both designers and customers collaboratively create 3D models of interior spaces[11]. In this system, AR technology is used to simulate furniture arrangements and decorative elements, allowing customers to visualize various design options in real-time. The use of augmented 3D models enhances customer participation by providing a vivid, interactive experience during the conceptual design stage. However, the system's effectiveness is limited by the requirement for stereoscopic equipment, which may not be accessible for all users. Unlike Hui's method, our project leverages mobile-based AR, making the technology more accessible and eliminating the need for specialized hardware.

Phan and Choo (2010) explored the use of AR in an interior design environment that enables real-time interaction with virtual furniture[12]. Their system allowed users to visualize and manipulate virtual furniture on screen, providing a flexible interface for designers to work collaboratively in real-time. A notable limitation of this approach is its reliance on external hardware for interaction, which could hinder its usability in practical design settings. Our project improves on this by using markerless AR techniques and mobile devices to simplify the interaction process, thereby providing a more intuitive user experience.

Patil (2018) presented a more recent approach using AR combined with real-time tracking and 3D mapping technologies to simulate interior design[13]. The system allowed users to interact with virtual furniture in a highly realistic setting, using features like FAST corner detection to enhance the accuracy of furniture placement. While the system provides a high level of interactivity and precision, it is limited by the complexity of its setup, which requires advanced algorithms and potentially higher processing power. Our project, in contrast, aims to reduce complexity by optimizing the rendering process for mobile devices, making the AR experience seamless and efficient.

6. CONCLUSIONS

While Designify successfully integrates AI and AR technology, there are several limitations that could be addressed to enhance the user experience. One key limitation is the AI's accuracy in handling irregularly shaped rooms, as the current model performs less effectively in non-standard layouts. To improve this, additional training data featuring more diverse room shapes could be incorporated into the model, allowing for better spatial understanding.

Another limitation lies in the gesture-based interactions within the AR system. Complex tasks like scaling and rotating furniture have higher error rates, indicating a need for more intuitive gesture recognition. Improvements could include refining multi-touch gestures and providing users with visual guides during these interactions.

Given more time, I would focus on gathering extensive user feedback, optimizing the AI's spatial reasoning, and refining AR gesture control for a smoother and more responsive experience across a variety of devices.

Designify has demonstrated the potential of combining AI and AR technologies to revolutionize the interior design process. While there are areas for improvement, the foundation laid in this project offers a promising solution that empowers users to make informed design decisions with ease and creativity.

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