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Preface

The International Conference of Education (CONEDU 2021), May 22~23, 2021, Zurich, Switzerland, 2nd International Conference on Networks, Blockchain and Internet of Things (NBIoT 2021), 2nd International Conference on Machine learning and Cloud Computing (MLCL 2021), 7th International Conference on Image and Signal Processing (ISPR 2021) and 7th International Conference on Computer Science, Information Technology and Applications (CSITA 2021) was collocated with International Conference of Education (CONEDU 2021). 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 CONEDU 2021, NBIoT 2021, MLCL 2021, ISPR 2021 and CSITA 2021 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, CONEDU 2021, NBIoT 2021, MLCL 2021, ISPR 2021 and CSITA 2021 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 CONEDU 2021, NBIoT 2021, MLCL 2021, ISPR 2021 and CSITA 2021.

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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CLASSROOM ACTS ON LOW LITERACY ADULTS EDUCATION SETTINGS

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ABSTRACT

This paper starts by discussing the relevance of dialogues in Adult Education and Training courses with low levels of literacy. In this group, the educational challenges are complex, and innovating the knowledge creation process involves a better understanding of the teaching/learning process. With these case study, we pretend to understand which Communicative Acts are effective in adult learning process, mainly in adults with low literacy.

Based on a mixed methods, applied to a convenience sample, we used an ethnographic approach, and the Grounded Theory Methodology. The results showed that it was important to integrate the learners' emotions in an existing framework, the SEDA Framework. We found also essential to expand the Communicative Acts coding, with a new set of 17 codes organized in 3 categories.

KEYWORDS

Adult Education; Literacy; Classroom acts; learning environments; Human-Computer-Interaction.

1. INTRODUCTION

Adults education with low levels of literacy is a fundamental condition for the full exercise of citizenship in contemporary societies, because "Education must aim at the full expansion of the human personality and the reinforcement of human rights [...]" [1]. We are facing fundamental educational challenges for this adult population, which has to face the constant changes and technological developments introduced in our daily lives.

A previous case study [2] helped us to identify several variables that can influence the learning process of these learners. Using a flow model from a Contextual Design approach we highlighted the number of transmitters and/or receivers and the high number of artefacts required for oral and written communication in the classroom. The quality of adult teaching/learning comprises communication, reorganizing learning environments, qualifying and training teachers, and assessing and validating acquired skills among others.

In this context, it is crucial to study the dialogues between teacher-learner / learner-teacher in order to improve the understanding of these teaching/learning processes.

Adult teaching/learning is characterized by its complexity, diversity of practices and contexts [3]. One of the concerns of this type of education is unequivocally related to the problem of the dialogue. The dialogue is a method of teaching and learning and one of the materials from which

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a learner constructs meaning (Edwards & Mercer, 1987), cited by D. Myhill[4]. Paulo Freire argued that education "is an exchange between people and, it can never be done by an isolated person (even self-education is a distance dialogue)" [5].

Communication therefore plays one of the relevant and important roles in this interactive, dynamic and complex process, being categorized into different types of events [6] - the so-called communicational events (EC).

Learning environments also generate a diversity of emotional experiences that impact the entire teaching/learning process [7]. In this sense, the study of emotions in this context allows us to introduce another component of study that may contribute to a better understanding of the complexity of the processes involved, as emotions may be important indicators of the underlying motivations and cognitions [8]. In this sense, Pekrun et al. [9], highlight that emotions in the context of teaching-learning are significantly linked to the learners motivation, the pedagogical strategies, cognitive and performance resources, personality, as well as the events experienced in the classroom.

This paper is organized in 8 sections. Following the introduction, section 2 defines literacy and identifies its different levels. Section 3 describes the concept and definition of Communicative Events, and section 4 is dedicated to the Emotions in the classroom. In section 5 we briefly describe the characteristics of the case under study, the methodology used, and the characteristics of the sample. The results of the research are presented in section 6. Section 7 offers the analysis and discussion of the results and section 8 presents a brief conclusion.

2. UNDERSTANDINGS OF LITERACY

The following formatting rules must be followed strictly. This (.doc) document may be used as a template for papers prepared using Microsoft Word. Papers not conforming to these requirements may not be published in the conference proceedings.

The assessment of cognitive and workplace skills needed to advance at work and participate in society was the objective of the Programme for the International Assessment of Adult Competencies (PIAAC), commissioned by Organisation for Economic Co-operation and Development(OECD), and was based on two previous studies with adults (16-65 years old): The International Adult Literacy Survey (IALS) and the Adult Literacy and Life's kills Survey (ALL). PIAAC identified three domains of literacy Skills [10]:

Literacy[10]: "Ability to understand, evaluate, use and engage with written texts to participate in society, to achieve one's goals, and to develop one's knowledge and potential;" [10]

Numeracy [10]: "Ability to access, use, interpret, and communicate mathematical information and ideas in order to engage in and manage the mathematical demands of a range of situations in adult life;"

Problem solving in technology-rich environments [10]: "Ability to use digital technology, communication tools and networks to acquire and evaluate information, communicate with others and perform practical tasks."

The measurement range of scores for each scale was 0 to 500. For each scale, five levels of literacy were defined [11]:

- Level 1 People with very poor skills. People can read relatively short digital or printed texts to locate a single piece of information.
- Level 2 People can paraphrase or make low-level inferences and can deal only with material that is simple, clearly laid out. It denotes a weak level of skill.
- Level 3 People should understand complex text, interpret, one or more pieces of information. They should construct significances across larger parts of text or perform multi-step operations in order to identify and express opinions.
- Levels 4 People should perform multiple-step operations to integrate, interpret or combine information from complex or multiple types of texts.
- Levels 5 People can search for, and integrate, information across multiple, dense texts; construct syntheses of similar and contrasting ideas or points of view; or evaluate evidenced based arguments.

With this description it is possible to provide a clear picture of adult proficiency in literacy, numbering and problem solving skills, and to understand if they are prepared for a better social integration and living conditions.

Having detailed the domain of literacy and its levels, in the next section we describe the concept and definition of communication.

3. COMMUNICATION MODELS

Communication is an essential element of the teaching-learning process and has been acquiring more and more visibility. Understanding the role of dialogue in learning and in the development of learners, should involve the whole community, making clear its importance and its implications for adult education and social integration.

John Fiske, in his work, Introduction to Communication Studies, outlines the existence of two major schools of investigation [12]: the process school and the semiotic school. The first sees communication as a linear process, where the transmitter places the information on a channel that takes it to the receiver. The second is based on the semiotic model, where relevance is placed on the creation of meanings and the creation of messages. In this model, the content and the communication process are inseparable and their analysis comprises the study of the signs used and the cultures in which they are integrated [13] and the way messages interact with learners, in order to generate meaning.

From a sociocultural perspective, teaching/learning is a dialogical process between the learner and the teacher in contexts that reflect the values and social behaviours of schools as cultural institutions [14]. According to N. Mercer [14], the quality of the educational dialogue is essential in the success or failure in the process. The teacher is responsible for the construction of the dialogical language and the main inputs producer. Quoting Paulo Freire, "It is not in silence that men make themselves, but in the word, at work, in action-reflection" [15].

Based on these facts, communication is an integrating concept, which allows the transmission and sharing of knowledge, ideas and information. For Van Dijk [16, p. 2], a communicative event is the result of the interaction between two people who express ideas or emotions in a verbal or non-verbal way [16, pp. 6–7] - through the presentation of codes (gestures, eye movements or voice features) that transmit messages exclusively in that context [12].

Hymes[17], reflects on the structure and organization of the discourse where there are rules or norms, called communicative situation (or speech), well defined hierarchically by units of

analysis (events). Thus, the communicative event (CE) will always comprise one or more communicative acts (CA). Taking into account this well-defined hierarchy, we can state that a communicative situation (SC) includes one or more CE, which, in turn, comprises one or more CA - Fig. 1. For Hymes, communicative situations are composed beyond speech by other types of events, not subject to communication rules, but dependent on the context. As a whole, language is without any doubt the most ubiquitous, flexible and creative tool of production and exchange of knowledge [18, p. 2], being the educational instrument by excellence, both at the pedagogical level and at the level of orientation of the teaching / learning process, being the object of investigation in several areas of knowledge.

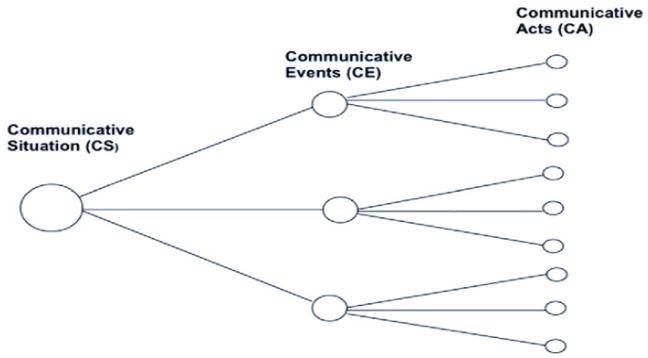

Figure 1- Hierarchical and nested levels - Source: Developing a coding scheme for analysing classroom dialogue across educational contexts

Paying more attention to the Communicative Acts (CA) in the classroom Hennessy et al. [19]–[21], focused on the systematic analysis of the dialogues, where each situation provides a certain number of information that can be coded and grouped. For such, they developed a framework called Scheme for Educational Dialogue Analysis (SEDA), Cambridge University - United Kingdom and National Autonomous University (UNAM) - Mexico. This framework of 33 codes, grouped into 8 categories [20], enables the analysis and interpretation of videos and/or audios collected, according to the CA framework, which allows the identification and study of the dialogues' acts by their function within an interaction. These studies are based on tools resulting from the Sociocultural Discourse Analysis [22]. According to Mercer, the Sociocultural Discourse Analysis seeks to understand the communicational acts, framed by its sociocultural context. In addition, it aims to explain how participants acquire a set of new knowledge over different time ranges. With this framework, the 'dialogic teaching-and-learning' (DTL) is the main analytical focus, involving the communicative interactions between teachers and learners, enabling the development of knowledge, skills and related behaviours in the classroom [22].

SEDA identifies these CA by their function within an interaction. Working at this micro-level is particularly enlightening since it allows carrying out fine-grained, systematic analyses of what learners actually do and say in practice during these dialogic interactions.

4. EMOTIONS IN THE CLASSROOM

Research in the context of classroom interactions, which generate and are the result of emotions, has recorded a noticeable increase in recent years, but, according to Pekrun[23], few studies have taken place in the context of teaching / learning, with two exceptions: a) test anxiety; b) emotions linked to success and failure. For Pekrun et al. and Schutz et al. [24] [25] [26] [8], educational contexts are marked by strong emotional experiences, capable of impacting teaching / learning processes, personal development, motivation and self-regulation.

Schutz, Hong, Cross and Osbon[26] concluded that emotions are socially created and personally activated, emerging from conscious and/or unconscious opinions regarding success/failure in the effort to achieve goals, in an interaction between the individual and the social environment.

Pekrun[27][28][29] and collaborators studied emotions in the academic context and developed the theory of the control-value of achievement emotions as an integrated model when considering the teaching/learning context when the learner feels in control, or out of control, of the activities and their outcomes. The perception of control or lack thereof is another factor that can assist to its success.

The control-value theory is based on a three-dimensional taxonomy of achievement emotions [[27][28][29][30]: 1) object focus (activity focus vs outcome focus); 2) its valence (positive vs. negative, or pleasant vs. unpleasant); 3) the degree of activation (activating vs. deactivating). This theory provides a more comprehensive and integrated view of the emotions experienced in this context - Table 1. From this taxonomy, three categories of emotions were outlined, depending on the moment in which they appear [28]: 1) prospective emotions; 2) emotions during the activity; 3) retrospective emotions - Table 2.

Table 1 - A three-dimensional taxonomy of achievement emotions - Source: [30]

	Positive[a]		Negative[b]	
Object Focus	**Activating**	**Deactivating**	**Activating**	**Deactivating**
Activity	Enjoyment	Relaxation	Anger Frustration	Boredom
Outcome/ Prospective	Hope Joy[c]	Relief[c]	Anxiety	Hopelessness
Outcome/ Retrospective	Joy Pride Gratitude	Contentment Relief	Shame Anger	Sadness Disappointment

[a]Positive = pleasant emotion.
[b]Negative = unpleasant emotion.
[c]Anticipatory joy/relief.

Table 2 - Basic Assumptions On Control, Values, And Achievement Emotions - Source: [28]

	Appraisals		
Object focus	Value	Control	Emotion
Outcome/prospective	Positive (success)	High Medium Low	Anticipatory joy Hope Hopelessness
	Negative (failure)	High Medium Low	Anticipatory relief Anxiety Hopelessness
Outcome/retrospective	Positive (success)	Irrelevant Self Other	Joy Pride Gratitude
	Negative (failure)	Irrelevant Self Other	Sadness Shame Anger
Activity	Positive Negative Positive/Negative None	High High Low High/Low	Enjoyment Anger Frustration Boredom

5. CHARACTERISTICS OF THE STUDY

In this case study we adopted a mixed-methods approach according to a sequential exploratory design (QUAL→ QUAN) [31], [32], regarding a convenience sample [31], [32] with two groups belonging to the Centro de Formação do Instituto do Emprego e FormaçãoProfissional of Coimbra. The first group was a group of learners from the Basic Skills Program, (Portaria nº 1100/2010, page 4766) with 300 hours of lessons which include Reading and Writing, Information and Communication Technologies and Math, and where learners can acquire basic skills that allow and stimulate them to proceed with further training The second group was a group of learners from the Adult Education and Training B1+B2 - with three main areas: 1) basic skills - 850 hours of lessons; 2) learning with autonomy - 40 hours of lessons; 3) Technological learning - 350 hours of lessons, and gives learners the possibility of acquiring both school qualifications and professional skills.

With the study of this two groups our purpose was to identify and understand, once removed the aspects that are related to the idiosyncrasies of the studied case, Communicative Acts that can be found in similar groups [33, pp. 121–143]. Based on this assumption we can formulate the following Research Questions (R.Q.): a) What types of Communicative Acts are linked to the teaching/learning process of adults with low literacy? b) Do all Communicative Acts contribute to this process? c) Are there any other types of acts that are present in the learning process?

In order to answer the set of questions that outline the rational of this research, the data collection was based on ethnographic research, taking the teachers perspective, “emic perspective” [34], [35], to collect data - filming, pictures and field notes captured during some sessions of the Reading and Writing training unit of this class, which allows to ‘re-create’ the teaching/learning process. The observation was not directed by any observation script, according to Eriksson &Kovalainen´s naturalist theory [34, pp. 149–162].

The qualitative analysis of the collected data followed some essential principles [32, pp. 232–253]: (I) organize and prepare the data; (II) carefully read and analyse the data; (III) identify and codify the data; (IV) analyse the contents. In this research data processing and qualitative analysis was done using the Computer Assisted Qualitative Data Analysis Software (CAQDAS) - NVivo 12. To use NVivo we adopted the principles and procedures of the codification of data as stated in its specific literature [35]–[37], following the traditional Grounded Theory steps, of a constructivist nature: open, axial and selective coding [38], enabling the content analysis [37] and the information selection. Regarding the systematically analysis of the dialogue in the CA classroom, the Scheme for Educational Dialogue Analysis Framework (SEDA) of 33 codes, grouped into 8 categories [20], was used in order to identify and study the dialogue acts by their function within an interaction [21]. In order to evaluate the emotions experienced by the students during the activity, according to the control-value theory, we based ourselves only in the second dimension valence. (positive - vs negative, or pleasant vs unpleasant) Table 2, because observing facial and postural emotional expressions in the classroom would be therefore used for analysing learners and teachers.

The specific strategies used to answer questions about scientific credibility in qualitative studies, in the perspective of Lincoln and Guba (1991), cited by Coutinho [39], are: "Triangulation; Member checking; Rich, thick description; Negative case analysis; Prolonged engagement; Peer debriefing; External Auditing” [40], [41].

In order to ensure the scientific reliability/credibility of this study and to reduce or control bias, three teachers involved in the education/training of adults (peer debriefers) participated in this

study, with whom we hold meetings, where we discussed issues, strategies, ideas and concerns related to it.

5.1. Sample characteristics

The first group was formed by 28 learners from Coimbra, aged between 21 and 56 years (average ≈ 42y), from which 46% were female. The second group was composed by 18 learners from Figueira da Foz, aged between 18 and 59 years (average ≈ 42y), 83% of which were female. The learners were advised to attend this programme in order to create new opportunities for social integration, since they were unemployed with a family at "risk of social exclusion".

6. DESCRIPTION OF THE RESULTS

These results are based on the monitoring and coding of several videos, pictures and field notes captured during some sessions of the training unit mentioned in the section about features of the study.

In a first stage of this exploratory analysis, the video transcription was carried out in such a way that it faithfully replicated the learners' dialogues and was used as the source to make a corpus[1] for the analysis [37].

In a second stage, an alignment between the NVivo functionalities, and in an inductive perspective [35, pp. 113–127], a cyclical and interactive process was used to "extract" meanings and identify concepts[2] [37] until reaching the "theoretical saturation[3]" [35, pp. 113–129], bearing in mind the objectives of this research: a) to think/understand the context (ontological question); and then it was possible to idealize the CA occurrence and also the presence of other type of acts not covered by SEDA b) determine the influence of the educational context and its variables in the teaching/learning process (epistemological question).

Starting by SEDA we could quantify the repetitive communicational acts observed. Through the observation of the first group Table 3 we verified that the communicational acts of the teacher were more frequent than those of the learners (70% versus 30%). The results obtained allow us to verify that out of the 8 categories of the SEDA the I - Invite elaboration or reasoning was the most frequent 28%, followed by the C - Connect and P - Positioning and Coordination both with 22%. Category B - Build on ideas, in turn, was the least used (1%), preceded by categories R - Make reasoning explicit (4%) and RD - Reflect on dialogue or activity (5%). From this first analysis it is pointed out that there is a small incidence of negative emotions (2%).

Table 3 - Repetitive communicational acts (first group)

	CA*	**Learner**		**teacher**	
		Neg.	Pos.	Neg.	Pos.
B – Build on ideas	B1	0	0	0	2
	Total	**0**	**0**	**0**	**2**
C – Connect	C1	0	0	0	12
	C2	0	0	0	51

1 Set of documents to be submitted for analysis procedures [37].

2 Concepts are given labels.

3 New or relevant data which does not repeat itself.

	CA*	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
	Total	0	0	0	63
G – Guide direction of dialogue or activity	G2	0	0	0	13
	G3	0	0	0	8
	G4	0	1	0	30
	G5	0	0	0	2
	Total	0	1	0	53
I – Invite elaboration or reasoning	I4	0	15	0	66
	I5	0	0	0	1
	Total	0	15	0	67
P – Positioning and Coordination	P3	5	48	0	11
	Total	5	48	0	11
R – Make reasoning explicit	R2	0	13	0	0
	Total	**0**	**13**	**0**	**0**
RD – Reflect on dialogue or activity	RD1	0	2	0	3
	RD3	0	5	0	4
	Total	0	7	0	7
Total		**5**	**84**	**0**	**203**

* B1 - Build on /clarify others' contributions; C1 - Refer back; C2 - Make learning trajectory explicit; G2 - Propose action or inquiry activity; G3 - Introduce authoritative perspective; G4 - Provide informative feedback; G5 – Focusing; I4 - Ask for explanation or justification; I5 - Invite possibility thinking or prediction; P3 - Propose resolution; R2 - Explain or justify own contribution; RD1- Talk about talk; RD3 - Invite reflection about process/ purpose/ value/ outcome of learning [20].

We have identified also some other acts, activities or strategies (that we called Dynamic Acts - DA), not included in the SEDA framework, and that may modify the quality of the teaching/learning process (see Table 4). The analysis and discussion of other individual and/or group actions presented in the learning environment can become more complete. The most common DA was BE – Behavioral acts (62%). We found a higher frequency (55%) of DA linked to the learner. It is worth to emphasize the existence of a high incidence of negative motivations (22%) in the behavioural group (BE - Behavioral acts).

Table 4 - Dynamic Acts (first group)

	DA*	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
BE -Behavioral acts	BE1	1	14	0	4
	BE2	0	1	0	0
	BE3	0	4	0	0
	BE4	6	0	0	0
	BE5	1	1	0	0
	BE6	13	17	5	40

	DA*	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
	BE7	0	9	0	0
	Total	21	46	5	44
LA - Learning acts	LA1	1	5	0	3
	LA2	0	4	0	1
	LA3	0	2	0	0
	LA4	0	2	0	0
	LA5	0	0	0	0
	LA6	0	1	0	1
	Total	**1**	**14**	**0**	**5**
S - Strategic acts	S1	0	12	0	6
	S2	0	0	0	15
	S3	1	7	0	3
	S4	1	1	9	0
	Total	**2**	**20**	**9**	**24**
Total		**24**	**80**	**14**	**73**

*BE1 - Sit up /down; BE2 - Clear the white board; BE3 - Get out/in; BE4 - Watch the mobile phone; BE5 - Answer the mobile phone; BE6 - Talk; BE7 - Everybody talks; LA1 - Write on the notebook, LA2 - Write on the white board; LA3 - Search text; LA4 - Reading; LA5 – Reading aloud; LA6 - Sign the attendance sheet; S1 – Ask for help; S2 - Positive reinforcement; S3 - Humor; S4 - Reprehension.

Regarding the second group, it is possible to observe, in Table 5, that the frequency of communication acts was balanced - Teacher 51% versus 49% of Learners. The acquired results obtained, based on the SEDA categories, the G - Guide direction of dialogue or activity was the most frequent 48%, followed by the RD - Reflect on dialogue or activity 20% and the I - Invite elaboration or reasoning with 19%. Furthermore, the categories C - Connect (1%) and B - Build on ideas (2%) were the least used, preceded by the category R - Make reasoning explicit (9%). From this first analysis, it must be stressed the existence of 11% of CA that provoked negative emotions on the learners.

Just like in the first group, a series of DA not identified by SEDA was identified (see Table 6), being the BE – Behavioral acts the most frequent (59%) of DA linked to the student. The behavioural group (BE – Behavioral acts) is the one which presents the highest frequency of negative emotions (30%)

Table 5 - Repetitive communicational acts (second group)

	CA	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
B – Build on ideas	B1	0	2	0	2
	Total	**0**	**2**	**0**	**2**
G – Guide direction of dialogue or activity	G2	1	4	0	5
	G3	5	13	2	16

	CA	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
	G4	1	6	1	7
	G5	1	6	0	14
	Total	**8**	**29**	**3**	**42**
I – Invite elaboration or reasoning	I4	2	13	1	13
	I5	0	1	0	3
	Total	**2**	**14**	**1**	**16**
R – Make reasoning explicit	R2	1	7	1	6
	Total	1	7	1	6
RD – Reflect on dialogue or activity	RD1	2	18	1	14
	Total	**2**	**18**	**1**	**14**
Total		13	71	6	81

Table 6 – Dynamic Acts (second group)

	DA	Learner		teacher	
		Neg.	Pos.	Neg.	Pos.
BE-Behavioral acts	BE2	0	1	0	2
	BE3	2	6	1	4
	BE4	1	1	1	1
	BE6	3	5	1	4
	BE7	5	8	2	6
	Total	**11**	**21**	**5**	**17**
LA - Learning acts	LA1	4	7	1	6
	LA2	3	4	1	7
	LA5	0	12	0	6
	LA6	0	1	0	1
	Total	**7**	**24**	**2**	**20**
S - Strategic acts	S1	2	4	0	5
	S2	1	2	0	2
	S3	0	3	0	1
	S4	3	3	2	2
	Total	**6**	**12**	**2**	**10**
Total		**24**	**56**	**9**	**46**

7. ANALYSIS OF THE RESULTS

In order to answer the research questions - a) What types of Communicative Acts are linked to the learning process of adults with low level of literacy? b) Do all Communicative Acts contribute to this process? c) Are there any other types of acts that are present in the learning

process? it was necessary to integrate the emotions of the learners with the SEDA Framework. This integration was based on the Pekrun and collaborators, theory of control-value of achievement emotions [27] [28] [29]. From all the three categories of emotions we only used the second one - during the activity according to their valence (positive vs negative)

A new set of three acts' categories emerged (Dynamic Acts - DA) creating 17 codes Table 7, in result of the material collected and the carefully and critically reading of the data obtained from the classroom. This table enables the summary of practices, knowledge, attitudes and strategies that contribute significantly to the purpose of this case study.

Table 7 - Dynamic Acts (DA)

Cluster	**Description**	**Concepts**
BE -Behavioral acts	Coding individual or group Behavioral acts that are witnessed in the learning environment and that have influence, directly or indirectly, in the acquisition of knowledge.	BE1 - Sit up /down; BE2 - Clear the white board; BE3 - Get out/in; BE4 - Watch the mobile phone; BE5 - Answer the mobile phone; BE6 - Talk; BE7 - Everybody talks
LA - Learning acts	Identifying different types of acts that are part of the learning process.	LA1 - Write on the notebook LA2 - Write on the white board LA3 - Search text LA4 – Reading LA5 - Read aloud; LA6 - Sign the attendance sheet;
S -Strategic acts	Identifying different types of strategies that are part of the process.	S1 – Ask for help S2 – Positive reinforcement S3 – Humour S4 – Reprehension.

We can see, through the CAs of the two groups (Table 3. And Table 6), the importance of contexts and their influence on communication and discursive practices. Asymmetries can be seen not only in the type of CA but also in terms of the emotions experienced.

It is important to underline that in the first group, the I - Invite elaboration or reasoning (28%) was the most significant during the teaching/learning process, followed by the C - Connect (22%) and the I - Invite elaboration or reasoning (22%).

However, this did not happen in the second group, where the CA G - Guide direction of dialogue or activity (48%) played a leading role, followed by the RD - Reflect on dialogue or activity (20%).

It is relevant to emphasize that the emotions experienced by the learners are different in the two groups, in the first we found 94% of positive emotions - Table 3, and in the second 85% of positive emotions - 0According to Meyer and Turner [13] positive emotions contribute to build a good learning environment, enabling an empathic relationship between all actors in the process.

In the LA - Learning Acts identified with codes LA1 - LA5, the frequencies obtained show that most of the activities are positive in both groups - 92% in the first and 77% in the second Table 3, 0This evidence linked with the high percentage of I – Invite elaboration or reasoning,

represents significant and essential variables for the learners´ encouragement and motivation. This standpoint is supported by the model developed by Carroll, "Model of School Learning"[33], in which the amount of time devoted to study or to a learning activity is an evidence of motivation and contributes to the success of teaching/learning.

On the contrary, the negative impact of some Behavioral acts, which are not directly related to the task, called "off-task behaviour" [34][35], Table 4 and Table 6, have destabilizing effects in this process.

8. CONCLUSIONS

This case study had as main objective to reflect/understand the influence of dialogue and emotions experienced by learners (adults with low literacy level) in the teaching/learning process. For such, we used a mixed method approach following a (QUAL-> QUAN).

We concluded that other types of acts were essential in the learning process. In fact, we have combined the learners' emotions with the SEDA´s framework and we observed that it is fundamental to complement the coding of the CA's, emerging a new set of 3 categories and 17 codes. Positive emotions were found to be essential for the construction of healthy learning environments, enabling an empathic relationship between all stakeholders in the process.

In the LA, most activities worked as an enabling and integrating element, allowing the learners to be more involved. Throughout the whole teaching/learning process, reading and writing stand out as important activities, thus allowing the promotion of these two transversal skills.

We would say that being a teacher implies reordering and reinventing pedagogical instruments that facilitate educational intervention and the learning process carried out by the learner. The appropriate use of DA is essential in relationships, which are not always assertive, between: teacher/learner; learner/teacher; learner/learner. Conditions that contribute to a bad environment hamper activities and the acquisition of knowledge, and DA that motivate the learners are critical in their participation and performance. Excessive participation may be harmful to the educational context, as witnessed by our "peer debriefers".

In this case study supplements, the elements that we had previously presented [2], where we reviewed aspects like flow of information, artefacts to support communication, cultural influences, actors in the educational process, the organization of the learning space, the pedagogical methods, that can influence learning and allow a better knowledge of the learning environment and of the mental model of this population. With this two studys we want to minimize the uncertainties associated with these closed spaces, in order to enrich systematically and comprehensively compared multiple Human-Computer-Interaction (HCI) interfaces to Face-to-Face (F2F).

We intend in this way to complete the knowledge about the learning environments experienced by these learners, in order to design them in a more accessible way making learning more attractive and integrative.

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REFERENCES

[1] United Nations General Assembly, "The Universal Declaration of Human Rights," 1948.
[2] C. Luis, H. Afonso, and M. J. Marcelino, "Low literacy adults education: Towards a holistic view of the context," 2019 Int. Symp. Comput. Educ. SIIE 2019, 2019.
[3] P. D. Ávila, "A literacia dos adultos: competências-chave na sociedade do conhecimento," p. 531, 2005.
[4] D. Myhill, "Talk, talk, talk: Teaching and learning in whole class discourse," Res. Pap. Educ., vol. 21, no. 1, pp. 19–41, 2006.
[5] C. R. Brandão, O que é método Paulo Freire. Brasiliense, 2017.
[6] M. Saville-Troike, "The Ethnographic Analysis of Communicative Events," Sociolinguistics, pp. 126–144, 1997.
[7] L. Mata, F. Peixoto, V. Monteiro, C. Sanches, and M. Pereira, "Emoções em context académico: Relações com clima de sala de aula, autoconceito e resultadosescolares," Anal. Psicol., vol. 33, no. 4, pp. 407–424, 2015.
[8] D. K. Meyer and J. C. Turner, "Re-conceptualizing Emotion and Motivation to Learn in Classroom Contexts," Educ. Psychol. Rev., vol. 18, no. 4, pp. 377–390, 2006.
[9] R. Pekrun, T. Goetz, W. Titz, and R. P. Perry, "Academic Emotions in Students' Self-Regulated Learning and Achievement: A Program of Qualitative and Quantitative Research," Educ. Psychol., vol. 37, no. 2, pp. 91–105, Jun. 2002.
[10] OECD, "Education & Skills Online Assessed," OECD. [Online]. Available: https://www.oecd.org/skills/ESonline-assessment/skillsassessed/. [Accessed: 23-Jan-2020].
[11] OECD, The Survey of Adult Skills: Reader's Companion. OECD Publishi, 2013.
[12] J. Fiske, Introduction To Communication Studies. 2002.
[13] A. Fidalgo and A. Gradim, Manual de semiótica. Covilhã: Universidade da Beira Interio, 2007.
[14] N. Mercer, "Sociocultural Discourse Analysis: Analysing Classroom Talk as a Social Mode of Thinking," J. Appl. Linguist., vol. 4, no. 2, pp. 1–15, 2004.
[15] P. Freire, Pedagogia do Oprimido, Paz & Terr. Rio de Janeiro, 1981.
[16] T. A. Van Dijk, Discourse as structure and process, vol. 1. Sage, 1997.
[17] D. Hymes, "Models of the Interaction of Language and Social Life: Toward a Descriptive Theory," Intercultural Discourse and Communication. pp. 4–16, 01-Jan-2005.
[18] N. Mercer and K. Littleton, Dialogue and the development of children's thinking: a sociocultural approach. London, UK: Routledge, 2007.
[19] S. Hennessy, "Analysing Video Recordings of Classroom Lessons Using the Scheme for Educational Dialogue Analysis (SEDA)," SAGE, pp. 1–7, 2018.
[20] S. Hennessy et al., "Developing a coding scheme for analysing classroom dialogue across educational contexts," LCSI, vol. 9, pp. 16–44, 2016.
[21] S. Hennessy, "Analysing Video Recordings of Classroom Lessons Using the Scheme for Educational Dialogue Analysis," SAGE Publ. Ltd., 2017.
[22] N. Mercer, "The analysis of classroom talk : Methods and methodologies," pp. 1–14, 2010.
[23] R. Pekrun, "Progress and open problems in educational emotion research," Learn. Instr., vol. 15, no. 5, pp. 497–506, 2005.
[24] R. Pekrun, T. Goetz, W. Titz, and R. P. Perry, "Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research," Educ. Psychol., vol. 37, no. 2, pp. 91–105, 2002.
[25] R. Pekrun, A. J. Elliot, and M. A. Maier, "Achievement goals and discrete achievement emotions: A theoretical model and prospective test," J. Educ. Psychol., vol. 98, no. 3, pp. 583–597, 2006.
[26] P. A. Schutz, J. Y. Hong, D. I. Cross, and J. N. Osbon, "Reflections on Investigating Emotion in Educational Activity Settings," Educ. Psychol. Rev., vol. 18, no. 4, pp. 343–360, 2006.
[27] R. Pekrun, A social-cognitive, control-value theory of achievement emotions, vol. 131, no. C. Elsevier Masson SAS, 2000.

[28] R. Pekrun, “The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice,” Educ. Psychol. Rev., vol. 18, no. 4, pp. 315–341, 2006.
[29] R. Pekrun, A. C. Frenzel, T. Goetz, and R. P. Perry, “The Control-Value Theory of Achievement Emotions. An Integrative Approach to Emotions in Education.,” Emot. Educ., pp. 13–36, 2007.
[30] R. Pekrun and E. J. Stephens, “Achievement Emotions : A Control-Value Approach,” vol. 4, pp. 238–255, 2010.
[31] J. W. Creswell, Educational research: Planning, conducting, and evaluating quantitative and qualitative research, vol. 4. 2012.
[32] J. W. Creswell, Research design : qualitative, quantitative, and mixed methods approaches, 4th ed. Sage Publications, 2014.
[33] J. Amado, Manual de investigaçãoqualitativa em educação, 2* EDIÇÃO. Coimbra: Imprensa da Universidade de Coimbra, 2014.
[34] P. Eriksson and A. Kovalainen, Qualitative Methods in Business Research: A Practical Guide to Social Research. SAGE Publications, 2015.
[35] M. Paul, E. Jean, and M. Bamberg, Qualitative Research in Psychology, First Edit. American Psychological Association, 2003.
[36] J. Saldaña, The Coding Manual for Qualitative Researchers, Second Edi. London, UK: SAGE Publications Ltd, 2013.
[37] L. Bardin, Análise de Conteúdo. São Paulo, 2012.
[38] J. Corbin and A. Strauss, “Grounded Theory Research: Procedures, Canona and Evaluative Criteria,” Zeitschrift fur Sociol., vol. 19, no. 6, pp. 418–427, 1990.
[39] C. P. Coutinho, “A qualidade da investiga çãoeducativa de naturezaqualitativa: questõesrelativas à fidelidade e validade,” Educ. Unisinos, vol. 12, no. 1, pp. 5–15, 2008.
[40] J. W. Creswell, Qualitative Inquiry and Research Design, Second Edi. Sage Publications, 2007.
[41] E. Taylor-Powell and M. Renner, “Analyzing Qualitative Data,” Screen, vol. 25, no. 3, pp. 2–10, 2003.

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I am a computer teacher/trainer at Centro de Formação Profissional de Coimbra, Portugal, and currently attending the doctoral program of the Department of Computer Engineering of the Faculty of Science and Technology of the University of Coimbra, being my doctoral thesis project subordinated to the theme "A contribution to accessibility and usability in learning environments for literate people". I was very interested in e-learning educational projects. My focus is to develop and/or study environments that can contribute to make the education more accessible to adults, combining new technologies of teaching and learning (virtual learning environments) to accessibility and usability needed for this group of individuals. The paper should be of interest to readers in the areas of Adults education and Human-computer interaction (HCI).

INTERNATIONAL HIGHER EDUCATION STUDENTS' PSYCHOLOGICAL EXPERIENCES OF COVID-19: A QUALITATIVE STUDY

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ABSTRACT

The Coronavirus pandemic 2019 (COVID-19) is hastily spreading, bringing pressure and challenges to international students in higher education institutions who were locked down on campus during the COVID-19 outbreak. We sought to explore psychological experiences of international higher education students during the COVID-19 pandemic in Eswatini. A qualitative phenomenological approach was adopted. Participants were 15 conveniently selected international higher education students who were locked down on Campus from March 20 to September 25, 2020. The interviews were conducted face to face. Data were thematically analysed. The study was informed by the ecological systems theory. The psychological experiences of international higher education students during COVID-19 pandemic were categorized in to four themes. Frist negative emotions present in early stages involving discomfort, anxiety and helplessness caused by isolation, fear and concern for safety. Second self-coping strategies included psychological and life adjustments, social distancing, acceptance of wearing of masks, hand sanitizing and online learning. Third we reported growth under the crisis which included affection for family members, peers and self-reflection. Finally, we reported that positive emotions occurred concurrently with negative emotions. During the COVID-19 crisis positive and negative emotions of international higher education students intertwined and co-occurred. Self-coping strategies and psychological growth played a crucial role in maintaining mental health of the students. The international students in higher education were resilient in coping with the COVID-19 crisis and lockdown situation which enhanced their participation in online learning.

KEYWORDS

International higher education students, psychological experiences, COVID-19, Eswatini.

1. INTRODUCTION

The Coronavirus pandemic 2019 (COVID -19) is hastily spreading, bringing pressure and challenges to international students in higher education institutions who were locked down on campus during the COVID-19 outbreak. According to the United Nation's Educational, Scientific, and Cultural Organization (UNESCO), COVID-19 outbreak interrupted the learning of more than one billion students in 191 countries around the world (UNESCO, 2020). The pandemic has affected different people in different ways such that activities of teaching and learning widened the gap between students and educators who can afford (rich) and those who cannot afford (poor). Those who afforded continued to expand their knowledge while those marginalised were diminished. The situation worsened as COVID-19 outbreak led to the suspension of on-going educational programmes. Universities had to drastically shift from face to face to introduce online teaching and learning, thus inducing anxiety among students, particularly

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international higher education students. Also, the cancellation of physical events and activities, and the formation of a "new normality" in higher education occurred globally (Tesar, 2020) including one higher education institution in Eswatini. International students were affected due to travel restrictions and institutional closures that followed in a very limited space of time to enforce prevention measures (social distancing, wearing of masks, washing and sanitizing of hands). In this way, international students had to be locked down in Eswatini, which affected their psychological wellbeing and their learning effectiveness.

Different countries including Eswatini immediately opted for online learning (Mhlanga & Moloi, 2020; Toquero, 2020) to continue with the education mandate of the institutions of higher learning. This is where some lecturers recorded and uploaded their lessons online for the students to access and to respond to learning activities. However, it is noted that a successful implementation of online teaching and learning requires stable technological infrastructure: hardware and software, steady internet connectivity, well-organized, knowledgeable and qualified lecturers and students who can engage meaningfully in online teaching and learning activities. Eswatini is a middle income country where most communities do not have stable electricity supply, let alone the access to internet connectivity to enable lecturers and students to fully engage in online teaching and learning. Additionally, the cost of data is too high that it cannot be afforded by some lecturers, as well as the students. These posed critical challenges of limited resources such that the majority of students including international students were directly affected, which impacted on their educational outcomes in Eswatini.

This study reports the psychological experiences of international students who were locked down in one higher education institution in Eswatini during COVID-19 pandemic first phase between March and September, 2020. The objectives of the study were to explore the experiences of COVID-19 on international undergraduate university students in Eswatini, particularly their psychological wellbeing, learning and coping strategies. The research questions were:

1. What were the international students' main psychological feelings during the COVID-19 outbreak?
2. What were the changes in international students' lives since the COVID-19 pandemic?
3. What were international students' coping strategies for COVID-19 crisis?

In this paper, we give an account of the theoretical underpinning of the Ecological Systems Theory (EST) by Bronfenbrenner (1979) at an institution of higher learning in Eswatini, among international undergraduate students' psychological experiences during COVID-19 crisis. We describe the COVID-19 crisis and how it has affected teaching and learning. We then present different aspects of psychological experiences of students in institutions of higher learning during the COVID-19 crisis in developed countries and its impact on educational outcomes in the literature review.

2. LITERATURE REVIEW

Corona virus outbreak has amplified the inequalities and struggles that some students face on a daily basis. The pandemic has put basic gross inequalities (Le Grange, 2020) among societies in the global south, Eswatini included. Casale and Flett (2020) anticipated that a persisting pandemic would have a considerable impact in the importance of an individual's psychological needs; due to implementation of preventive measures of social distancing, quarantine, self-isolation, to stop individuals from being exposed to COVID-19 contaminations. However, remaining indoors in isolation for an extended period was shown to affect risk factors for anxiety and stress disorders (Ansari & Yousefabad, 2020). The lockdown decision that happened due to COVID-19 has forced institutions of higher learning to abruptly use online learning to minimize

the disruption in education delivery. However, many students from marginalized and poverty stricken communities do not have access to the digital devices or the necessary skills that are required for online learning (Mhlanga & Moloi, 2020). This is typical in both developed and developing countries such as Eswatini (Demuyakor, 2020; UNESCO, 2020). In addition, in achieving Sustainable Development Goals (SDG) the use of Information and Communications Technology (ICT) is critical.

Sustainable Development Goal 4 seeks to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations, 2015 p.14). Furthermore, the government of Eswatini through its Ministry of Education & Training (MoET) has aligned its education strategic plan with SDG 4 and has included plans of infusing ICT in education. In its ICT Policy Goal, The MoET in Eswatini states that:

> Teaching and learning content shall be progressively digitised and ICT as a subject area shall be introduced into all schools in Eswatini as qualified teaching personnel and resources become available. ICT will also be used as a tool for teaching and learning of knowledge and skills throughout the education and training sector for blended learning … (MoET, 2018 p.26).

The above goal means that not all the educators and students are equipped with ICT skills due to shortage of personnel in the ICT field of study. This is despite the role that ICT plays in "the development of 21st Century skills." and it being a key aspect in "Eswatini's fulfilment of its national development goals." (MoET, 2018, p. 26). Paradoxically, inequality between the poor and the rich, rural and urban residents, males and females in institutions of higher education has also been widening, thus corresponding with the current global trends in social inequality (Ayelazuno & Aziabah 2021). The Education Sector Policy of MoET in Eswatini indicates that ICT is a vital teaching and learning tool throughout the education and training sectors. However, many students and educators do not possess the necessary ICT skills and knowledge to embark on online teaching and learning. Moreover, the situation brought by the COVID-19 pandemic has caused tremendous stress on the higher education system, for lecturers and tutors, but most especially for students' particularly international students whose psychological wellbeing was and is still affected due to lockdown.

According to Browning et al. (2021) university students are increasingly known as a psychologically weak populace, which suffer from higher levels of misery, anxiety, substance abuse and disorderly eating compared to the general population. Browning et.al conducted a survey on 2,534 students from seven United States (US) universities and colleges between mid-March and early-May 2020, to gauge psychological impact of COVID-19 pandemic on university and college students. The authors found that more than half of all university students have experienced high levels of psychological impact from the COVID-19 pandemic (Browning et al., 2021) with college students having been among the most strongly affected by COVID-19 because of uncertainty regarding academic success, future careers and social life during college, among other concerns. The authors further indicated that females, younger students, students with pre-existing health conditions, and students who knew someone infected with COVID-19 were in the high risk group. Moreover, the authors reported that lower-income and Asian students also appeared to be at higher risk. It was reported that many students felt increased stress levels, anxiety and depressive symptoms as a result of the changed delivery and uncertainty of university education. Additionally, technological concerns of online learning, being far from home, social isolation, decreased family income, and future employment were reported to have affected the same students (Browning et al., 2021).

A study by Dodd et al. (2021) in Australian universities outlined that the pandemic raised significant challenges that disrupted teaching and learning. The authors reported that due to travel restrictions that were in place, many international and interstate students were unable to begin semester one as planned, with courses and programmes rapidly transitioning from face-to-face to online delivery to ensure the continuity of teaching and assessment. Dodd et al. (2021) noted that online learning with its challenges, affected many students who experienced lost learning opportunities particularly if their chosen field of study was not amenable to exclusive online teaching (medicine, health sciences) thus, causing them to have psychological distress and severe depressive symptoms.

In another instance, Händel et al. (2020) investigated the digital readiness and its effects on higher education students' socio-emotional perceptions in the context of the COVID-19 pandemic, in Germany. They recommended the need for support of higher education students in successfully coping with the challenges of emergency remote studying. This is because according to Händel et al. (2020) the limited social exchange that resulted from the COVID-19 pandemic raised negative emotions among students, while social isolation triggered stress-related emotions and reduced their psychological wellbeing.

Mok, Xiong, Ke, and Cheung (2021) conducted a quantitative study that examined the Mainland China and Hong Kong students' studying abroad expectations after the pandemic. The authors found that of the 2,739 respondents, 84 percent showed no interest in studying abroad after the pandemic. They also reported negative emotions such anxiety, anger, fear and guilt to have increased among students during the pandemic. The psychological experiences of international undergraduate higher education students of COVID-19 were understood by applying the EST (Bronfenbrenner, 1979). The EST explains how different systems have been disrupted during the COVID-19 outbreak in our study. In this study the individual (international student) was placed at the centre of the different sub-systems.

2.1. Theoretical Framework

The theory was proposed by Urie Bronfenbrenner in 1979 that considers environmental conditions apart from intrapersonal and genetic factors (Bronfenbrenner, 1979). The EST includes four interrelated levels (micro, meso, exo and macro systems) that must be considered to show how COVID-19 crisis intertwined with students' support systems. The individual is at the center and all other systems are nested around. In our study, the individual (international student) was placed at the centre of all sub-systems. Bronfenbrenner suggests that an ecological perspective encourages individuals to consider the holistic environment for themselves.

Microsystem, describes interactions in individual's immediate environment such as family, school, neighbours, friends or peers (Bronfenbrenner, 2005). The EST recognizes the significance of the immediate environment (microsystem) through the broader layers [exo, macro and chrono systems] (Bronfenbrenner, 2005). The Microsystem incorporates the immediate environmental surroundings of the individual and those with whom the individual (international student) interacts such as friends, parents, educators and wardens. COVID-19 pandemic raised challenges for higher education institutions that had to drastically migrate from face-to-face to online delivery to ensure the continuity of teaching (Dodd et al., 2021). It should be noted that COVID-19 experience is different for families with low, middle, and high socio-economic status. The use of online learning became a serious challenge as students of lower socio economic status may not have the same accessibility to digital devises due to limited resources (Fegert et al., 2020; Sun et al., 2021). This means that students coming from families who can afford (rich) continued to expand their knowledge by engaging fully in online learning, while those who cannot afford digital devises (poor) are likely to diminish, thus affecting their psychological wellbeing. This

situation could be applicable to international students as some may come from poor and rich socio economic backgrounds (Jacobs & Daniels, 2020). However, some studies have shown that online learning offers many benefits for students because it involves student-centeredness, it is more flexible (Dhawan, 2020), and it can also improve interaction with students by providing asynchronous and synchronous tools such as e-mail, forums, chats and others.

COVID-19 facilitated an increase in disparities based on family's ability to provide sufficient resources for students in the higher institution of learning including international students. Additionally, international students who were locked down due to COVID-19 may have experienced additional stress due to limited support as they could not meet their families during the lockdown period (Elmer, Mepham, Stadtfeld, 2020; Sun et al., 2020). Another disadvantage could result from social distancing whereby international students could not borrow or share digital learning devises.

Mesosystem involves connections between setting such as in the relationship between home and school (Bronfenbrenner, 2005). The COVID-19 pandemic has forced leaders at universities to take drastic measures that affect how educators and students interact and socialize with each other (Elmer et al., 2020). An institution of higher learning is the second place for students and the replacement of families and parents (Eliasa, 2012) that have a duty in helping students achieve their education and developmental tasks. COVID-19 crisis made it difficult for international students to interact with their close support systems such as family, educators and friends. This is because individuals are required to reduce physical contact to others outside one's household and social distancing (Elmer et al., 2020). While social distancing measures may positively slow down the spread of the virus, the increase of social isolation of international students affected their psychological wellbeing (Van Bavel et al., 2020). This also included lecturers who were not able to interact with these students since the university staff was working from home. Reduced social interactions, lack of social support, and newly arising stressors associated with the COVID-19 crisis could potentially affect students' mental health negatively (Elmer et al., 2020). In the absence of the support from parents, issues of food insecurity, income for purchasing of data among others disproportionately affected international students who were locked down, thus affecting their psychological wellbeing (Elmer et al., 2020; Mhlanga & Moloi, 2020).

Likewise, Exosystem describes settings in which the individual is not directly involved, but which nonetheless affect them (Bronfenbrenner, 2005). This may include experiences in social setting in which an individual does not have an active role but which nevertheless influence experience in an immediate context (Eliasa, 2012). For instance parents' stress on job loss, affects their family life, and financial insecurity. During COVID-19 outbreak, non-essential businesses such as universities and industries were closed, which affected economies and some parents lost their jobs. The intensity of parental stress and family burden has the potential to heavily impact children (Lawson et al., 2020) as children are not immune to their parent/guardian's feelings. Similarly, international students whose parents may have lost jobs as a consequence for COVID-19 crisis. The Macrosystem refers to the larger social and cultural environments in which all the other systems exist (Bronfenbrenner, 2005). It consists of the wider environment and draws mostly on attitudes, ideologies, culture and beliefs that have indirect effects on the other systems and the individual. This system includes the international students' psychological experiences of COVID19, where their closest individuals provide support, skills and guidance (Ministry of Health, educators, and friends) to sustain them. In view of the challenges and constraints encountered by students and their effects over the life course transitions depicts chronosystem (Bronfenbrenner, 2005).

Bronfenbrenner (1979) asserts that, in many cases, families respond to different stressors within the societal constraints existent in their lives. For instance, during COVID-19 crisis, many families were happy to be alive and to have a job and food, which was the case for international students. The EST has been adapted mainly to help in comprehending the COVID-19 effects on psychological experiences of international students. Thus, challenges, coping strategies, support or a combination of both positive and negative experiences exist. The experiences of being an international higher education student are formed at many levels. The EST provides a framework to explore these levels and the interactions between and among them. This, theory is relevant in this study because it includes multi-dimensional social context and provides a multi-layered approach for data analysis.

3. METHOD

3.1. Research Design

We adopted the Colaizzi's phenomenological method (1978) to qualitatively analyze the psychological experience of international undergraduate higher education students of the COVID19 pandemic during an institutional lockdown in Eswatini. The Colaizzi's phenomenological method emphases on the experiences and feelings of participants and stresses on shared patterns and not individual features in the research. This approach allowed for genuineness of the collected experience of the participants to observe scientific standards. Phenomenology is not only about description of the phenomenon but also an interpretive process. In essence, we connect the different meanings of lived experiences and perspectives shared by international higher education students (Van Manen, 2016).

3.2. Participants and Setting

The participants were fifteen (n=15) international higher education students from one institution in the Manzini region of Eswatini (females = 8). The participants were conveniently selected based on having been locked down in an institution due to COVID19 pandemic from March 20 to September 25, 2020. The inclusion criteria included (1) being an international undergraduate higher education student who could not travel back home due to COVID-19 pandemic; (2) volunteering to participate in the study. The exclusion criteria were being a local student and failure to participate in at least two interviews during the study period. We determined the number of the required participants by interviewing students who met the inclusion criteria until data were saturated and no new information were produced. See Table 1 for more details on participants' demographic information.

Table 1. Demographic Information of Participants (n = 15)

Characteristic	**Frequency**	**%**
Gender		
Male	07	47
Female	08	53
Age range		
20- 25	09	60
26-30	06	40
Level of Study		
3rd year	05	33
4th year	10	67
Nationality		

Motswana	03	20
Mosotho	02	13
Zimbabwean	10	67
Religion		
Christian	12	80
Islamic	02	13
Traditional African Beliefs	01	07
Number of interviews		
2 -3	09	60
4-5	06	40

3.3. Interview Outline

For developing the interview outline we started off by reviewing relevant literature, seeking experts' opinions. Then we selected two (2) students for piloting the interview outline. The main probe questions for the participants included: (1) what were the main psychological feelings of COVID19 pandemic? (2) What were the coping strategies? (3) What were the insights amidst the pandemic? (4) What has changed in your life since the COVID-19 pandemic? (5) How do you cope with changes in your school and life? (6) What are your thoughts and feelings about the pandemic?

3.4. Procedure

Permission to conduct the research was granted by the Eswatini Ministry of Education and Training. We contacted all 15 international student participants of the study individually and provided them with a participant booklet. The booklet included: invitation letter, information sheet, informed consent form, and the purpose and significance of the study. The participants individually consented to partake in the study by signing informed consent forms which included authorization that allowed the use of transcripts for publication. We informed them that all names and identifiable data would be changed within the transcript to ensure confidentiality and anonymity. In addition, participants were also informed that all data collected were confidential. Furthermore, we informed the participants that their participation in the study was appreciated, but that it was purely voluntary and that they could withdraw from the study at any time without any explanation and penalty. Following the confirmation of their interest to participate in the study, we then individually met with all fifteen participants as they were recruited and explained their roles in the study in more detail in observance with the COVID-19 preventive measures. We then scheduled the interview time at their convenience and adhered to the COVID-19 preventive measures suggested by the World Health Organization and Eswatini Ministry of Health.

3.5. Data Collection

All participants (n=15) took part in individual face to face interviews in an unoccupied room for privacy and without interruptions. Both the first and second authors conducted the face to face interviews and have experience in qualitative interview in education of over six (6) years respectively. They also possess doctoral qualification in Education and Counselling, hence were able to offer psychological support for participants who exhibited emotional distress during the interviews to prevent psychological harm. The interview took approximately 25 minutes per person. The participants were interviewed in English. Interviews were audiotape recorded for easy recall of responses. Audio recordings were transcribed using forward translation procedure (Africa Scholarship Development Enterprize [ASDE], 2009). We remained neutral during data collection and established good rapport with the participants. We employed techniques such as

unconditional acceptance, active listening and clarification to encourage trustworthiness of data. We also arranged for each participant to take part in at least 1-2 face to face interviews and 1-2 telephone interviews to allow for data collection at multiple time points.

3.6. Ensuring Study Trustworthiness

We implemented two data trustworthiness processes: credibility and dependability. Our data credibility checks included interviewing the participants in their institutional setting with member checks, cross-checking the interview records for accuracy during multiple time points.

3.7. Data Analysis

After every interview, the recording was transcribed and analysed using a procedure suggested by (Colaizzi, 1978). This included having two researchers who independently reviewed the interview materials, summarized and deduced meaningful statements, and then developed themes. Contradictory opinions on the contents of the themes were discussed and resolved by consensus by a group of researchers comprising of two (2) masters of education and two (2) doctors of education.

4. FINDINGS

Colaizzi's phenomenological analysis of the data yielded four (4) major themes in exploring the psychological experiences of international undergraduate higher education students of COIVD-19 in an institution in Eswatini. The four (4) themes included: (1) negative emotions present in early stages; (2) self-coping strategies; (3) growth under the crisis; and (4) positive emotions occurred concurrently with negative emotions. The four themes are summarized below. We present example statements in Table 2.

4.1. Theme 1: Negative Emotions Present in Early Stages

All participants reported to experience negative emotions during the first few weeks of the COVID-19 lockdown. As the number of COVID-19 cases continued to rise, the anxiety of all the international higher education students (n=15) increased causing discomfort from not knowing how the disease was spread and if they were next to contract the disease.

All participants reported to experience fear, which increased as they heard from friends, family and read of COVID-19 death cases increasing in the country. It is evident that the microsystem has some influence on international higher education students when it came to acquiring information about COVID-19 updates in the country as well as their countries of origin. The participants expressed a sense of helplessness and concern for their safety as they were away from their homes. Most students (n = 9) expressed concern about being isolated in their halls of residence. They were mainly concerned about the unknown emerging infectious disease and their susceptibility to contracting the disease. They also reported being uncertain about the mode of transmission for the virus, which psychologically affected them.

Most (n= 9) students in this study were between 20 and 25 years old. All students expressed concern about the impact of the pandemic on the health of their families. They also reported that their families were worried about their health. Most of the participants (n=9) reported to feel anxious and guilty due to not being home and were mainly worried of their families.

4.2. Theme 2: Self Coping Strategies

All participants indicated that they used humor and isolation as psychological defense mechanisms. Participants reported to rely on their friends and family as a source of support to defuse their worry about contracting COVID-19. All participants reported to joke about the new normal of wearing masks which made some of them appear funny. Most students (n =12) reported to use isolation as time for prayer to ask for protection against contracting COVID-19. All participants indicated that they took the initiative to contribute money to buy groceries including fruits and vegetables that they sold as a way of generating income. They reported that they took turns in cooking meals to avoid buying meals from the cafeteria which they reported to be tasteless, and this made them eat meals they preferred and enjoyed.

All participants (n=15) expressed their need to adjust their lifestyles by accepting to wear masks when in public places and social distancing to avoid contracting COVID-19. Some students (n=7) indicated that they tried to wash and sanitize their hands regularly even though this was hard to do as they were not used to this practice. They indicated having challenges in always using hand sanitizers as this was a habit they were not used to. Most students (n = 8) reported to be frustrated with online learning which presented itself with challenges such as poor internet connectivity and lack of technology skills. Additionally, participants reported not understanding content uploaded on online platforms by course instructors as well as not having the digital devises to use for their online learning. Participants had to navigate support systems (microsystem) to survive within their institution of higher learning. For example, they had to balance the interaction between them, and institutional policies such as online learning and adhering to COVID-19 preventive measure, thereby observing the mesosystem.

4.3. Theme 3: Growth Under Crisis

All the participants (n=15) reported their appreciation for the support from friends, relatives, families, churches, wardens and the institution. They also understood the importance of health and family. Most students (n=10) reported that they would work hard even though online learning was challenging and live with state of appreciation and gratitude in the future. This is because they revealed that they would now be knowledgeable about online learning, which is a new culture as indicated in the macrosystem. The majority of students (n=12) reported that online learning made them to temporarily forget about the pandemic since they continued to learn. Most of the students (n=8) reported to value the institution decision to continue with the learning and teaching despite COVID-19 situation and were very happy.

4.4. Theme 4: Positive Emotions Occurred Concurrently with Negative Emotions

Even though most of the participants experienced negative emotions such as fear, anxiety and discomfort, they also had positive emotions progressively. Most students (n=10) reported to experience positive emotions after a few weeks. Although fear and anxiety were brought on by the pandemic, participants reported to have assessed the pandemic prevention and control progress and had confidence in medical ability of the institutional support. Simultaneously, they felt confidence in self-prevention and control ability after taking COVID-19 orientation training by the Ministry of Health in collaboration with the institution. Additionally, participants' psychological experiences of COVID-19 enabled them to get support, skills and guidance to sustain them in view of the COVID-19 challenges. They also reported to encounter constraints and their effects over face to face transition to online learning. This evidently depicts the chronosystem, where students adapted to a life stressor (COVID-19) and still continued with their education (online learning).

In the face of difficult living conditions and challenges in the fight against the pandemic, the majority (n=9) of the participants reported feeling happy. The students felt happy and gratitude for being alive and continuing with their learning during the pandemic. Furthermore, friends and family support brought happiness. Contact with family through social media platforms such as what's App, Facebook, Twitter, Snap chats were key in this study. Additionally, the institution had a COVID19 task group in place to support and motivate all students. The encouragement of friends also brought happiness to the students.

Table 2. Themes identified through interviews with international higher education students

Theme	**subtheme**	**Examples of Verbatim Quotations**
Negative emotion present in early stages	Discomfort Anxiety Fear Helplessness Guilty	*It is not easy to stay for over six months without going home, we are not comfortable at al* *We do not know what will happen in the next step* *I felt helpless knowing that there is nothing I could do to protect my family back home from COVID-19* *I was very scared to live with my peers in the residence hall.*
Self-coping strategies	Humour Isolation Team work initiatives Lifestyle adjustment Prayer	*I jog with my friends that we are now locked down together and do not know when we will go home* *We contribute money to buy fruits and vegetables that we re-sell to generate more money* *I pray every day for myself, my family so that we don't contract COVID-19* *I pray for myself and friends here, not to contract this virus and to have money for buying data bundles.* *We are now like a family, we cook food together and eat together* *I have to always remind my friends to wear masks and to wash and sanitize their hands regularly- they now call me warden*.
Growth under crisis	Team Support Appreciation Gratitude Hard work during online learning	*I am happy to receive donations from our church members, some lecturers and friends* *I appreciate what the university has done for us, to keep us together as international students* *I am grateful to the decision of the university to embrace online learning, even though it has its challenges* *I just want to finish and work hard on my online tasks as this is my last semester, which we don't know when it will end* *I thank God that I am alive during this crisis*
Positive emotions occurred concurrently with negative emotions	Calmness Happiness Confidence in Self-prevention	*The COVID-19 training brought calmness and peace of mind in my life, regarding my safety* *I am happy to be alive and I am able to continue with online learning, despite the challenges* *I can still survive as long as I observe the COVID-19 ways of prevention* *I wear a mask every time I go out in public.*

5. DISCUSSION

This study reports the psychological experiences of international undergraduate students in a higher education institute in Eswatini when there was lockdown that caused significant disruptions due to COVID-19 pandemic. The findings of the study are summarized into four major themes: Negative emotions present in early stages, Self coping strategies, Growth under crisis and Positive emotions occurred concurrently with negative emotions.

Participants experienced discomfort caused by uncertainty of COVID-19 and the drastic shift to online learning brought anxiety and fear. In this study participants concern was about the seriousness of COVID-19, which forced them to be isolated from their lecturers and peers. The rapid shift to online learning has had a substantial negative influence on both the overall learning experience of international higher education students, and their psychological wellbeing. The finding of this study mirrors what previous studies have reported among university students in developed countries about psychological wellbeing and academic experience of University Students during COVID-19 (Browning et al., 2021; Dodd et al., 2021; Händel et al., 2020). Moreover, the finding indicated that the participants were anxious and fearful about their families' health due to the rapid spread of COVID-19 virus. The COVID-19 pandemic has evolved into a serious threat to education, economic, social and health sectors given its prolonged impact, geographical spread and lack of cure or effective treatment (Sun et al., 2021). The finding that participants were fearful and anxious about their family members' health seems to be unique to our study. Consequently participants' fear about health and their families disrupted their concentration for online learning. They also experienced a sense of helplessness due to fear of contracting the virus and being isolated in Eswatini. The acquiring of information by participants about COVID-19 updates which relied on their peers and families is consistent with the microsystem domain of EST (Bronfenbenner, 2005).

There is research evidence to suggest that coping strategies and social support are mediators of stress (Sun et al., 2020). The finding revealed that the participants adopted humour and isolation as their coping strategies to psychologically adjust to the COVID-19 situation. The pressure of COVID-19 pandemic caused the students to actively make psychological adjustments. The participants did this by adjusting their lifestyle to observing preventive behaviours against COVID-19 of social distancing, wearing masks and washing and sanitizing of hands. The participants also adopted prayer as their coping strategy during the outbreak. Seemingly, their adoption of prayer could be consistent with their religious beliefs, which is in support with what previous studies among university students' experiences with COVID-19 pandemic have reported (Sun et al, 2021). In addition, the findings showed that the participants engaged in team work initiatives that reflected greater solidarity for survival. This is where the students contributed money to buy fruits and vegetables to re-sell in order to accord them finances to eat healthy food and buy data bundles to sustain online learning. This finding supports what other studies have reported that as the economic consequences of COVID-19 have continued to unfold, it has become apparent that individuals from lower socioeconomic background have been excessively burdened across the globe (Ahmed et al., 2020; Mhlanga & Moloi, 2020; Sun et al., 2021) which was the case in this study. The pandemic has negatively affected the students' interactions with their peers and families including lecturers, which is inconsistent with the microsystem level of the EST (Bronfenbenner, 2005).

Literature indicates that crisis outbreaks can cause psychological distress to those affected. In this study the finding suggest that the participants grew under the COVID-19 crisis. The participants shared in self-reflection of their own education (shift to online) and gratitude for being alive (Sun et al., 2020). The finding in our study revealed that engaging in online learning temporarily preoccupied the students to forget about the crisis. The participants demonstrated positive forces

such as expressing more appreciation for health, family and gratitude for social support, which previous studies have confirmed (Sun et al., 2021). Furthermore, the students took the initiative to seek team support to adapt to internal (shift to online learning, observe COVID-19 preventative measures) and external (scare of contracting COVID-19 virus) environment changes, which enhanced their psychological wellbeing. The shift to online learning and initiative to seek team support by the students highlight the relevance of the macrosystem domain of EST by (Bronfenbenner, 1979).

The finding of the existence of positive emotions in the participants such as calmness, relaxation, and happiness, occurred concurrently with negative emotions, such as fear, anxiety and discomfort during the first weeks of the pandemic. Other studies have reported the presence of negative emotions during COVID-19 crisis (Browning et al., 2021; Dodd et al., 2021; Elmer et al., 2020; Händel et al., 2020). The participants seemingly believed that positive emotions were generally related to support from peers, families, institution and Ministry of Health. Apparently, social support was critical in overcoming stressful situations (Lawson et al., 2020). The calmness, relaxation and happiness of the participants after taking part in the COVID-19 training are hardly mentioned in other studies (Dodd et al., 2021). Literature suggests that positive emotions play a significant role in recovery and adjustment of psychological distress (Sun et al., 2020; Elmer et al., 2020; Van Bavel et al., 2020). Our finding in this study revealed that psychological the participants during COVID-19 crisis strengthening social support, promoting coping strategies and encouraging positive emotions are important in promoting psychological wellbeing and adjusting to the drastic shift of online learning. This affirms the chronosystem (Bronfenbenner, 2005) where the participants adapted to a life stressors (COVID-19, rapid shift to online learning) and still continued with their educational activities.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

The study had the following limitations. Firstly, the small sample size restrains the reproducibility of findings due to the characteristics of qualitative research. Secondly, due to the nature of COVID-19 outbreak we could not conduct focus group discussions with the participants to ovoid potential transmission of the virus. Thirdly, we relied heavily on review of literature on psychological experiences of students in developed countries as we could access limited literature from developing countries. Future studies could consider using larger samples to allow for deeper understanding of international students' psychological experiences of COVID19. Psychological experiences of COVID-19 of students with disabilities and locals could further be explored. However, our study can serve as a basis for higher education professionals who want to conduct a similar study.

7. CONCLUSION

The study provided a detailed understanding of psychological experiences of international students with COVID-19 applying a phenomenological design. We found that during the pandemic, negative and positive emotions of the particpants against the pandemic intertwined and co-occurred. Self-coping strategies and psychological growth played a crucial role in maintaining psychological wellbeing of the international students. Our study provided preliminary data for further psychological intervention to enhance online teaching and learning in higher educational institutions. The participants in a higher education institution in Eswatini appeared to be resilient in coping with the COVID-19 crisis and abrupt shift to online learning.

REFERENCES

[1] Africa Scholarship Development Enterprize [ASDE]. (2009).Development of a framework for implementation of tests in Ministry of Education and Skills Development. Botswana: Africa Scholarship Development Enterprize.

[2] Ahmed, F., Ahmed, N. E., Pissarides, C., & Stiglitz, J. (2020). Why inequality could spread COVID-19. The Lancet Public Health, 5(5), e240.

[3] Ansari, M., & Yousefabad, S. A. (2020). Potential threats of COVID-19 on Quarantined families. Public Health, 183, 1.

[4] Ayelazuno, J.A. & Aziabah , M.A. (2021). Leaving No One Behind in Ghana Through University Education, Interrogating Spatial, Gender and Class Inequalities, Working Paper 2021-1, United Nations Research Institute for Social Development [UNRISD]: Geneva.

[5] Bronfenbenner, U. (2005). Making Human Beings Human: Biocological Perspective on Human Development. London: Sage Publication

[6] Bronfenbrenner, U. (1979). The ecology of human development: Experiments by nature and design. Harvard university press.

[7] Browning, M. H., Larson, L. R., Sharaievska, I., Rigolon, A., McAnirlin, O., Mullenbach, L., ... & Alvarez, H. O. (2021). Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States. PloS One, 16(1), e0245327.

[8] Casale, S., & Flett, G. L. (2020). Interpersonally-based fears during the COVID-19 pandemic: reflections on the fear of missing out and the fear of not mattering constructs. Clinical Neuropsychiatry, 17(2).

[9] Colaizzi, P. F. (1978). Psychological research as the phenomenologist views it. New York: Oxford University Press.

[10] Demuyakor, J. (2020). Coronavirus (COVID-19) and online learning in higher institutions of education: A survey of the perceptions of Ghanaian international students in China. Online Journal of Communication and Media Technologies, 10(3), e202018.

[11] Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. Journal of Educational Technology Systems, 49(1), 5-22.

[12] Dodd, R. H., Dadaczynski, K., Okan, O., McCaffery, K. J., & Pickles, K. (2021). Psychological Wellbeing and Academic Experience of University Students in Australia during COVID-19. International Journal of Environmental Research and Public Health, 18(3), 866.

[13] Dodd, R. H., Dadaczynski, K., Okan, O., McCaffery, K. J., & Pickles, K. (2021). Psychological Wellbeing and Academic Experience of University Students in Australia during COVID-19. International Journal of Environmental Research and Public Health, 18(3), 866.

[14] Eliasa, E. I. (2012). Counsellor roles on students' lifelong learning understanding (A psychological study based on ecological system theory). Procedia-Social and Behavioral Sciences, 46, 5703-5706.

[15] Elmer, T., Mepham, K., & Stadtfeld, C. (2020). Students under lockdown: Comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. Plos One, 15(7), e0236337.

[16] Fegert, J. M., Vitiello, B., Plener, P. L., & Clemens, V. (2020). Challenges and burden of the Coronavirus 2019 (COVID-19) pandemic for child and adolescent mental health: a narrative review to highlight clinical and research needs in the acute phase and the long return to normality. Child and Adolescent Psychiatry and Mental Health, 14, 1-11.

[17] Händel, M., Stephan, M., Gläser-Zikuda, M., Kopp, B., Bedenlier, S., & Ziegler, A. (2020). Digital readiness and its effects on higher education students' socio-emotional perceptions in the context of the COVID-19 pandemic. Journal of Research on Technology in Education, 1-13.

[18] Jacobs, C., & Daniels, D. (2020). Their capital has value, too: Exploring parental educational support in low-socioeconomic single-mother families. Journal of Education (University of KwaZulu-Natal), (80), 160-175.

[19] Lawson, M., Piel, M. H., & Simon, M. (2020). Child maltreatment during the COVID-19 pandemic: consequences of parental job loss on psychological and physical abuse towards children. Child Abuse & Neglect, 104709.

[20] Le Grange, L. (2020). Covid-19 pandemic and the prospects of education in South Africa. Prospects, 1-12.

[21] Mhlanga, D., & Moloi, T. (2020). COVID-19 and the Digital Transformation of Education: What Are We Learning on 4IR in South Africa? Education Sciences, 10(7), 180.

[22] Ministry of Education and Training (2018). The Swaziland Education and Training Sector Policy 2018. Mbabane: Government Printer.
[23] Mok, K. H., Xiong, W., Ke, G., & Cheung, J. O. W. (2021). Impact of COVID-19 pandemic on international higher education and student mobility: Student perspectives from mainland China and Hong Kong. International Journal of Educational Research, 105, 101718.
[24] Sun, N., Wei, L., Shi, S., Jiao, D., Song, R., Ma, L., ... & Wang, H. (2020). A qualitative study on the psychological experience of caregivers of COVID-19 patients. American Journal of Infection Control, 48(6), 592-598.
[25] Sun, S., Goldberg, S. B., Lin, D., Qiao, S., & Operario, D. (2021). Psychiatric symptoms, risk, and protective factors among university students in quarantine during the COVID-19 pandemic in China. Globalization and Health, 17(1), 1-14.
[26] Tesar, M. (2020). Towards a post-Covid-19 'new normality?': Physical and social distancing, the move to online and higher education. Policy Future in Education, 18(5), 556- 559.
[27] Toquero, C. M. (2020). Challenges and Opportunities for Higher Education Amid the COVID-19 Pandemic: The Philippine Context. Pedagogical Research, 5(4).
[28] UNESCO (2020). Global Monitoring of School Closures caused by COVID-19. Retrieved from https://en.unesco.org/covid19/educationresponse.
[29] United Nations [UN]. (2015). Resolution adopted by the General Assembly on 25 September,NewYork:UN.https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pd.
[30] Van Bavel, J. J., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., ... & Willer, R. (2020). Using social and behavioural science to support COVID-19 pandemic response. Nature Human Behaviour, 4(5), 460-471.
[31] Van Manen, M. (2016). Researching lived experience: Human science for an action sensitive pedagogy. New York: Routledge.

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THE EVALUATION CASE STUDY OF ONLINE COURSE DURING PANDEMIC PERIOD IN MONGOLIA

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ABSTRACT

This paper describes a test and case study of self-evaluation of online courses during the pandemic time. Due to the Covid-19, the whole world needs to sit on lockdown in different periods. Many things need to be done in all kinds of business including the education sector of countries. To sustain the education development teaching methods had to switch from traditional face-to-face teaching to online courses. The government made decisions in a short time and educational institutions had no time to prepare the materials for the online teaching. All courses of the Mongolian University of Pharmaceutical Sciences switched to online lessons. Challenges were raised before professors and tutors during online teaching. Our university did not have a specific learning management system for online teaching and e-learning. Therefore professors used different platforms for their online teaching such as Zoom, Microsoft teams for instance. Moreover, different social networking platforms played an active role in communication between students and professors. The situation is very difficult for professors and students. To measure the quality of online courses and to figure out the positive and weak points of online teaching we need an evaluation of e-learning. The focus of this paper is to share the evaluation process of e-learning based on a structure-oriented evaluation model.

KEYWORDS

Key target, sub target, SURE model, evaluation of evaluation, Mongolian university of pharmaceutical sciences.

1. INTRODUCTION

The Mongolian University of Pharmaceutical Sciences (MUPS), the leading private university in pharmacy was founded in 2000 and it offers courses in Pharmacy, Traditional Medicine, Pharmaceutical Engineering and Technology, and Nursing. The Drug Research Institute and the GMP-Pharmaceutical Industry are the main components of the MUPS, and it has the great advantage of training to conduct a combination of Training-Research-Industry [1]. Due to the global pandemic, it was moved on public alert in Mongolia by Resolution No. 62 of February 12, 2020, and Resolution No. 178 of November 11, 2020, of the Government of Mongolia, and classroom learning at Universities and Colleges were temporarily closed and continue to move to a form of online learning [2]. E-learning has expanded since last year in all kind of education. Starting from the second semester of 2019-2020, the MUPS moved from classroom learning to online learning. As well as the first semester of 2019-2020, a total of 3001 video lessons, 489 enclosed files, and 41056 online test databases were created and 18,534 hours of electronic

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lectures, seminars, and workshops were organized under the basis of the cloud program [2]. From here, a total of 36 subjects of 93 credit hours, including general academic, professional foundation, and specialization, are taught online to first to fifth-grade students in pharmacy. As of the first semester of 2020, a total of 1277 students are studying at the MUPS, of which 1062 are studying in the Pharmacy Department. Our study involved 552 students, including 52 male and 500 female students.

The "Vision-2050" long-term development policy of Mongolia, the medium-term development plan of the education sector of Mongolia 2021-2030, and the Government action plan set the goal of "creating equal opportunities for everyone to receive quality education and strengthening the system of equal inclusion" [3]. In the future, it is necessary to reform the legal environment of the education sector to live and work in the age of digital technology, and to develop a humane and ethical citizen with active social participation and continuous development potential. In order to implement these policy objectives, there is an urgent need to reform the legal environment in the education sector. In addition, for the first time, the draft law regulates global development trends, the electric transition in education, online learning, distance learning, and open educational resources to provide citizens with equal and accessible access to education. This is the first time that electric learning, technology, and content have been legalized. Mongolia needs to have a well-structured, integrated research university that combines teaching and research in the present and future when the world needs to improve its competitiveness, efficiency, and rapid development of communication and information technology. Consequently, we need to compete as a world-class university. Accordingly, the teacher must have the knowledge and ability to organize non-classroom, mixed forms of training; to support the continuous development of the teaching profession at the national level by organizing pieces of training on teaching methods and professional skills development in a centralized, regional, distance and electronic form. In addition, communication, information technology infrastructure, software, and hardware for distance and electronic education are the responsibility of the relevant departments [4]. It has been a long time since the introduction of an online learning management system in the Mongolian education system. A common challenge for today's educational institutions is to manage online learning activities, disseminate training content, monitor student learning, motivate teachers and students in the learning process, and required the development of a learning environment to improve indicators, methodologies, and models for evaluating learning activities.

Although there are many examples and experiences of universities in developed countries using electronic learning systems, and it's clear that the most important thing is to adapt these systems to the characteristics of the country's education system and to develop a new system that suits the country's education system and reflects the needs of educational institutions [5]. Due to the outbreak of Covid-19, a new coronavirus pandemic, classroom learning was banned from the spring semester of the 2019-2020 academic years. The introduction of fully online learning was a major challenge for the entire community, as many teachers who were not systematically trained in online learning techniques conducted the full course online for the first time throughout the semester. Each teacher went online and faced various problems, but each of them was able to solve the problem on their own and continue the training. However, in this article, we have selected our own assessment for a bachelor's degree in Pharmacy in order to evaluate our learning process, draw conclusions, and clarify our focus on future electric learning.

2. EVALUATION OF E-LEARNING

Evaluation of e-learning is one of the main points of discussion for researchers. Many researchers and educators developed different methods for the evaluation of e-learning. Successful e-learning can run as a result of collaboration where many different groups are working together: Professors,

Technical people, Administration, Tutors, Students, and others. Therefore evaluation of e-learning can be done in different complexity and level. As defined by Christopher Pappas, evaluation of e-learning was done before, during and end of e-learning. These are so-called assessment, formative and summative evaluations [6]. The e-learning and multimedia evaluations developed by Sage Learning Systems 17 major categories and 105 separate criteria on which e-learning courses can be applied for evaluation [7]. Prasad explains how an evaluation of e-learning should be done. By his idea understanding own value is important. Counting benefits of e-learning, convenient and flexible access, budget-friendly, measurable results, and reporting are key points of Prasad's view [8]. Petrone offers to use a famous method for evaluation from Kirkpatrick. He thinks that the Kirkpatrick model can be applied to measure the learning effectiveness of e-learning evaluation in the best way [9]. Donald Kirkpatrick developed an evaluation method for educational programs in four levels during his dissertation [10]. Level 1 focuses on reaction, level 2 focuses on learning, level 3 is for behavior and level 4 focuses on results. Kirkpatrick's four-level evaluation methodologies are well known and widely distributed model. Anstey and Watson established a method called "Rubric for E-Learning Tool" Evaluation. The main aim of this method is to identify the functionality and success of e-learning. They defined categories: functionality, accessibility, technical, mobile design, privacy, data protection and rights, social presence, teaching presence, cognitive presence. Each category consists of several covering spaces [11]. Bates described nine steps for the evaluation of online courses. Decide how you want to teach online is stands as the main question for the first step. Decide on what kind of online course stands for the second step. Work on a team defines the third step. Build on existing resources explains the fourth step. Master the technology describes the fifth step. Set appropriate learning goals are linked to the sixth step. Design course structure and learning activities are standing for the seventh step. Communicate, formulates the eighth step, and innovate explains the ninth step [12]. William Horton Consulting offers checklists for course comparison [13]. The quick and systematic way for evaluation is the key point of Horton. eLSE Methodology: a Systematic Approach to the e-Learning Systems Evaluation focuses on the most important aspects like Technology, Interaction, Content, Services [14]. The user-system interaction is an emphasizing aspect of the eLSE method. The newest approach in e-learning is to apply smart solutions based on artificial intelligence algorithms in medical teaching [15-16].

Evaluation of e-learning in Mongolia is not well developed till today. Before the pandemic period e-learning was more local issues of universities and evaluation of e-learning was not in the focus of accreditation institutions or the interest of professors. But some non-governance organizations (NGOs) put effort to develop national perspectives to the evaluation of e-learning early in 2012. Founder and directors of the NGO "E-Campus", Tsetseg-Ulzii cooperated with international quality assurance organizations together and published a report on criteria for evaluation of e-learning [17]. At the beginning of April of this year the UNESCO, United Nations Educational, Scientific and Cultural Organization reported on COVID-19 impact on education [18]. The report focused on the actual state of e-learning in Mongolia and its quality assurance issues. Some universities started to make decisions on university governance level focused on e-learning quality assurance and evaluation of online teaching. The Mongolian University of Science and Technology delivered new rules for e-learning management [19].

3. THE SURE MODEL

For self-evaluation of online courses, we selected the structure-oriented evaluation, SURE model. The SURE model was developed by the first author of the paper for the evaluation of e-learning. The SURE model consists of eight steps to evaluate the selected object [20-23].

Table 1. Eight steps of the SURE model

Steps	Focus	Process
1	Definition of key goals	In this step evaluators should define key goals of evaluation. The SURE result will be positive, only if all defined key goals reach its target successfully.
2	Definition of sub goals	After definition of key goals evaluators should define sub goals which support in reaching key goals target. If any of sub goal reached its target then the corresponding key goal is evaluated as successful.
3	Confirmation of goal structures	Pre-defined key and sub goals structure should be discussed by all interested groups of evaluation results. Only after confirmation of goal structures the next step can be taken. If evaluators cannot accept the goal structures the first and second steps should be repeated until goal structures are accepted.
4	Preparation of questionnaire	Based on confirmed goal structures questions for the questionnaire should be prepared.
5	Confirmation of questionnaire	Prepared questionnaire should be checked and confirmed by all interested groups in evaluation results. Until full acceptance of all questions previous step should be repeated.
6	Collection of data	When questionnaire is ready data should be collected by objective ways. Best method to collect objective data is to use online survey.
7	Processing of data	The collected data should be processed by mathematical rules of the SURE model. There are exists an online calculator for the SURE evaluation [24].
8	Reporting of results	The processed data will be shown via table from online calculator. Four main evaluation scores are available from table: General evaluation score, Evaluation scores for key goals, Evaluation scores for sub goals and Evaluation scores of each participants.

To implement the SURE model we applied all eight steps in corresponding order.

3.1. The Evaluation of Online Course

For self-evaluation we selected Pharmacy courses of Bachelor students from MUPS. In course 1062 enrolled 552 students including 52 male and 500 female students.

3.2. Step From One to Three

These steps are focused on definition and confirmation of evaluation goals.

- Definition of key goals. Based on discussion of evaluators we defined four key goals (Figure 1):
  - Lecture quality (B_1);
  - Seminars/Practices/Laboratories quality (B_2);
  - Teaching performance (B_3);
  - Teacher skills for e-learning (B_4).

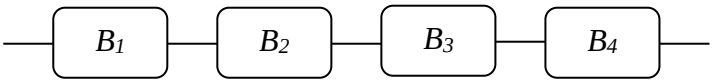


Figure 1. Key goal structure

- Definition of sub goals. To reach defined key goals here described sub goals (Figure 2):

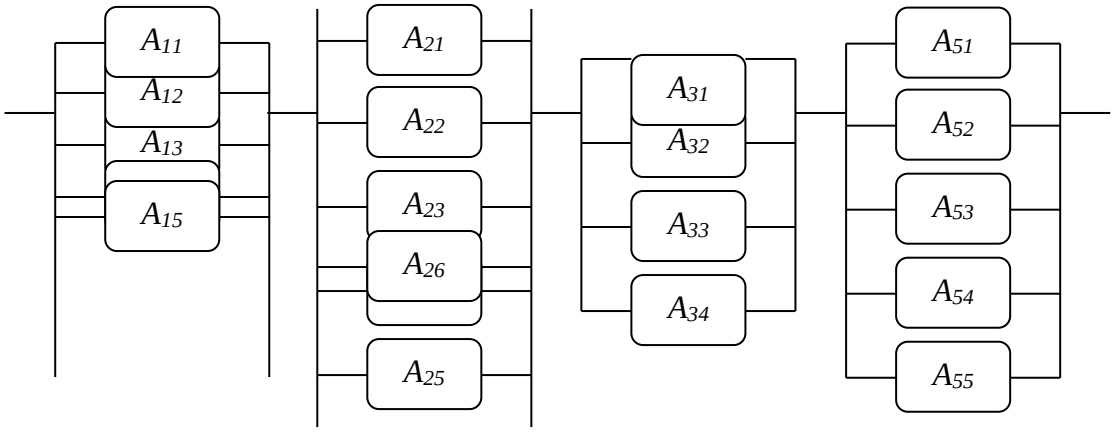


Figure 2. Sub goal structure

  - Lecture quality (B_1):
    - Content of lecture (A_{11});
    - Lecture lesson (A_{12});
    - Time management of teacher during lecture (A_{13});
    - Online synchronic lecture (A_{14});
    - Offline video lecture (A_{15}).
  - Seminars/Practices/Laboratories quality (B_2):
    - Knowledge (A_{21});
    - Practical skills (A_{22});
    - Learner centred learning (A_{23});
    - Knowledge (A_{24});
    - Online synchronic practice (A_{25});
    - Offline video practice (A_{26}).
  - Teaching performance (B_3):
    - Preparation to lesson (A_{31});
    - Teaching methods (A_{32};
    - Oral skills (A_{33});
    - Technical skills (A_{34}).
  - Teacher skills for e-learning (B_4):
    - Preparation level (A_{41});
    - Files for lessons (A_{42});
    - Motivation for students (A_{43});
    - Communication with students (A_{44});
    - Feedback speed and style (A_{45}).

- Confirmation of goals structures. The SURE evaluation expert and professors who teach courses confirmed the goal structures.

3.3. Step four and five

The focuses of these steps are preparation of the questionnaire. In step four questions based on sub goals structure have to be formulated. Scale for measurement designed from 0 to 4. 0 = Disagree at all, 1 = Up to 30% agree, 2 = 31-50% agree, 3 = 51-70% agree and 4 = 79-100% agree (Table 2).

Table 2. Example of question

№	Evaluation indicators	Disagree at all	Up to 30% agree	31-50% agree	51-75% agree	76-100% agree
1.	The content of the lecture was clear					
2.	Lecture is comprehensible					
3.	The teacher was able to use the class time perfectly for the lecture content					
4.	It was convenient to teach the lecture online directly in accordance with the schedule					
5.	It was convenient to watch the lecture on video and study it independently					

Formulated questions should be checked and controlled by all interested groups of evaluation results. Only tested and accepted questionnaires can be used for data collection.

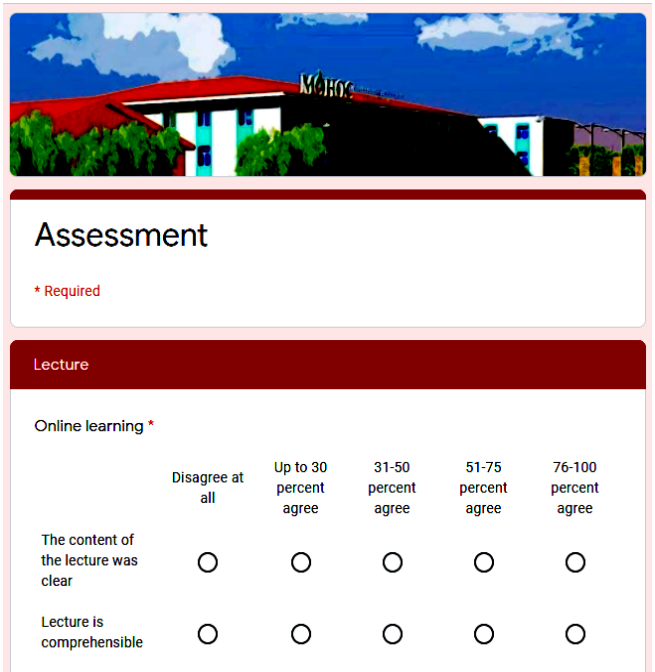


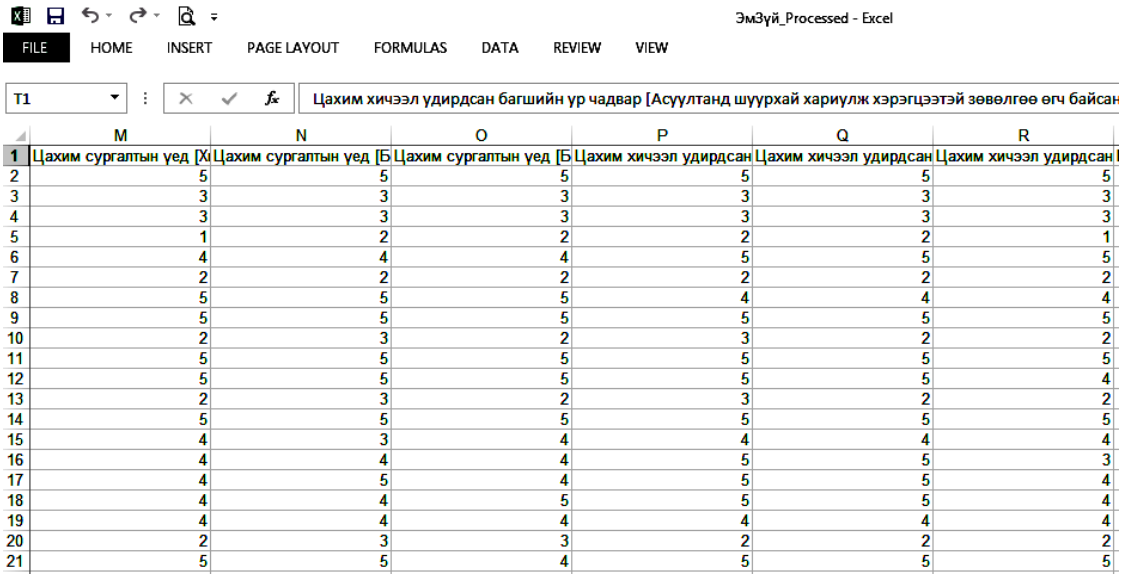
Figure 3. Online data collection

3.4. Step six

Data collection is a important part of any evaluation process. Objectively in good time collected data can increase probability of final evaluation score. For objective data collection we applied Google Form as online tool (Figure 3).

3.5. Step seven

Data which collected by Google form in original shows in Figure 4. The collected data should be processed by the SURE evaluation rules. Main mathematic rules defined based on goal structures [20]. To process the collected data (Figure 5) by online calculator the original data should be transferred to comma separated vector (CSV) files (Figure 6).


ЭмЗүй_Processed - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW

T1 Цахим хичээл удирдсан багшийн үр чадвар [Асуултанд шүүрхай хариулж хэрэгцээтэй зөвөлгөө өгч байсан

	M	N	O	P	Q	R
1	Цахим сургалтын үед [Х	Цахим сургалтын үед [Б	Цахим сургалтын үед [Б	Цахим хичээл удирдсан	Цахим хичээл удирдсан	Цахим хичээл удирдсан
2	5	5	5	5	5	5
3	3	3	3	3	3	3
4	3	3	3	3	3	3
5	1	2	2	2	2	1
6	4	4	4	5	5	5
7	2	2	2	2	2	2
8	5	5	5	4	4	4
9	5	5	5	5	5	5
10	2	3	2	3	2	2
11	5	5	5	5	5	5
12	5	5	5	5	5	4
13	2	3	2	3	2	2
14	5	5	5	5	5	5
15	4	3	4	4	4	4
16	4	4	4	5	5	3
17	4	5	4	5	5	4
18	4	4	5	5	5	4
19	4	4	4	4	4	4
20	2	3	3	2	2	2
21	5	5	4	5	5	5

Figure 4. Original data Excel sheet

...
5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,
3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,
3,3,3,2,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,3,
2,2,2,3,3,2,2,2,2,2,2,1,1,2,2,2,2,1,2,2,
4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,5,5,5,5,5,
2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,
5,5,4,5,5,5,4,5,4,5,4,5,5,5,5,4,4,4,5,5,
5,5,5,5,4,4,4,5,5,5,5,5,5,5,5,5,5,5,5,5,
3,2,3,2,1,3,2,2,3,2,1,2,2,3,2,3,2,2,1,2,
5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,
...

Figure 5. Part of CSV file

The CSV file should be entered to online calculator of the SURE model (Figure 6).

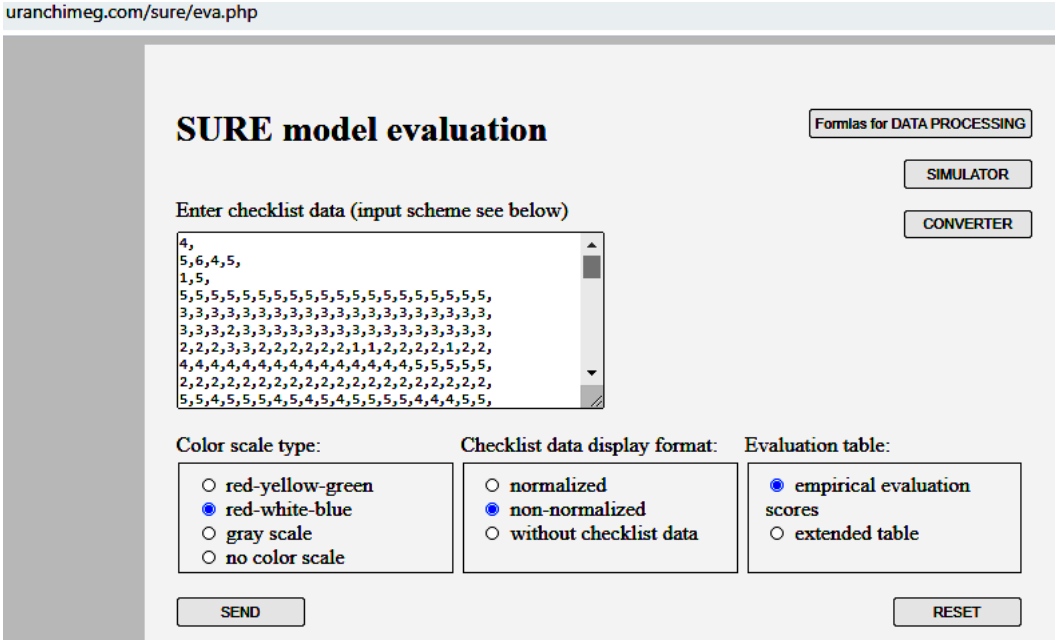


Figure 6. CSV file as enter data for online calculator

The given data will be processed by online tool and as outcome from online tool table with evaluation scores will be returned (Figure 7).

	B_1					B_2						B_3				B_4					
	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{21}	A_{22}	A_{23}	A_{24}	A_{25}	A_{26}	A_{31}	A_{32}	A_{33}	A_{34}	A_{41}	A_{42}	A_{43}	A_{44}	A_{45}	
$Q^*(A_{ij})$	0.69	0.66	0.68	0.63	0.65	0.64	0.61	0.62	0.62	0.61	0.59	0.65	0.68	0.72	0.71	0.73	0.73	0.66	0.67	0.69	$Q_e^*(C) = 0.7022$
$Q_e^*(B_i)$	0.75					0.68						0.73				0.75					

Figure 7. The evaluation result

3.6. Step Eight

The SURE model calculated four different evaluation scores.

- Main evaluation score. $Q^*_e(C)=0.70$
- Evaluation scores of key goals.
  - $B_1=0.75$;
  - $B_2=0.68$;
  - $B_3=0.73$;
  - $B_4=0.75$.
- Evaluation scores of sub goals.
  - $A_{11}=0.69$; $A_{12}=0.66$; $A_{13}=0.68$; $A_{14}=0.63$; $A_{15}=0.65$;
  - $A_{21}=0.64$; $A_{22}=0.61$; $A_{23}=0.62$; $A_{24}=0.62$; $A_{25}=0.61$; $A_{26}=0.59$;
  - $A_{31}=0.65$; $A_{32}=0.68$; $A_{33}=0.72$; $A_{34}=0.71$;
  - $A_{41}=0.73$; $A_{42}=0.73$; $A_{43}=0.66$; $A_{44}=0.67$; $A_{45}=0.69$;
- Evaluation scores of each response. We received 552 responses from students. Due to this big amount of data, the table with students' response data could not be included into the paper. Therefore, we noted here some results as example. 155 students evaluated the course with maximum score 1. 17 students evaluated with worst score 0.

3.7. Result of Evaluation

1062 students studied professional “Pharmacy” but only 552 students sent responses and it was 51.98% of total enrolled students. From them 500 were female and 52 were male students. Out of 97 students studying in a physician of traditional medicine, 60 students or 61.85% (50 female, 10 male), 25 students or 60.97% (17 female, 8 male) out of 41 students studying in Pharmaceutical Engineering and Technology, 56 students or 72.72% out of 77 students studying in Nursing % (54 female, 2 male) students took part in the evaluation process. The reason for some students not participating in the process was the hard accessibility to the Internet in rural areas.

The general evaluation score is 0.70 which is not so high, which is expected of professors who teach selected courses. Key goals are similar to general score: B1=0.75, B2=0.68, B3=0.73 and B4=0.75. There is no key goal that could reach over 80%. That means professors need to do a detailed analysis on each key goal and to focus on weak points of online teaching. The worst score of 0.59 received is “Offline video practice (A26)”. That means students cannot accept or adapt to studying from video by themselves. Further reasons can be not well-developed self-study ability of students or quality of video lessons could not meet expectations of students. Here we need a more detailed study to find out the reasons why this score is the worst and how it can be improved in the next courses. The best evaluation score 0.73 received are “Preparation level (A41)” and “Files for lessons (A42)” from the fourth key goal “Teacher skills for e-learning (B4)”. Students are satisfied with teaching skills for online teaching. Students respect the efforts of teachers for the preparation of online courses. However, 0.73 is not 1 and there are a lot of spaces for improvement of teacher skills for e-learning.

One of the most interesting results of the evaluation is 157 students evaluated online courses with a maximum score of 1. Against this 17 students evaluated online courses with the worst score of 0. Here, a big variance can be observed. This result shows more analyses on other questions relating to the learning environment, quality of internet connection speed, and other issues is needed to be done which can influence the evaluation to such an extent.

4. DISCUSSIONS

Educational evaluation, especially evaluation of e-learning is a huge space for research and study. Therefore we need to discuss and reflect on existing evaluation models and methods, evaluation cases. Evaluators need to openly share their study and experiences on e-learning evaluation. There are several evaluation models and methods distributed among educational intuitions and accreditation organizations. But not all models and methods are suitable for all types of courses and e-learning. Most existing models and methods are fit to use at the university level, not for single online courses. The structure-oriented evaluation model tried to cover all nuances of the evaluation process. Beginning with the definition of evaluation goals until reporting of evaluation results included eight steps or the structure-oriented evaluation model. The second and third authors first time applied the SURE model for their case and it helped them to understand e-learning more deeply from the perspective of students.

There are can come to arise questions: need to do include professors or teaching staff into the evaluation process? Do we need self-evaluation for teaching courses? What is the aim of such activities? Which kind of evaluation methods or models should apply for self-evaluation? Do we need a standard question for self-evaluation of e-learning? and so on. It will be great if evaluators can unite their effort for such us study and cooperate more on same topics. Our opinion is self-evaluation is essentially important to understand the whole evaluation process and get a deeper

feeling of online teaching. We will continue to do self-evaluations and share our experiences in the e-learning field.

5. CONCLUSIONS

The main aim of this paper is to share the evaluation case of online courses during the pandemic period at the Mongolian University of Pharmaceutical Sciences. This case study was the first test of the self-evaluation process for online courses by professors. Such kind of self-evaluation helps professors get a deeper understanding of the e-learning process, different roles, and functions of involved groups, expectations of students during online teaching. The cooperation with the SURE expert helped professors to understand the selected model and to do a successful self-evaluation. Professors collected experiences from the self-evaluation of e-learning by structure-oriented evaluation model. To learn to do a scientific self-evaluation for their online courses give opportunities to professors to look at detailed elements of e-learning from the inner structure of online teaching. Evaluation results show successful pars of online teaching and figure out weaknesses of e-learning. Such results are support professors to create a development plan for further teaching online.

We conclude this evaluation case study as the beginning point of a long-term study in direction of e-learning evaluation. In the future, the evaluation goals structure will be updated and the formulation of questions based on sub-goals will be improved. Moreover, we will distribute our case study to our colleagues not only from our university, but we will also share these experiences as well as with faculties from other universities, too. The most key conclusion is educators need to train with self-evaluations to learn more about their teaching methodologies during e-learning and to understand students' expectations from professors.

REFERENCES

[1] Pharmaceutical Indicators, (2018), "Annual report from Ministry of Health, Mongolia", pp.16-19. Online available: http://hdc.gov.mn/media/files/2018_Kedu7Vn.pdf

[2] Zultsetseg, N., (2021), "Online learning in the MUPS", Journal of Mongolian Pharmacy and Pharmacology. V.1 (18), p.131.

[3] Government of Mongolia, (2019), "Vision 2050, a project to be implemented within the framework of Mongolia's long-term development policy", Package Discussion of the Education. Ulaanbaatar.

[4] Resolution No. 52 of the Parliament of Mongolia. May 13, (2020), "Vision-2050" On approving Mongolia's long-term development policy. Government House, Ulaanbaatar.

[5] B. Munkhchimeg, (2015), "A study of the use of data mining in training management systems for electric learning assessment". Data and Knowledge Management. MMT 2015.

[6] Christopher Pappas, (2011), "Introduction to Evaluation in eLearning", Online available: https://www.efrontlearning.com/blog/2011/01/introduction-to-evaluation-in-elearning.html

[7] Sage Learning Systems, (2011), "e-Learning Evaluation", Online available: http://www.sagelearning.com/papers/Evaluation%20Forms.pdf

[8] RK Prasad, (2020), "The Five Evaluation Levels Of your eLearning Program", online article in eLearning Industry, Online available: https://elearningindustry.com/five-evaluation-levels-of-elearning-program

[9] Paul Petrone, (2017), "The Best Way to Use the Kirkpatrick Model", Online available: https://www.linkedin.com/business/learning/blog/learning-and-development/the-best-way-to-use-the-kirkpatrick-model-the-most-common-way

[10] Kirkpatrick, D. L., (1959), "Techniques for evaluating training programs", Journal of American Society of Training Directors, Vol.13. No.3. pp.21-26.

[11] Lauren Anstey and Gavan Watson, (2018), "A Rubric for Evaluating E-Learning Tools in Higher Education, Educause", Online available: https://er.educause.edu/articles/2018/9/a-rubric-for-evaluating-e-learning-tools-in-higher-education

[12] Tony Bate, (2012), “Nine steps to quality online learning: Step 9: Evaluate and innovate, Online learning and distance education recourses”, Online available: https://www.tonybates.ca/2012/07/09/nine-steps-to-quality-online-learning-step-9-evaluate-and-innovate/

[13] Horton, W., (2001), “Evaluating E-Learning”, American Society for Training and Development, Alexandria.

[14] Lanzilotti, R., Ardito, C., Costabile, M. and Angeli, A., (2006), “A Systematic Approach to the e-Learning Systems Evaluation”. School of Informatics. 9, 4: pp.42-53.

[15] Salem, A.-B.M. (Ed.). (2020), “Innovative Smart Healthcare and Bio-Medical Systems: AI, Intelligent Computing, and Connected Technologies” (1st ed.). Routledge. https://doi.org/10.1201/9781003044291

[16] Salem, Abdel-Badeeh M., and Michael Gr Voskoglou, (2020), "Smart Learning Systems", in proceedings of International Journal of Applications of Fuzzy Sets and Artificial Intelligence (ISSN 2241-1240), Vol.10, pp.103-120. Online available: http://eclass.pat.teiwest.gr/modules/document/file.php/523103/Vol.%2010%20%282020%29/SALEM%20%26%20VOSKOGLOU%2C%20103-120.pdf

[17] Yadamsuren, Ts, (2012), E-Campus, “Technical report on e-learning evaluation”, Online available: http://www.mongolcampus.org/mek/images/pdffile/Work_and_study_report_eLQA_criteria.pdf

[18] UNESCO Educational report, (2021), “COVID-19 impact on education”, Online available: http://www.mier.mn/wp-content/uploads/2020/08/asuudal_4_2.pdf

[19] The University Governance Decision, (2021), “New rules for e-learning management and quality assurance of online teaching”, Online available: http://erdenetis.edu.mn/web_2/resources/files/Image_002-1-merged.pdf

[20] Tudevdagva, U., and Hardt, W., (2012), “A measure theoretical evaluation model for e-learning programs”. In Proceedings of the IADIS on e-Society 2012, March 10-13, 2012, Berlin, Germany, pp.44-52.

[21] Tudevdagva, U., (2014), “Structure Oriented Evaluation Model for E-Learning”, Wissenschaftliche Schriftenreihe Eingebettete Selbstorganisierende Systeme, Universitätsverlag Chemnitz, July 2014. pp. 123. ISBN: 978-3-944640-20-4, ISSN: 2196-3932.

[22] Tudevdagva, U., Bayar-Erdene, L. and W. Hardt, (2014), “A Self-Assessment System for Faculty Based on the Evaluation SURE Model”. In Proceedings of The 5th International Conference on Industrial Convergence technology, ICICT2014, IEEE Computer Society, 10- 11 May, 2014, Asan, Korea, pp. 266-269. ISBN 978-99973-46-29-2.

[23] Tudevdagva, U. (2020), “Structure-Oriented Evaluation an Evaluation Approach for Complex Processes and Systems”, Gewerbestrasse 11, 6330 Cham, Switzerland, Springer, 2020, pp.92, ISBN 978-3-030-44805-9 ISBN 978-3-030-44806-6 (eBook), https://doi.org/10.1007/978-3-030-44806-6.

[24] Online calculator of the SURE model, (2021), Online available: http://uranchimeg.com/sure/eva.php

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IOT-BDMS: SECURING IOT DEVICES WITH HYPERLEDGER FABRIC BLOCKCHAIN

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ABSTRACT

IoT is a rapidly evolving field with an increasing number of connected devices. This naturally leads to a need to ensure good scalability but also to guarantee the identity of devices, for better security. Most of existing solutions for identifying IoT devices are centralized (CA server), which results in lower fault tolerance and in less scalability. To address these issues, we introduce in this paper a new IoT Device Management System based on the Blockchain technology (IoT-BDMS). Our system offers two services through two Smart Contracts deployed on a multi-channel Hyperledger Fabric network: an Identification Smart Contract (ISC) to manage the devices identities stored over multiple channels, and an Authentication Smart Contract (ASC) to validate authentication requests from devices. An identity is generated by involving the actors of the device's ecosystem and evolves according to the device's lifecycle.

KEYWORDS

Blockchain, IoT Security, Hyperledger Fabric, Smart Contracts, Authentication.

1. INTRODUCTION

The Internet of Things (IoT) can be defined as a network of objects able to interact with each other and with their environment, via the Internet. These objects - which are more and more intelligent - collect data via sensors and processes are performed on this data to create value for their users or owners (decision making, recommendations, etc.).

IoT remains a rapidly evolving field, with predictions of several billion connected objects in the coming years (41 billion connected objects by 2027, and 125 billion by 2030) [21]. This rapid evolution enables new applications and usages to be imagined and explored, in areas such as manufacturing (Supply Chain), Industry 4.0, e-health, etc.

At the same time, the growth of IoT (both in terms of number of connected objects and of amount of data generated) is giving rise to new needs, mainly linked to the efficient management of objects and their security. And as already seen in the last years, security issues of IoT can cause disastrous consequences for humans (Mirai DDoS-attack in 2016 [22]). Along with security challenges, other issues such as scalability or interoperability need to be also tackled. An *Identity Management System* (IdMS) refers to the management of an *identity*, whereas an *identity* is a set of information to uniquely identify a given entity (a human, a device, …). *Authentication* refers to the verification of the identity of a given entity and comes along with Identification. Generally, authentication methods are based on something that you know (like a password), or you own (like a smart card), or you are (like a fingerprint). As with identification [28], there are several authentication methods [27] for IoT devices: symmetric-key based authentication schemes, public-key authentication schemes (PKIs, X509 certificates), token-based authentication schemes (*OAuth2.0*), RFID-based schemes, etc.

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Existing IdMS for IoT generally ignore, during the identity generation process, the device lifecycle and the ecosystem in which this device evolves. From the authentication side, the use (for instance) of symmetric cryptography is not adapted to all types of devices (large keys size), and the mobility capacity of devices is often left aside. Finally, whether for identification or authentication, the traditional approaches used in IoT are most often centralized, which leads to a larger attack surface and therefore a lower fault tolerance, but also a low response to scalability needs.

Because of its decentralized, immutable and secure design, Blockchain technology could address some issues of identification and authentication in an IoT context. In fact, several authors [1, 3, 5, 6, 12, 16, 17, 18, 19] have explored the potential of using Blockchain technology to secure IoT devices. This Blockchain-based security generally includes a method for identifying devices, but also a use of the Blockchain to verify the identities of devices, and thus authenticate them.

Our work fits in with this Blockchain-based security for IoT, while addressing some of the issues mentioned above (consideration of the device's lifecycle and ecosystem, scalability). In this paper, we propose a Blockchain-based identification and authentication system for IoT devices, based on a single private Blockchain (Hyperledger Fabric). Our system is comprised of multiple Fabric channels, giving a prior response to IoT scalability needs for Enterprise Use Cases. We designed two Smart Contracts models (an Identification Smart Contract – **ISC** - and an Authentication Smart Contract - **ASC**) and deployed them on a multi-channel Hyperledger Fabric Blockchain. Each Smart Contract pair (ISC, ASC) is responsible of managing and validating devices identities related to its channel. Identities are generated so that they evolve according to devices lifecycle and are stored on specific ledger channels of the global Blockchain network. Devices do not communicate with the Blockchain network, but either send their authentication request through dedicated IoT gateways configured as light nodes.

Our contributions are structured as follows:

1) In **Section 2**, we give an overview of existing works related to Blockchain-based Identification and Authentication for IoT, and highlight some of their limitations.
2) Our contributions are presented in **Section 3**. We list prerequisites of our system and give an overall description of it. We define the components of the system and design its architecture, based on Hyperledger Fabric's channels. Then we describe our identification and authentication schemes. The Section ends with a short analysis of our IoT-BDMS proposal w.r.t to some of the existing methods.
3) We finish in **Section 4** by giving an overview of our implementation on Hyperledger Fabric (with simulated IoT end-devices and gateways) and a Use Case example.

2. RELATED WORK

Traditional digital Identification and Authentication systems can be transposed to the IoT field. But this means addressing at the same time IoT issues, including the need for decentralization for more security, performance and scalability, as well as mobility and interoperability management. And as we mentioned above, the Blockchain, by design, has the potential to remove some of these limitations; indeed, several studies have been carried out to explore the use of the Blockchain to secure the IoT [12], but also to address its scalability requirements.

Regarding scalability, even before discussing that of architectures based on the Blockchain and supporting IdMS and Authentication protocols for IoT, we can already mention the IOTA platform, which defines itself as the (public) Blockchain for the IoT (note that IOTA is actually a DLT - *Distributed Ledger Technology* – based on a structure of DAG - *Directed Acyclic Graph*-

called *Tangle*). IOTA has been specially designed and optimized for the IoT. Hence, it proposes feeless transactions, low-latency micro-payments and claims to guarantee the scalability required in the IoT context (due to the *Tangle* structure used to store transactions). But IOTA actually suffer from many limitations, among which: a kind of "recentralization" via the existence of a *coordinator* in charge of validating transactions (even if work – the *Coordicide* - towards eliminating this *coordinator* seems to be progressing), use of Smart Contract and numerous criticisms around the use of its own cryptographic algorithms. And until now, the scalability highlighted by IOTA seems to remain theoretical.

Unlike IOTA (which is a Blockchain platform designed for the IoT), several works [13] to propose Blockchain-based IdMs and Authentication mechanisms have been carried out; for some of these works, a response (often partial or theoretical) to the IoT issues (such as scalability) is given [2,6,18].

Li et al. [2] designed Blockchain-based identity authentication and data protection mechanisms for IoT devices. In their system, each device is assigned a unique ID which is stored on the Blockchain and allows to authenticate mutually to any other device. However, each device is considered as a node of the Blockchain network, which may not be suitable for devices with low capacities.

In *HIBEChain* [16], authors propose an alternative to traditional IoT identification schemes, using Blockchain technology and based on a decentralized and hierarchical identity-based signature scheme (HIBS - *Hierachical Identity-based Signature Scheme)*. The system uses a collection of private Blockchains to form a hierarchical architecture: each private Blockchain forms a node of the global tree structure and will manage a set of devices. Thus, their hierarchical layered architecture seems to be a real opportunity for scalability issues, by decentralizing and distributing the management of devices identities between several nodes (the management would no longer be done by a single authority). But the solution remains rather theoretical and with a heavy implementation to consider; indeed, the authors do not mention what type of Blockchain could be suitable, what would be the validator nodes, etc. And the solution does not consider the ecosystem in which the device is supposed to evolve.

Authors of [18] propose an identification scheme relying “on three interconnected Blockchains: a (local) private Blockchain for each use case, a shared Blockchain (private) and an overly Blockchain (public). Their solution seems to resolve the identification issue, but it has multiple limitations, like the number of network communications (at least 8) generated by each operation, and the centralization of the local blockchains.

In [14], authors propose to combine a *central* Blockchain (in this case a consortium Blockchain like Hyperledger Fabric) with several *sidechains* (IOTA *sub-Tangles*), in order to make the IoT data management more efficient and secure. Data generated by a device is encrypted before being transmitted to its sub-Tangle coordinator (sub-Tangles coordinators form the nodes of the consortium Blockchain). The system heavily relies on identity control to manage and protect access to IoT data, using Fabric Smart Contracts. A prototype has been set up with software simulations and experimental tests (with performance measures) have also been conducted to motivate the authors' proposal.

From the authentication side, the use of Blockchain has also been widely explored, like in [9, 10, 11, 16, 17, 19].

In [17], author propose *Bubbles-of-Trust*, an Ethereum-based mechanism to mutually authenticate IoT devices and gateways. *Bubbles-of-Trust* was implemented upon the public blockchain

Ethereum, and aims at the creation of secured virtual zones, where devices can communicate securely.

In *Homechain* [19], a Blockchain-based mutual authentication system is proposed for Smart Homes. To provide mutual authentication between users and the home gateway in a Smart Home context, the Blockchain is used together with *group signatures* and MACs (Message Authentication Code); thanks to group signatures, a user is authenticated without disclosing any specific information about him or it's associated gateway,. The system also allows for the efficient tracking of any user who misbehaves in the future. Authors carried out experimental implementations to demonstrate the technical feasibility of their solution (with a few dozen group users). However, these implementations do not consider either the ecosystem of devices or their hardware capabilities. Moreover, *HomeChain*, as its authors point out, has been designed for a specific use case, in this case that of Smart Homes.

To summarize, most of the existing proposals (both for identification and authentication) use architectures either based on public Blockchains [12] such as Ethereum or on hybrid public-private [17] networks, or use Blockchain's hierarchical [16] architectures. But public Blockchains generally come with transaction fees and do not meet all performance requirements for IoT. The use of hybrid architectures often add complexity, with a non-obvious integration and less performances; and the multiplication of communications inside the global Blockchain architecture [18] can also limit the system's performances. On the other hand, as for traditional IdMS, most of the proposals based on the Blockchain technology do not consider the fact that the device's lifecycle can evolve, and therefore its identity as well.

Thus, there is a need to propose a Blockchain-based IdMS and Authentication scheme providing a solution to these limitations.

3. A NEW BLOCKCHAIN-BASED SYSTEM FOR SECURING IOT DEVICES

3.1. Hyperledger Fabric

Hyperledger Fabric (HLF) [4, 6] is part of the Hyperledger suit [7] and is a platform for building consortium/private Blockchain networks. HLF proposes *Smart Contracts* to automate transactions, *channels* for privacy-preserving transactions and allows *membership management* (via Certificate Authorities). HLF ensures good performance metrics (in terms of numbers of transactions per Second for instance) and good scalability.

In our **IoT-DBMS** system, the use of a private/consortium Blockchain such as HLF allows the main actors of the device's ecosystem (manufacturer, administrator, customer or end user, etc.) to be involved in theZ transaction validation process, and therefore in the verification and validation of device identities. Also, HLF Smart Contracts can act as brokers for authentication between devices and their associated gateways.

3.2. Overall Description

Our starting point is a pool of IoT devices spread over several geographical zones. On each of these zones, there is an IoT gateway acting as a bridge between the devices and the IoT Cloud Server. We propose a system based on Blockchain technology to secure the IoT devices of the pool. We use Hyperledger Fabric [7] to build our blockchain network, comprising of multiple channels, each of then representing one of the geographical zones (**Fig. 1**). To take in account the limited capacity of the end devices – and sometimes of the gateways also -, neither the end

devices nor the gateways are considered as nodes of the Blockchain. Instead, gateways can communicate with the Blockchain via API calls, and IoT devices do not communicate in any way with the Blockchain network.

The global workflow comprises two parts: the *Identification Phase* (section **3.4**) and the *Authentication Phase* (section **3.5**).

Through the *Identification Phase*, each new device in the pool will be assigned an identity, stored on the ledger of the appropriate channel. The *Authentication Phase* comes in second, and refers to the validation of a device authentication request before sending data to the IoT server: it is required from the device to send an authentication request at its associated gateway (at least once -after the device first deployment-, and after expiration of the device session).

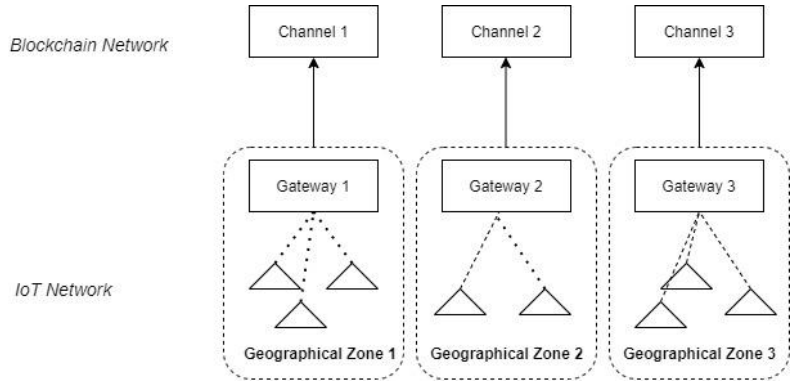

Figure 1. Overview of the System Components:

3.3. Prerequisites

Our system assumes that the following conditions are met:

- **Use of a secure information channel**: To avoid man-in-the-middle attacks (MITM) [23], we assume that devices and gateways exchange data through a secure channel, by communicating for instance over the MQTT (*Message Queuing Telemetry Transport*) protocol [23] secured with TLS(*Transport Layer Security*) [24].
- **Multiple channels on the Blockchain network**: The Fabric network is configured with multiple *channels*, each of them representing a geographical zone containing many IoT devices. And two Smart Contracts (more details in the next section) are deployed on each channel of the Fabric Blockchain.
- **IoT gateways as Blockchain light clients**: The IoT gateways are configured as Blockchain light clients (via a Fabric SDK/REST API), and hence they can communicate with the Blockchain network via the Smart Contracts. Each IoT gateway can only communicate with one channel of the Blockchain network (this can be configured/specified when configuring the gateway as a Blockchain client).
- **Devices keys**: We assume that the manufacturer generates for each device an ECDSA (Elliptic Curve Digital Signature Algorithm) [25] keypair. The private key is then injected into the device (in a kind-of "secured zone"); the corresponding public key is given to the device owner (or to the platform administrator).

3.4. The System Architecture

The system is divided into two parts: the Blockchain network and the IoT network. figure below gives an overview of the (principal) components of our system: the administrator, the Fabric Blockchain network deployed with two Smart Contracts, and the IoT gateways as light clients of the Fabric network.

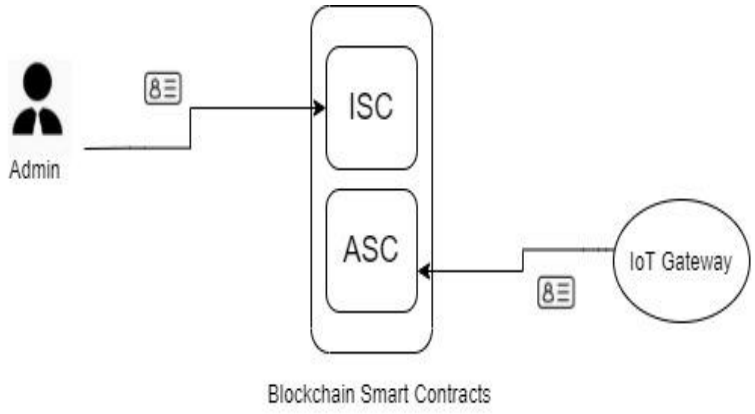

Figure 2. Actors interacting with the Blockchain

a) Two Smart Contracts are deployed on each channel of the Fabric network**:** the **Identification Smart Contract (ISC)** and the **Authentication Smart Contract (ASC).** As their name suggests, the **ISC** is responsible of all transactions related to devices identities (it contains all identity-related functions: registration, update, deletion), and the **ASC** contains functions to authenticate devices (e.g. check existence of devices identities on the Ledger, and verify/validate identities proofs).
b) The **administrator** is responsible of identifying devices. In our system, the identification step refers to assigning to each device an identity and to writing this identity on the appropriate ledger channel on the Fabric network. Administrator is given in advance credentials to access the Identification Smart Contract (ISC), which is in fact responsible of writing on and querying the Ledger.
c) **IoT Gateways** act like intermediaries between end devices and the IoT Server (or Cloud). In our solution, the gateways are also used to check and validate authentication requests coming from their associated devices…. Gateways are configured as light nodes of the Blockchain network (through API clients and calls with the required credentials), an only have access to the Authentication Smart Contract (ASC).

In our system, the Smart Contracts, the administrator and the IoT gateways are the main actors, interacting with the Blockchain network at various levels. But the end devices and the Fabric Blockchain “full” nodes are also part of the system.

```
boolean authenticate_device (device_id_number, challenge, signature) {
        boolean device_authentication_status;
        public_key = ledger[device_id_number].device_public_key;
        if (public_key = null) {
                device_authentication_status = false;
        }
        else {
                device_authentication_status = ECDSAverify (challenge, signature);
        }
        return device_authentication_status;
}
```

Figure 3. Overview of the *authenticate_device* function in the ASC

3.5. The Identification Phase

This phase involves the different actors of the device's ecosystem. Initially, the device is delivered with a kind of secret (an ECDSA private key) injected by the manufacturer. Then the IoT platform administrator will enter certain information related to the device (including data related to its lifecycle, its geographical zone and its deployment context) through a User Interface.

Finally, this information is hashed as follows to construct the device identity:

device_identity = keccak256(serial_number||gateway_id||deployment_date)

where:

* *keccak256* is the SHA3 [26] hash function with a 256 bits-output;
* *serial_number* is the serial number of the device, and *deployment_date* is the date of deployment of the device;
* *gateway_id* is the identifier of the unique gateway in the geographical zone where the device is (or will be) deployed.

The identity will thus vary according to the device's lifecycle (for instance, a change in the *gateway_id* - meaning the deployment of the device in another geographical zone – will result in a complete change of the device's identity). And following needs of the Use Case, other device data (for example the device status: *DEPLOYED*, *MANUFACTURED*, the firmware version, etc.) can be added before the hashing process, to obtain device identity.

After the generation of the identity, the following data structure is stored on the appropriate channel of the Blockchain network, using the Identification Smart Contract (**ISC**):

[device_id_number, device_identity, device_public_key], where:

- *device_id_number* is a unique number identifying the device (generally obtained from (or linked to) the IoT platform)

- *device_public_key* is the device's ECDSA public key. The corresponding private key was previously injected in the device by the manufacturer.

3.6. The Authentication Phase

The next part is to authenticate a device via its associated gateway, and thus to guarantee its authenticity at the IoT platform level. This assumes that the device already had an identity stored at the Blockchain ledger (on the appropriate channel). At this step, the process uses the Authentication Smart Contract (**ASC**).

To show how our Blockchain-based authentication process works, we assume for instance that we have a certain with temperature sensors on it. And the device must periodically send the measures to the IoT Server (Cloud).

Once identified on a channel of the Blockchain (*Identification Phase*), the device will have at first to be authenticated by the appropriate IoT Gateway. The workflow is described as follows:

1) The device generates a MQTT message including its **device_id_number** and sends it to its associated gateway.
2) The gateway generates a challenge and returns it to the device.
3) The device signs the challenge with its ECDSA private key and sends the signature to the gateway.
4) The gateway (as a Fabric light client) calls the ASC on a specific channel, to verify the correctness of the device signature, by giving he **device_id_number** and the device signature.
5) The ASC queries the channel ledger with the **device_id_number** to retrieve the device public key if the device already had an entry on the ledger (else, the authentication process is stopped). The *authenticate_device()* function is called on the ASC to verify the device signature, and the validity status (*true*, *false*) is sent back to the gateway.
6) Following the response received by the gateway, the device will then be considered as authenticated and will send sensors data to the IoT Server, again through the gateway.

- once authenticated, device can then send data to the Cloud, through the IoT gateway.

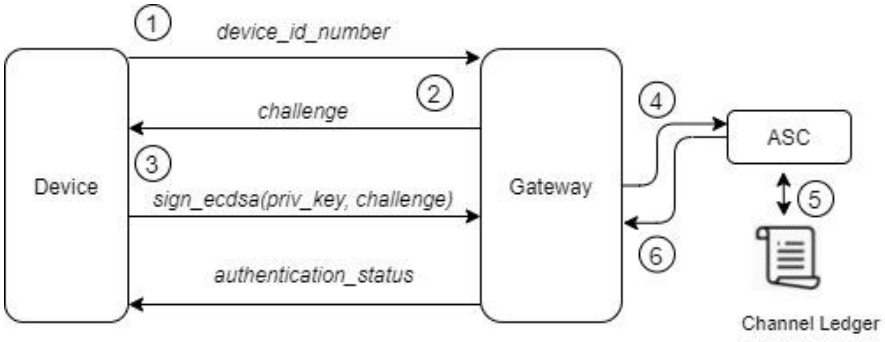

Figure 4. Authentication Workflow

3.7. Short Analysis

Compared to the methods we have analysed in section 3, our IoT-BDMS system has some advantages. First, we do not use a public Blockchain, and we manage to define a potentially scalable architecture using only concepts (in this case *channels*) specific to Hyperledger Fabric.

The fact that we only use HLF allows us to avoid issues related to the integration of several Blockchains (*hybrid* architecture) (like in [16, 18]). To identify and authenticate devices, we use specific Smart Contracts (ISC and ASC); these concepts are not new and have already been used in [1,12]; but unlike [12], and to consider the weak capacities of devices, our identification and authentication features defined in the Smart Contracts do not require the device to participate as a node in the Blockchain network. The identification of the device on the Blockchain is therefore delegated to an administrator for example, and its authentication is done through its gateway which will itself communicate with the ASCs. And this identification takes into account the life cycle of the device, by providing in this identity, from the beginning, information related to this life cycle (such as for instance the geographical area where the device is located at a certain time). To finish, we implemented a proof-of-concept for our system.

4. IMPLEMENTATION AND CASE STUDY

We implemented a prototype (*proof-of-concept)* of our proposal on HLF, with Smart Contracts written in Javascript. and MQTT/Java for the exchanges between the end device and the gateway. Our Fabric Blockchain consortium was made up of 3 channels, each maintained by 2 organisations. Each organisation contains 2 peers, and 1 ordering node. All the Fabric nodes were deployed as Docker containers on a single Linux (Ubuntu 18.04) server hosted on Azure.

On each of the 3 channels, we deployed the ISC and the ASC contracts (**Fig. 5**).

Beside this Blockchain architecture, we also simulated an IoT gateway and an end device, as well as their exchanges (via *WebSockets* and the Mosquitto [15] MQTT broker). On the gateway, we have configured a REST Client to communicate with the ASC (a REST API was developed to expose the services of our Smart contracts). We have tested the end-to-end scenario of the authentication protocol, from the registry of the device identity (done by an administrator through an Angular User Interface) on one channel of the Blockchain, to the authentication request of the device and its validation by the gateway via the Blockchain REST API.

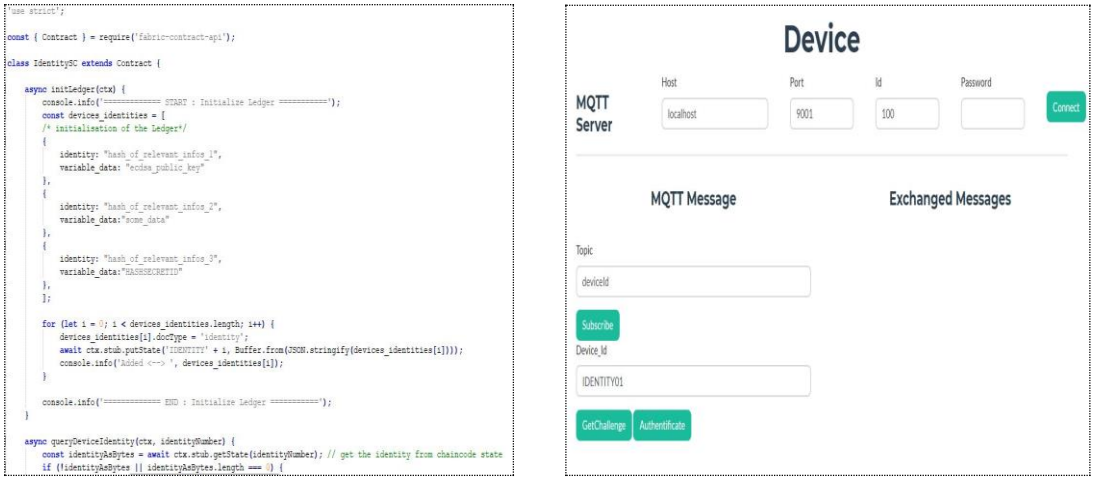

Figure 5. Overview of the ISC (*left*) and the simulated end-device (*right*)

Our system could be deployed for a multi-site manufacturing enterprise, with a dedicated Fabric channel for each site. On each site (e.g. geographical zone), there will be a gateway acting as a broker for the end devices to the authentication functionality on the ASC. This multi-channel architecture could help to handle Blockchain-based authentication for a large amount of IoT devices, at least from a theoretical point of view. In fact, the next step will be to carry out load

testing to identify the maximum number of channels and devices per channel that our architecture is able to support, while continuing to ensure a minimum of performance (*latency* among other indicators).

5. CONCLUSIONS

We proposed an IoT Device Identity Management System (IoT-DBMS) based on Blockchain technology. We distributed the devices identities over multiple Fabric channels hosted on the same Blockchain network and proposed a light Blockchain-based authentication protocol for those devices. We have also implemented our IoT-BDMS by simulating IoT devices and gateways, which provides a sustainable proof-of-concept. As perspectives, we plan to conduct performance tests in order to give some concreteness to the theoretical scalability of our architecture. Integration and deployment in a real IoT environment – thanks to the XIoT [20] platform – are also planned. We also plan to make enhancements so that our Blockchain-based identification and authentication protocols could address the mobility features of some devices, an aspect that has been very - if not completely - unexplored in most existing solutions.

REFERENCES

[1] Y. Zhang, S. Kasahara, Y. Shen, X. Jiang, and J. Wan, ‘‘Smart contract-based access control for the Internet of Things,’’ IEEE Internet Things J., vol. 6, no. 2, pp. 1594–1605, Apr. 2019.

[2] D. Li, W. Peng, W. Deng and F. Gai, "A Blockchain-Based Authentication and Security Mechanism for IoT". In Proceedings of the 2018 27th International Conference on Computer Communication and Networks (ICCCN), Hangzhou, China, 30 July–2 August 2018; pp. 1–6.

[3] H. Liu, D. Han and D. Li, "Fabric-iot: A Blockchain-Based Access Control System in IoT", in IEEE Access, vol. 8, pp. 18207-18218, 2020, doi: 10.1109/ACCESS.2020.2968492.

[4] E. Androulaki, A. Barger, V. Bortnikov, C. Cachin, K. Christidis, A. De Caro, D. Enyeart, C. Ferris, G. Laventman, and Y. Manevich,‘‘Hyperledger Fabric: A distributed operating system for permissioned blockchains,’’ in Proc. 13th *EuroSys Conf.*, 2018, p. 30.

[5] M. Banerjee, J. Lee, Q. Chen and K. R. Choo, "Blockchain-Based Security Layer for Identification and Isolation of Malicious Things in IoT: A Conceptual Design", *27th International Conference on Computer Communication and Networks (ICCCN)*, Hangzhou, 2018, pp. 1-6, doi: 10.1109/ICCCN.2018.8487447.

[6] O. Novo, ‘‘Blockchain meets IoT: An architecture for scalable access management in IoT’’, *IEEE Internet of Things J.*, vol. 5, no. 2, pp. 1184–1195, Apr. 2018.

[7] “Hyperledger”, at https://www.hyperledger.org/. Last accessed on January 15, 2021.

[8] “ Comprehensive Guide to IoT Statistics You Need to Know in 2020”, at https://www.vxchnge.com/blog/iot-statistics. Last accessed on January 15 2021.

[9] Zhu Xiaoyang, and Youakim Badr. “Identity Management Systems for the Internet of Things: A Survey Towards Blockchain Solutions”, *Sensors (Basel, Switzerland)* vol. 18,12 4215. 1 Dec. 2018, doi:10.3390/s18124215.

[10] Inayat Ali and Sonia Sabir. “Internet of Things Security, Device Authentication and Access Control: A Review”, *(IJCSIS) International Journal of Computer Science and Information Security*, Vol 14, No 8, August 2016.

[11] Achraf Fayad, Badis Hammi and Rida Khatoun. “An adaptive authentication and authorization scheme for IoT's gateways: a blockchain based approach”, *Third International Conference on Security of Smart Cities, Industrial Control System and Communications (SSIC)*, Shanghai, 2018, pp. 1-7, doi: 10.1109/SSIC.2018.8556668.

[12] R. Neisse, J. L. Hernández-Ramos, S. N. Matheu, G. Baldini and A. Skarmeta, "Toward a Blockchain-based Platform to Manage Cybersecurity Certification of IoT devices," *2019 IEEE Conference on Standards for Communications and Networking (CSCN)*, GRANADA, Spain, 2019, pp. 1-6, doi: 10.1109/CSCN.2019.8931384.

[13] Shu Yun Lim, Pascal Tankam Fotsing, Abdullah Almasri, Omar Musa, Miss Laiha Mat Kiah, Tan Fong Ang and Reza Ismail. “Blockchain Technology the Identity Management and Authentication

Service Disruptor: A Survey", *International Journal on Advanced Science Engineering Information Technology*, Vol 18, No. 4-2

[14] Yiming Jiang, Chenxu Wang, YaweiWang and Lang Gao. "A Cross-Chain Solution to Integrating Multiple Blockchains for IoT Data Management", *Sensors* 2019, 19, 2042; doi:10.3390/s19092042.

[15] "Mosquitto Broker", at https://mosquitto.org/documentation. Last accessed on January 15, 2021.

[16] Zhiguo Wan, Wei Liu and Hui Cui , "HIBEChain: A Hierarchical Identity-based Blockchain System for Large-Scale IoT", *IACR Preprint*, at https://eprint.iacr.org/2019/1425.pdf. Last accessed on January 1, 2021.

[17] Mohamed Tahar Hammi, Badis Hammi, Patrick Bellot and Ahmed Serhrouchni, "Bubbles of Trust: a decentralized Blockchain-based authentication system for IoT". *Computers & Security*. 78. 10.1016/j.cose.2018.06.004.

[18] Ali Dorri, Salil S Kanhere, Raja Jurdak, and Praveen Gauravaram. "Blockchain for iot security and privacy: The case study of a smart home", In *Pervasive Computing and Communications Workshops (PerCom Workshops)*, 2017 IEEE International Conference on, pages 618–623.

[19] C. Lin, D. He, N. Kumar, X. Huang, P. Vijayakumar and K. R. Choo, "HomeChain: A Blockchain-Based Secure Mutual Authentication System for Smart Homes", *in IEEE Internet of Things Journal*, vol. 7, no. 2, pp. 818-829, Feb. 2020, doi: 10.1109/JIOT.2019.2944400

[20] "Internet of Things – XIoT Platform". At https://www.capgemini.com/service/digital-services/digital-engineering-and-manufacturing-services/iot-and-connected-products/internet-of-things-xiot-platform/ . Last accessed on January 15, 2021.

[21] "Leaked Mirai Malware Boosts IoT Insecurity Threat Level". At https://securityintelligence.com/news/leaked-mirai-malware-boosts-iot-insecurity-threat-level/ (October 4, 2016). Last accessed on January 15, 2020.

[22] F. Callegati, W. Cerroni and M. Ramilli, "Man-in-the-Middle Attack to the HTTPS Protocol", in *IEEE Security & Privacy*, vol. 7, no. 1, pp. 78-81, Jan.-Feb. 2009, doi: 10.1109/MSP.2009.12.

[23] "MQTT - The Standard for IoT Messaging". At https://mqtt.org. Last accessed on January 16, 2021.

[24] Tim Dierks and Eric Rescorla. "RFC 5246: The Transport Layer Security (TLS) Protocol Version 1.2", *Internet Engineering Task Force (IETF)*, August 2008.

[25] National Institute of Standards and Technology. "Digital Signature Standard (DSS)", FIPS PUB A86-4. At https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.186-4.pdf, July 2013.. Last accessed on January 15, 2021.

[26] National Institute of Standards and Technology. "SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions", FIPS PUB 202. At https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf, August 2015. Last accessed on January 18, 2021.

[27] El-hajj, Mohammed & Fadlallah, Ahmad & Maroun, Chamoun & Serhrouchni, Ahmed. (2019). "A Survey of Internet of Things (IoT) Authentication Schemes". *Sensors* 2019. 10.3390/s19051141.

[28] Cremonezi, Bruno, Borges Alex, Miranda Nacif and José Nogueira, Michele. "Survey on Identity and Access Management for Internet of Things". 2020. 10.21203/rs.3.rs-66793/v1.

BLOCKCHAIN-BASED APPROACH TO FOSTER STUDENT ENGAGEMENT ON CAMPUS

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ABSTRACT

On-campus activities like positions of responsibility in campus amenities and participation in research, benefit the students as well as the university, while also making students financially self-sufficient to a certain extent. However, this student participation is stymied by lack of awareness and motivation. Significant impetus to innovation and student participation can be provided by incentivization of these activities. In this paper, we propose a system to create a blockchain-based economy, to incentivize students with empirical benefits or monetary awards calculated using objective algorithms. The incentivization algorithms have been designed for three promising use cases: research work, positions of responsibility in universities, and crowdfunding. The demonstrated implementation of this system utilises VJTI Chain, an already established Proof of Authority blockchain in VJTI Mumbai, India. This creates a circular economy within the university which encourages students to earn more rewards by reinforcing positive feedback.

KEYWORDS

Blockchain, Cryptocurrency, Incentivization Algorithms, Student Engagement.

1. INTRODUCTION

Academic success includes curiosity and innovation, and is not limited to course grades. [1] Many students try to contribute to the fields of scientific research in tandem with the growing technologies of today's age. Technological innovations that contribute to helping the society in some way, like consolidating resources to channel them towards areas of need, provide inspiration to make students into productive citizens of the world.

Globally for years, there have been many university students taking positions of responsibilities, and pedagogical and scholastic roles in their campus offices to earn while they are studying. [2] The responsibilities include - but aren't limited to - clerical as well as academic roles. Such opportunities help students in being self-sufficient to an extent. Campus facilities like the library, the canteen, and the bookstore are provided to the students, aided by the staff.

To incentivize the overall development of students as well as the institution that they are a part of, an incentive-based system can be employed, where students earn rewards for performing certain activities. [3] In this paper, we propose a blockchain-based student activity incentivization system. Compared to a regular secure database, a blockchain-based system provides increased trust and security due to its immutability which is essential in a transactions-based application. This system leverages the power of an existing blockchain ecosystem, the VJTI Blockchain (introduced in March 2019), which uses the Proof of Authority (PoA) consensus mechanism.

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pp. 53-65, 2021. CS & IT - CSCP 2021 DOI: 10.5121/csit.2021.110605

Advantages of a PoA-based blockchain system include a high transaction rate due to the acceptance of transactions only by authorized nodes, enhanced trust in the system since it will be tamper-resistant and transparent, and lastly, the obviation of the prerequisite of high-performance hardware.

There are a few reasons that find apposite use of VJ Chain in the proposed implementation. Firstly, the existing infrastructure of VJ Chain has been in use for occasional canteen transactions and this has immense scope to be extended to other use cases. Secondly, with the creation of a circular economy, students can spend their rewards within the same ecosystem as they were received, which creates an additional incentive for earning them. Lastly, this implementation serves as a premise to be an impetus to technology as one of the emerging applications of blockchain. The usage of a growing technology means more scope for innovative avenues in the future.

The system proposed in this paper aims to be an augury of digitally-facilitated innovation havens. Implementations of this system have the main objective of providing a solution for students to get motivated and inspire others into having a more enriching university experience. This paper aims to encourage more students to participate in this campus-experience. Consequently, an improvement in facility qualities (due to the new perspective brought in by the youth) complements the experiences newly gained by the students.

The rest of the paper is organized as follows: Section II adumbrates implementation of blockchain-based projects for university campuses. In Section III, we give a case-wise overview of the proposed methodology. Section IV discusses the design and implementation of this framework. Section V describes the future scope. The conclusion is presented in Section VI with references at the end.

2. RELATED WORK AND TERMINOLOGIES

This approach to incentivize students draws inspiration from previous works. Awaji et. al. [4] extensively survey the relevance of blockchain application frameworks in higher education. The authors address current implementations categorising the usage into academic record verification (degrees and certificates), assessments, credit transfer between universities, admissions, general data management, and review papers. The most number of reviewed implementations focussed on data management. Further, the work also enumerates the challenges recognised while reviewing these implementations, the most significant ones being privacy, scalability, and blockchain usability.

Services offered by blockchain in education as noted by Hameed et al.[5] include its function as a content library and a medium for inter-business connections. The paper mentions applications like Tutellus and Echolink, where blockchain is used as a platform for cooperative learning. Tutellus expects to resolve the problem of high costs for higher education by paying students for learning. It had become popular among 1,000,000 Spanish-speaking users. Echolink is an abbreviation for ‘Education Career Skills Human Capital Opportunity Link’. It is a blockchain-based system that stores the hash of verified data of an entity (here, student, teacher, or other educational organisation) on a permissionless blockchain. The data source is trustworthy. The paper also enlists some supplemental technologies used by these applications, like BOLT (enables provenance in blockchain technology), hyper ledger, and sharding.

Chen et al. [6] mention the use of blockchain in education from the perspective of students as well as teachers. One such use of blockchain is the submission and evaluation of assignments, which will be stored on the blockchain. The paper also provides a use case such that the work

done by the student is not constantly monitored by teachers, rather the information submitted by both parties is directly stored on the blockchain. Applications of blockchain in the field of education have been summarized by SJ Ralston et al. [7] The paper mentions a number of different applications, like the usage of blockchain in academic degree management, summative evaluation of learning outcomes and monetization of academic skills and reward for scholastic achievement.

Bhagwat et al. [8] have built an academic governance ecosystem based on the VJTI Chain, leveraging the power of its Proof of Authority consensus mechanism for different aspects of academic governance like storing student records, verification of student records and assignment incentivization.

We define some of the common terminologies that are required to build an incentivization system based on the blockchain ecosystem.

2.1. Blockchain

A blockchain[9] is an append-only list of blocks linked using cryptography. The header in each block contains a field having a cryptographic hash of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree).

Components of a blockchain are:

1. Node: The smallest independently operational entity in the blockchain network;
2. Transaction: The data concerning the transfer of value units between at least two nodes;
3. Block: A data structure aggregating transaction and other metadata to be added to the blockchain;
4. Chain: The link established between blocks due to each block referring to the hash of its immediate predecessor;
5. Miners: Nodes that add new blocks to the chain and broadcast the updated chain;
6. Consensus: A set of rules regarding blockchain operation mutually accepted by all the nodes.

The key properties of a blockchain are:

1. Distributed: All versions of the ledgers present on all nodes are in sync. An update on one part of the chain reflects throughout.
2. Secure: The data of each block is hashed. Verification of its integrity uses proof of zero-knowledge.
3. Tamper-resistant: Mutation in block contents results in an avalanche effect, changing all subsequent hashes, altering the blockchain itself. This means a change in a block would require an infeasible operation of re-hashing the entire chain after it.
4. Transparent: All nodes in the chain have access to the data in it.

2.2. Consensus Mechanism

A consensus mechanism is used to tackle fault-tolerance. It is used to arrive at a group consensus regarding the data to be added to the network or the state of the network. The famous consensus mechanisms are Proof of Work (used by Bitcoin, Litecoin, and Monero), Proof of Stake (used by Ethereum 2.0 and Dash). Other consensus mechanisms include Proof of Authority, Proof of Vote, and Proof of Burn.

Proof of Authority [10] has all transactions validated by (an) approved account(s), known as validators. These validators are similar to “admins”. In PoA-based networks, transactions and blocks are validated by approved accounts, known as validators. Since the authority is already established, the competition between validators to mine blocks is absent. Characteristics native to PoA blockchains include high transaction rate, predictable time intervals between mined blocks, and obviating the prerequisite of high-performance hardware.

2.3. VJ Chain and VJCoin

VJ Chain is a complete implementation of a public PoA Blockchain, as can be seen in Figure 1. [11] Since the institution authorities are honest nodes, transactions are trustable and cannot be tampered with by other nodes (students). The tokens exchanged in VJ Chain are called VJCoins. Each user can register on the chain as a full node with a wallet. Light nodes are implemented via accounts using the Android Application for VJ Chain. The wallet address will hold the VJCoins of the user. In the circular economy so established within the campus, VJCoin rewards are spent within the same ecosystem as they were received in, creating an additional incentive for earning them. Complete serialization is done via JSON and HTTP REST API is used for interaction with VJ Chain.

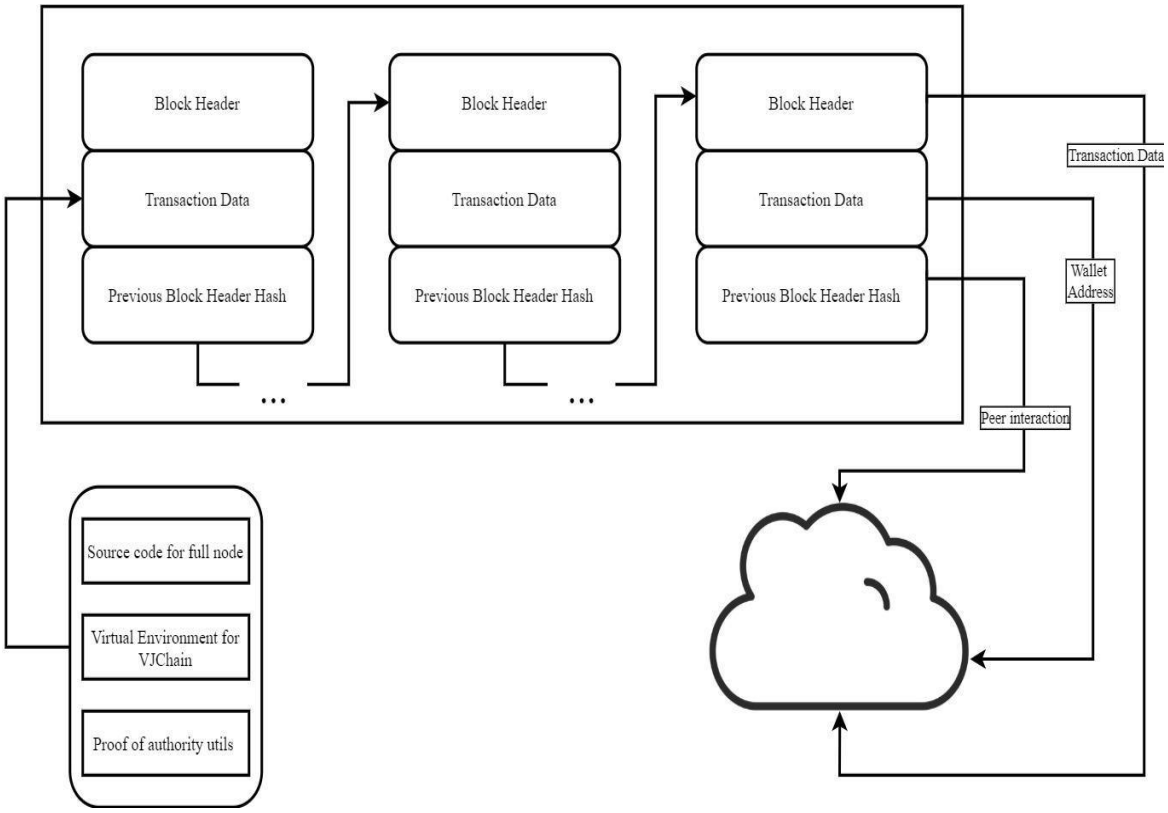

Figure 1: Structure of VJ Chain: Shows source code requisites for deploying the chain (such as the virtual environment and libraries used to construct the consensus mechanism) and the main fields of each node in the chain. The data that is sent to and from the cloud is public.

3. PROPOSED METHODOLOGY

The system addresses the most common challenges with blockchain-based implementation for higher education: Scalability is easier because of PoA and a NoSQL database, and blockchain usability is abstracted using an application layer and an API. Students are already registered on the system when they register with VJ Chain externally. The corresponding wallet address of the student is stored in the system's data layer which is explained in Section IV. All transactions using VJCoins that occur as a result of student activities use this wallet address.

3.1. Use Case I: Research incentivization

3.1.1. Motivation

As the name suggests, research incentivization serves to encourage students to participate in research activities by providing them with monetary benefits. This is a win-win situation for the institution and the students. For universities, this is a positive cycle as increased research activity will improve the reputation of the university which would, in turn, attract better students and teachers. Many of the students do not undertake research work due to a lack of awareness as well as incentivization. This use case aims to increase participation among students to perform research by directly transferring VJCoins to the student's wallets after the successful completion of a research activity.

3.1.2. Workflow

Students register under a faculty for a project topic. Once the faculty approves of the team, the students must upload biweekly reports about the project. The faculty grades these reports on their novelty, invested efforts, and relevance to the topic, with feedback for the same. Based on these grades provided by the mentors for all submitted research work submitted, the student receives appropriate monetary compensation. This use of grades creates a rating system to promote healthy competition, ensuring that the works regarded to be of the best overall quality are awarded.

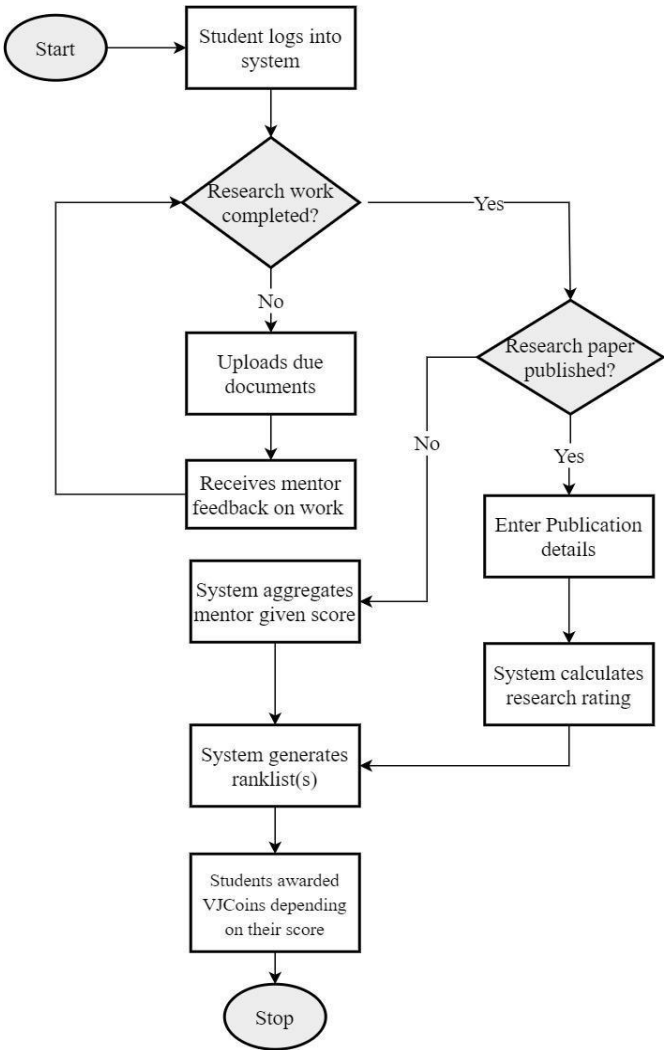

Figure 2: Workflow of research incentivization: The student undertaking work in this field may or may not choose to publish a research paper. A different ranklis is generated for students with published papers. In each ranklist, VJCoins are awarded based on rank

If the student is able to publish a research paper on this topic, the student must provide these details to the system. A metric would be maintained by using the "Weighted Publication Approach". In this approach, the reputation of the journal in which the paper is published (quantified using its impact factor of the journal) is used to compute the quality of the paper. The research rating metric is defined as the impact factor divided by the total number of authors, as the contribution to a paper is inversely proportional to the number of authors. A student's impact score is the summation of all of his research ratings. This is denoted in the following way:

$$\text{student\_impact\_score} = \sum \text{research\_rating},$$

$$\text{where, research\_rating} = \frac{impact\_factor\_of\_journal}{no\_of\_authors}$$

Based on the final mentor given rating (and research rating, if the student submits publication details) of a student, the corresponding amount of coins are transferred to the student's wallet address by sending API requests to VJ Chain.

3.2. Use Case II: Temporary Positions in Campus for VJTI Students

3.2.1. Motivation

This use case revolves around students working in temporary positions within the campus itself, eliminating additional travel. Students would work part-time and earn money to support themselves financially. The institution benefits by harnessing in-campus work skills instead of hiring outside help. The institution will have a steady and varied supply of students to match the demand for these temporary positions.

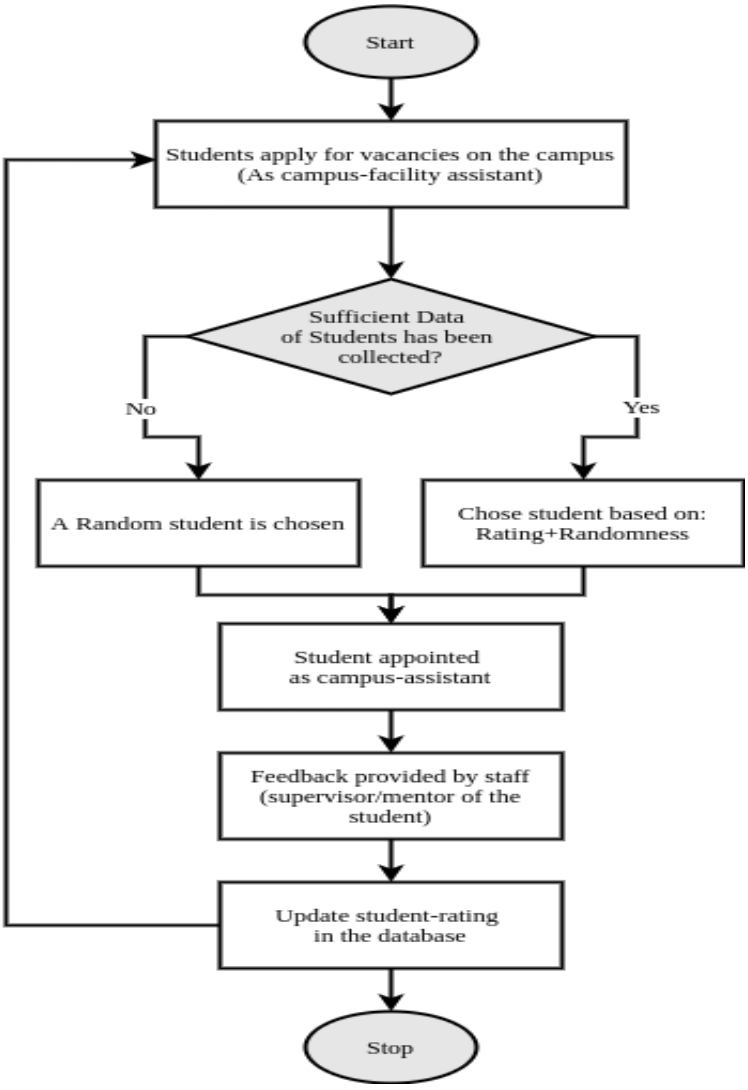

Figure 3: A depiction of the workflow for the assignment of Temporary Positions on Campus to the students chosen using a combination of ratings and randomness

3.2.2. Workflow

The supervisor in charge of appointing students will post an opening for the temporary position on the system. Students can apply for temporary positions on the system. The campus jobs would be for a reasonable duration of time (8-10 hours a week) to ensure that these temporary positions do not interfere with the student's academics.

The initial allocation algorithm for this use case is based purely on randomness as there is no method to pick one student over another. The initial proposed time for these jobs is 1-2 weeks, till a basic database of 10-12 students is available for each job. After completion of each job, the employer will provide a rating(from a scale of 1-10) based on the tasks' performance. Students are paid per-hour for the work they put in using a predetermined rate in the form of VJCoins that are transferred to their wallets.

Once this basic database is created, the allocation algorithm for this use case starts factoring in the ratings of the student but a small factor of randomness is still present. This is done to ensure that the same student(s) do not get picked repeatedly and other students also get a chance to apply for these jobs. Over time, the performance of students will be averaged and students with better ratings will have a higher probability of securing further jobs in that position. A student who has newly entered the system would be given a "default" rating of 9 to allow a fair chance to all students. This default rating provided to the student would not contribute to his average rating as that rating is simply present for initial allocation.

On surveying VJTI college, we found some temporary positions where students could work: the canteen, where the positions could be of a waiter or a cooking/cleaning assistant; the computer lab(s), as a monitor or for technical assistance with lab devices; and as an assistant at the general stationery center or the library.

3.2.3. Verification Mechanism

As mentioned previously, the employer provides a rating for each job completed by each student. A supervisor would have no reason to provide falsified ratings as the employer would then have a subpar quality of accomplished tasks.

3.3. Use Case III: Crowdfunding

3.3.1. Motivation

This use case leverages the familiarity bred amongst university members to facilitate aggregation of financial aid. Envisioned beneficiaries are the students or employees of this institution who need to raise an amount for a crisis. The system allows all members to donate some amount of money to those who require it.

3.3.2. Workflow

The beneficiary posts an announcement on the system which provides information on his/her problems, and the amount of money required. All members registered on VJ Chain can view this announcement and they have an option to transfer some money from their wallet to the beneficiary's wallet. Once the goal has been reached donation to that particular announcement will be disabled automatically. As all transactions happen on VJ Chain, there is an implicit ease of transfer of money.

4. IMPLEMENTATION AND EVALUATION OF PROPOSED BLOCKCHAIN BASED FRAMEWORK

4.1. Implementation

As can be seen in Figure 4, the project consists of mainly three layers which are: the Application Layer, the Business Layer and the Data Layer. In order to complete the Use Cases, the three layers work together to manipulate data and perform transactions.

4.1.1. Application Layer

The application layer has been designed to be intuitive and abstracted so as to not trouble the user with underlying complexities. Students, faculty, and supervisors are provided with dashboards once they have successfully logged in. Web-based applications are convenient and preferred as they are compatible with all types of devices. We have built these dashboards using HTML5, CSS3 and javascript on the frontend. Proven to assist well with browsers, jQuery is used which is a javascript framework.

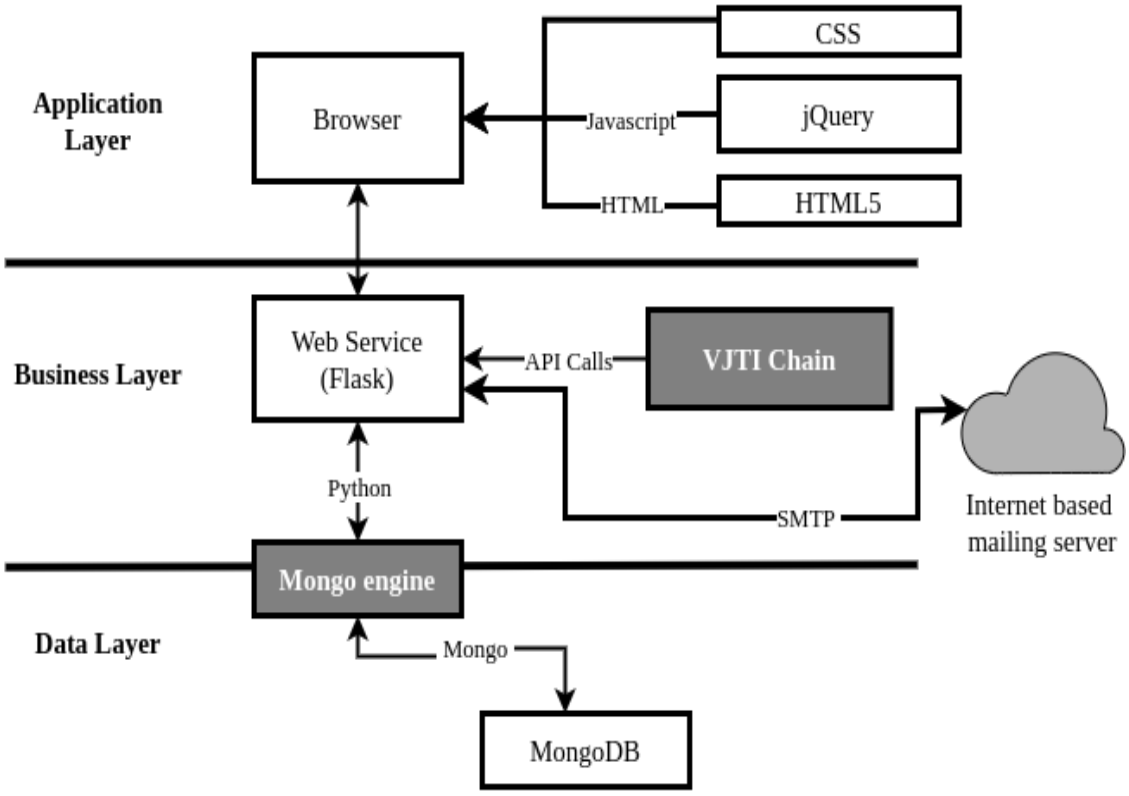

Figure 4: Technology Stack: Each layer is responsible for a specific part of the project, with the application layer being the frontend, the business layer managing connection with VJChain and logic implementation, and the data layer for organisation of all stored information

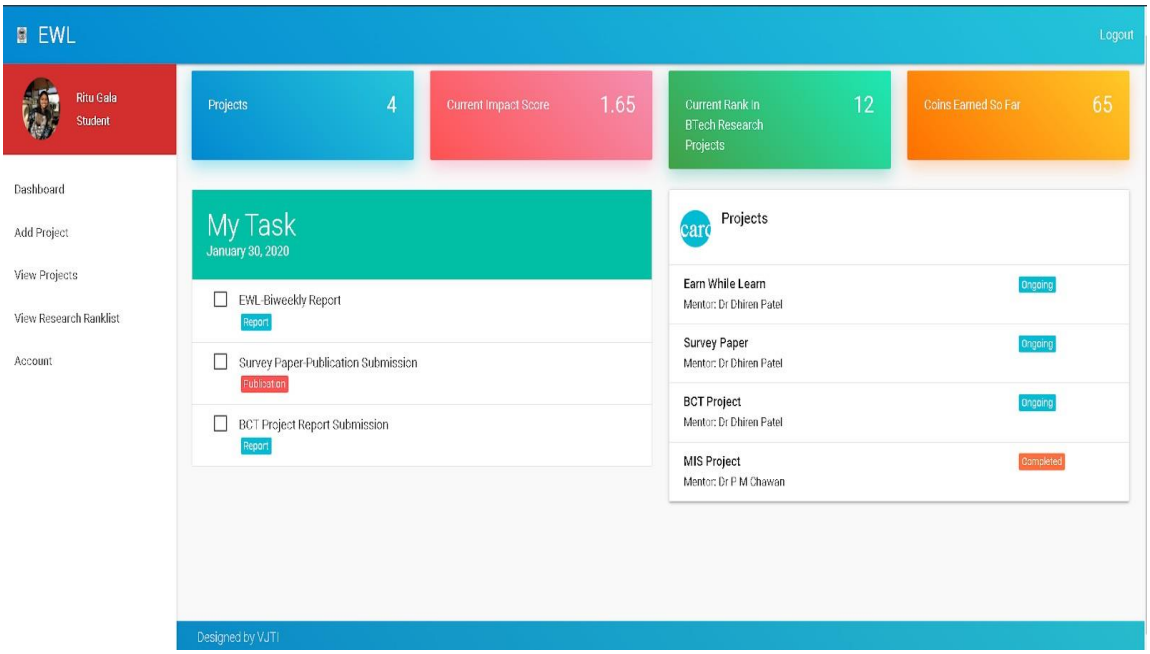

Figure 5: Student Dashboard: Ongoing projects and jobs are displayed for the respective student, with their current position in ranklist(s) corresponding to their work in use cases. The status of their work is also displayed. A navigation bar allows for browsing to other sections

The student dashboard allows students to view and apply for jobs. It also allows them to view their ongoing research projects under their respective faculty. The faculty dashboard allows the faculty to view research teams working under him, grade reports and verify publications. The supervisor dashboard allows the supervisor to add job postings, view current postings, view applicants who have applied for a posting and assign a job to an applicant. The user interface for a student dashboard is as shown in Figure 5.

4.1.2. Business Layer

The core logic for each use case discussed in section III has been implemented using Python Web Flask Service. Features like mail notifications have been included to increase the convenience of users. Students and staff receive news and updates via mail and not just on their dashboards. The mail notifications system has been built using the Simple Mail Transfer Protocol (SMTP) and is used to send reminders and updates regarding publications, reports, feedback or grading results. Users are also provided with a chat feature which has been built using Sockets.io, for real-time communication. The business layer also makes API calls to the VJTI Chain which allows for transactions to be reflected on to student wallets.

As mentioned by M. Bhagwat et al. [8], on the VJ Chain, a wallet structure was designed using JavaScript in order to be able to process transactions on the client-side without having to send the private key over the server. This wallet could sign (and add) transactions and verify/validate fetched transactions, for this purpose Elliptic Curve Digital Signature Algorithm (ECDSA) is used, which is an elliptic curve analogue of the Digital Signature Algorithm (DSA) [12].

4.1.3. Data Layer

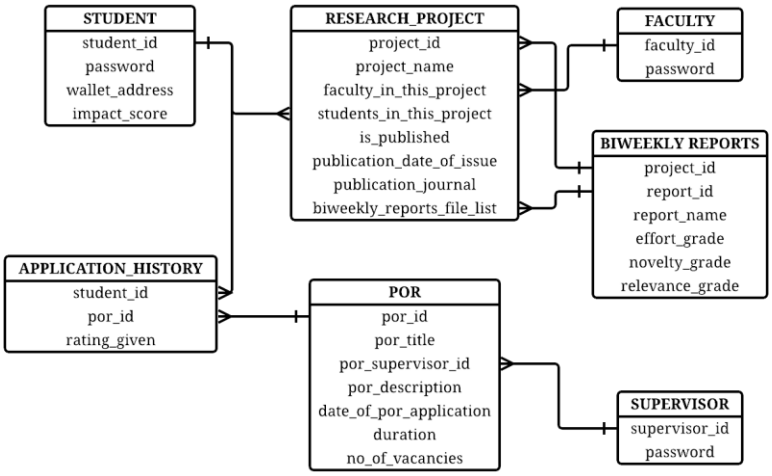

Figure 6: Database Design: This shows the collections used in the project database and their relations with one another

Consistent with the high transaction rate in the PoA blockchain that the system interacts with, the related information is organised and stored in MongoDB for convenient scaling of high read-write traffic. The horizontal scale-out NoSQL architecture enables support for greater data volumes over iterative development. As Győrödi, Cornelia & Gyorodi, Robert & Pecherle, George & Olah, Andrada.[10] have described, MongoDB can handle unstructured data with high efficiency i.e. operations like Insert and Select are much faster with MongoDB, when huge amounts of data are to be queried.. The fields and interaction between these collections are shown in Figure-6. The fields and interaction between the following collections are shown in Figure 6.

1. Student: The primitive collection which has student information. It also contains the student wallet address
2. Faculty: The collection contains details about faculty under whom students work for research
3. Research Project: The collection contains details about all the projects on which students are working on and also contains details of any publication made related to that project
4. Biweekly Reports: This collection contains all the reports submitted by students along with their grading metrics of novelty, effort and relevance.
5. Supervisors: The supervisors are the employers in the position of responsibility
6. Position of Responsibility: This is the collection that contains details of positions of responsibility posted by a supervisor along with student applicants
7. Application History: This collection contains all the applicants and the jobs which they have applied to as well the rating given for an applicant by supervising staff.

4.2. Evaluation

Evaluation and Demonstration of Blockchain Applicability Framework [14] mention a panoply of parameters to gauge blockchain application frameworks. The aforementioned paper mentions five domains for evaluating these frameworks. We use [14] as a reference for the evaluation of our platform and delineate the domains that are the most relevant to our platform.

Domain 1: Data Participation provides relevant questions to evaluate whether blockchains are required or not, whether they are permissioned or permionelsess, and the issues around the

known identity of the reader and writers, and any synchronization in the writer's interests. The basis of our system relies on a proof of Authority VJ Chain. The subdomains Authority Nodes (DP.AN) and Reader and Writer Characteristics (DP.RWC) contain the most apposite questions for the evaluation of our system.

Domain 5 introduces controls for Performance and Efficiency. The platform that we propose in this paper relies on a circular economy of a cryptocurrency, hence parameters like latency, transaction speed, cryptocurrency volatility, and customization in the platform are pertinent for a quantitative analysis of it. Subsections from Domain 5 that contain pertinent questions are System Performance (PE.SP), Expandability Attributes (PE.EA), and Market Design (PE.MD).

5. FUTURE WORK

Although the aforementioned use cases are our main focus, we recognise that a platform that caters to many different use cases will help modernize our efforts while benefiting a larger group. Those students who have excelled in a certain course can tutor those students who are currently studying the course. This win-win solution relieves teachers of mundane work on teachers and allows these tutors to receive a small monetary compensation for their efforts.

The institution campus is home to a lot of collaborative activities organised and hosted by students. These activities include workshops, marathons and guest lectures. The students that contribute to make these events a possibility will be incentivized using the proposed system. The incentive however will not be monetary but points-based.

6. CONCLUSION

In this work, we have discussed the potential of a blockchain-based cryptocurrency system to incentivize student participation in campus activities. In traditional systems, there is an evident lack of participation of students in activities that can retard the development of both the student and the institution. The proposed system leverages the power of VJTI blockchain to incentivize students to participate in campus activities. The implementation aims to improve the drawbacks of previous works by an appropriate choice of techstack. The platform caters to many different use cases that will help modernise student-researchers' efforts and revolutionise campus-assistantship in a university setting. Monetary incentives can then be withdrawn or reused by the students and may prove useful to the student as financial-aid.

REFERENCES

[1] Micari, M., Pazos, P. Beyond grades: improving college students' social-cognitive outcomes in STEM through a collaborative learning environment. Learning Environ Res 24, 123–136 (2021).

[2] Crisp, Gloria, Amaury Nora, and Amanda Taggart. "Student characteristics, pre-college, college, and environmental factors as predictors of majoring in and earning a STEM degree: An analysis of students attending a Hispanic serving institution." (2009): 924-942.

[3] Jones, Richard D. "Strengthening student engagement." international Center for Leadership in Education 1 (2008).

[4] Awaji, Bakri & Solaiman, Ellis & Albshri, A.. (2020). Blockchain-Based Applications in Higher Education: A Systematic Mapping Study. https://doi.org/10.1145/3411681.3411688

[5] Hameed, Bushra & Khan, Muhammad Murad & Numan, Abdul & Ahmed, Muhammad & Talib, M & Ashfaq, Faiza & Usman, Hafiz & Yousaf, M. (2019). A Review of Blockchain based Educational

Projects. International Journal of Advanced Computer Science and Applications. 10. https://dx.doi.org/10.14569/IJACSA.2019.0101065

[6] Chen, G., Xu, B., Lu, M. et al. Exploring blockchain technology and its potential applications for education. Smart Learn. Environ. 5, 1 (2018). https://doi.org/10.1186/s40561-017-0050-x

[7] Ralston, Shane J. "Postdigital prospects for blockchain-disrupted higher education: Beyond the theater, memes and marketing hype." Postdigital Science and Education (2019): 1-9.

[8] M. Bhagwat, J. C. Shah, A. Bilimoria, P. Parkar and D. Patel, "Blockchain to improve Academic Governance," 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), Bangalore, India, 2020, pp. 1-5, doi: 10.1109/CONECCT50063.2020.9198665.

[9] Blockchain - Wikipedia: https://en.wikipedia.org/wiki/Blockchain [accessed 23 Oct, 2020]

[10] Hyeon-Ju Yoon. A Survey on Consensus Mechanism for Blockchain. DOI 10.17148/IJARCCE.2018.761 https://ijarcce.com/wp-content/uploads/2018/06/IJARCCE-1.pdf

[11] https://github.com/VJTI-AI-Blockchain/vjtichain

[12] Johnson, D., Menezes, A. & Vanstone, S. IJIS (2001), “The Elliptic Curve Digital Signature Algorithm (ECDSA),” 1: 36. https://doi.org/10.1007/s1020701000

[13] Győrödi, Cornelia & Gyorodi, Robert & Pecherle, George & Olah, Andrada. (2015). A Comparative Study: MongoDB vs. MySQL. 10.13140/RG.2.1.1226.7685. https://www.researchgate.net/publication/278302676_A_Comparative_Study_MongoDB_vs_MySQL

[14] S. N. G. Gourisetti, M. Mylrea and H. Patangia, "Evaluation and Demonstration of Blockchain Applicability Framework," in IEEE Transactions on Engineering Management, vol. 67, no. 4, pp. 1142-1156, Nov. 2020, doi: 10.1109/TEM.2019.2928280.

FUNCTIONAL AUTOMATION TESTING OF PALACE PROPERTY MANAGEMENT SOFTWARE

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ABSTRACT

Till today, there are many web applications developed and tested so that end- user gets maximum user-friendly experience and satisfaction. For testing these applications and their functionalities manual testing is not always feasible. To overcome the challenge. Automation testing is used in which the testing process is automated with minimal manual intervention. Regression testing is deployed to perform the testing for routine flow of an application and when new features are added then automation testing becomes very useful. The focus of this study on automation testing. With the help of Selenium Web driver scripts are executed and reports are generated. The default reports do not show any graphical representation of results. Hence, the main idea behind this study is to focus on automation testing with the combination of Selenium Web driver, Maven, TestNG and Page Object Model which provides cutomised results to our study.

KEYWORDS

Automation testing, Regression testing, Visual Studio, C#, Selenium Web driver, Agile- Scrum.

1. INTRODUCTION

PALACE Company was established in 2006 and is a cloud-based property management solution that caters to residential property managers and management organizations. Accounting, tenant and lease tracking, maintenance management and many more are the key features. With the central dashboard features, Palace helps property managers to keep track of different types of properties. Users can view incoming mail, invoices, charges, and reminders. Palace is rapidly growing in New Zealand as it offers additional features such as role-based access permissions, key tracking and mobile applications for iOS and Android devices that help users to remotely manage operations and routines.

The purpose of this study is to determine the challenges faced by the Palace company in the context of Manual testing. Manual testing is inadequate, as it is labor-intensive, error prone and the same kind of quality checks are not supported that are possible with the use of an automated testing framework. Some of the problems faced with manual testing are:

- Leads to changes in the requirements.
- Documenting of the bugs that were logged and bugs fixed.
- Maintaining Requirements Traceability Matrix without using any tools manually is a very tedious job.

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- Carrying out regression testing daily or weekly or as needed by manual testers is not possible.

Our objective for this study to identify test cases in the Palace Property Management Software application which needs to be automated and should generate automated test reports which can help Palace to save time and money in the future.

This research project is organized as follow: Section 2 focuses on the related work of various studies concentrating on automation testing. Section 3 is focused on the research methodology for this research project. Section 4 of this research is focused on project execution results. Results of this project are provided in section 5. Discussion to results of this project are provided in section 6. Section 7 is dedicated towards conclusion of this research project. Finally, in section 8 future work recommendations are presented.

2. RELATED WORK

There are various studies conducted on automation testing. We will go through the major studies one by one and will explore their significance relevant to our project.

Automation testing is the process of software development, to provide high quality, robust and reliable software product [1]. Selenium Web driver tool is pointed out as an appropriate solution when creating a framework and its widely used.

Test Automation is essential in agile development environments. The main goal is to speed up the test execution cycles and to reduce the effort involved in running tests manually. Test is automated to speedup execution cycles, provide prompt feedback, free from repetitive tasks, and reduce human effort [2].

Test engineer is responsible for generation of script, execution, and deployment of the project. If failures occur at any stage, then it creates a larger impact on the project execution [3]. Selection of correct test cases for automation is very important as it impacts on development cost and scheduled time.

A study was conducted to discuss the existing and improved testing techniques for better-quality assurance purposes [4]. The study emphasizes the knowledge of test execution along with stakeholders' preferences is necessary in test execution.

Nowadays, technologies, requirements, ideas, implementation strategies and deployment tools are changing rapidly. In order to face such challenges a new movement called DevOps is proposed [5].

A study was conducted to provide a clear understanding and complete overview of Agile software development culture and practice [6].

Various aspects of functional testing were discussed [7]. Further, it looked at the relation between changing business strategies and changes to applications in development.

Selenium Web driver helps to minimize the risks, reduce the time for development and increase the return on investment [8].

Testing aims to make sure the quality of the software is as efficient as possible were discussed in the study [9]. Software testing is a verification process for the assessment of software quality and process for achieving quality.

A study was conducted which focuses on the automation of the document uploading process [10]. It was further stated in the study that any website which maintains the company's documents are of high importance.

A study was conducted which presents the case for one who is developing its automation framework for testing its enterprise products. The test automation is acquiring more importance in an enterprise, as it is helping in improving the product quality at the expenditure of optimum time and cost [11].

All above studies highlights various aspects of testing. However, automation testing is a major factor in the success of the project. Hence, in this project will perform functional automation testing for Palace software.

3. RESEARCH METHODOLOGY

Research methodology for Palace software research project has been discussed below.

3.1. Tools for the Research

Automation tools are software developed which helps in performing testing activities are called test management tools and few tools are developed which are specific to different needs of testing like functional testing, performance testing, security testing, web services testing, database testing, usability testing, etc. Once the manual test cases are automated, the manual effort of executing the test case for regression testing can be eliminated by executing the scripts using test execution tools. Some of the automation tools that help in carrying out the test script design and execution are Selenium Web driver2.0, QTP and Test Complete [12].

The Palace Company Software project works on an agile methodology for development and testing throughout SDLC. The project is divided into sprints and each sprint is for one week. Daily stand up meeting and discussion will be held to give detail description of project progress and roadblocks and issues facing.

All above studies highlights various aspects of testing. However, automation testing is a major factor in the success of the project. Hence, in this project will perform functional automation testing for Palace software.

Agile projects deliver working software on a regular schedule, either weekly or fortnightly. The components delivered at each iteration are defined by the business which is prioritized in such a way where the highest value features go first. These practices together help to reduce the risk of shifting resources away from an agile project. Following this methodology ensures that there is not much half-done work at any point, the work that is finished is high value and the state of the project is always unambiguous.

Table 1: Comparison of Test Automation Tools

PARAMETER	SELENIUM	TEST COMPLETE	QTP
Programming Language	Scripts are commonly designed using Java, Ruby, Python, PHP, and Perl.	Support scripting using JavaScript and VBScript only.	Allows scripts to be designed in VBScript, JS Script, Delphi Script, C++ Script, C# Script.
Platform Supported	Windows, MAC, UNIX operating systems.	Supports only in windows.	Runs on Windows Vista and 7.
Open-Source/ Licensed	Completely Open-Source	Paid tool based on each project	It is a licensed tool
Customer Support	Community support	Online support provided	Customer support is provided
Test Execution Report	With plug-in like TestNG can execute and generate reports in HTML format.	The test execution report is generated using QTP and determines the execution status.	Execution results are generated as a separate file

3.2. Selenium Web driver

Selenium Web driver is the latest version that is selected by the Palace team for performing the testing activities. The tool allows the designed test scripts to communicate with the browser directly with the help of native methods. Testing of web applications on desktop well as on mobile devices like Android and iOS devices is supported by Selenium. Since it is an open-source tool the cost of the project is reduced, and the time taken to execute the testscripts on Web driver is less. It allows designing the test scripts that can be executed with multiple browsers.

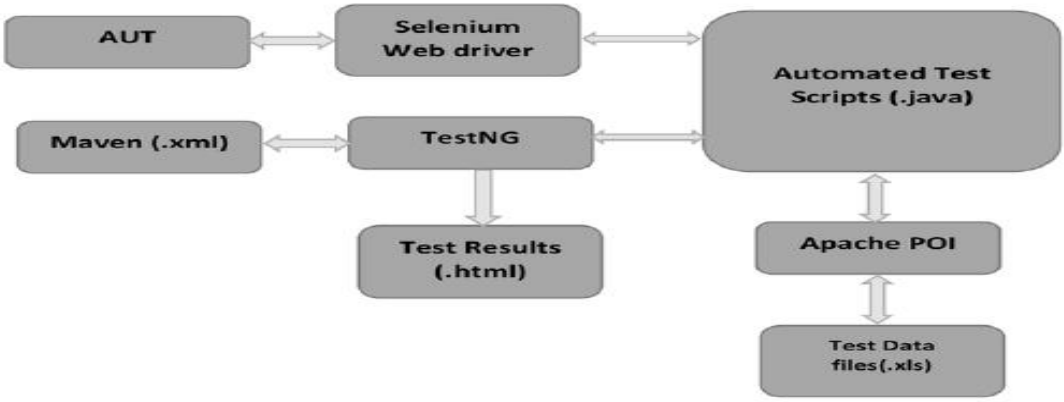


Figure 1: Architecture of the Proposed Automation Framework

3.3. Testing

TestNG commonly named "Test New Generation" is a testing framework used for automation testing along with selenium. With TestNG various levels of testing like unit, integration, system, and user acceptance testing can be performed (UAT) [12].Advantages of TestNG: There is the number of advantages from Selenium viewpoint, real favourable circumstances of TestNG are:

- Enables to deliver HTML reports of execution.
- Annotations made analysers life simple.
- Test case scan be grouped and Prioritized

4. PROJECT EXECUTION

The test plan is a document that acts as a point of reference to the QA team and the testing activities are performed based on the test plan document.

4.1. Test Plan

The test plan is a document that acts as a point of reference to the QA team and the testing activities are performed based on the test plan document.

4.2. Project Scope

The test plan is to identify and prescribe the scope, approach, and resources of testing activities that need to be performed in the Palace property management software project. In this research project, the features of the application that need to be tested are identified from the requirements.

4.3. Quality Objective

The test objectives are to verify the functionalities of the Palace application. The project should focus on testing the login functionality, Add New User, Current User, Archive User, Add New Owner, Custom Views and Logout functionalities.

4.4. Deliverables

Test deliverables along with the testing task id are given in the below table 2.

Table 2: Testing tasks along with Test Deliverables

TESTINGTASK ID	TEST DELIVERABLES
#1	Review and analyse the guidelines of the Palace website.
#2	Understanding the software.
#3	Read the documents related to the application.
#4	Set up the testing environment.
#5	Manual test case design.
#6	Manual test execution.
#7	Automation environment set up.

4.5. Manual Test Cases

Manual test cases for palace property management software are given below in table 3.

Table 3: Manual Test Cases for Palace Application

MANUAL TEST CASES – PALACE PROPERTY MANAGEMENT SOFTWARE						
Test Case ID	**Test Case Description**	**Test Steps**	**Test Data**	**Expected Output**	**Actual Output**	**Status**
TC_001	Verify the **User Login Functionality** for valid Email and Password	1. Open the Chrome browser 2. Enter the URL 3. Enter the valid Email and Password4. click the sign-in button	URL= https://preprod.getpalace.com/ Email= "divyapodduturi27@gmail.com" Password="XXXXXX"	User should land on the Palace Login Page and should be logged in successfully	As Expected	Pass
TC_002	Verify the User Login Functionality for Invalid Email and valid Password	1. Open the Chrome browser 2. Enter the URL 3. Enter the Invalid Email and Valid Password4. click the sign-in button	URL= https://preprod.getpalace.com/ Email="divyapoduturi27@gml.com" Password="XXXXXX"	User should land on the Palace Login Page and should not be logged in	As Expected	Pass
TC_003	Verify the User Login Functionality for valid Email and invalid Password	1. Open the Chrome browser 2. Enter the URL 3. Enter the Valid Email and Invalid Password4. click the sign-in button	URL= https://preprod.getpalace.com/ Email="divyapoduturi27@gmaill.com" Password="XXXXXX"	User should land on the Palace Login Page and should not be logged in	As Expected	Pass
TC_004	Verify the User Login Functionality for Invalid Email and invalid Password	1. Open the Chrome browser 2. Enter the URL 3. Enter the Invalid Email and Invalid Password4. click the sign-in button	URL= https://preprod.getpalace.com/ Email="divyapoduturi27@gmaill.com" Password="XXXXXX"	User should land on the Palace Login Page and should not be logged in	As Expected	Pass
TC_005	Verify the Users Feature functionality	1. Click the "Users" icon		User should see the "Current users", "Archived users", and "Add users"	As Expected	Pass
TC_006	Verify if the User can "Add new user" without filling any fields	1. Click the "Users" icon 2. Click the "Add users" icon 3. click the "Save & Close" button		User should be able to see error information "Please enter in a username"	As Expected	Pass
TC_007	Verify if the User can "Add new user" without filling mandatory fields	1. Click the "Users" icon 2. Click the "Add users" icon 3. Click the "Save & Close" button		User should be able to see error information "Please enter in a username"	As Expected	Pass
TC_008	Verify if the User can "Add new user" with filling the mandatory fields	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the "Username" field 4. click the "Save & Close" button	Username="XYZ"	User should be able to create a New user and should be able to see the user in the current user list with only the Username	As expected	Pass

TC_009	Verify if the User can "Add new user" with filling all the fields in the form	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user, "Username" and "Position" 4. Fill in the Personal details of the New user, ''Title", "User code", "First name", "Last Name", "Full Name", "Postal Address", "Region" and "Branch" 5. Fill in the User codes of the New User REAXML codes and Real estate code6. Fill in the Contact Information of the New user, "(ph.)Home", "(ph.)Work", "(ph.)Mobile", "Fax", "primary email" and "Secondary email" 7. Select the Date started, and Date ended" 8. click the "Save & Close" button	Username="XYZ" Position="Property Manager" Title="Owner" User code="1234" First name="XYZ1" Last name="XYZ2" Full name="XYZ1 XYZ2" Postal Address="3214" Region="Auckland" Branch "Auckland" REAXML Codes=''000" Real Estate code="0001" (Ph)Home=123456 (Ph)Work=321654 (Ph)Mobile=147852 Primary email=xyz@gmail.com Secondary email=xyz@gmail.com	User should be able to create a New user and should be able to see the user in the current user list with all the user details	As expected	Pass
TC_010	Verify if the User can "Add new user" with filling only a few primary details	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user "Username" 4. Fill in the Personal details of the new user "Title" and ''Full name" 5. Fill in the User codes of the New user REAXML codes6. Fill in the Contact Information of the New user "Primary email" 7. Click the "Save & Close'' button	Username="XYZ" Title="Owner" Full name="XYZ1 XYZ2" REAXML Codes=''000" Primary email ="xyz@gmail.com"	User should be able to create a new user and should be able to see the user in the current user list with the provided user details	As expected	Pass
TC_011	Verify if the User can "Add new user" with filling only Profile details	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user, "Username" and "Position" 4. Click the "Save & Close'' button	Username="XYZ" Position= "Property Manager"	User should be able to create a new user and should be able to see the user in the current user list with the provided user profile details	As expected	Pass
TC_012	Verify if the User can "Add new user" with filling only "Profile" and "Personal details"	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user, "Username" and "Position" 4. Fill in the Personal details of the New user, ''Title", "User code", "First name", "Last Name", "Full Name", "Postal Address", "Region" and "Branch" 5. Click the "Save & Close'' button	Username="XYZ" Position= "Property Manager" Title="Owner" User code="1234" First name="XYZ1" Last name="XYZ2" Full name="XYZ1 XYZ2" Postal Address="3214" Region="Auckland" Branch "Auckland"	User should be able to create a new user and should be able to see the user in the current user list with the provided user profile and Personal details	As expected	Pass

TC_013	Verify if the User can "Add new User" with filling only "Profile", "Personal details" and "User codes"	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user, "Username" and "Position" 4. Fill in the Personal details of the New user, ''Title", "User code", "First name", "Last Name", "Full Name", "Postal Address", "Region" and "Branch" 5. Fill in the User codes of the new user REAXML codes 6. Click the "Save & Close'' button	Username="XYZ" Position= "Property Manager" Title="Owner" User code="1234" First name="XYZ1" Last name="XYZ2" Full name="XYZ1 XYZ2" Postal Address="3214" Region="Auckland" Branch "Auckland" REAXML Codes=''000" Real Estate code="0001"	User should be able to create a new user and should be able to see the user in the current user list with the provided user profile, Personal details, and REAXML codes	As expected	Pass
TC_014	Verify if the User can "Add new User" with filling only "Profile", "Personal details", "User codes" and "Contact information"	1. Click the "Users" icon 2. Click the "Add users" icon 3. Fill in the profile details of the new user, "Username" and "Position" 4. Fill in the Personal details of the New user, ''Title", "User code", "First name", "Last Name", "Full Name", "Postal Address", "Region" and "Branch" 5. Fill in the User codes of the new user REAXML codes6. Fill in the Contact Information of the New user, "(ph.)Home", "(ph.)Work'', "(ph.)Mobile", "Fax", "primary email" and	Username="XYZ" Position= "Property Manager" Title="Owner" User code="1234" First name="XYZ1" Last name="XYZ2" Full name="XYZ1 XYZ2" Postal Address="3214" Region="Auckland" Branch	User should be able to create a new user and should be able to see the user in the current user list with the provided user profile, Personal details, REAXML codes, and Contact information	As expected	Pass
		''Secondary email" 7. Click the "Save & Close'' button	"Auckland" REAXML Codes=''000" Real Estate code="0001" (Ph)Home=123456 (Ph)Work=321654 (Ph)Mobile=147852 Primary email=xyz@gmail.com Secondary email=xyz@gmail.com			
TC_015	Verify if the user can view the current user's list	Click the "Current users" icon		User should land on the "List of current users" page and should be able to see the current users list	As Expected	Pass
TC_016	Verify if the user can search for a user from the current user list	1. Click the "Current users" icon 2. Enter the username in the Search text box 3. Click on the Search button	username=''System"	User should land on the "List of current users" page and should be able to key in the username and should be able to see the requested user details	As Expected	Pass
TC_017	Verify if the user can search for a user who is not added to the	1. Click the "Current users" icon 2. Enter the username in the Search text box 3. Click on the Search button	username=''John"	User should land on the "List of current users" page and should be able to key in the username and should see	As expected	Pass

				"custom views''		
TC_022	Verify if the User can "Add new owner" without filling any fields	1. Click the ''Owners'' icon 2. Click the "Add owner" icon 3. Click the "Save & Close'' button		Users should be able to see error information "Because you selected 'Direct Credit' as a Payment Type you will now be required to enter an owner bank account." and "The Last name * field is required."	As Expe cted	Pass
TC_023	Verify if the User can "Add new owner" without filling any fields	1. Click the ''Owners'' icon 2. Click the "Add owner" icon 3. Click the "Save & Close'' button 4. Click "OK" once the "Owner bank account" error message appears		Users should be able to see error information "The Last name * field is required."	As Expe cted	Pass
TC_024	Verify if the User can "Add new Owner" with filling only mandator y fields in Owner details	1. Click the ''Owners'' icon 2. Click the "Add owner" icon 3. Enter the last name 4. Click the "Save & Close'' button"	Last name = "John"	User should be able to see error information "Please enter an email address"	As Expe cted	Pass
TC_025	Verify if the User can "Add new owner" without filling mandator y fields	1. Click the "Owners" icon 2. Click the "Add owner" icon 3. Enter the last name 4. Enter the primary email Id5. Payment type drop-down is selected as either "hold" or "cheque" 4. Click the "Save & Close'' button"	Last name = "John" Primary email="jo hn@gmail .com"	User should be successfully created a new owner	As Expe cted	Pass
TC_026	Verify the User can "Add new	1. Click the ''Owners'' icon 2. Click the "Add owner" icon3. Enter the Profile	Title= "Mr" First	User should see error information	As Expe cted	Pass
	current user's list			an error message saying "There are no items to display"		
TC_018	Verify if the user can view the Archived users list	Click the "Archived users" icon		User should land on the "List of archived users" page and should be able to see the archived users list	As expe cted	Pass
TC_019	Verify if the user can search for a user from the current user list	1. Click the "Archived users" icon 2. Enter the username in the Search text box 3. Click on the Search button	username ="Xyz"	User should land on the "List of archived users" page and should be able to key in the username and also should be able to see the requested user details	As expe cted	Pass
TC_020	Verify if the user can search for a user who is not added to the archived user's list	1. Click the "Archived users" icon 2. Enter the username in the Search text box 3. Click on the Search button	username ="John"	User should land on the "List of archived users" page and should be able to key in the username and should see an error message saying "There are no items to display"	As expe cted	Pass
TC_021	Verify the Owners Feature functionali ty	1. Click the ''Owners'' icon		User should see the "Current owners", "Archived owners", "Add owners", "owner reports" and	As Expe cted	Pass

			@gmail.com Secondary email=xyz@gmail.com Country code=""0064""			
	owner" with only filling the Profile details	details of the new owner 4. Click the "Save & Close" button	name="Peter" Last name="John" Postal address="10 Rosedale Road"	"Please enter an email address"		
TC_027	Verify the user can "Add new owner" with only filling the Contact information	1. Click the "Owners" icon 2. Click the "Add owner" icon 3. Enter the Contact Information of the new owner 4. Click the "Save & Close" button	Ph)Home=123456 (Ph)Work=321654 (Ph)Mobile=147852 Primary email=xyz@gmail.com Secondary email=xyz@gmail.com Country code="0064" Alternate address="100 Rosedale Road"	Users should be able to see error information "The Last name * field is required."	As Expected	Pass
TC_028	Verify the user can "Add new owner" with filling all the fields in the Details page and selecting the "Payment set up" dropdown as "Hold"	1. Click the "Owners" icon 2. Click the "Add owner" icon 3. Enter all the details of the owner 4. Click the "Save & Close" button	Title="Mr" First name="Peter" Last name="John" Postal address="10 Rosedale Road" "Ph)Home=123456 (Ph)Work=321654 (Ph)Mobile=147852 Primary email=xyz	User should see the success message as "Page has been saved successfully"	As Expected	Pass

4.6. Functional Test Cases

Functional test cases for Palace property management software are given below in Table 4.

Table 4: Functional Test Cases for Palace Application

TEST CASE ID	TEST SCENARIO	TEST STEPS	EXPECTED OUTPUT
FTC_001	Launching the browser and Login Functionality	1. Launch the browser, navigate to the URL "https://preprod.getpalace.com/ 2. Enter valid username 3. Enter valid Password 4. Click on the Sign-in button	• Verify that the browser is launched, and the Palace application is opened. • Verify that the user successfully logged in to the application. • Verify that the homepage is opened.
FTC_002	Add New User Functionality	1. Click the User icon 2. Select the Add User icon 3. Fill in all the Mandatory fields 4. Click the "Save & Close" button	• Verify the user can click the Add User icon. • Verify the user can fill the mandatory fields. • Verify the user can click the save & close button.
FTC_003	Current User Functionality	1. Click the Current users' icon 2. Enter the username in the search text box 3. Click the search button	• Verify the user can click the current user icon. • Verify the user can enter the username in the search box. • Verify the user can click the search button.
FTC_004	Archived User Functionality	1. Click the Archived users' icon 2. Enter the username in the search text box 3. Click the search button	• Verify the user can click the archived user icon. • Verify the user can enter the username in the search box.

			• Verify the user can click the search button.
FTC_005	Add Owner Functionality	1. Click the Owner icon 2. Select the Add Owner icon 3. Fill in the Mandatory fields 4. Click the "Save & Close" button	• Verify the user can click the add owner icon. • Verify the user can fill the mandatory fields. • Verify the user can click the save & close button.
FTC_006	Custom views Functionality	1. Click the Owner icon 2. Select the custom views icon 3. Select the owner list 4. Enter the owner name in the search text box	• Verify the user can click the add owner icon. • Verify the user can select the custom view icon. • Verify the user can enter the owner's name. • Verify the user can see the details of the selected owner.
FTC_007	Logout Functionality	1. Users should see the logout icon on the top right corner. 2. Click the Logout button. 3. Users should successfully log out of the application.	• Verify the user can see the logout icon. • Verify the user can click the logout button.

4.7. Gantt Chart for Project

Gantt chart for the project is given below in Table 5.

Table 5: Gantt Chart for Palace Application

	Oct 28th - Nov 1st	Nov 4th - 8th	Nov 11th - 15th	Nov 18th - Nov 22nd	Nov 25th - 29th
	M T W T F	M T W T F	M T W T F	M T W T F	M T W T F
SPRINT 1					
Discussion about the Palace					
Analyzing documents of the project					
Understanding the website					
SPRINT 2					
Exploratory testing on Palace website					
Review document and tools that are to be used in a website					
Set up the test environment, links provided by a project manager					
SPRINT 3					
Manual test cases are to be designed for the Palace website					
Test case execution					
Finding the issues					
SPRINT 4					
Raised issues are to be assigned to the Developer					
The automation test environment will be set up					
Automation test scripts will be generated					
Meeting with the project manager if any roadblocks in generating the automation scripts					
SPRINT 5					
Automation test execution					
Report generation					
Feedback will be taken for issues that need to resolve to continue further testing					

4.8. Research framework

The framework for the research project is depicted in figure 2.

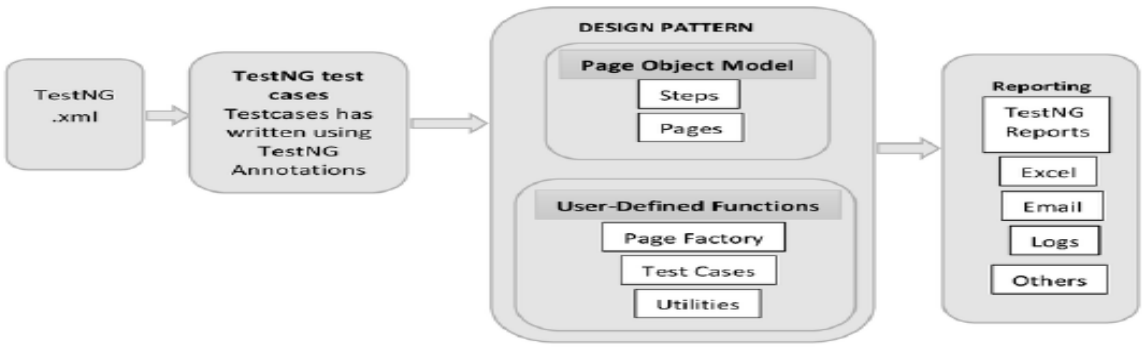


Figure 2: Architecture of Testing Framework with POM Design Pattern

Project Object Model (POM) is the fundamental unit of work in the Maven framework. The framework contains many helpers, utilities, reporters, etc. that are extended by the TestNG framework. Some of the classes are:

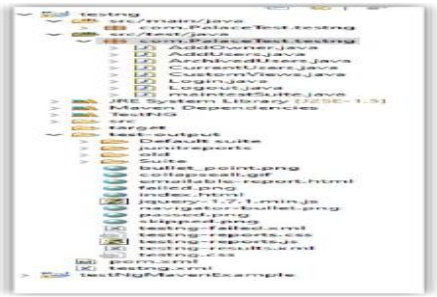
Testcase Helper: This is the main and important class which helps the test cases to execute correctly.

Browser Helper: This class gets the browser name to launch the Palace application with like Chrome. It has methods to set the capabilities of the browser to maximize the window, get the URL name, get the Page Title name, etc.

Page Factory Action Helper: This class gets methods that perform actions of the web elements like button clicks, finding an item in the drop-down list, input for the textbox, select the checkbox/radio button, etc.

Wait: This class gets various wait events such as wait until the element is visible, page to load, the element is clickable.

TestNG Test Cases: The Test cases are written using annotations such as @Test, @Before Test, @AfterTest, @@BeforeSuite, @AfterSuite, @AfterMethod, etc. The test cases read data from ReadTestData class as TestNG does not involve feature files and writing scenarios into it. The test cases execute based only on the annotations. TestNG finds for its annotations when executing test cases. The executing can be done in two ways: Firstly, by creating testing.xml: The .xml file contains the name of the classes to execute, the name of the test suite, etc. Secondly, by right-clicking on any test and selecting Run As~ TestNG, the test is executed.



- The architecture of the test suite is demonstrated using the following figure 3:
- The POM design is integrated into the test suite. For each page of the application, there is a corresponding java page in the test suite.
- The test cases are divided into different test scenarios on application functionality.

Due to the time constraint, only two Palace application functionalities are taken to perform the automation testing.

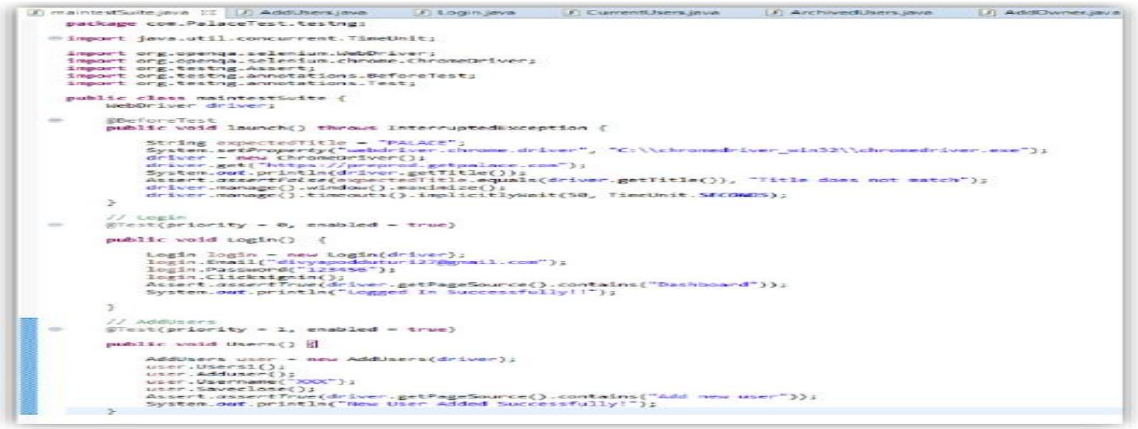
Figure 3: Architecture of Pages and Tests

Figure 4 shows the snippet of the pom.xml file is by default created in which dependencies, suite files, project details, etc, are added. Once the dependencies are added, jars and packages are automatically downloaded from the maven repository into the project.

```
<project xmlns="http://maven.apache.org/POM/4.0.0" xmlns:xsi="http://www.w3.org/200
  xsi:schemaLocation="http://maven.apache.org/POM/4.0.0 http://maven.apache.org/xsd
  <modelVersion>4.0.0</modelVersion>

  <groupId>com.PalaceTest</groupId>
  <artifactId>testng</artifactId>
  <version>0.0.1-SNAPSHOT</version>
  <packaging>jar</packaging>

  <name>testng</name>
  <url>http://maven.apache.org</url>

  <properties>
    <project.build.sourceEncoding>UTF-8</project.build.sourceEncoding>
  </properties>

  <dependencies>
    <dependency>
        <groupId>org.seleniumhq.selenium</groupId>
        <artifactId>selenium-java</artifactId>
        <version>3.141.59</version>
    </dependency>

<dependency>
        <groupId>org.testng</groupId>
        <artifactId>testng</artifactId>
        <version>7.0.0</version>
        <scope>test</scope>
</dependency>

<dependency>
        <groupId>com.aventstack</groupId>
        <artifactId>extentreports</artifactId>
        <version>4.0.9</version>
</dependency>

  </dependencies>
</project>
```

Figure 4: POM.XML file for Test Suite Configuration

Below figures 5, 6 and 7 shows the main test suite of the Maven project where all the class methods are called in this test suite.



```
package com.PalaceTest.testng;

import java.util.concurrent.TimeUnit;

import org.openqa.selenium.WebDriver;
import org.openqa.selenium.chrome.ChromeDriver;
import org.testng.Assert;
import org.testng.annotations.BeforeTest;
import org.testng.annotations.Test;

public class maintestSuite {
    WebDriver driver;

    @BeforeTest
    public void launch() throws InterruptedException {

        String expectedTitle = "PALACE";
        System.setProperty("webdriver.chrome.driver", "C:\\chromedriver_win32\\chromedriver.exe");
        driver = new ChromeDriver();
        driver.get("https://personal.getpalace.com");
        System.out.println(driver.getTitle());
        Assert.assertTrue(driver.getTitle().equals(driver.getTitle()), "Title does not match");
        driver.manage().window().maximize();
        driver.manage().timeouts().implicitlyWait(50, TimeUnit.SECONDS);
    }

    // Login
    @Test(priority = 0, enabled = true)
    public void LogIn()  {

        LogIn logIn = new LogIn(driver);
        logIn.Email("dsvyapadhatur127@gmail.com");
        logIn.Password("123456");
        logIn.ClickSignIn();
        Assert.assertTrue(driver.getPageSource().contains("Dashboard"));
        System.out.println("Logged In Successfully!!");

    }
    // AddUsers
    @Test(priority = 1, enabled = true)
    public void Users() {

        AddUsers user = new AddUsers(driver);
        user.Users1();
        user.Address();
        user.Username("xxx");
        user.SaveClose();
        Assert.assertTrue(driver.getPageSource().contains("Add new user"));
        System.out.println("New User Added Successfully!");
    }
```

Figure 5: Main Test suite where all Class Methods Called

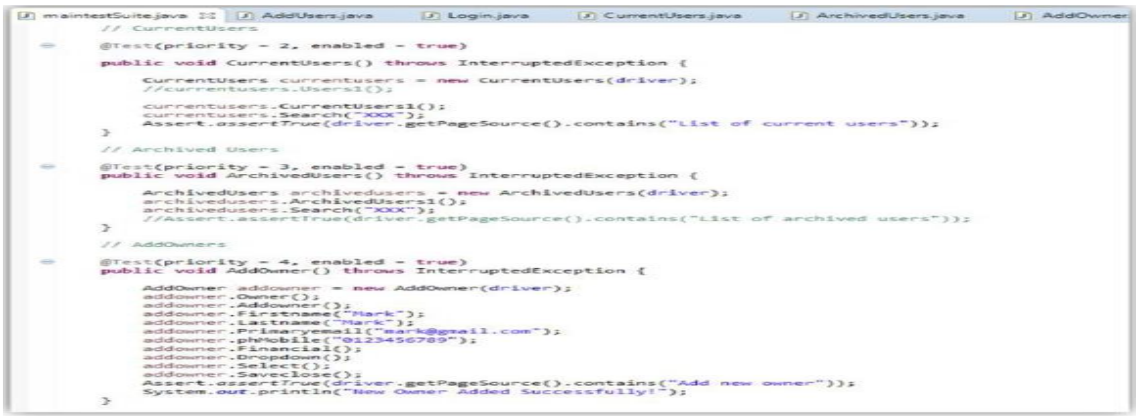


Figure 6: Main Test suite where all Class Methods Called

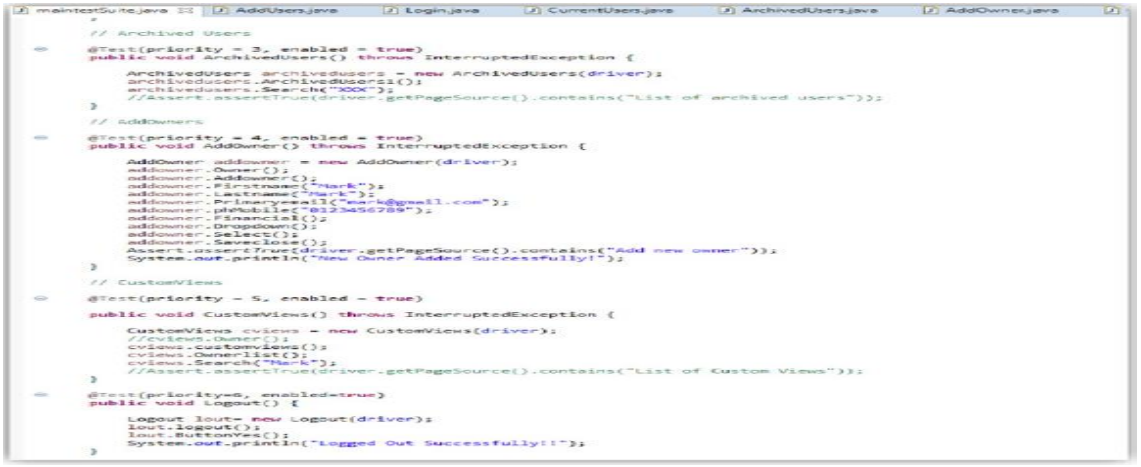


Figure 7: Main Test suite where all Class Methods Called

5. RESULTS

The results are shown in figure 8, 9, 10, 11 and 12 followed by discussion in section 6 discussion.

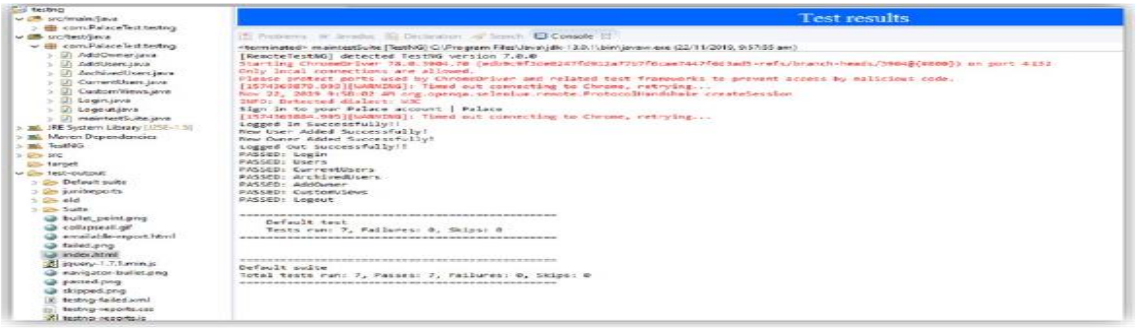


Figure 8: Output of the Execution on the Console

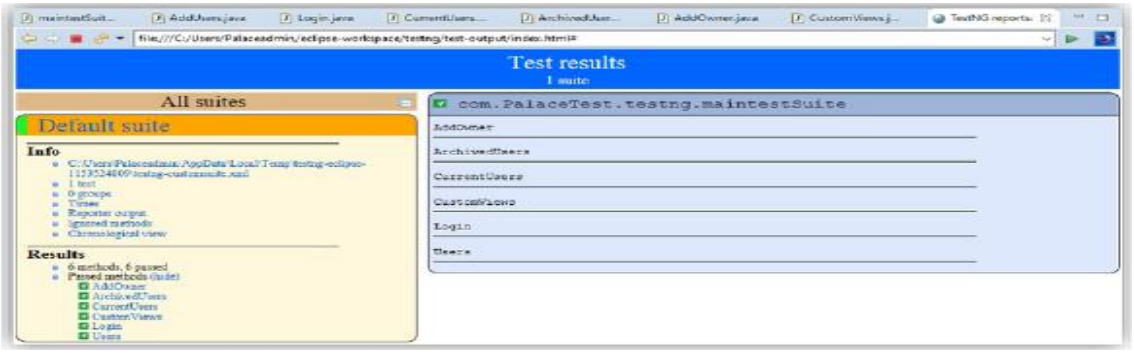


Figure 9: Report 1 Generated by Testing

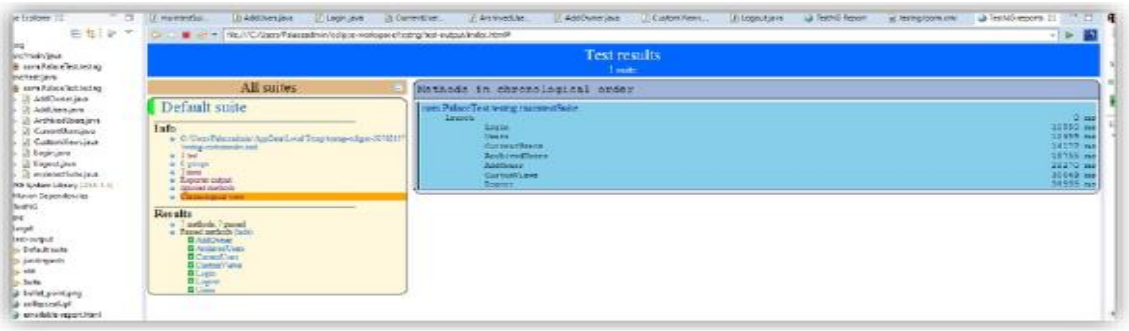


Figure 10: Report 2 Generated by Testing

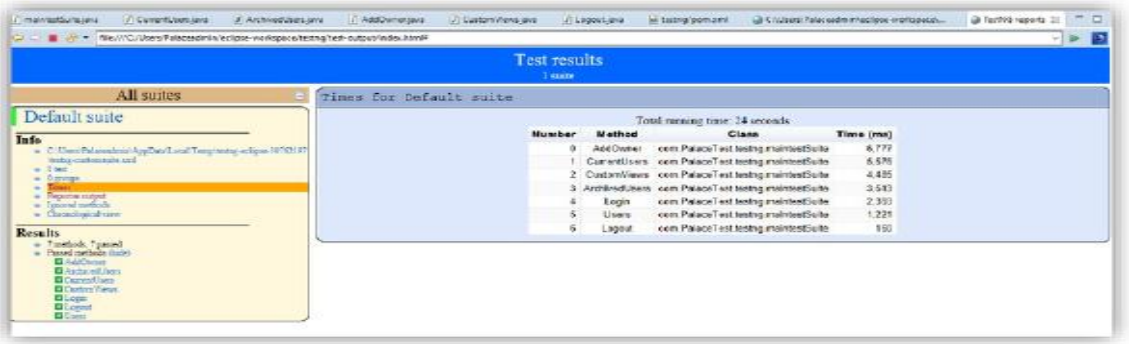


Figure 11: Report 3 Generated by Testing

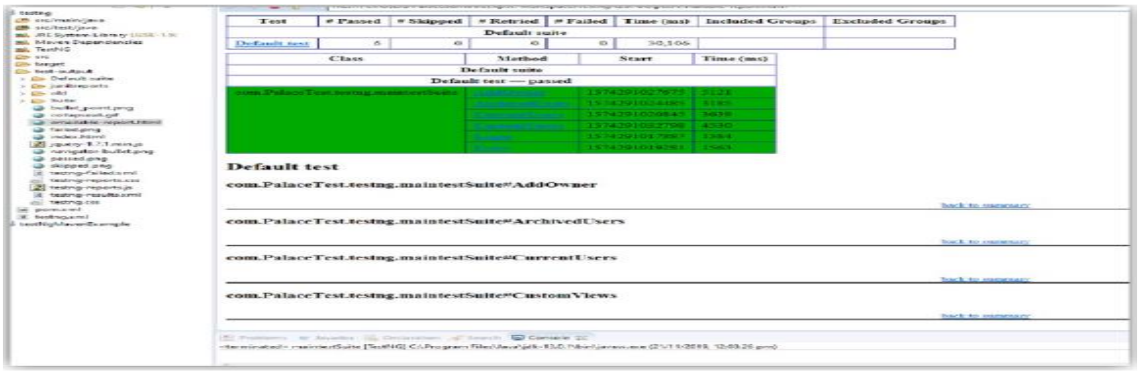


Figure 12: Report 4 Generated by Testing

6. DISCUSSION

TestNG library provides a very easy understanding and handy reporting feature. Once the execution is done, TestNG will generate a test-output folder at the root of the project. Two types of reports are included in this folder: a) Index.html b) emailable-report.html.

Index.html: This file is a complete report of the current execution which has information like reporter logs, TestNg XML files, errors, groups, time, etc.

Emailable-report.html: This file is a summarized report of the current execution which shows the passed test cases highlighting in green colour and for the failed test cases in red colour.

- **Figure 8**: is the real-time console report which shows the default test that has the number of tests run, the number of tests failed, and several tests skipped.
- **Figure 10**: is the index.html file which gives the details of all Suites. Information on all the test methods, results of test methods and the test methods are shown in the chronological order.
- **Figure 11**: is the index.html file which gives the number of methods executed, the name of the methods, under the specific class the methods are, the time (ms) each method takes to execute and the total running time of all the methods to get executed is shown.
- **Figure 12**: is the emailable report which is colourful and easy to understand. The passed test cases are highlighted in green, the test methods, start time and the execution time of each method is displayed.

7. CONCLUSION

This research project discusses the Palace property management software that covers a brief introduction to the company's Palace, about the website and its achievements. The Palace team is using an agile methodology for the development of their project. Exploratory and manual testing is being performed by the team to check the functionalities of the website against the client requirements. To overcome the challenges facing by the Palace team, the proposed solution is to be implementing a robust and specific automation framework (maven) and using the selenium web driver interface for testing the Palace software.

8. FUTURE WORK RECOMMENDATIONS

The findings of this research project demonstrates that automation testing has a minimum of two benefits when compared to manual testing, accuracy, and efficiency. During this research project, when automation testing is performed efficiency increases, the cost gets down and manual intervention is reduced. In this research project Selenium with the TestNG framework is used as the test automation tool which provides a serious cost-benefit. Though, initially switching to automation is time-consuming, the switch to Selenium has a lot of long-term benefits.

By using the TestNg framework with Maven, one can generate the customized test reports and analyse the failures using screenshots of failed test cases. This framework is very useful for dynamically changing web applications. A tester can easily read and understand the automation test scripts using this framework. In this way, the automation framework help organizations to test web applications efficiently.

REFERENCES

[1] Vila, E., Novakova, G., & Todorova, D. (2017, August). Automation testing framework for web applications with Selenium WebDriver: Opportunities and threats. In Proceedings of the International Conference on Advances in Image Processing (pp.144-150).ACM.

[2] Klammer, C., & Ramler, R. (2017, July). A Journey from Manual Testing to Automated Test Generation in an Industry Project. In the 2017 IEEE International Conference on Software Quality, Reliability and Security Companion (QRS-C) (pp. 591-592). IEEE.

[3] Mahajan, P., Shedge, H., & Patkar, U. Automation Testing in Software Organization. International Journal of Computer Applications Technology and Research,5(4),198-201.

[4] Jamil, M. A., Arif, M., Abubakar, N. S. A., & Ahmad, A. (2016, November). Software testing techniques: A literature review. In 2016 6th International Conference on Information and Communication Technology for The Muslim World (ICT4M) (pp. 177-182). IEEE.

[5] Sandobalin, J., lnsfran, E., & Abrahao, S. (2017). End-to-End automation in cloud infrastructure provisioning.

[6] Anand, R. V., & Dinakaran, M. (2016). Popular agile methods in software development: Review and analysis. International Journal of Applied Engineering Research, 11 (5), 3433-3437.

[7] Lewis, W. E. (2017). Software testing and continuous quality improvement. Auerbach publications.

[8] Patil, R., & Temkar, R. (2017). Intelligent Testing Tool: Selenium Web Driver.

[9] Jan, S. R., Shah, S. T. U., Johar, Z. U., Shah, Y., & Khan, F. (2016). An innovative approach to investigate various software testing techniques and strategies. International Journal of Scientific Research in Science, Engineering, and Technology (IJSRSET), Print ISSN, 2395-1990.

[10] Bulla, A., & Brunda, S. (2016). A Study: Automation Technique Using Selenium Web Driver.

[11] Goel, S., & Vartak, K. Selenium with Support of both TestNG and Cucumber Frameworks. International Journal of Computer Applications, 975, 8887.

[12] Jain, C. R., & Kaluri, R. (2015). Design of automation scripts execution application for selenium web driver and test NG framework. ARPN J EngAppl Sci, 10, 2440-2445.

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A NEW LIDAR-BASED APPROACH FOR POLES AND DISTRIBUTION LINES DETECTION AND MODELLING

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ABSTRACT

Vegetation is the major cause of overhead power line failures. According to a recent Hydro-Quebec analysis, more than 60% of the power outages are related to vegetation. Specifically, when branches/trees nearby the distribution network interact with extreme weather conditions, e.g., melting snow and heavy rain, they may bend and cause power outages. To ensure the reliability of our distribution network, millions of dollars are yearly spent for pruning trees and trimming branches. Aiming to reduce these costs, we recently adopted a new approach based on light detection and ranging (LiDAR) data. Indeed, we scanned 150 km of Hydro-Quebec's network using a mobile LiDAR system. Through data analysis, we target automatic detection of hot spots, i.e., locations of threatening branches to distribution lines. However, such an operation cannot be accurately completed without a prior efficient detection of poles and lines locations, even for incomplete or missing LiDAR data. Hence, we propose here a low-complex and robust method for poles/distribution lines detection and lines modelling. Through customized filtering and detection, we efficiently detect poles and distribution lines with high accuracy and recall. Indeed, poles are detected with an accuracy of 94.5% and a recall of 89.7%, while lines are detected with an accuracy of 84% and a recall of 98.9%. Finally, our approach reconstructs power lines with a distance deviation from the real ones below 20 cm, in 89% of the cases. Such accuracy is required to automatically evaluate the closeness of vegetation to distribution lines and prevent power outages.

KEYWORDS

Mobile LiDAR, power lines, distribution lines detection, poles detection, distribution lines modelling.

1. INTRODUCTION

Distribution overhead power lines are often victims of outages caused by vegetation. According to a recent study by Hydro-Quebec, vegetation, specifically tree branches, are the cause of more than 60% of the power outages in the province of Quebec, Canada [1]. Such phenomenon is mainly triggered by extreme weather conditions, such as melting snow, gust, and heavy rain, which force the tree branches to bend and hit the power lines causing outages. To improve the reliability of the distribution network, power utilities spend millions of dollars yearly to trim and cut vegetation and to secure the space around the power lines. At Hydro-Quebec, to identify the lines that require vegetation pruning interventions, past historical data on vegetation outages are analyzed, then processed to identify the worst lines requiring an immediate intervention. Subsequently, the identified lines information is transferred to the "Department of Vegetation

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Management", which evaluates the intervention tasks. A forester is then sent to inspect visually each line, identify the exact locations of the trees to be pruned, and evaluate the workload. This process is complex since it involves several resources and expertise, in addition to a high coordination level between different departments.

Aiming to optimize these processes, recently we decided, at Hydro-Quebec, to adopt a novel colorized light detection and ranging (LiDAR) based approach. Indeed, using a mobile LiDAR system (MLS) mounted over a motorized vehicle; we scanned 150 km of our distribution network. The MLS is a new scanning technique that uses a dense point cloud laser to measure distances between the laser source and any object in the surrounding three-dimensional (3D) space, i.e., according to the *x, y* and *z* planes.

The MLS technique is becoming popular as it provides a high-level of details and it returns valuable information on the vegetation and the asset's location. Also, its acquisition costs have significantly dropped over the last ten years, thus making it an interesting alternative to the airborne laser scanning system [2].

The objective of using the MLS point cloud is to automatically detect, as a forester, "The Hot Spot", i.e., locations where branches are close to the distribution network. In this paper, we present a novel algorithm that accurately detects the location of power poles and distribution lines. The detection of the power lines is possible even using incomplete or highly obstructed LiDAR data. Thus, any point cloud that is close to the lines are identified as being vegetation. Later, this information will be used as an insight for vegetation workload.

1.1. Related Work

Power line mapping using an airborne laser scanning (ALS) system was studied in several works [3]-[5]. In many studies the intensity of the laser beam reflection or the height of the pulses are used to locate the lines and the transmission pylon. Such techniques are adequate with LiDAR-based ALS due to the direct line-of-sight between the lines and aircraft above them. However, these specific techniques may not be suitable for the distribution network due to the wire diameters of the low voltage network [2]. In contrast, the number of LiDAR points per square metre collected by the ALS is between half and a tenth of that collected by the MLS, which makes the detection of low-voltage lines very approximate.

Power line detection using MLS data was initially investigated in [6]-[8]. In [9], Guan *et al.* presented a method for extracting power transmission lines and pylons from MLS data. After removing the ground, they extract the power transmission lines according to the height, spatial density, shape, and points' density criteria. A 3D power line was modelled through its projection as a horizontal line in the *(x, y)* plane and as a two-dimensional (2D) catenary curve in the *(x, z)* plane. This projection procedure simplifies the calculation of the 3D catenary curve parameters. Then, the detected lines from the top-down view are clustered and used to accurately detect the power poles. However, this method requires high density point clouds for accurate power lines detection, which would be inefficient for power lines obstructed by vegetation or with low points' density. The overhead power lines with low point density affect the accuracy of the proposed method.

Yadav and Chousalkar proposed in [10] a different power lines extraction method. First, the horizontal segments containing power lines are filtered based on the distance between the ground and the points' heights. Then, a 2D density approach is used to remove trees and buildings. Finally, the Hough-Transform is applied to extract the lines, and missing lines portions are reconstructed using a second-order curve fitting technique. They reported a reconstruction

precision rate of 84% in an urban site and of 99% in a rural environment. Although their method works well in partially occluded environments, it is still limited for areas heavily occluded by vegetation.

Recently, the authors of [2] combined several techniques to improve the detection capability. After filtering out the ground and buildings, they extracted horizontal lines from the remaining LiDAR point clouds using a modified version of the well-known random sample consensus (RANSAC) algorithm. Subsequently, the extracted horizontal line candidates were classified based on several criteria, i.e., the vertical distance above the ground, the points' density, and the linearity measure. Next, the authors proceeded with the poles' detection. The main reason is to retrieve less false positive pole candidates based on the detected power line data. Specifically, poles closer than 2m to the extracted power lines and where the angle between the lines and the poles is approximately 45° were detected and retrieved. However, this study did not approximate the power lines to compensate for the missing LiDAR points. Moreover, if many power lines LiDAR points are missing or are occluded by the vegetation, the lines and poles detection procedure would fail.

1.2. Contributions

To tackle the limitations of state-of-art works, we propose in this paper an efficient and powerful approach for poles and power lines detection and extraction using MLS acquired data. Then we reconstruct overhead model power lines.

The contributions of our work can be summarized as follows:

1. First, unlike the previous works, we start by detecting the power poles before power lines. By doing so, we significantly reduce the system's complexity since power lines detection becomes limited into small volumes bounded by subsequent pairs of poles.
2. Second, through our proposed colour-based filtering, the accuracy of our line detection method is improved and operates efficiently even in heavily occluded areas by vegetation.
3. Finally, using a 3D parabola equations system, we rapidly reconstruct the 3D power lines shapes with a very high precision rate.

2. PROPOSED POLES AND DISTRIBUTION LINES DETECTION APPROACH

In this study, we develop a new approach for poles and power lines detection, whose steps are summarized in Figure 1 and are detailed below. All the described steps were developed with the C++ point cloud library (PCL) [11].

For the sake of clarity, we illustrate the following steps using a sample file of LiDAR data selected from the Hydro-Quebec dataset. The sample file contains the LiDAR point cloud of a rural single-phase distribution lines corridor, as illustrated in Figure 2. The point cloud contains many objects within the area, including the road, the vegetation, the power poles, and the power lines.

2.1. Power Poles Detection

Prior to the detection of poles, we reduce the search space within the LiDAR point cloud. To do so, we start by removing the ground surface points. This is executed using the "Progressive Morphological Filter", proposed by Zhang *et al.* in [12]. A simple implementation of this filter is

available in the PCL library. Consequently, the LiDAR point cloud is reduced, on average, by 40%.

Next, we cluster the 3D points based on a Euclidean distance rule, applied on the points' locations, and using a point cloud density function. Then, clusters are filtered according to their size, width, and height. Figure 3 shows the obtained clusters from the original track. We notice that it contains 9 distinct clusters including 7 poles.

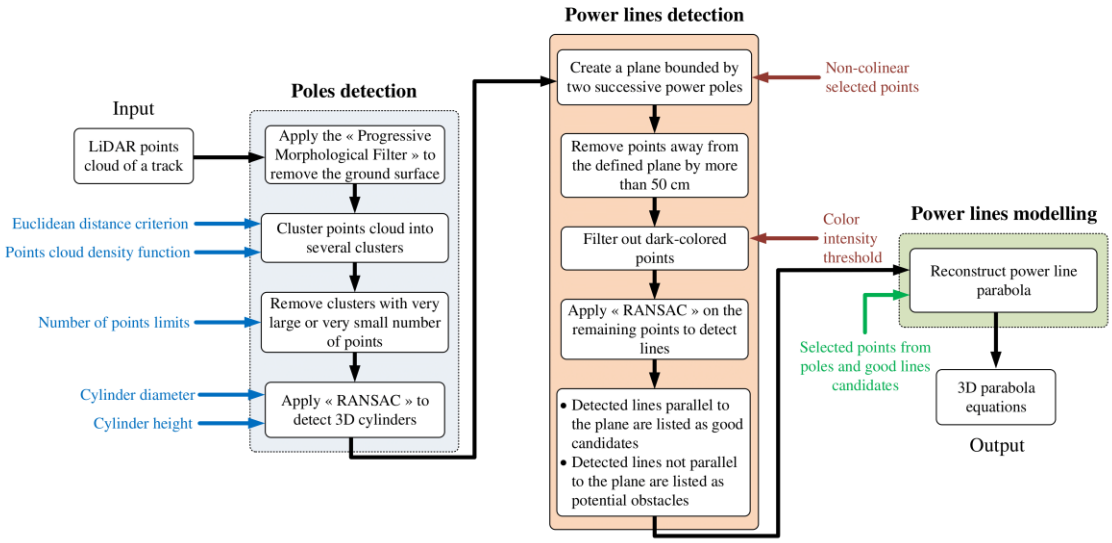

Figure 1: Flowchart of the proposed poles and power lines detection approach

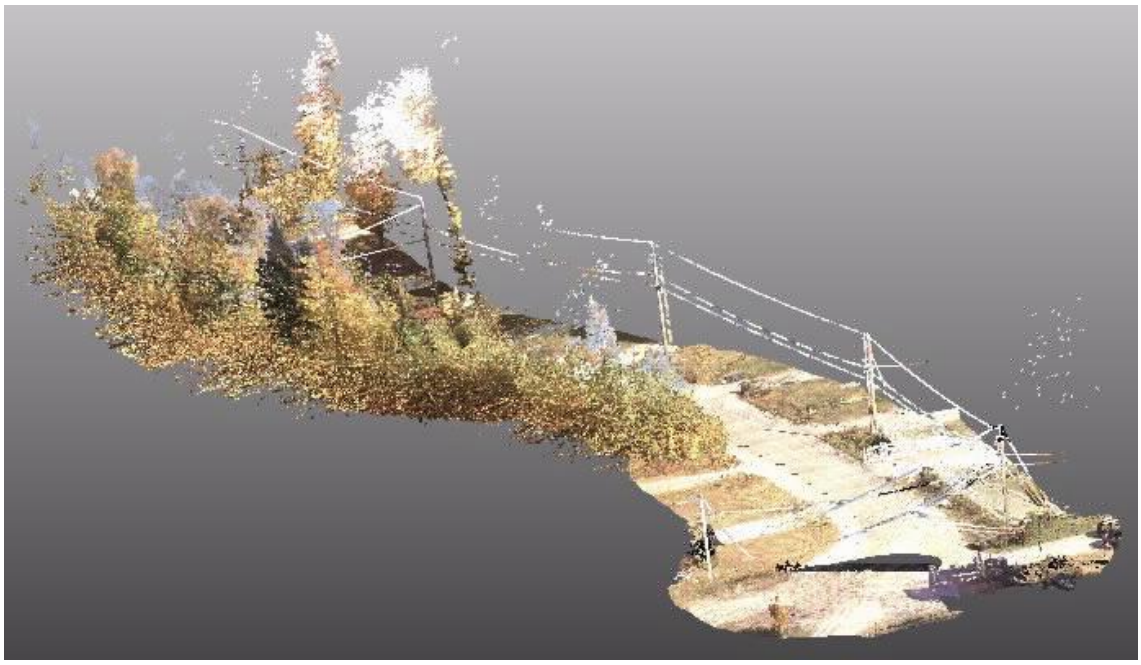

Figure 2: A sample of collected mobile LiDAR data along a distribution power lines in a rural area

Finally, for each cluster, we use the RANSAC algorithm to detect 3D cylinder shapes from point clouds [13]. Each detected cylinder must be parallel to the z-axis with a maximal deviation of 15°

and should not exceed a diameter of 60 cm with a maximum height of 11.5 m. Furthermore, the number of points composing a pole must be more than 3k LiDAR points. When several collocated cylinders are detected within the same point cloud cluster, it is inferred that these cylinders belong to the same pole. The accuracy of our algorithm is summarized in the next section.

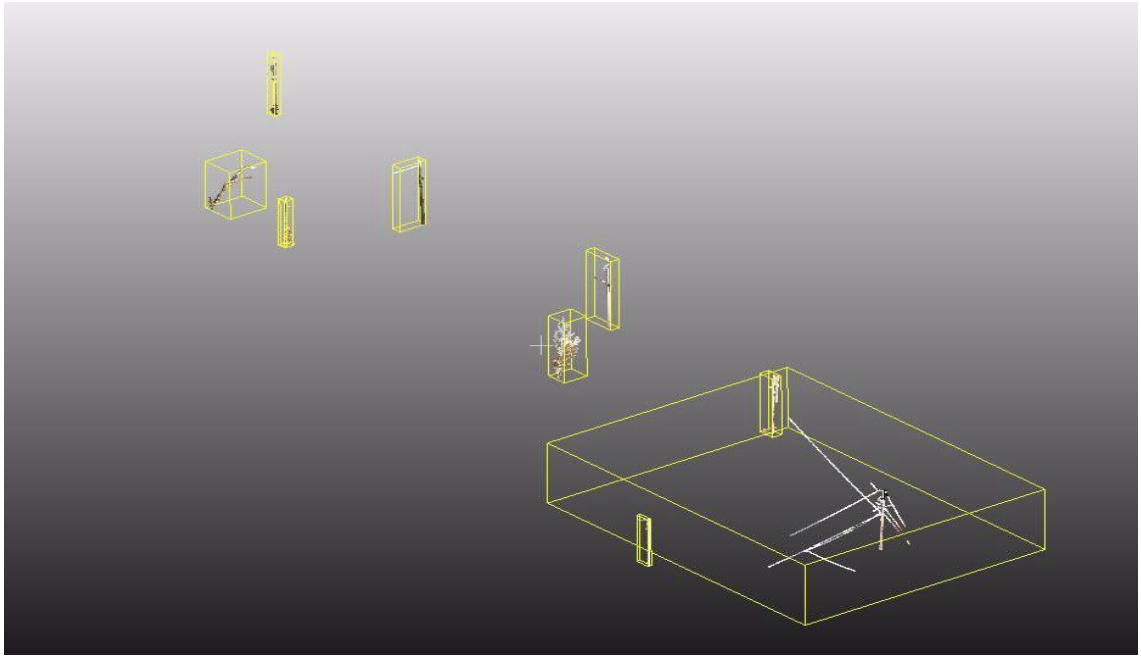

Figure 3: Clustering the point cloud

2.2. Power Lines Detection

Once the poles are detected, we create a plane bounded by two successive power poles. This plane offers valuable information to detect power lines. First, it tremendously reduces the amount of data to process since power lines are necessarily close to the defined plane. Second, all the power lines are inevitably parallel to this plane. When a line is not parallel to our plane, it is inferred that it is part of the vegetation. Later, this information will be used as an insight for vegetation workload.

To create a plane, at least three non-collinear points are required. Since single-phase distribution lines are typically attached at the top of poles, we select the first two points of the plane from the top of two consecutive poles. Then, the third point is selected from the bottom of one of the poles. In the 3D space, a plane P is characterized by the following equation:

$$P : ax + by + cz + d = 0, \qquad (1)$$

where the parameters a, b, c, and d are real numbers and (x,y,z) are the coordinates of a point belonging to the plane.

Subsequently, we calculate the distances between any points and the defined plane. Assume that a point O has coordinates (x_0, y_0, z_0), then the perpendicular distance from the plane P can be defined by

$$d(O,P) = |ax_0 + by_0 + cz_0 + d| / \sqrt{(a^2+b^2+c^2)}, \qquad (2)$$

where |.| is the absolute value function.

In the following step, we filter out all points having $d(O,P)$>50 cm, as illustrated in Figure 4. This operation significantly reduces the number of power lines candidate points, compared to the original track. Hence, searching lines using the RANSAC algorithm becomes very efficient and returns good candidates with a higher probability of being overhead power lines [14].

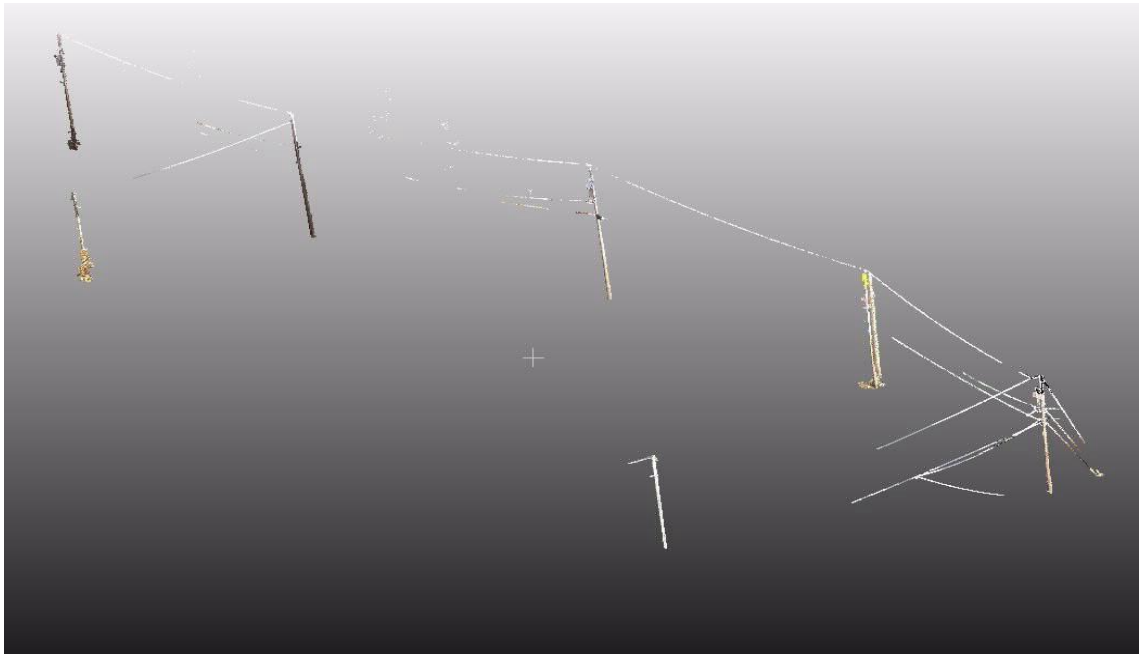

Figure 4: Filtered point cloud close to the planes delimited by the poles

Indeed, the RANSAC algorithm is very efficient when the number of points to process is low. It starts by randomly selecting points and calculates the number of inliers and outliers according to a mathematical model, e.g., it selects two points to draw a 3D line and finds inliers and outliers within the defined line. This process is iteratively repeated until the highest number of inliers is obtained.

In our approach, we propose to classify all the lines detected by RANSAC as follows. When a line is parallel to *P*, it is classified as a power line candidate; otherwise, it is listed as a potential branch or vegetation. This classification eliminates the false positive candidates, i.e., the detected lines falsely seen as candidates of real power lines.

To classify a RANSAC detected line, which is delimited by extremity points $O_1(x_1,y_1,z_1)$ and $O_2(x_2,y_2,z_2)$, as a good candidate or not, we check if it is parallel to plane *P* through the following condition:

$$a\,(x_2 - x_1) + b\,(y_2 - y_1) + c\,(z_2 - z_1) = 0. \qquad (3)$$

Remark. Note that the efficiency of RANSAC in this step is highly dependent on the quality of the reduced point cloud. If relying only on the 50 cm distance condition to filter points around the defined plane, there is a high probability that several non-relevant points, e.g., vegetation and other obstacles, would be kept within the area of interest, particularly when heavily occluded by

vegetation. The presence of such points may distort the line detection procedure as RANSAC is forced to maximize the number of inlier points, while including them as potential line points.
In order to tackle this limitation, we propose for the first-time colour-based filtering. Indeed, we noticed that typically power line points have a brighter colour than other objects in the environment. Hence, we apply a filter that removes dark-coloured points after the distance-based filtering. This process is conducted with respect to a selected colour intensity threshold. Practically, we only keep the following red-green-blue (RGB) values:

$$RGB = (185 \pm 75, 185 \pm 75, 185 \pm 75). \quad (4)$$

Although this approach may sacrifice several relevant points, it doesn't affect RANSAC's performance due to the latter's robustness using a low number of points.

2.3. Power Lines Modelling

The power lines recorded by the MLS are sometime incomplete or obstructed. Indeed, depending on the power line location with respect to the LiDAR scanner's position, on the height and diameter of the line and on the extent of the vegetation's encroachment, important sections of the line are frequently missing or invisible. In this situation, it becomes mandatory to accurately model those missing line parts and fully exploit them to recover the absent line sections and correctly evaluate the encroachment of the tree branches along the power line.

For the single-phase distribution network, we reconstruct the 3D parabola shape of a power line by strategically selecting three points. The first and second points, denoted by $O_1(x_1,y_1,z_1)$ and $O_2(x_2,y_2,z_2)$, are selected from the top of two consecutive poles, while the third point, $O_3(x_3,y_3,z_3)$, is taken from the detected lines between the same poles. The 3D parabola can be characterized by two equations as follows. By projecting the parabola on the (x,y) horizontal plane, it can be seen as a line with equation $L_1 : y=a_1x+b_1$ whereas, when projected on the (x,z) vertical plane, it is modelled as a 2D parabola with equation $L_2 : y=a_2x^2+b_2x+c_2$.

By substituting the coordinates of the selected points into L_1 and L_2, respectively, two systems of equations are obtained and solved to determine the parameters. The latter can be given by:

$$a_1 = (y_2 - y_1) / (x_2 - x_1) \quad (5a)$$

$$b_1 = y_1 - a_1 x_1 \quad (5b)$$

$$a_2 = [y_3 (x_2 - x_1) + y_2 (x_1 - x_3) + y_1 (x_3 - x_2)] / [(y_1-y_2) (y_1 - y_3) (y_2 - y_3)] \quad (5c)$$

$$b_2 = [(y_3)^2 (x_2 - x_1) + (y_2)^2 (x_1 - x_3) + (y_1)^2 (x_3 - x_2)] / [(y_1-y_2) (y_1 - y_3) (y_2 - y_3)] \quad (5d)$$

$$c_2 = z_1 - a_2(x_1)^2 - b_2x_1. \quad (5e)$$

Figure 5 shows the 3D parabola curves built from the detected poles and lines. As it can be seen, it efficiently recovers the line's missing points and returns, with high accuracy, the exact location of the single-phase power lines.

3. CASE STUDY AND RESULTS

3.1. Case Study

3.1.1. MLS Setup and Datasets

The 3D mobile LiDAR point cloud data was collected with the Leica Pegasus mobile mapping system using seven 4 Megapixels cameras and a ZF 9012 sensor, having the accuracy of 9 mm at 50 m. Data acquisition was realized in Mont-Laurier, Quebec, in October 2019, and the linear surveyed distance was 150 km long and included both urban and rural sections.

For this work, we used two datasets of LiDAR points. The first, used for the approach's development and fine-tuning, contains subsections of 68 poles. The second, used for the approach's testing and validation, possesses subsections of 98 poles. Both sets of data are Hydro-Quebec's property and cannot be publicly shared.

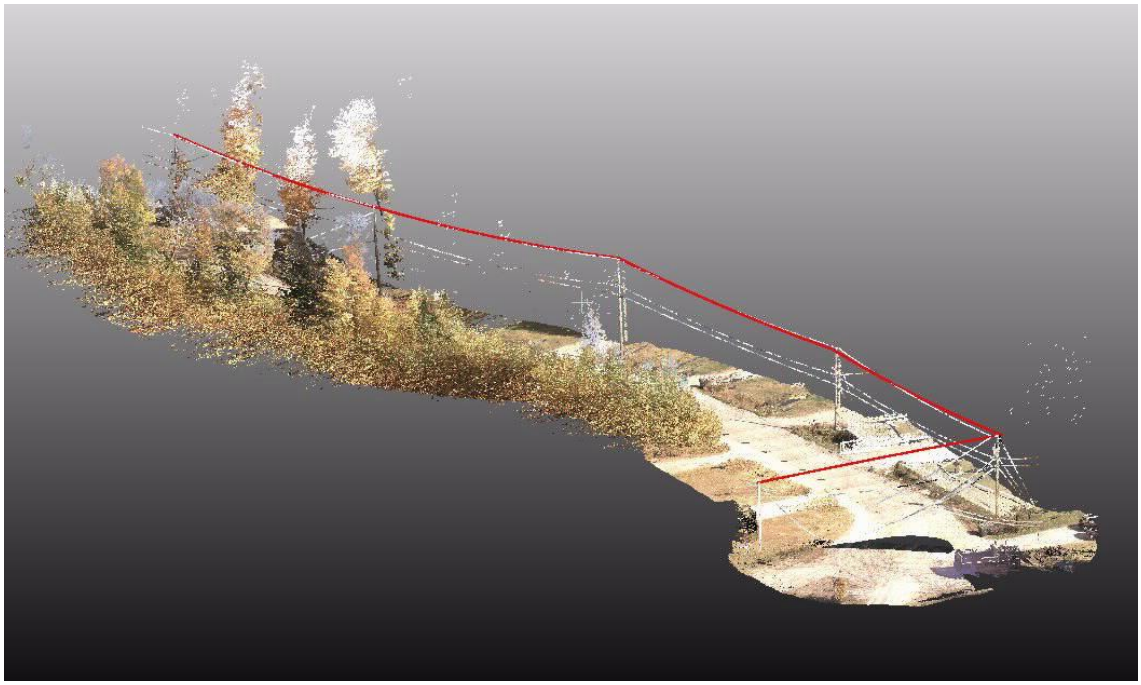

Figure 5: Power lines modelling using 3D parabola equation (in red)

3.1.2. Poles Detection Setup

During the clustering step, we keep all the clusters that have a point cloud size between 3k and 100k points (i.e., the "Point cloud density function" and "Number of points limits" criteria). The height of the cluster should not exceed 11.5 m and the width should be less than 2 m. With this technique, we only keep potentially good candidates.

For each cluster, we execute the RANSAC 3D cylinder detection algorithm. The diameter and the height of the cylinder should not exceed 60 cm and 11.5 m, respectively (i.e., "Cylinder height" and "Cylinder diameter" criteria), while its orientation is below 15°, along the Z-axis.

3.1.3. Power Lines Detection and Modelling Setup

After the poles' detection step, we link the poles two-by-two according to their Euclidean distances that should be more than 20 m and less than 65 m. A plane can be created between two linked poles, and points that are within a distance up to 50 cm from the plane, with respect to the RGB colouring criterion (4), are extracted. The obtained region of interest is then analyzed to detect sticks (i.e., 3D lines) that have a radius ranging between 1 cm and 3 cm, and a minimum point cloud density of 40 LiDAR points. When the sticks are parallel to the plane and have the appropriate length and size, they are selected to mathematically model a parabola between two poles.

All the modelled parabolas are ranked according to their proximity with the previously detected sticks. The distance between the sticks and the parabola is incrementally processed and should not exceed 20 cm.

Finally, the parabola with the highest number of LiDAR sticks points is selected as the best one representing the overhead power line.

3.2. Results

In Table 1, we present the pole detection performances in terms of the number of true positive poles (i.e., real detected poles), the number of false positive poles, the accuracy, and the recall, for different values of the RANSAC minimum height parameter.

Table 1: Poles detection accuraccy and recall for different RANSAC poles height

Min. pole height	No. of true positive poles	No. of false positive poles	Accuracy	Recall
7.5 m	154	26	92.7 %	85.5 %
6 m	157	18	94.5 %	89.7 %

As it can be seen, an accuracy of 92.7% and a recall of 85.5% are obtained for the minimum pole height of 7.5 m, while the accuracy and recall increase to 94.5% and 89.7%, respectively, for the minimum pole height of 6 m. This is expected since lowering the minimum pole height parameter to 6 m allows considering more relevant poles cloud points in the RANSAC algorithm. However, going below 6 m would consider irrelevant cloud points causing a high number of false positives. The obtained results are promising; however, they require extensive probing to ensure that the minimum height parameter value of 6 m is valid for any recorded point cloud cluster. Also, depending on the LIDAR hardware tuning and speed of the vehicle, the LIDAR points density may vary, thus affecting our algorithm's performances in terms of accuracy and recall. Hence, prior to any LIDAR recording, we strongly recommend using the same hardware settings to have reproducible results.

For power lines detection, we reached in our experiments the accuracy of 84%, given minimum pole height of 6 m. Such a high result is achieved due to the efficient poles detection and LiDAR data filtering steps prior to RANSAC based lines detection. Also, an outstanding line detection recall of 98.9% is realized. This result is mainly since all sticks candidates are representative of the final solution. Moreover, highly obstructed lines were correctly detected, thus making lines detection very efficient compared to state-of-art methods.

In order to emphasize the performance of our lines modelling approach, we illustrate in Figure 6 the distribution of the distance gap between the real and reconstructed power lines, given three different reconstruction methods. The latter differ in the selection of the poles' points $O_1(x_1,y_1,z_1)$ and $O_2(x_2,y_2,z_2)$ when modelling the power lines with 3D parabolas. In each pole, the z_i coordinate of point O_i ($i = 1, 2$) is selected as the highest point of the pole. However, optimally selecting (x_i, y_i) coordinates is not straight-forward. Indeed, the extracted cylinder that represents the pole is not perfectly cylindrical and can contain cloud points of vegetation, wires, signs, or any equipment attached to the pole.

For the sake of simplicity, we developed three methods to adequately select the (x_i, y_i) coordinates ($i = 1, 2$). Specifically, "Method 1" selects the averaged (x, y) location on the upper half subsection of the pole, "Method 2" takes the averaged location on the lower half subsection of the pole, whereas "Method 3" selects the average (x, y) location on the central subsection of the pole. In Figure 6, both "Method 1" and "Method 3" present the best performances with a preference to "Method 1". Indeed, the obtained distance gap between the real and reconstructed lines is less than 10 cm and 20 cm in 66% and 89% of the cases, respectively. In contrast, "Method 2" has the worst performance, with a gap of 20 cm or less in 78% of the cases. We conclude that the selection of the 3D parabola reconstructing points' locations is crucial for

accuracy. Hence, a precise 3D parabola model of power lines would allow accurately estimating the vegetation closeness and thus evaluating the risk of outages.

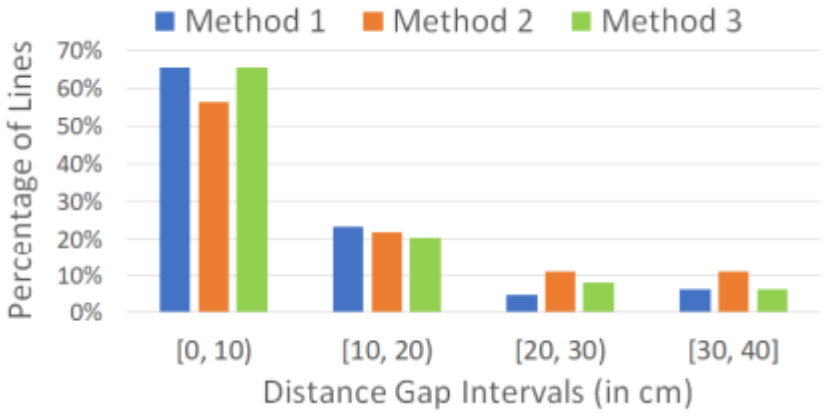

Figure 6: Distribution of distance gap between real and reconstructed overhead power lines for three modelling methods

4. LIMITATIONS AND FUTURE WORK

As demonstrated in the previous section, our approach is effective in detecting poles and power lines. However, it is limited to single-phase lines, and still experiences some issues in fully occluded environments. In any case, we believe that our approach's accuracy can be further improved using the following rules.

First, more selective filtering techniques should be applied. For instance, we noticed that relevant LiDAR data is located at distances less than 7.5 m from the MLS detector. Indeed, the poles are usually close to the road and within a clear view from the MLS. Hence, only this data should be processed and analyzed. Second, the poles are typically located within one side only of the road. Thus, our algorithm can be used on the right or left side of the motorized LiDAR. Once the poles and cables are detected on one side of the road, it can skip processing remaining data on the

opposite side. To do so, an indicator can be used to guide the detection algorithm and can help decide which side of the road to process first. This simple rule reduces the algorithm's processing time by at least 25%.

Finally, recent MLS systems have, in addition to the laser scanner, six digital cameras recording 360° images. These 2D pictures are recorded along the LiDAR scanner data at different timestamps.

Since deep learning neural networks are highly efficient in detecting objects in 2D images [15], it becomes interesting to integrate this feature into our approach to improve the LiDAR data segmentation process. Indeed, combining several images of the same object at different timestamps allows building a corresponding frustum in the 3D LiDAR space [16], [17]. The latter reduces the original LiDAR space into a small 3D box. Thus, object detection and segmentation of the LiDAR data become a simple clustering process. We conducted preliminary experiments on this approach, and we had promising results.

In order to generalize our algorithm's application beyond single-phase line detection, e.g., to three-phase power lines detection, additional steps have to be introduced into our approach. For instance, since the horizontal distances between the three-phase lines are known, it is easy to mathematically split the 3D box between two poles (steps 1-2 in "Power lines detection", Figure 1) into three adjacent and parallel planes and their corresponding new 3D boxes. In each new plane, a line parabola modelling the phase is then built. Hence, generalization to three-phase line detection can be processed with minimum change.

5. CONCLUSION

In this paper, we proposed a new method to recognize and model the overhead power lines. We detected with high accuracy poles and power lines, even in heavily occluded environments.

To do so, we proposed an original approach that relies on multiple filters to parse the point cloud data, detects at first the poles, detects segments of the lines in second, and finally model the distribution lines with precise parabolas. The key idea is to use the locations of the detected poles to guide the lines detection and extraction process through simple geometrical operations.

Through our approach, we were able to detect power poles with accuracy up to 94.5%, while power lines were detected with the best accuracy of 84% and recall of 98.9%. Also, the reconstructed distribution lines, using the 3D parabolas, have a maximum deviation of 20 cm from the LiDAR data in 89% of the cases, which is very accurate for our application.

As a future work, further refinements will be applied to generalize our algorithm to detect three-phase power lines. Also, since 2D poles' images can be automatically segmented using convolutional neural networks, we start using image segmentation to automatically extract frustum. First experiments revealed that the power poles cloud detection within a frustum is highly accurate and the number of false positive is close to zero. With these promising results, our next step is to start detecting all the poles and the distribution lines for the recorded Lidar track of 150 km including both urban and rural sections.

REFERENCES

[1] Hydro-Québec. (2019) Setting new sights with our clean energy. Annual Report. [Online] https://www.hydroquebec.com/data/documents-donnees/pdf/annual-report-2019-hydro-quebec.pdf

[2] M. Lehtomaki, A. Kukko, L. Matikainen, J. Hyyppa, H. Kaartinen, and A. Jaakkola, "Power line mapping technique using all-terrain mobile laser scanning," Automation in Construction, vol. 105, p. 102802, Sep.2019.

[3] M. Ax, S. Thamke, L. Kuhnert, and K. D. Kuhnert, "UAV based laser measurement for vegetation control at high-voltage transmission lines," in Adv. Power and Elec. Engineer., ser. Adv. Mater. Res., vol. 614, 22013, pp. 1147–1152.

[4] A. Jaakkola, J. Hyyppa, A. Kukko, X. Yu, H. Kaartinen, M. Lehtomaki, and Y. Lin, "A low-cost multi-sensoral mobile mapping system and its feasibility for tree measurements," ISPRS J. Photogramm. Remote Sens., vol. 65, no. 6, pp. 514–522, Nov. 2010.

[5] A. Jaakkola, J. Hyyppa, X. Yu, A. Kukko, H. Kaartinen, X. Liang, H. Hyyppa, and Y. Wang, "Autonomous collection of forest field reference — The outlook and a first step with UAV laser scanning," Remote Sens., vol. 9, no. 8, p. 785, Jul. 2017.

[6] A. Kukko, C.-O. Andrei, V.-M. Salminen, H. Kaartinen, Y. Chen, P. Ronnholm, R. Chen, H. Haggren, I. Kosonen, and K. Capek, "Road environment mapping system of the Finnish geodetic institute- FGI roamer," in Proc. of ISPR Wrkshp., 2007, pp. 241–247.

[7] G. Petrie, "An introduction to the technology: Mobile mapping systems," Geoinformatics, vol. 13, no. 1, pp. 32–43, Jan./Feb. 2010.

[8] I. Puente, H. Gonzalez-Jorge, J. Martinez-Sanchez, and P. Arias, "Review of mobile mapping and surveying technologies," Measurement, vol. 46, no. 7, pp. 2127–2145, Aug. 2013.

[9] H. Guan, Y. Yu, J. Li, Z. Ji, and Q. Zhang, "Extraction of power-transmission lines from vehicle-borne LiDAR data," Int. J. Remote Sens., vol. 37, no. 1, pp. 229–247, Jan. 2016.

[10] M. Yadav and C. G. Chousalkar, "Extraction of power lines using mobile LiDAR data of roadway environment," Remote Sensing Applications: Society and Environment, vol. 8, pp. 258 – 265, Nov. 2017.

[11] R. B. Rusu and S. Cousins, "3D is here: Point Cloud Library (PCL)," in IEEE Int. Conf. Robot. Autom. (ICRA), Shanghai, China, May 9-132011.

[12] K. Zhang, S.-C. Chen, D. Whitman, M.-L. Shyu, J. Yan, and C. Zhang, "A progressive morphological filter for removing nonground measurements from airborne LIDAR data," IEEE Trans. Geosci. Remote Sensing, vol. 41, no. 4, pp. 872–882, Apr. 2003.

[13] T. Chaperon and F. Goulette, "Extracting cylinders in full 3D data using a random sampling method and the Gaussian image." in Proc. Vision Model. Visualization Conf. (VMVC). Aka GmbH, 2001, pp. 35–42.

[14] M. A. Fischler and R. C. Bolles, "Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography," Commun. ACM, vol. 24, no. 6, p. 381–395, Jun. 1981.

[15] S. Ren, K. He, R. Girshick and J. Sun, "Faster R-CNN: towards real-time object detection with region proposal networks, " IEEE Trans. Pattern Analysis and Machine Intelli., vol. 39, no. 6, pp. 1137-1149, 1 Jun. 2017.

[16] K.-L. Low, and A. Ilie. "Computing a view frustum to maximize an object's image area," J. of Graphics Tools, vol. 8, no. 15, pp. 1–14, 2003.

[17] W. Zhang, C. Witharana, W. Li, C. Zhang, X. Li and J. Parent, "Using deep learning to identify utility poles with crossarms and estimate their locations from Google street view images," Sensors J., vol. 18, no. 8, Aug. 2018.

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FABRIC DEFECT DETECTION BASED ON FASTER RCNN WITH CBAM

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ABSTRACT

In the production process of fabric, defect detection plays an important role in the control of product quality. Consider that traditional manual fabric defect detection method are time-consuming and inaccuracy, utilizing computer vision technology to automatically detect fabric defects can better fulfill the manufacture requirement. In this project, we improved Faster RCNN with convolutional block attention module (CBAM) to detect fabric defects. Attention module is introduced from graph neural network, it can infer the attention map from the intermediate feature map and multiply the attention map to adaptively refine the feature. This method improve the performance of classification and detection without increase the computation-consuming. The experiment results show that Faster RCNN with attention module can efficient improve the classification accuracy.

KEYWORDS

Fabric defects detection, Faster RCNN, Convolutional block attention module, Deep learning.

1. INTRODUCTION

In order to produce highquality garments, it is an important step to apply a defect detection link in the process of fabric manufacturing to ensure the quality. Defect detecting is the process to find out and locate defects on the surface of fabric. Finding out defects on fabric also improves the efficiency of manufacturing process by abandoning unqualified intermediate products. Traditionally, manual inspection which carried out on wooden board is the only method to assure the quality of textile. Sometimes workers also do fine defects detection with the help of equipment like magnifiers and microscopes. Manual defect detection can do prompt correction of small defects. However, error may occur due to fatigue, and small defects are usually undetected [1].

Since fabric defect detection has a great effect on the quality control of textile manufacture and the conventional manual inspection method does not suit the requirement of developed automated manufacture, automatic fabric defects detection becomes a natural way to improve fabric quality and lower labor cost. Fortunately, with the development of deep learning technology and the progress of computer vision technology, a new automated fabric detection method which can replace manual inspection appears. By applying computer vision and machine learning technology, automated visual inspection is widely used to detect the surface defects of machined parts and components. According to the research of Rajalingappaa Shanmugamani [2] published in 2015, visual inspection method can provide rapid quantitative assessment and improve quality and productivity.

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Two defects detection algorithms are compared in this project, the Faster RCNN and Faster RCNN with convolutional block attention module (CBAM). The difference between these two algorithms is that the backbone net is different. The backbone net for Faster RCNN is Resnet-50[21], which is a 50 layers deep neural network and used for feature extraction of defects,classification and regression. CBAM will combine with Resnet-50 to improve the performance. Both algorithm detector is Faster RCNN. By comparing the result of two detect algorithms, the role of attention module will be revealed, and the effect of the faster R-CNN is going to be shown.

2. RELATED WORK

At present, textile defects detection approaches can be simply divided into spectral approach and learning approach. Gabor filters provide the optimal joint position in spatial and frequency domain [3], it becomes the most popular approach in spectral-based method. The initial application of Gabor filter is to build a filter bank with numerous sets of filters, which is predetermined the parameters in frequency and orientation [4]. In [5], Shu calculates the frequency and direction data obtained from 16 Gabor filters convolution with 4 different angles and scales to detect fabric defects. This method accuracy will be affected by the computationally intensive and the frequency plane coverage. Bodnarova [6] utilizes optimal filters to reduce the amount of filters, the computation time is greatly reduced resulting in an increased speed of detection. However, the correct choice of optimal filter is difficult and crucial. Tong [7] has developed composite differential evolution (CoDE) to optimize the parameters of Gabor filters, and get high performance in limited samples. LI [8] integrated Gabor filter and Gaussian mixture model to inspect simple texture defects, the classification accuracy from 360 images of 9 different defect types reach 87%.

Neural network has advantages in feature extraction, segmentation and optimization tasks of fabric defects detection area [9,10]. In 2001, Stojanovic[11] proposed a three-layer back-propagation neural network for low-cost fabric real-time detection, and the accuracy achieved 86%. Kumar [12] combines forward neural network with Principal Component Analysis (PCA) for faster detection. In [13], Kuoproposes a three-layers back-propagation neural network to detect white fabric defects. This model a high dimensional system by non-linear regression algorithm, achieve 91.88% recognition accuracy for 160 simple defects image. Asimilar architecture of network is proposed in [14], the detection accuracy of holes and oil stain of twill fabric reach 91% and 100%. However, the amount of sample is limit and the reliability is unknown. Semnani and Vadood [15] develop an intelligent model based on artificial neural network to estimate the appearance of knitted fabrics.

With the development of deep learning, such as R-CNN [16], fast R-CNN [17], SSD [18] and YOLO [19], fabric defects automatically detection has more potential possibilities. R-CNN is the abbreviation of Region-based Convolutional Neural Networks and it is put forward by Girshick and his team since 2014 [16]. This method mainly includes two steps. In the first step, R-CNN applies a controllable amount of bounding boxesto select candidates.ThenR-CNN independently extracts features from each candidate to classification. To improve the performance of R-CNN and increase its operation speed, Girshick (2015) [17] reconstructed the network architecture. Girshick combines three independent CNN into one joint trained framework andshare union parameters. Fast R-CNN integrates the scattered feature vectors into a feature matrix shared by all the region proposals. The feature matrix is realized by the forward propagate of CNN on the entire image, and then it is separated to train the classifier and regressor to classification and point out their locations.

3. METHOD

3.1. Date augmentation

In this paper, we collected 185 fabric defect images in three different typesfrom textile factory. They are broken hole, fly yarn and drop needle. Since the database is too small, we adapt random real-time data augmentation to increase the amount of image, we flip the image in horizontal and vertical direction, and distort the image.

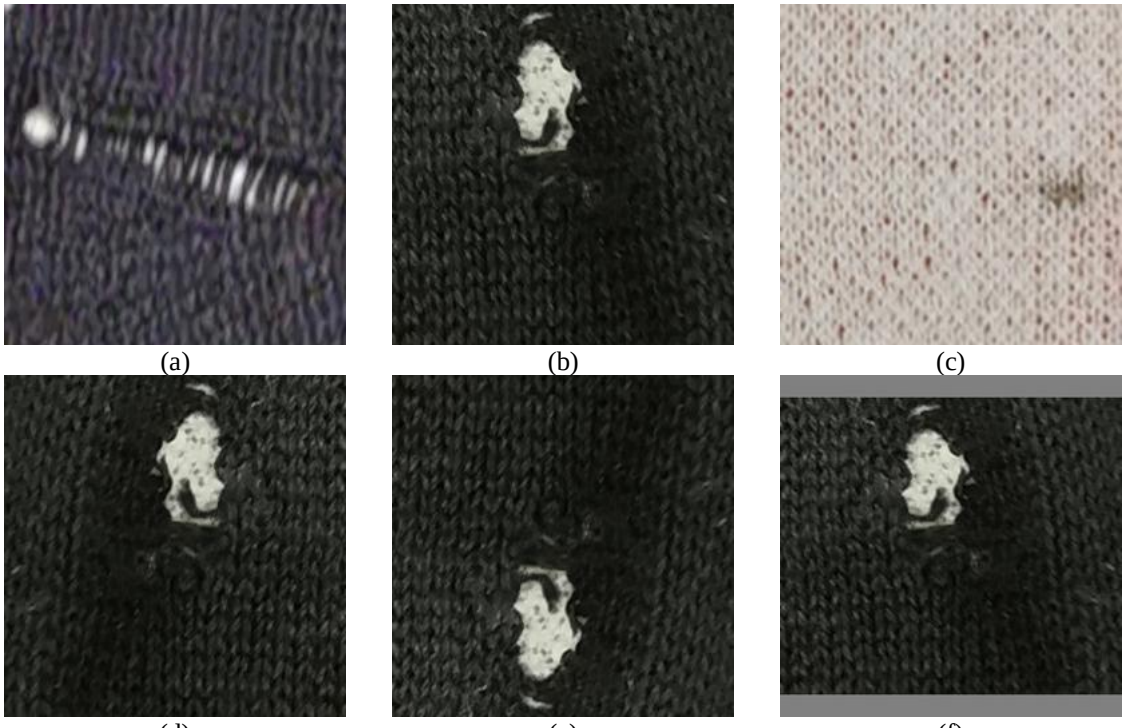

Fig 1. The examples of fabric defects image and augmentation results. (a) is drop needle. (b) is broken hole. (c) is fly yarn. (d) and (e) are (b) flipped in horizonal and vertical direction, (f) is (b) distorted and resized in standard size.

3.2. Faster RCNN

Faster R-CNN does the job of object detection in this project. It is developed based on R-CNN and Fast R-CNN technology and was proposed by Girshick and his team in 2015 [20].Faster R-CNN integrates the step of creating boundary boxes into CNN model. The overall frame of Faster R-CNN is shown in Figure 2. Faster RCNN contains four main parts, which are convolution layers, region proposal network, region of interest (RoI) pooling and classification.

In this paper, we use ResNet-50 [21] as the backbone net. Firstly, the input fabric defects image feature map is extracted by convolutional layer with ReLu activation function and pooling layers.Region proposal network (RPN) is used to generate proposals with feature matrix. We use boundary conditions and non-maximum suppression [22] to select the appropriate anchor on feature map. The output of regression layer indicates the coordinate position of fabric defect. RoI pools collect region proposal and feature maps, the bounding box regression provides the final exact target box position.

CBAM (Convolutional Block Attention Module) [23] is an efficient improvement algorithm in detection presented by Sanghyun Woo, Jongchan Park and their team in 2018.The structure of these two modulesshows in Figure 3.The function of the entire attention module can be expressed by the following two equations. The first equation represents the function of channel attention module and the second equation shows the function of spatial attention module.

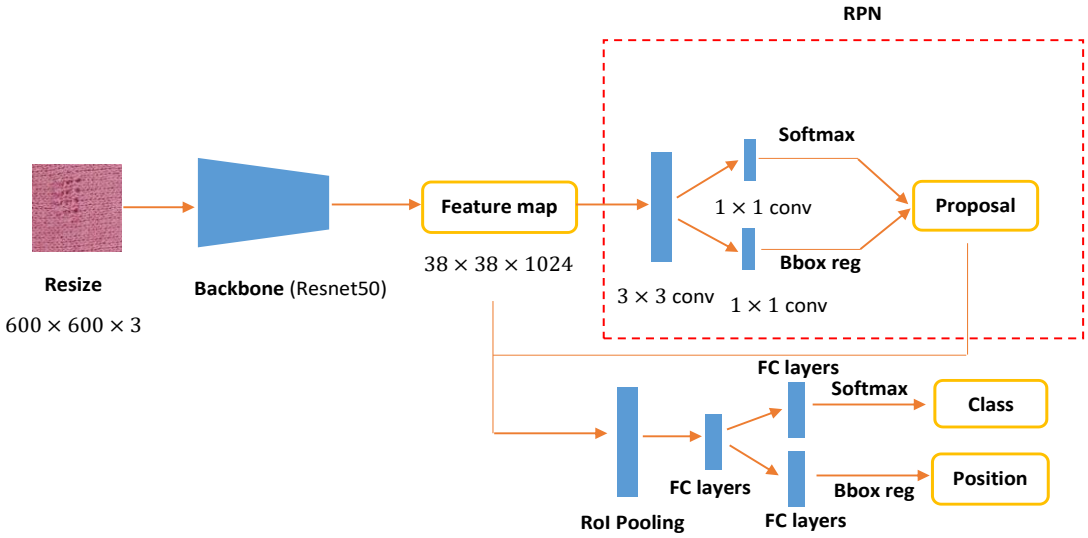

Fig 2. An illustration of Faster R-CNN model

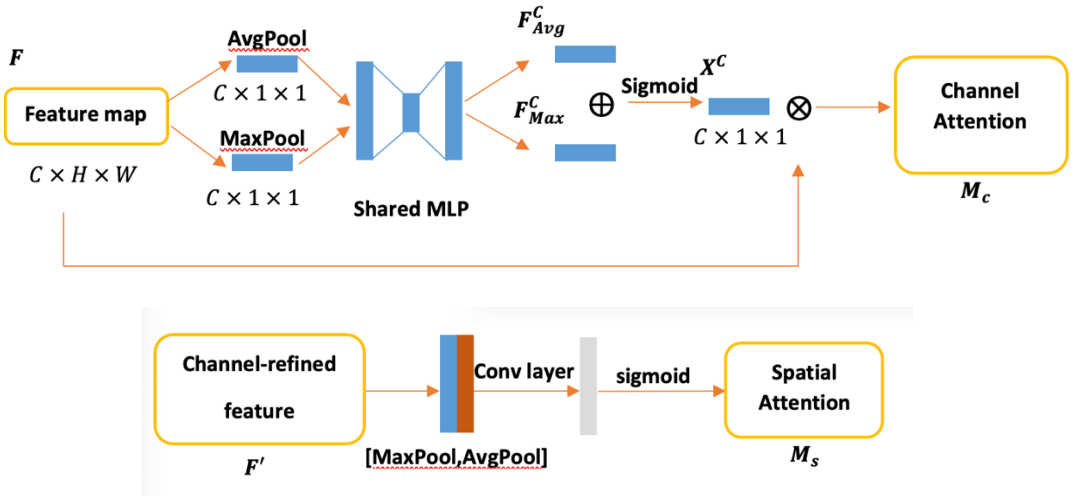

Fig 3. Diagram of each attention sub-modules

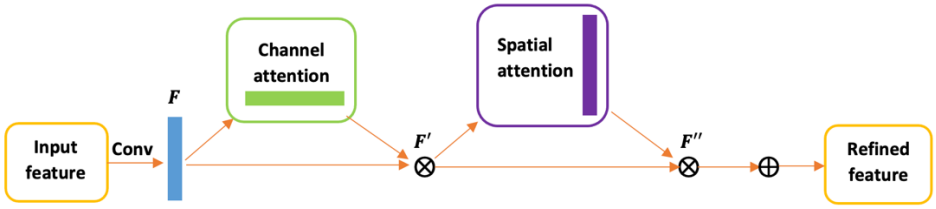

Fig 4. CBAM integrated with a ResBlock in ResNet

$$F' = M_c(F) \oplus F$$
$$F'' = M_s(F') \oplus F' \quad (1)$$

$\oplus$ represents element-wise multiplication. M_c represents the operation of attention extraction on the channel dimension, and M_s represents the operation of attention extraction on the spatial dimension. $F \in \mathbb{R}^{H \times W \times C}$ is the intermediate feature map, F' is the product of feature map after channel attention module process, F'' represents the final output feature map after channel attention and spatial attention. H means the height of input feature map, W is the width of input feature map. C is the channel number of input feature map.

Table1. ResNet-50 Architecture

Layer Name	Output Size	ResNet-50
conv1	$112 \times 112 \times 64$	7×7, 64, stride 2
conv2_x	$56 \times 156 \times 64$	3×3 max pool, stride 2 $\begin{bmatrix} 1 \times 1, 64 \\ 3 \times 3, 64 \\ 1 \times 1, 256 \end{bmatrix} \times 3$
conv3_x	$28 \times 28 \times 128$	$\begin{bmatrix} 1 \times 1, 128 \\ 3 \times 3, 128 \\ 1 \times 1, 512 \end{bmatrix} \times 4$
conv4_x	$14 \times 14 \times 256$	$\begin{bmatrix} 1 \times 1, 256 \\ 3 \times 3, 256 \\ 1 \times 1, 1024 \end{bmatrix} \times 23$
conv5_x	$7 \times 7 \times 512$	$\begin{bmatrix} 1 \times 1, 512 \\ 3 \times 3, 512 \\ 1 \times 1, 2048 \end{bmatrix} \times 3$
average pool	$1 \times 1 \times 512$	
softmax	1000	

As shown in Figure 3, the input feature map suffersglobal average-pooling F^c_{avg} and globalmaxi-pooling F^c_{max} in channel attention module. It is worth to note that the global average pooling and global maximum pooling are used in parallel, whichcan minimize the information loss during the pooling process. F^c_{avg} and F^c_{max} forward to a shared network which composed of multi-layer perceptron with one-hidden layer, to produce channel attention map M_c. It can be represented as following equation (2):

$$M_c(F) = \sigma\left(MLP\left(AvgPool(F)\right) + MLP\left(MaxPool(F)\right)\right)$$
$$= \sigma\left(W_1(W_0(F^c_{avg})) + W_1(W_0(F^c_{max}))\right) \quad (2)$$

Where σ presents sigmoid function, $W_0 \in \mathbb{R}^{C/r \times C}$, $W_1 \in \mathbb{R}^{C \times C/r}$ is the MLP layers wight, r is the reduction rate. First layer has ReLu activation function.

Different from channel attention module, spatial attention module applies a convolutional layer to generate a spatial attention map to concatenate max-pooling and average-pooling. It can be represented as following equation (2):

$$M_c(F) = \sigma\left(f^{7\times7}\left(AvgPool(F)\right); MLP\left(MaxPool(F)\right)\right) \quad (3)$$

$$= \sigma\left(f^{7\times7}\left|F^s_{avg}; F^s_{max}\right|\right)$$

Where σ presents sigmoid function, $f^{7\times7}$ represents a convolution operation with 7×7 size filter. In this paper, we use sequential arrangement attention modules.

4. EXPERIMENT AND RESULT

In this paper, we used 90 percent samples in the database as training dataset. For one experiment, 50 epochs are run with a base learning rate of 0.001 and 0.0001 with another 50 epochs. In both of the two iteration stages, the learning rate will decay to 92% of the original in each iteration. Batch size is 1 and we carry 2 experiments for each method separately. Totally, we have taken 40,000 iterations on each method. The test environment is a HP desktop with an Inter(R) Core(TM) i5-4200 3.3 GHZ CPU, the simulation software is python2.7.

There are 185 images in the database, 10% of which is test dataset. Limited by the sample size, only 3 types of defects are involved in training and testing. All of the three types of defects can be detected under both the Faster R-CNN with a modified backbone net and the normal one as shown in the Fig 3. we just show some examples of the detection results. It can be seen that both these two methods can detect the fabric defects accurately. For the two figures in each group, the left one is the result of the normal Faster R-CNN using Resnet 50 as backbone; the right one is the result of the Faster R-CNN with a modified backbone using Resnet50 and CBAM. Both of the two experiments use Faster R-CNN as the detector. It is clear that using Faster R-CNN with CBAM leads a higher confidence of the detected defect object compared with the normal one. After adapting CBAM, the confidence is 2%-3% higher than before. Therefore, the detection model can be regarded more reliable.

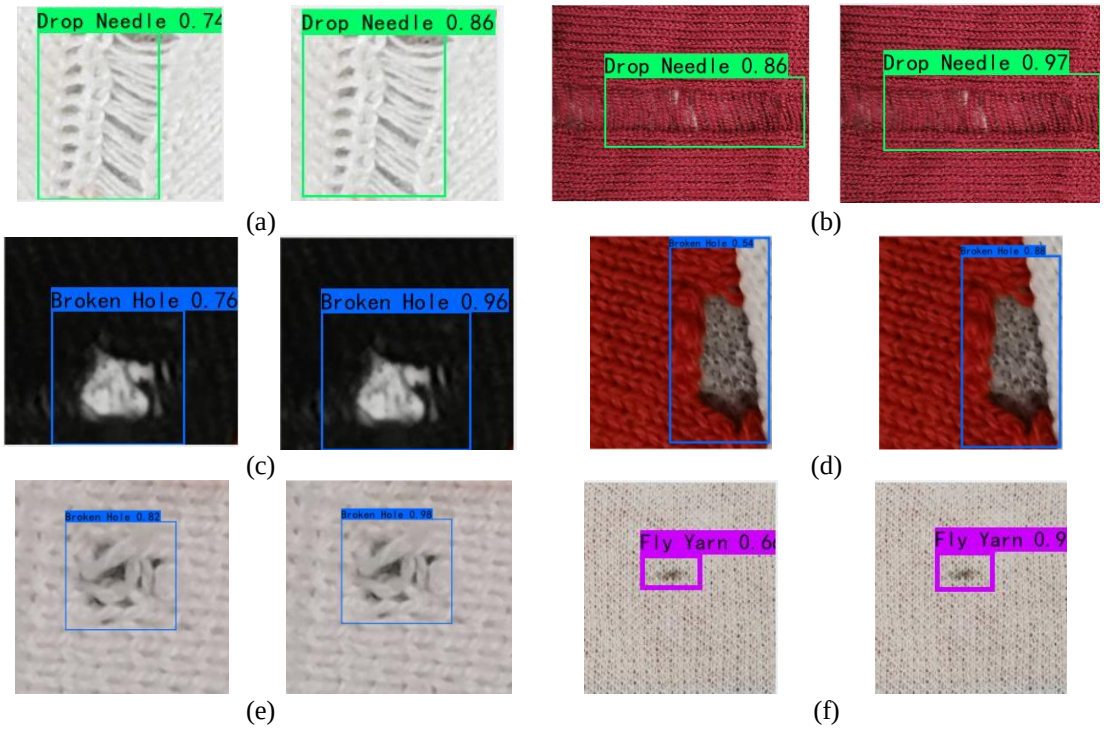

Fig 3. Results display and comparison between the different backbones: Resnet50 (left figure) and Resnet50 + CBAM (right figure). (a), (b) drop needle, (c), (d), (e)broken hole, (f) fly yarn.

The comparison and performance of the two methods are shown in the follow table separately. Average precision (AP) of each class and mean average precision (mAP) on the test dataset are used to evaluate the detection effect. The confidence threshold in mAP is 0.01. Training with CBAM can improve the mAP of fabric defects detection, it will become nearly 1% higher than before.

Table. 2 Object detection AP (%) of each class and mAP (%) on the test dataset.

Backbone	**Detector**	**AP of broken hole**	**AP of drop needle**	**AP of fly yarn**	**mAP**
ResNet-50	Faster R-CNN	93.26	61.03	55.50	69.93
ResNet-50+CBAM	Faster R-CNN	95.31	61.89	55.48	70.89

Global recognizable ratio is the percentage of samples that can be recognized in all test samples. Correspondingly, we can describe the percentage of samples that can be recognized in a certain class in all samples of that class as class recognizable ratio. Broken hole is the most easily to be detected since its structure feature is obvious and simple. As for drop needle, it is not very easy to be detected since it has many kinds of different structures in the database. Fly yarn is most difficult to be detected since its sample size is small and it does not have special structures.

Table. 3 Global recognizable ratio (%) and class recognizable ratio (%) on the test dataset.

Backbone	Detector	Global ratio	Broken hole	Drop needle	Fly yarn
ResNet-50	Faster R-CNN	46	86	50	36
ResNet-50+CBAM	Faster R-CNN	62	100	56	67

In addition, to determine whether every recognized sample is classified correctly, the ratio of samples with correct classification in all samples that can be recognized is accuracy. It can also be divided into global accuracy and category accuracy, like the recognizable ratio. Adapting CBAM makes the global accuracy becomes 1% higher than before. For each class, the accuracy of drop needle is the highest, although it is not easy to be detected out, its accuracy is high. With CBAM, broken hole can reach 100% accuracy and accuracy of fly yarn is also improved.

We also test the detection speed of Faster R-CNN which is 1.10 seconds per image.

Table. 4 Global accuracy (%) and class accuracy (%) of each class on the test dataset.

Backbone	Detector	Global accuracy	Broken hole	Drop needle	Fly yarn
ResNet-50	Faster R-CNN	87	83	100	71
ResNet-50+CBAM	Faster R-CNN	88	100	100	83

5. CONCLUSIONS

In this paper, we compared Faster RCNN and CBAM performance in fabric defects detection area. The experiment result proved CBAM can get better accuracy and recognizable ratio in our fabric defect database. Dueto the difference in image quality and pattern complexity, some defects cannot be successfully detected. Collecting fruitfulness high-quality fabric defect and defect-free image, updating existing network model will be the focus of future research. The different training time between CBAM and Faster RCNN is negligible. However, compared with the traditional approaches, the training time is more time-consuming. Reduce the required timefor training the model, realize real-time detection is crucial to whether this technology can be applied in industrial production, which is also the focus of future research.

REFERENCES

[1] Ngan, H. Y., Pang, G. K., & Yung, N. H. (2011). Automated fabric defect detection—a review. *Image and vision computing*, *29*(7), 442-458.

[2] Shanmugamani, R., Sadique, M., &Ramamoorthy, B. (2015). Detection and classification of surface defects of gun barrels using computer vision and machine learning. *Measurement*, *60*, 222-230.

[3] Kumar, A., & Pang, G. K. (2002). Defect detection in textured materials using Gabor filters. IEEE Transactions on industry applications, 38(2), 425-440.

[4] Mak, K. L., & Peng, P. (2008). An automated inspection system for textile fabrics based on Gabor filters. *Robotics and Computer-Integrated Manufacturing*, *24*(3), 359-369.

[5] Shu, Y., & Tan, Z. (2004). Fabric defects automatic detection using Gabor filters. In *Fifth World Congress on Intelligent Control and Automation (IEEE Cat. No. 04EX788)*(Vol. 4, pp. 3378-3380). IEEE.

[6] Bodnarova, A., Bennamoun, M., & Latham, S. (2002). Optimal Gabor filters for textile flaw detection. *Pattern recognition*, *35*(12), 2973-2991.

[7] Tong, L., Wong, W. K., &Kwong, C. K. (2016). Differential evolution-based optimal Gabor filter model for fabric inspection. *Neurocomputing*, *173*, 1386-1401.

[8] Zhang, Y., Lu, Z., &Li, J. (2009). Fabric defect detection and classification using gabor filters and gaussian mixture model. In *Asian conference on computer vision* (pp. 635-644). Springer, Berlin, Heidelberg.

[9] Jain, A. K., Duin, R. P. W., & Mao, J. (2000). Statistical pattern recognition: A review. *IEEE Transactions on pattern analysis and machine intelligence*, *22*(1), 4-37.

[10] Egmont-Petersen, M., de Ridder, D., & Handels, H. (2002). Image processing with neural networks—a review. *Pattern recognition*, *35*(10), 2279-2301.

[11] Stojanovic, R., Mitropulos, P., Koulamas, C., Karayiannis, Y., Koubias, S., & Papadopoulos, G. (2001). Real-time vision-based system for textile fabric inspection. *Real-Time Imaging*, *7*(6), 507-518.

[12] Kumar, A. (2003). Neural network based detection of local textile defects. *Pattern Recognition*, *36*(7), 1645-1659.

[13] Kuo, C. F. J., Lee, C. J., & Tsai, C. C. (2003). Using a neural network to identify fabric defects in dynamic cloth inspection. *Textile Research Journal*, *73*(3), 238-244.

[14] Yin, Y., Zhang, K., & Lu, W. (2009). Textile flaw classification by wavelet reconstruction and BP neural network. In *International Symposium on Neural Networks* (pp. 694-701). Springer, Berlin, Heidelberg.

[15] Semnani, D., & Vadood, M. (2010). Improvement of intelligent methods for evaluating the apparent quality of knitted fabrics. *Engineering Applications of Artificial Intelligence*, *23*(2), 217-221.

[16] Girshick, R., Donahue, J., Darrell, T., & Malik, J. (2015). Region-based convolutional networks for accurate object detection and segmentation. *IEEE transactions on pattern analysis and machine intelligence*, *38*(1), 142-158.

[17] Girshick, R. (2015). Fast r-cnn. In *Proceedings of the IEEE international conference on computer vision* (pp. 1440-1448).

[18] Liu, W., Anguelov, D., Erhan, D., Szegedy, C., Reed, S., Fu, C. Y., & Berg, A. C. (2016, October). Ssd: Single shot multibox detector. In *European conference on computer vision* (pp. 21-37). Springer, Cham.

[19] Redmon, J., Divvala, S., Girshick, R., & Farhadi, A. (2016). You only look once: Unified, real-time object detection. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 779-788).

[20] Ren, S., He, K., Girshick, R., & Sun, J. (2015). Faster r-cnn: Towards real-time object detection with region proposal networks. *arXiv preprint arXiv:1506.01497*.

[21] He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 770-778).

[22] Neubeck, A., & Van Gool, L. (2006, August). Efficient non-maximum suppression. In *18th International Conference on Pattern Recognition (ICPR'06)* (Vol. 3, pp. 850-855). IEEE

[23] Woo, S., Park, J., Lee, J. Y., &Kweon, I. S. (2018). Cbam: Convolutional block attention module. In *Proceedings of the European conference on computer vision (ECCV)* (pp. 3-19).

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FABRIC DEFECT DETECTION BASED ON OBJECT AS POINT

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ABSTRACT

In the field of fabric manufacturing, many factories still utilise the traditional manual detection method. It requires a lot of labour, resulting in high error rates and low efficiency.in this paper, we represent a real-time automated detection method based on object as point. This work makes three attributions. First, we build a fabric defects database and augment the data to training the intelligence model. Second, we provide a real-time fabric defects detection algorithm, which have potential to be applied in manufacturing. Third, we figure out centernet with soft nms will improved the performance in fabric defect detection area, which is considered an nms-free algorithm. Experiment results indicated that our lightweight network based method can effectively and efficiently detect five different fabric defects.

KEYWORDS

Fabric defects detection, Object as point, data augmentation, Deep learning.

1. INTRODUCTION

Fabric is a world widely used material in our daily life, which is made from textile fibers. The defect is a flaw on the fabric surface, occurring in fabric manufacturing process, which determines the quality of the product [1]. The fabric defects can reduce the price of the product by 45% - 65% [2]. Therefore, in the process of fabric production, “defect detection” plays a quite significant role which is a determination process of the position, class and size of the defects occurred on the surface of fabric. Traditionally, the manual inspection method is carried out on the board to contribute the instant correction of the defect, which mainly depends on the professional skills and experience of humans. Also, human inspection has very high error rates as well as the slow detection speed, because of their carelessness [1,3]. Besides of the human error occurring due to fatigue, the small-scale defects can be hard to be detected and optical illusion also has the probability to ignore defects.

A variety of algorithms including statistical analysis methods [4,5], spectrum analysis methods [6,7,8] and model-based methods [9] have been employed in the automation of fabric inspection which is based on the traditional machine vision. Among all the machine vision algorithms developed for detecting fabric defects, the method based on multi-channel Gabor filtering [8] has been considered to be one of the most successful ones. Gabor filter is able to transform the fabric images into the spectrum domain and then detect the defects by some energy criterion whose efficiency depends on the selection of filter banks [3]. However, the parameter selection of Gabor functions in all approaches depends on the dyadic decomposition, which can cause redundancy and correspondingly need excessive storage of data [10]. Also, the network structure cannot be modified since Gabor filter method, a supervised method of weight updating, is usually trained for one special database [11].

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In the recent research, deep learning method has made a great success in object detection and image classification. By using advanced algorithm model such as convolutional neural network (CNN) [3], a deep learning approach can provide an unsupervised way in the fabric defects detection and classification. Compared with the traditional methods, it can obviously improve the detection and classification accuracy and speed, even make the real-time defect detection to be feasible [3, 11]. Also, the deep learning algorithm may build an effective model for all kinds of fabric images since it has highly optimized weight and can extract the required features effectively [11]. Nowadays, common object detection algorithms usually use the setting of a priori frame, that is, set a large number of a priori frames on the picture first, and the network's prediction result will adjust the prior frame to obtain the prediction frame. The a priori box greatly improves the detection ability of the network, but it will also be limited by the size of the object and detection speed. The CenterNet's detector uses keypoints estimation to find the center point and returns to other object attributes [12].

In this paper, we modify the CenterNet algorithm to meet the requirement of fabric defects detection. ResNet-50 is used as the feature extraction and the soft non-maximum suppression (Soft-NMS) is used for the expectation for improving the detection accuracy in the subsequent optimization of object detection. First, the training database for supervised learning needs to be built. In order to solve the over-fitting problem due to the lack of fabric defects images sample and improve the stability and anti-jamming ability of the neural network model, we expand the fabric image database by image cropping and rotation, add random real-time data augmentation in training process as well. After data augmentation, there are total 2,000 images in the experiment database which contains 5 kinds of fabric defects: snag, yarn thickness, hole, missing lines, fly yarn.

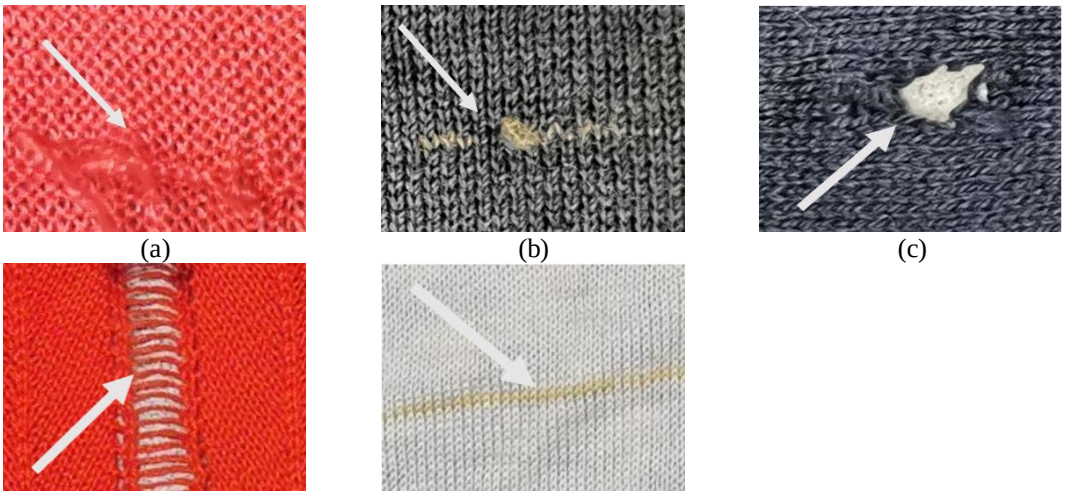
2. MATERIALS AND METHOD

2.1. Fabric defects data

There are more than 70 classes of fabric defects are defined in the textile manufacturing industry. Most of defects are occurring in the same direction of motion or in the direction that is perpendicular to it. According to the standards of quality, the fabric defects can be divided into two classes: surface color change and local texture irregularity [13]. According to the samples we have got, we select the five most numerous defects on pure fabric as shown in the Figure 1.

Normally, object detection and image classification based on deep learning rely on a large number image database. In this paper, single-sample database augmentation method, a kind of supervised database augmentation methods is used to expand the database size on the basis of the original data based on the preset data change rules. When augmenting a sample image, all operations are performed around the sample itself [14, 15].

We expand the existing fabric defects database by cropping and rotating each image. Finally, there are 2,000 fabric defect images in the database for detection model training. Besides expanding the database to improve the generalization ability, this operation also can help avoid overestimating and improve the robustness of the model and reduce the sensitivity of the model the images [16].



(a) (b) (c)

(d) (e)

Fig 1. The examples of fabric defects. (a) snag. (b) yarn thickness. (c) hole. (d) missing lines and (f) fly yarn

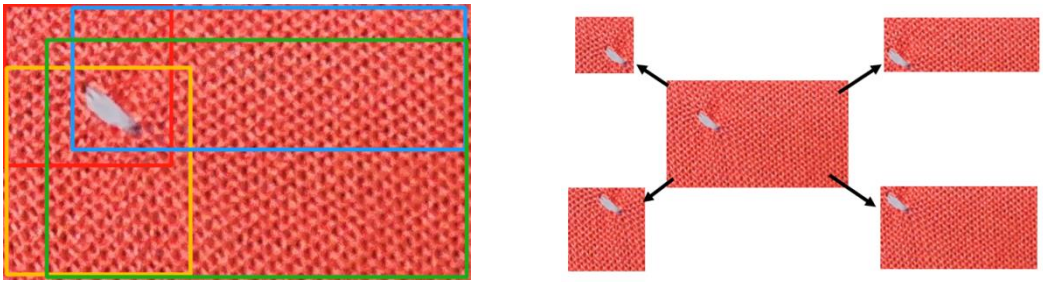


Figure 2. Image cropping and result

Image cropping means selecting a part of region in an image and discarding the rest. Using this technology, we can increase the database by selecting a large number of different regions in each original image. In this paper, as shown in Figure. 2, crop an image according to its four corners and all of the four new images should contain the defect region.

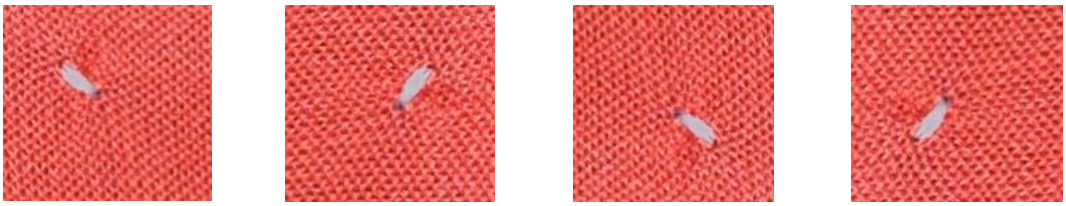


Fig 3. Original image is rotated0°,90°,270° and 180°

Each fabric defects image, including the original image and cropped image, is rotated with90°, 180° and 270° clockwise rotation in turns, the number of the expanded database is four times as the original database as shown in Figure 3.The images generated by this operation can be similar to the fabric images which are taken under different cameras' position.

2.2. CenterNet

For object detection, it is common to set large number of priori bounding boxes first. One-stage methods use anchor to set a lot of bounding boxes in the image and score each box directly. Two-

stage methods will recalculate the feature maps in those boxes. These sliding window-based detection methods need to enumerate various potential object position and sizes, which leads to the heavy computational cost and time. To address the problem, CenterNet method uses boundingbox's center point to represent the object, and then on the basis of the point, other attributes of the object such as size and dimension are regressed. In this way, object detection has become a standard keypoint estimation problem, which greatly improved the detection efficiency [12]. Resnet-50 and the deconvolutional module compose the backbone network together for higher resolution output (final stride=4). The whole framework of the CenterNet used in this paper is shown in Figure 4.

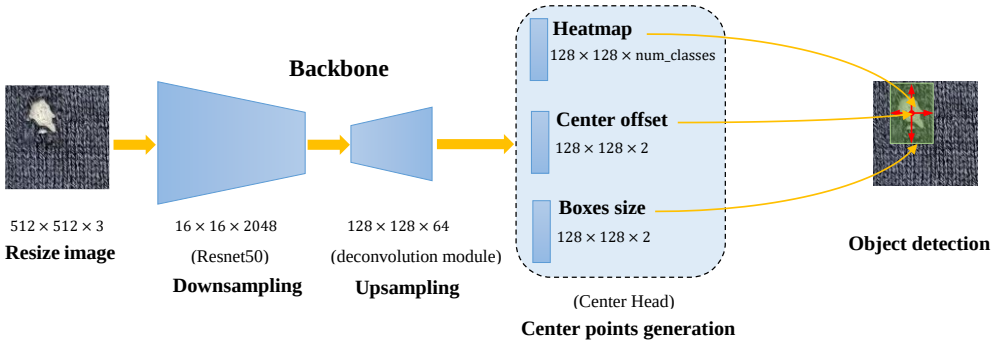


Fig 4. An illustration of CenterNet structure

There are three types of backbone neural networks for feature extraction used in the CenterNet method, normally it can be Hourglass Network, DLANet or Resnet [12]. Hourglass Network is a network which uses multi-scale features for extraction by taking advantages of multiple feature maps at the same time [17]. It is suitable for different gesture recognition of the one object, which is meaningless for fabric defects detection. and the number of Hourglass Network parameters used by CenterNet is too large, there are 190 million parameters. Therefore, we have chosen the Resnet as the backbone neural networks.

2.2.1. Heatmap prediction

Heatmap can be used to represent the classification information [12] and each class has its own heatmap. On each heatmap, if there is a center point of the object at a certain coordinate, a keypoint (represented by a Gaussian circle) is generated at that coordinate. $I \in R^{W \times H \times 3}$ is an input image with width W and height H from backbone network. The aim of this step is to generate the keypoint heatmap $\hat{Y} \in [0,1]^{\frac{W}{R} \times \frac{H}{R} \times C}$, where R is output stride=4, C is the number of object classes and keypoint heatmap value $\hat{Y}$ is a measure of detection confidence of each class. Therefore, we can get whether there is object in the keypoint, its class and the probability of belonging to each class. Output shape is $(128,128, num\_classes)$.

2.2.2. Points to boxes

Center offset calculation is necessary since each keypoint located on top-left corner is responsible for predicting an object whose center is in the bottom-right corner. To extract the peaks in the heatmap for each class separately, we detect all responses whose value is greater or equal to its 8-connected neighbors and keep the top 100 peaks according to detection confidence through adapting a 3×3 max pooling operation [12]. This is similar to the NMS method in the anchor-based detection. $\hat{\mathcal{P}}_C$ is a set of n detected points of class c. The location of each point is given by

(x_i, y_i) and the value of $\hat{Y}_{x_i y_i c}$ is the detection confidence of this point in class c. Points coordinates contribute to determine the location of bounding boxes:

$$(\hat{x}_i + \delta\hat{x}_i - \hat{\omega}_i/2, \hat{y}_i + \delta\hat{y}_i - \hat{h}_i/2, \hat{x}_i + \delta\hat{x}_i + \hat{\omega}_i/2, \hat{y}_i + \delta\hat{y}_i + \hat{h}_i/2), \quad (1)$$

where $(\delta\hat{x}_i, \delta\hat{y}_i) = \hat{O}_{\hat{x}_i, \hat{y}_i}$ is the prediction of center offset of the top-left corner keypoint to the bottom-right corner predicted object's center and $(\hat{\omega}_i, \hat{h}_i) = \hat{S}_{\hat{x}_i, \hat{y}_i}$ is the size prediction of the object corresponding to this point. Their output shape both are (128,128,2).

2.3. Soft-NMS

As an NMS-free method, CenterNet adapts max pooling operation to search on the heatmap and keep the boxes with the highest confidence in a certain area before decoding, replacing NMS post-processing. However, in the experiments we found that this operation similar to NMS performed well for small-size objects detection. For large-size objects, CenterNet cannot always find the object center correctly, NMS is needed to delete extra boxes.

However, NMS method performs not very well when two defects are quite close to each other and it is difficult to determine a suitable value. In order to solve the problem, Soft-NMS is proposed to improve the detection accuracy [18]. For the detected boxes b_i which has a high overlap with the maximum confidence detection box M, we decay their confidence rather than completely delete them. Gaussian penalty function as shown in the formula (2) is applied that is continuous to avoid a sudden decay which can lead to the change of the ranking of all the detection boxes. When the overlap is low, the penalty increases to ensure that there is no effect of M on other boxes which have a very low overlap with it.

$$s_i = s_i e^{-\frac{iou(M,b_i)}{\sigma}}, \forall b_i \notin D \quad (2)$$

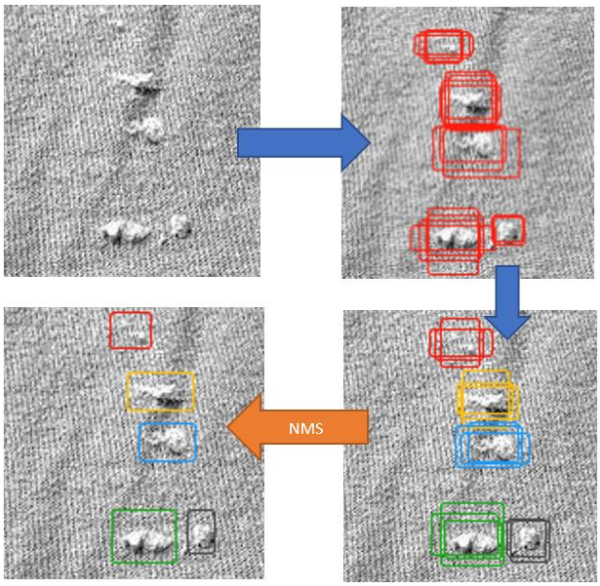


Fig 5. Overview of object detection using NMS method

3. EXPERIMENT AND RESULT

In this paper, we used 90% samples in the database as training and validation set in which 90% data for training. To train the model faster, we use a pre-trained model of ResNet-50. Freezing training is adapted to speed up training efficiency as well as prevent weights from being destroyed, since the feature map extracted by the backbone part of the neural network are universal. The backbone network is frozen in the first 50 epochs, and mainly the later detection and classification part of the training are trained. The last 50 epochs are unfrozen, and the entire network is trained at the same time. The weights of model are saved in each epoch and when the loss of validation is not decrease, the training process will stop early. The learning rate is set as 0.001 initially for freezing training and 0.0001 initially after unfreezing. It will decrease by monitoring validation loss. When there is no change in validation loss for 2 epochs, learning rate will decay by half. The large learning rate can accelerate learning to reach local or global optimal solution quickly, but the loss function fluctuates greatly in the later stage and it is difficult to converge. Decaying learning rate can help be closed to optimal solution. Also, we set σ to 0.5 with the Gaussian weights function for Soft-NMS, the overlap represented by IoU in NMS is 0.5 as well. The threshold of mAP is 0.01.

The test environment is Asus desktop with Inter(R) Core(TM) i7-900K CPU@ 3.60GHz, 8GB RAM and Nvidia GTX 1600 Ti, the simulation software is python 3.6, Tensorflow-GPU 2.3.1 and CUDA 10.1.

Firstly, we evaluate the effect of database augmentation methods and NMS methods on detection accuracy based on mAP (mean average precision) is average precision of all class as shown in the follow formula:

$$mAP = \frac{1}{|Q_R|} \sum_{q \in Q_R} AP(q) \tag{15}$$

where AP (average precision) is the area under $precision - recall$ curve. We divide the database augmentation method into two strategies: image cropping and rotation. The results of test dataset detection are shown in the Figure 6.

It is clear that NMS is necessary, mAP is quite low without NMS since there are too many extra boxes. mAP of the Soft-NMS method is almost 1%higher than NMS. Therefore, the results show that the Soft-NMS can improve the detection accuracy in CenterNet model.

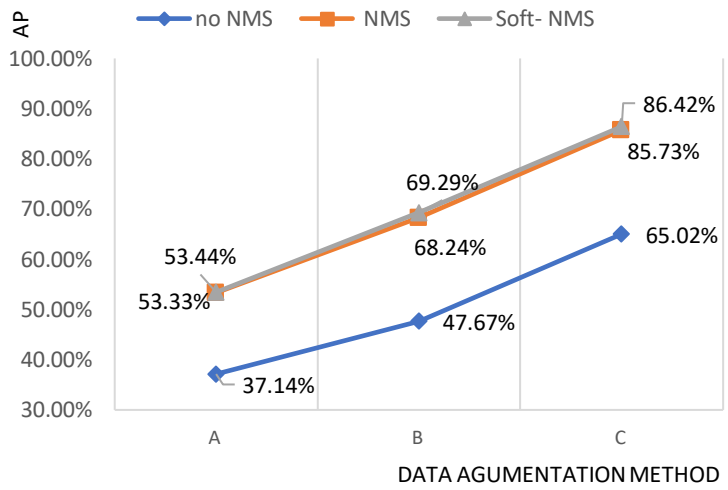


Fig. 6 The mAP of Soft-NMS and NMS with different database augmentation methods

We also train the Faster R-CNN model to detect the fabric defects, but the model is not trained very well, since it takes too much time to train, much more than that of CenterNet. The result is shown in the follow table. The detection speed of CenterNet is much higher than that of Faster R-CNN, therefore, CenterNet is more suitable for real-time detection, meeting the requirement of real manufacturing.

Table 1. Comparison between Faster R-CNN and CenterNet.

Method	Faster R-CNN	CenterNet
Speed	1.15it/s	17.85it/s
mAP	69.93%	86.42%

In the experiments, we have found the calculation formula of Gaussian circle radius is inconsistent with that in mathematics. After correcting it, the mAP becomes 89.55%, more than 3% higher than the previous 86.42%. The AP of each class is shown in the Figure 7. We can see hole can be detected totally, yarn thickness and missing lines are easy to detect as well. Snag and fly yarn cannot always be detected, since their structure is diverse, and our sample size is not enough.

As shown in the Figure 8, epoch loss of training and validation process are used to monitor the training process. We use validation loss change to determine whether the model is converged. In the two curve, loss value decreases as the epoch increases, meaning the model is learning. After 50 epochs, the loss value increases suddenly, since we adapt freezing training before. In the later 50 epochs, the weights of backbone network will change meanwhile, leading to the increase of the CenterNet loss. The training epoch loss curve is smoother than the validation epoch loss curve.

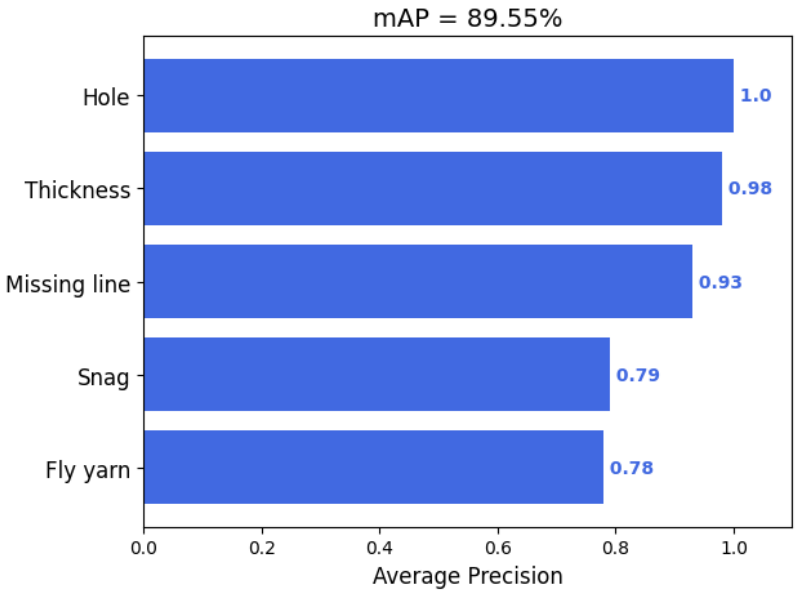
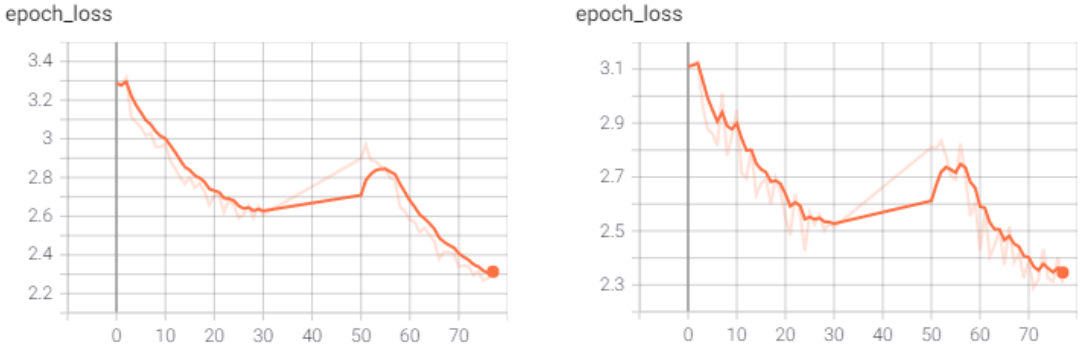


Fig 7. The AP (%) of each class in the final model.



(a) (b)

Fig 8. Epoch loss curve of (a) training process, (b) validation process

4. CONCLUSIONS

In this paper, we have proposed an effective fabric defect detection method based on CenterNet algorithm. Our objective is to detect the certain fabric defects on pure textile automatically in real time. To achieve this, we use a modified Resnet-50 to extract the feature map. And then three different convolutional layers are used to determine the object as point with classification information and its center offset as well as box size. After prediction, Soft-NMS is involved to improve the detection accuracy. CenterNet is a simple neural network but it has both high accuracy and high detection speed. It takes both detection precision and speed into consideration compared with Faster R-CNN. Therefore, it is suitable for fabric detection in real manufacturing, reducing human source sharply. As a lightweight network, it may even be able to be applied to a small computing platform like mobile.

In future research, we will continue to improve the accuracy of the model and increase the types of detectable defects. Existing algorithm and our method have difficulties in the detection of

complex pattern textile. The reason is the lack of sufficient defect-free and defect samples to train reliable models. These difficulties also result in manufacturing processing cannot apply this technic to inspect the quality of fabric. We hope in the future, this real-time method can be installed in the manufacturing line to improve production efficiency and collect more data through manual assistance. This allows other art-to-date deep learning technique to be experimented and applied in fabric defect detection.

In term of improving our method, there are three research gap that should be resolved: 1) This method is difficult to detect small defects. When checking the negative sample of snag detection, we noticed if the defects area is small, this method cannot recognize. 2) If the textile structure is similar, and the color is wrong (fly yarn defects), the accuracy of this method will be relatively poor. Part of the situation stems from the inability of the method to determine the center point of the defect. 3) The Soft-NMS technology can solve part of the overlapping situation. Normally overlapping defects will not be considered to have the same center point. However, if the centers of two objects overlap in the process of extracting feature map, they will be trained as one object, leading to some prediction error. We will focus on solving these disadvantages in our future work.

REFERENCES

[1] Ngan, H. Y., Pang, G. K., & Yung, N. H. (2011). Automated fabric defect detection—a review. Image and vision computing, 29(7), 442-458.

[2] Srinivasan, K., Dastoor, P. H., Radhakrishnaiah, P., & Jayaraman, S. (1992). FDAS: A knowledge-based framework for analysis of defects in woven textile structures. Journal of the textile institute, 83(3), 431-448.

[3] Liu, Z., Liu, X., Li, C., Li, B., & Wang, B. (2018, April). Fabric defect detection based on faster R-CNN. In Ninth International Conference on Graphic and Image Processing (ICGIP 2017) (Vol. 10615, p. 106150A). International Society for Optics and Photonics.

[4] YUAN, L. H., Fu, L., Yang, Y., & Miao, J. (2009). Analysis of texture feature extracted by gray level co-occurrence matrix [J]. Journal of Computer Applications, 29(4), 1018-1021.

[5] Youting, Z. X. D. Z. R. (2012). Detection of Fabric Defect Based on Weighted Local Entropy [J]. Cotton Textile Technology, 10.

[6] Arivazhagan, S., & Ganesan, L. (2003). Texture classification using wavelet transform. Pattern recognition letters, 24(9-10), 1513-1521.

[7] ZHOU, S., ZHANG, F. S., & LI, F. C. (2013). Image Feature Extraction of Fabric Defect Based on Wavelet Transform [J]. Journal of Qingdao University (Engineering & Technology Edition), 2.

[8] Kumar, A., & Pang, G. K. (2002). Defect detection in textured materials using Gabor filters. IEEE Transactions on industry applications, 38(2), 425-440.

[9] Xiaobo, Y. (2013). Fabric defect detection of statistic aberration feature based on GMRF model. Journal of Textile Research, 4, 026.

[10] Mak, K. L., Peng, P., & Lau, H. Y. K. (2005, December). A real-time computer vision system for detecting defects in textile fabrics. In 2005 IEEE International Conference on Industrial Technology (pp. 469-474). IEEE.

[11] Jeyaraj, P. R., & Nadar, E. R. S. (2019). Computer vision for automatic detection and classification of fabric defect employing deep learning algorithm. International Journal of Clothing Science and Technology.

[12] Zhou, X., Wang, D., & Krähenbühl, P. (2019). Objects as points. arXiv preprint arXiv:1904.07850.

[13] Hanbay, K., Talu, M. F., & Özgüven, Ö. F. (2016). Fabric defect detection systems and methods—A systematic literature review. Optik, 127(24), 11960-11973.

[14] Chaitanya, K., Karani, N., Baumgartner, C. F., Becker, A., Donati, O., & Konukoglu, E. (2019, June). Semi-supervised and task-driven data augmentation. In International conference on information processing in medical imaging (pp. 29-41). Springer, Cham.

[15] Leng, B., Yu, K., & Jingyan, Q. I. N. (2017). Data augmentation for unbalanced face recognition training sets. Neurocomputing, 235, 10-14.

[16] DeVries, T., & Taylor, G. W. (2017). Improved regularization of convolutional neural networks with cutout. arXiv preprint arXiv:1708.04552.
[17] Newell, A., Yang, K., & Deng, J. (2016, October). Stacked hourglass networks for human pose estimation. In European conference on computer vision (pp. 483-499). Springer, Cham.
[18] Bodla, N., Singh, B., Chellappa, R., & Davis, L. S. (2017). Soft-NMS--improving object detection with one line of code. In Proceedings of the IEEE international conference on computer vision (pp. 5561-5569).

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MAPPING OUT O*NET DATA TO INFORM WORKFORCE READINESS CERTIFICATION PROGRAMS

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ABSTRACT

*The Occupational Information Network O*NET did not explore possible uses of O*NET data to inform workforce readiness certification programs. In this study, the O*NET database is used to map out education requirements and how they relate to professional certifications as required by the employers and job designers in accordance with the National Initiative for Cybersecurity Careers and Studies (NICCS). The search focuses on the "Information Security Analysts" occupation as listed on O*NET, Careeronestop, U.S. Bureau of Labor Statistics (BLS), and finally tied back to NICCS source work role to identify certifications requirements. No site has listed any certification as required, desirable or mandatory. NICCS under the NICE Cybersecurity Framework Work Roles offered general guidance to potential topics and areas of certification. Careeronestop site under certification finder provided the ultimate guidance for this role certification. Professional certifications are still not an integral part of the Cybersecurity Workforce Framework official guidance.*

KEYWORDS

*Occupational Information Network O*NET, NICE Framework, NICCS, Certification & Information Security Analyst.*

1. INTRODUCTION

The Occupational Information Network (O*NET) website was launched in 1998 by the U.S. Department of Labor (DOL). At the heart of this model is a content framework to organize the characteristics of occupational data into what is referred to as hierarchically structured taxonomy comprised of six categories or "domains" [1]. The O*NET model consists of a valuable electronic database containing information designed to help students, educators, job seekers, employers, and workforce trainers and developers, among others. This data collection system organizes job titles into more than 1,102 occupations. However, O*NET did not explore possible uses of O*NET data to inform workforce readiness certification programs. The O*NET database is used in this study to map out education requirements and how they relate to professional certifications as required by the employers and job designers in accordance with the National Initiative for Cybersecurity Careers and Studies NICCS. The search focuses on the "Information Security Analysts" occupation as listed on O*NET with all related job titles, cross-referenced with Information Security Analysts on the U.S. Bureau of Labor Statistics, on Careeronestop, the site sponsored by the Department of Labor (DOL), and mapped back to the NICCS work role titles "All-Source Analyst", and "Information Systems Security Manager". This establishes a simple guide for professionals to align education requirements to potential certifications based on an occupation role for a successful and sustainable career in cybersecurity.

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2. BACKGROUND AND METHOD

The O*Net foundational framework is based on a content model that integrates the most important component of an occupation broken down into six areas. The worker-oriented attributes are the workers characteristics, requirements, and experience. The job-oriented are the occupational requirements, characteristics, and occupation-specific information (see Figure 1, O*NET content model).

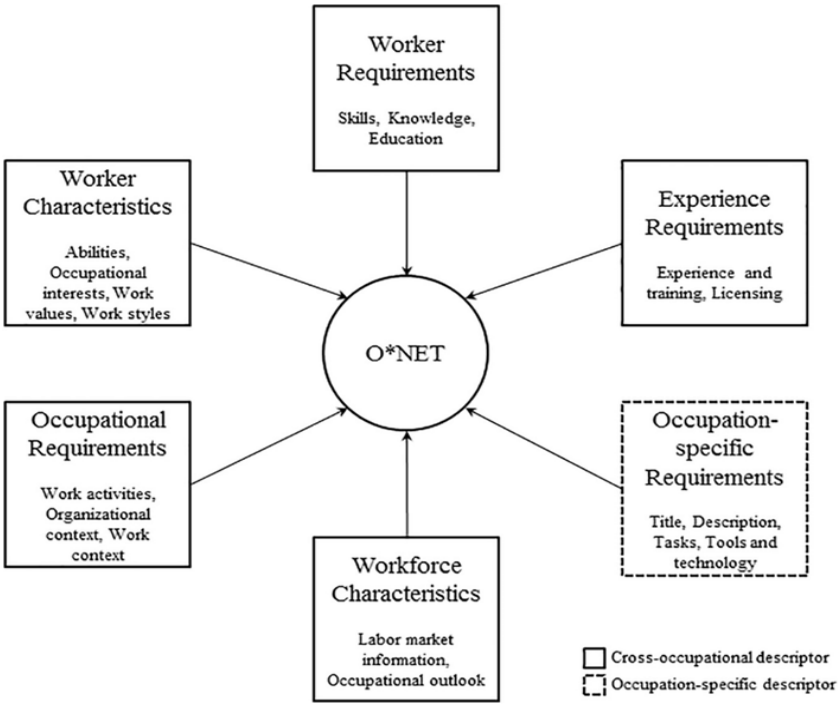

Figure 1. O*NET Content Model [3]

2.1. O*NET Content Model Analysis

Three of these six areas are worker-oriented:
Worker characteristics: Abilities, occupational interests, work values, work styles.
Worker requirements: Skills, knowledge, and education.
Experience requirements: experience and training skills – entry requirements licensing.
The other three are job–oriented:
Occupational requirements: generalized work activities, detailed work activities, organizational context, and work context.
Workforce characteristics: Labor market information, occupational outlook.
Occupation-specific information: tasks, tools, and technology.
Worker characteristics and occupational requirement are cross occupations descriptors while experience requirements and occupation-specific information are occupation specific descriptors as can be inferred [2].

2.2. O*NET Electronic Database

The second instrument in the O*NET model consists of a valuable electronic database containing information designed to help students, educators, job seekers, employers, workforce trainers, and workforce developers, among others. This data collection system organizes job titles into more

than 1,102 occupations. The National Center for O*NET development continually collects data related to these occupations and identifies ways to improve data collection, use, efficacy, and efficiency. With the ever-evolving technology and new job titles, positions, and duties being added constantly to the workplace and workforce, the need to create a standard common description and acknowledged skills, abilities, and other related factors is crucial to stay current and relevant to the users for career and employment guidance as well as workforce development and human resource management. After exploring the site for cyber-related occupations, it appears that O*Net framework does not explicitly list professional certification required or recommended for cybersecurity jobs.

2.3. O*NET Information Security Analyst Work Role Analysis

On the O*NET site, the search is focused on the occupation "Information Security Analyst" to compare with the outcomes of All-Source Analyst, Information Systems Security Developer, and Information Systems Security Manager and draw connections for certificates recommended or required on the NICSS site. The summary report of Information Security Analyst contained a list of activities undertaken by an information security analyst each starting with a specific action verb: "Plan, implement, upgrade, or monitor security measures for the protection of computer networks and information. May ensure appropriate security controls are in place that will safeguard digital files and vital electronic infrastructure. May respond to computer security breaches and viruses" [4]. The Information Security Analyst work role includes a sample of related job titles: Data Security Administrator, Information Security Officer, Information Security Specialist, Information Systems Security Analyst, Information Systems Security Officer, Information Technology Security Analyst (IT Security Analyst), Information Technology Specialist, Network Security Analyst, Security Analyst, Systems Analyst. It lists 12 tasks, 51 technology skills, 8 knowledge areas, 15 related skills, 17 abilities, 21 work activities, 10 detailed work activities, 22 work context criteria. The education lists four-year degree for some jobs but not for all, some job-related skills, knowledge and experience, job training, with job zone examples. 53% of subjects surveyed reportedly hold a bachelor's degree, 23% a post – baccalaureate certification, and 13% an associate degree. The report is available in a detailed fashion with a customized option. The page provides a link to (ISC)2, COMPTIA, ISACA, and National Initiative for Cybersecurity Education (NICE) among others as resources for additional information. O*NET provides a crucial design for employers and human resource professionals to employ job descriptions and selection tools pursuant to Americans with Disabilities Act (ADA) and Equal Employment Opportunity (EEO) requirements [5]. Recruitment officers and human resource personnel employ these detailed descriptions to design job titles, duties, and requirements to attract the needed workforce. Furthermore, the detailed skills, education requirements, experience, and other qualifications provide a framework for standard job description, requirements, and qualifications. An equally important function is to show that the knowledge, skills, abilities, and other characteristics (KSAO) employees need to do their work effectively are related to critical tasks to document the adequacy of hiring and the need for training and workforce development [6]. No certification requirement is listed. Under Credentials, Find Certifications link redirects to Careeronestop.

2.4. U.S Bureau of Labor Statistics: Information Security Analyst

The Bureau of Labor Statistics (BLS) estimates a faster-than-average growth rate in employment of information security analysts, a labor category that represents a significant subset of the cybersecurity workforce. The U.S. Bureau of Labor Statistics in its Occupational Outlook Handbook under Computer and Information Technology, summarizes the job outlook for an Information Security Analyst with quick facts, lists and bachelor's degree as a requirement for most related positions and links back to the O*NET site for additional resources and information

[7]. However, it is noted that, on how to become one, under Licenses, Certifications, and Registrations, BLS states that most employers prefer that employees hold certifications which validate knowledge required for an Information Security Analyst. It distinguishes between more generic certifications such as Certified Information Systems Security Professional (CISSP), and more specific ones like penetration testing and systems auditors specifically.

2.5. National Initiative for Cybersecurity Careers and Studies NICCS: All-Source Analyst

For validation purposes, this work role was searched for on the National Initiative for Cybersecurity Careers and Studies NICCS website under the NICE Cybersecurity Workforce Framework Work Role [8]. The Information Security Analyst is not listed independently rather it has to be searched under All-Source Analyst work role title and any work role ID. This search resulted in the following description: "Analyzes data/information from one or multiple sources to conduct preparation of the environment, respond to requests for information, and submit intelligence collection and production requirements in support of planning and operations." [9]. The role description listed 18 abilities, 56 knowledge areas, 18 related skills, and 42 related tasks for all-source analyst. The capabilities indicators were listed by certification/credentials, education, continuous learning, and experiential learning and divided into three categories: entry level, intermediate, and advanced. Education was not essential for entry level with bachelor's as an example. For intermediate level, a bachelor's degree was recommended. For advanced level, a master's or Doctorate degree was recommended. As for certifications, for an entry level they were labeled as not essential but may be beneficial with potential areas covering new attack vectors such cloud computing and mobile platforms. Other areas included vulnerabilities, threats, audit, IT governance and management and information systems related topics without specifying designated commercial certificates. At the intermediate level, a certificate was recommended with topics covering security and risk management, security engineering, communications and network security, software development security, and identity and access management security among very defined security topics. At the advanced level, certifications were deemed not necessary but might be beneficial with focus on project management areas, other topics listed at the entry and intermediate level in addition to specific topics focusing on U.S. privacy laws and practice areas. For this work role, it is obvious that the O*NET framework provides a valid context to generate KSAO and other related job requirements to compile job descriptions, roles, qualifications and attract qualified workforce looking for a common standard in a more increasingly non-conventional world and workplace. However, the guidance is very generic and the language is not authoritative as it relates to certifications. For comparison purposes, the Information Security Systems Manager had education recommended for all three levels starting with a bachelor's degree for the first two up to a Master's and Doctorate for an advanced level. However, certifications ere not essential for entry level but provided an extensive list of potential beneficial areas of certifications. Certificates were recommended for the other two levels with areas of focus identical on the intermediate level to the all-source analyst topics area, and more focused on security, risk, and management areas on the advanced level. The NICCS in its 2020 cybersecurity workforce toolkit stated "Earning certifications enables staff to stay current on in-demand skills and become leaders in the cybersecurity field" [10]. The three certifications listed were COMPTIA+, Certified Information Security Specialist CISSP, and GIAC Security Essentials (GSEC).

2.6. Careeronestop Certification Finder

Using the toolkit on the Careeronestop site and searching for "Information Security Analysts", the results included 116 certifications from 26 providers. These certifications are available by providers in a downloadable excel file. The providers included: Broadcom Inc., Amazon.com

Web Services, Cisco Systems, EC-Council, IBM Corporation, Dell, Oracle, Microsoft, Wireshark, Global Information Assurance Certification, Hewlett Packard Certification and Learning, COMPTIA, International Information Systems Security Certification Consortium, Inc., and several other specific ones. The 116 certifications focused on different areas on information security and topics listed on NICCS site under the NICE Cybersecurity Framework roles for all-source analyst.

2.7. To Certify or not to Certify?

A certification is considered a measurable outcome to assess the knowledge and information acquired within academia and the workplace. Not surprisingly, conceptual knowledge would not replace practical skills and operational excellence for cybersecurity jobs. Recent research shows that holding an IT certification positively influences hiring and job retention, in addition to earning potential. However, two-to-four-year degree holders are less likely to be laid off and potentially earn higher income than non-degree holders [11]. Industry certifications help qualify that individuals possess the knowledge, skills, and abilities for work in the job field as much as one-third of cybersecurity-related jobs require some form of certification [12]. The Bureau of Labor Statistics [13] in its current population survey (CPS) on labor force, employment, and unemployment statistics for persons with or without certifications and licenses reported answers to questions to identify persons with professional certifications and licenses after they were added to the Current Population Survey (CPS) in January 2015. Computer and mathematical occupations of 5,352 were included in the 37,237 professional and related occupations constituting a 12.5% of a population size of 45.3%. Only 5.6% had a certification but no license, 6.9% held a license and 87.5% held neither a certification nor a license. Certificates and certifications are helpful to employers to evaluate the skills and knowledge of applicant especially in small organizations where managers are not well versed in cybersecurity issues [14]. Certifications are not conclusive, but they may be given greater importance as construed as indicators of embodiment of knowledge in a specific area as well as interest and commitment in a field of work. Certifications are often pursued as an addition to an academic degree to highlight an area of interest and expertise. In a workshop conducted by the National Research Council in 2013, some workshop participants expressed that certifications played a crucial role in their careers to establish credibility and competence. Others dissented and pointed out that CISSP certification is a perfect example of an over-glorified certification where highly qualified individuals do not hold it or any other certifications and lamented the hyper-emphasis on certifications which would restrict their employment prospects if required in the candidate selection process. Some participants indicated that some certifications are not viewed positively in some organizations where the experience, the practical skills, the educational attainment, and other factors were better measure and more sought after. They reported omitting certain certifications on their resumes for specific jobs. Views and perceptions on certification differ. While some job seekers, mostly entry and intermediate levels, view certifications as an entry ticket initially and advancement as they pursue career growth, other professionals focus on gaining experience, practical skills, knowledge and furthering their educational goals. Indeed, almost all sites listed educations and degree from Associate to a Doctorate as recommended and beneficial acquisition ability, or educational achievement, were seen as better measures. A few said that they sometimes omitted listing them on their resumes for this reason.

3. CONCLUSIONS AND FUTURE WORK

In analyzing O*NET database for Information Security Analyst for work role certifications, no valuable and actionable information was available. Links to other government sites were listed for additional resources. The Bureau of Labor Statistics listed general guidance while offering an

example of CISSP for general certifications and cited other specific areas like pen testing or systems auditing. NICCS under the NICE Cybersecurity Framework Work Roles similarly offered general guidance as to potential topics and areas of certification for this work role based on the career level: entry, intermediate, and advanced. Finally, Careeronestop site under certification finder was the ultimate guidance for certification tied to the role "Information Security Analyst". Not one site has listed any certification as required, desirable or mandatory. Certifications are still not an integral part of the Cybersecurity Workforce preparation and requirements even as they gain more momentum with job seekers and employers. Current frameworks do not integrate certifications in a prominent manner contrary to the popular belief. In the context of shortage of skilled workforce, the cybersecurity workforce dilemma is more than a solution to a staffing problem; rather it should be a competitive advantage in a proactive agile business model. With private and public sectors competing for the same assets in a time when the pipeline is still lagging in preparing adequately educated and trained cybersecurity professionals, this problem is widespread in academia, business, government, and other types of organizations [15]. Future potential work is possible exploration of adequate workforce preparation mechanisms, and avenues for investing in the human power as it is reported that 71% to 76 % of the businesses are not investing in their long-term assets of "manpower" via training, professional development, and career path development [16] while companies are investing more in infrastructure and advanced technology. The human factor is still trying to grasp the extent of the new landscape complexity. The shortage itself creates a vicious circle as understaffed departments and overworked professionals are led to burnout and eventually turnout.

REFERENCES

[1] National Research Council, 2010. *A Database for a Changing Economy: Review of the Occupational Information Network (O*NET)*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12814 https://www.nap.edu/read/12814/chapter/11

[2] Researchgate.net (n.d.). https://www.researchgate.net/figure/ONET-content-model-21_fig1_317600739

[3] www.onetcenter.org, 2020. *The O*NET Content Model*. Retrieved from https://www.onetcenter.org/content.html

[4] www.onetonline.org, 2020. National Center for O*NET Development, Bureau of Labor Statistics, O*Net Online Summary Report for 15-1122.00—Information Security Analysts. https://www.onetonline.org/link/summary/15-1122.00

[5] SHRM (2020) *Performing Job Analysis.* https://www.shrm.org/resourcesandtools/tools-and-samples/toolkits/pages/performingjobanalysis.aspx

[6] Bauer, T., Erdogan, B., Caughlin, D., & Truxillo, D. (2019). *Fundamentals of Human Resource Management*. Sage Publication Inc.

[7] Bureau of Labor Statistics (2020, July 12). U.S. Department of Labor, *Occupational Outlook Handbook*, Information Security Analysts.https://www.bls.gov/ooh/computer-and-information-technology/information-security-analysts.htm

[8] Newhouse, W., Keith, S., Scribner, B. & Witte, G (2020). National Initiative for Cybersecurity Education (NICE) Cybersecurity Workforce Framework. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-181.pdf#page21

[9] National Initiative for Cybersecurity Careers and Studies NICCS, 2020. *NICCS Education and Training Catalog.* https://niccs.us-cert.gov/training/search

[10] NICCS, 2020. https://niccs.us-cert.gov/sites/default/files/documents/pdf/cybersecurity_workforce_development_toolkit.pdf?trackDocs=cybersecurity_workforce_development_toolkit.pdf

[11] Belanich, J. & Morriosn, J. (2019, March). *Impact of Professional Credentials on Employability*. https://www.researchgate.net/publication/334170431. DOI: 10.13140/RG.2.2.20406.96324

[12] Stines, A. (2020, March 24). Faculty Perceptions of Open Educational Resources in Cyber Curriculum: A Pilot Study Curriculum: A Pilot Study. *Beadle Scholar*

[13] Bureau of Labor Statistics (2020, January 21). Labor Force Statistics from the Current Population Survey. https://www.bls.gov/cps/demographics.htm#certs_licenses

[14] National Research Council, 2013. *Professionalizing the Nation's Cybersecurity Workforce?: Criteria for Decision-Making*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18446

[15] Mailloux, L. & Grimaila, M. (2018, May/June). "Advancing Cybersecurity: The Growing Need for a Cyber-Resiliency Workforce," in *IT Professional*, vol. 20, no. 3, pp. 23-30. doi: 10.1109/MITP.2018.032501745.

[16] Olstik, J., (2019, April). The lives and Times of Cybersecurity Professionals. https://www.esg-global.com/hubfs/pdf/ESG-ISSA-Research-Report-Life-of-Cybersecurity-Professionals-Apr-2019.pdf

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