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A thermal camera based continuous body temperature measurement system for pandemic emergencies

Nkunzimana, Libere

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**A THERMAL CAMERA BASED CONTINUOUS BODY
TEMPERATURE MEASUREMENT SYSTEM FOR PANDEMIC
EMERGENCIES**

Libere Nkunuzimana

**A Project Report Submitted in Partial Fulfillment of the Requirements of the Award
the Degree of Master of Science in Embedded and Mobile Systems of The Nelson
Mandela African Institution of Science and Technology**

Arusha, Tanzania

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ABSTRACT

In medicine, high body temperature is a symptom that characterizes an abnormality of human body. By checking body temperature, it allows doctors to well monitor the effectiveness of treatment and also can show that human health is not normal. During pandemic period like COVID-19, high temperature was a sign that allows a doctor to recommend people to pass to COVID-19 test in order to ensure their conditions. However, most of existing system required human interaction while social distance was one of measures taken by World Health Organization (WHO). In COVID-19 pandemic people are afraid to travel because they think that they can be contaminated. Airport considered first to check if passengers have a normal body temperature or not as is the first symptom of COVID-19 even if they have their COVID test certificate. However, the existing system which was used to do this exercise of body temperature sampling was not fair because it could be away of contamination. Scrum Agile software development method has been used from the requirements phase to test and Validation of the developed system. To come out of the problem settled, a thermal Camera based Continuous Body Temperature Measurement system for Pandemic Emergencies has been developed. This system is contactless of body temperature sampling in real time. Passengers are required to pass in corridor to the waiting room where the system is implemented and measure everyone who pass in. when a high body temperature more than 38 is detected, the system alert airport staff in charge by sending notification with a picture of the person with high temperature. Temperature of passengers to the airport has to be sampled without contact, or line up in real time. The developed system through its options gives the possibility to administrators to generate report, to produce an alarm when high temperature detected which were absent in existing system. It has been an answer for time management, minimization of errors when writing report and increased health security. The system has been liked by passengers and administration at different borders and airport of Burundi.

DECLARATION

I, Libere Nkunzimana, do hereby declare to the Senate of The Nelson Mandela African Institution of Science and Technology that this project report is my original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

Libere Nkunzimana



03-08-2022

Name of Candidate

Signature

Date

The above declaration is confirmed by:

Dr. Ramadhani Sindi



04-08-2022

Name of Supervisor 1

Signature

Date

Dr. Elizabeth Mkoba



03.08.2022

Name of Supervisor 2

Signature

Date

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by The Nelson Mandela African Institution of Science and Technology, a project report titled “**A Thermal Camera Continuous Body Temperature Measurement System for Pandemic Emergencies**” in partial fulfillment of the requirements for the degree of Master of Science in Embedded and Mobile Systems, Embedded Systems specialty of The Nelson Mandela African Institution of Science and Technology.

Dr. Ramadhani Sindi



04.08.2022

Name of Supervisor 1

Signature

Date

Dr. Elizabeth Mkoba



03.08.2022

Name of Supervisor 2

Signature

Date

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DEDICATION

I dedicated this work to my wife and my children for their patience dedicated encouragement that strengthened me throughout the academic journey.

TABLE OF CONTENTS

ABSTRACT	i
DECLARATION	ii
COPYRIGHT	iii
CERTIFICATION	iv
ACKNOWLEDGMENTS	v
DEDICATION.....	vi
LIST OF FIGURES	xi
LIST OF TABLES	xii
LIST OF APPENDICES	xiii
LIST OF ABBREVIATIONS AND SYMBOLS	xiv
CHAPTER ONE.....	1
INTRODUCTION	1
1.1 Background of the Problem	1
1.2 Statement of the Problem.....	2
1.3 Rationale of the Study	2
1.4 Project Objectives.....	3
1.4.1 Main Objective	3
1.4.2 Specific Objectives	3
1.5 Research Questions	3
1.6 Significance of the Study	3
1.7 Delineation of the Study	4
CHAPTER TWO	5
LITERATURE REVIEW	5
2.1 Related Works	5
CHAPTER THREE.....	7

MATERIALS AND METHODS.....	7
3.1 Area of Study	7
3.2 Research Methods	7
3.3 Targeted Population, Sample size and Sampling technique	7
3.4 Data Collection Methods	8
3.5 Data Analysis	8
3.6 Conceptual Framework.....	9
3.7 System Development Approach.....	10
3.7.1 Why Scrum Agile System Development?.....	12
3.8 System Requirements	15
3.9 System Architecture	19
3.10 System Development.....	19
3.11 System Validation	19
CHAPTER FOUR.....	20
RESULTS AND DISCUSSION.....	20
4.1 Results Presentation.....	20
4.1.1 Demographics Characteristics	20
4.1.2 Traveling Representation of Respondents.....	20
4.1.3 Observed Challenges in Temperature Sampling	21
4.2 System Requirements	24
4.3 System Design Results	24
4.3.1 System Architecture.....	25
4.3.2 Block Diagram.....	25
4.3.3 Flowchart Diagram	26
4.3.4 Selection of Sensing Unit Components of the System	26
4.3.5 Database Design	27

4.4	System Development Results.....	27
4.4.1	System Testing and Validation.....	31
CHAPTER FIVE		32
CONCLUSION AND RECOMMENDATIONS		32
5.1	Conclusion	32
5.2	Recommendations	32
5.2.1	Implications to the Policy Makers	32
5.2.2	Implication to the Practitioners.....	33
5.2.3	Future Research	33
REFERENCES		34
APPENDICES		37

LIST OF FIGURES

Figure 1:	Melchior NDADAYE International Airport.....	4
Figure 2:	Conceptual framework	9
Figure 3:	Scrum agile system development.....	11
Figure 4:	MLX90640 far-infrared thermal camera	16
Figure 5:	Pi camera module.....	16
Figure 6:	Raspberry Pi.....	17
Figure 7:	Alarm module buzzer	17
Figure 8:	Screen monitor	18
Figure 9:	Travels of respondents.....	20
Figure 10:	Temperature passenger sampling	21
Figure 11:	Methods used in temperature sampling.....	21
Figure 12:	Waiting time	22
Figure 13:	Technique used for temperature sampling in the East Africa community region	23
Figure 14:	Block diagram.....	25
Figure 15:	Flowchart diagram.....	26
Figure 16:	Database view in phpMyAdmin tool	27
Figure 17:	Login window	28
Figure 18:	Home page interface.....	28
Figure 19:	Addition and users' view	29
Figure 20:	Report generation and view	29
Figure 21:	Device's packaging	30
Figure 22:	Temperature sampling.....	30

LIST OF TABLES

Table 1: Demographics characteristics	20
Table 2: Functional system requirements.....	24
Table 3: Non-functional system requirements.....	24
Table 4: Test and validation results	31

LIST OF APPENDICES

Appendix 1: Interview guide	37
Appendix 2: Internship Offer letter.....	39
Appendix 3: Programming codes.....	40
Appendix 4: Poster Presentation.....	44

LIST OF ABBREVIATIONS AND SYMBOLS

AACB	Autorité Aviation Civil du Burundi
CBTM	Continuous Body Temperature Measuring
CENIT@EA	Centre of Excellence for Information and Communication Technology in East Africa
DC	Direct Current
FLIR	Forward Looking Infrared
FPS	Frames Per Second
ICT	Information and Communication Technology
IR	Infrared
IRI	Infrared Thermal Imaging
IT	Information Technology
LCD	Liquid-Crystal Display
SCM	Supply Chain Management
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Pandemic is a disease outbreak that spreads quickly over a wide area across many countries or continents and affects a large population. A good example of a pandemic is COVID-19 outbreak that spread to more than 200 countries and caused a lot of deaths (Tharakan *et al.*, 2020). The preventive measures such as wearing face masks, quarantining, hand washing, social distancing, covering coughs and sneezes and other methods have been used to limit the spread of the disease. During the pandemic period people have been living with fear, in difficult conditions such as isolation and staying at home. Governments around the world have established and implemented rules and regulations to prevent the spread of that COVID-19 pandemic and to protect their citizens. Among these measures passengers were not allowed to cross countries' borders without having the negative certificate of COVID-19 test. Fever was the first symptom to be checked before entering in defined testing phases of COVID-19 infections. In the case when a suspect is detected, the suspected person should be isolated and diagnosed in more detail.

Often, in different places such as education institutions, airports, hospitals, supermarkets and the like, the people's body temperature measurement was taken in the first place before crossing the entrance. According to Hamidreza (2017), fever is a common symptom that indicates severe acute respiratory syndrome coronavirus 2 (SARS-COV-2) infection. Fever has driven to temperature checking in healthcare facilities, open spaces and private offices where numerous individuals are expected (Fallah-Haghmohammadi & Necsulecsu, 2017). Fever often occurs in response to infection, inflammation and trauma. However, this view of fever is merely an oversimplification as a growing body of evidence now suggests that fever represents a complex adaptive response of the host to various immune challenges whether infectious or non-infectious (Fallah-Haghmohammadi & Necsulecsu, 2017). In general, the normal body temperature is between 36.8 °C (98.2 °F) it can reach the maximum of 37.2 °C in the morning (0600 h) and a temperature of 37.7 °C in the afternoon (1600 h) (Aryal, 1998). Based on the previous studies, fever in healthy middle-aged adults may be defined as an early morning oral temperature of >37.2 °C (>99 °F) or a temperature of >37.7 °C (>100 °F) at any time during the day (Ogoina, 2011). The fever is not a simple sign which has to be taken for granted. It has

been shown that when COVID-19 patients have fever, they become seriously ill resulting in severe inflammation due to the degree of temperature elevation (Tharakan *et al.*, 2020). Different equipment such as digital thermometers of various types including rectal, forehead is mostly used in medicine (Brzezinski *et al.*, 2020). Infrared thermography scanners have also been widely used as body temperature measurement tools that assess human body absolute temperature (Brzezinski *et al.*, 2020). Pandemic diseases are very dangerous and easily transmissible, the contactless method for body temperature measurement is the best compared to the previous methods (Perpetuini *et al.*, 2021). The developed system is based on thermal imaging which measures and is able to uniquely identify the scanned body and his temperature.

1.2 Statement of the Problem

Several precautions were made throughout the COVID-19 pandemic phase to prevent the virus from spreading. People who were found to have COVID-19 symptoms were to be isolated. Body Temperature measurement is the first test to be done to identify if the person has a high or normal temperature (Yusuf *et al.*, 2020). When high temperature is detected, the person who has the fever is immediately suspected. However, most of the existing methods are manual which require human interaction and encompasses a lot of limitations such as queries errors, disabilities of face detection which becomes a challenge during dressing report, not able to read temperature of more than one person (Priest *et al.*, 2011).

When people enter or leave the airport, hospitals, schools, and other places, it is difficult to take the temperature of everyone in a short period of time, and it is very easy to be contaminated due to used devices which require close distance when doing tests. Based on that in certain institutions such as universities, private institutions and like. The people who take the temperature are not technical persons in health, (gate guards) certain institutions, in most cases they don't remember to take precautions such as wearing individual protection tools when taking temperature as well as other precautions more risks of being contaminated can be associated. However, the developed system came to solve the existing problem by proposing a compatible system which would enable the involved person to do a test, save and send data in contactless mode by using a thermal camera..

1.3 Rationale of the Study

For satisfactory thermal camera based continuous body temperature measurement system for pandemic emergencies, was to understand how sampling body temperature using thermal

camera is important part in health domain as well as in emergency pandemic cases, consist of an easiest body temperature measurement in real time and encompasses stationaries and also human resources in terms of cost. Subsequently, this study offered assistance to airport terminals, institutions, hospitals and the like to computerize the body temperature tests exercises, gives a decrease of staff stress timesaving.

1.4 Project Objectives

1.4.1 Main Objective

The main objective of this study is to develop a thermal camera based continuous body temperature measurement system for pandemic emergencies.

1.4.2 Specific Objectives

- (i) To identify the requirements for developing a thermal camera based continuous body temperature measurement system for pandemic emergencies.
- (ii) To develop a thermal camera based continuous body temperature measurement system for pandemic emergencies.
- (iii) To test and validate the developed system for continuous body temperature measurement for pandemic emergencies.

1.5 Research Questions

- (i) What are the system requirements for a thermal camera based continuous body temperature measurement system for pandemic emergencies?
- (ii) How to develop a thermal camera based continuous body temperature measurement system for pandemic emergencies?
- (iii) How to test and validate the developed system?

1.6 Significance of the Study

This system has reduced the time used for manual temperature sampling, bring contactless features when measuring temperature which has increase the avoidance of contamination COVID-19 infections and automate system features such as report generation, sampling more than one person per second.

1.7 Delineation of the Study

This study aimed at developing a thermal camera based continuous body temperature measurement system for pandemic emergencies at the Melchior NDADAYE International Airport. The system provides features of maximization of time, contactless temperature sampling, reducing the use of stationeries, auto regeneration of the temperature sampling report. The large number of passengers passing through this airport and the medical team is not sufficient to collect the temperature of all passengers entering in a short time. The main objective of this project is to develop a thermal camera based continuous body temperature measurement system for contactless temperature sampling. For this reason, the Melchior NDADAYE international airport has been selected among the other entrances to Burundi.



Figure 1: Melchior NDADAYE International Airport

CHAPTER TWO

LITERATURE REVIEW

2.1 Related Works

According to Lin *et al.* (2018b) the body temperature plays an important part in medicine which can show that a person's body has an abnormality. The doctor can also track the success of therapy by monitoring body temperature. However, the existing Continuous Body Temperature Measuring (CBTM) technology is constrained primarily by reaction time, movement noise, and labor costs (Lin *et al.*, 2018a). Furthermore, traditional touch body temperature measuring wastes consumables while also creating discomfort (Lin *et al.*, 2019).

Lin *et al.* (2019) implemented the system using the Keysight U5855A thermal imaging camera using infrared (IR) techniques that eliminate the need for skin tissue contact during the temperature sampling. However, the developed system can measure the body temperature at a distance of 40-80 cm to the thermal camera and one by one which is a small distance and is taking the body temperature of one person after another.

Lin *et al.* (2019) developed the continuous body temperature measurement system which came to help the reduction of consumables used for the existing systems. Two main types of infrared systems are used in this proposed system, IR thermometers and thermal cameras. They chose the thermal camera to take the temperature of the body in the form of an image and measure the temperature in multiple points on a specific area which cannot generate the report automatically because it is only for viewing the body temperature and writing it down on a paper. However, if medical offices are asked to give out the report of 3 days ago, they cannot have it, and there is no alarm for detecting high temperatures.

Perpetuini *et al.* (2021) developed a system which can be used in biomedical applications and in real-life situations where the temperature of the human body is measured. In this system the technology used is Infrared thermal imaging (IRI) which gives the automatic estimation of skin temperature measurement. The only problem with this system is that it takes the temperature of the body of a single person per outlet. In the environment such as the airport where a lot of passenger pass, an automatic system that can do sampling of more than ten people per second is needed.

Fallah-Haghmohammadi and Necsulecsu (2017) argued that the temperature measurement in the past was the touch of the body and over the years technology has evolved into the use of a thermometer. In their study the proposed technology was Forward Looking Infrared (FLIR) thermal imaging setup used in mass fever screening (Fallah-Haghmohammadi & Necsulecsu, 2017). This technology has some limitations in screening body temperature such as thermal drift, the smallest observable temperature difference, non-uniformity, distance effects, temperature reading inaccuracy and stability, spatial resolution, and a variety of environmental and subject variables should all be considered.

Thus, in this project a thermal camera based continuous body temperature measurement System was developed. The developed system can take the sampling body temperature without even knowing that a person is being sampled. This system is also sending an email to alert the emergency medical personnel when a passenger's body temperature is above the normal body temperature for further investigation by testing the other symptoms related to the pandemic.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Area of Study

This study was carried out in Bujumbura, Burundi and other borders of the country. The study focused on designing an automation system using the Thermal Camera based Continuous Body Temperature Measurement for Pandemic Emergencies activities. The system has been tested and validated at the Melchior NDADAYE International Airport in Bujumbura, Burundi where the internship was conducted.

3.2 Research Methods

This study employed a qualitative research method. Qualitative research method is characterized as a showcase investigate strategy that centers on getting information through open-ended and conversational communication. This strategy isn't as it were approximately "what" individuals think but too "why" they think so (Allen-meares, 1995). This method is more helpful, in the recording of interviews and focus group discussions it is where reliable responses were collected that helped to achieve the research objectives.

3.3 Targeted Population, Sample size and Sampling technique

The target population are passengers and medical officers at the Melchior NDADAYE International Airport, Bujumbura, Burundi. The simple random sampling technique has been used. This technique gives the equal probability to each person of being selected as a participant of the research population. As with all probability sampling methods, simple random sampling allows the sampling error to be calculated and reduces selection bias. A specific advantage is that it is the most straightforward method of probability sampling.

The sample size consisted of 154 participants where structured face to face interviews were conducted ten passengers per day, focus group discussion were conducted to five passengers per day within 10 days. Furthermore, focus group discussions were also conducted to four medical officers of the Melchior NDADAYE International Airport.

3.4 Data Collection Methods

A variety of methods and procedures such as observations, documentation, interviews, focus group discussions and experimentation have been used in this research. Interviews were conducted to passengers to know how long they spending at the airport or border waiting temperature sampling then COVID-19 test. The interviews were conducted also to hear from the how the developed system can be benefic to them. Interviews and focus group discussions were conducted to the medical officers in order to know the system requirements and the pandemic emergencies techniques used at the Melchior NDADAYE International Airport. Appendix 1 shows how the interview has been conducted. The documentation method has been used to gather and analyze what other researchers have done in the existing systems. The observation method was used to see the behavior of passengers at the arrival gate and time used in sampling before reaching the COVID-19 test for instance, and a lot of stationaries were used for sampling, observation method has been used.

3.5 Data Analysis

The Microsoft Excel was used to represent how the data collected is looked like. Thematic analysis was used to analyze qualitative data where the common patterns have been identified to come up with a number of themes (Braun *et al.*, 2008).

Familiarization with the data recorded, initial code generation to the data to describe the content, searching for patterns or themes in codes generated, reviewing of the patterns or themes, named the patterns or themes, production of the report has been used in thematic analysis.

The digitally recorded interviews and focus group discussions were transcribed manually through listening to the audio and taking notes of the transcripts. In the responses received, the similar responses were given the same code when generating them, and there were other comments which were in the same categories as the first and were given the same code as previous. It was also needed to look for patterns or themes in the codes across the various interviews and focus group discussions made.

This iterative process was to be able to move the codes several times in order to form different themes. Codes on sticky notes have been written to make it easier to move around and get a better overview. The themes have been reviewed and refined.

All interview excerpts were read in each topic and the clear consistency within each was determined, as well as a clear difference between the topics. Themes that were found to be similar were combined and those that were not consistent were split. Themes were added and deleted iteratively until it was satisfactory that the topics appropriately represent the interview information.

The themes were defined and named. For this, an appropriate name has been given to each topic and has been defined in order to properly prepare the report.

The report was produced after consensus of the medical officers and be used for the development of the system.

3.6 Conceptual Framework

The thermal camera provides the body temperature in real-time. The conceptual framework to guide the study (Fig. 2).

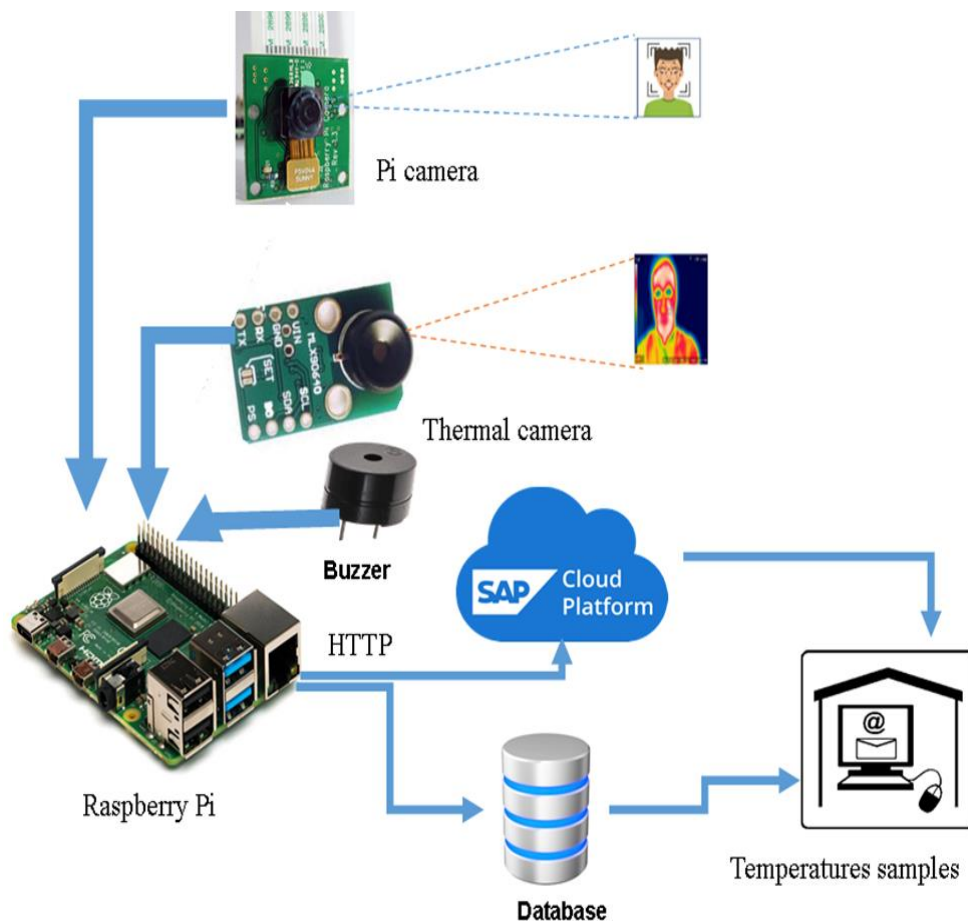


Figure 2: Conceptual framework

The conceptual framework presents different working parts of the system. The main part is the Raspberry Pi which is the microcontroller, where all configuration is done. This equipment is the core part whereby the thermal camera sensor is connected and configured.

The thermal camera sensor is responsible for screening body temperature for a passenger who passed through it. The temperature is sampled automatically and sent with the thermal image of the person to the Raspberry Pi and viewed on screen. The Pi Camera has been used to identify the clear and real image of the passenger. The Pi camera is for easy identification of who is corresponding to the thermal image given by the thermal camera. When someone with high temperature is detected, the sound alarm from the buzzer is activated to alert the medical officers that there is a person who has high temperature.

This system has been used for viewing and saving information to be seen for a long time regarding the need of data and report generation. To save data and viewing information as much as you can at any time, the data base has been created in the Cloud as a back-up. To monitor the temperature sampling at the arrival terminal of passengers, a screen to display body temperature and the corresponding image has been installed at the desk of medical officers.

3.7 System Development Approach

Scrum Agile software development method has been used as a system development methodology. Scrum is a project management framework that is applicable to any type of project in any industry including Information Technology (IT). Scrum method has been the most popular agile method used in various organisations. This methodology involves five phases, namely product backlog, Sprint planning and creating backlog, working on sprint, Testing and Product Demonstration, finally Retrospective and the next sprint planning as shown in Fig. 3. These scrum phases are working based on the phase of agile methodology composed by the requirements for conceptual creation analysis, system design, system development, testing validation and finally system deployment (Digital, 2021).

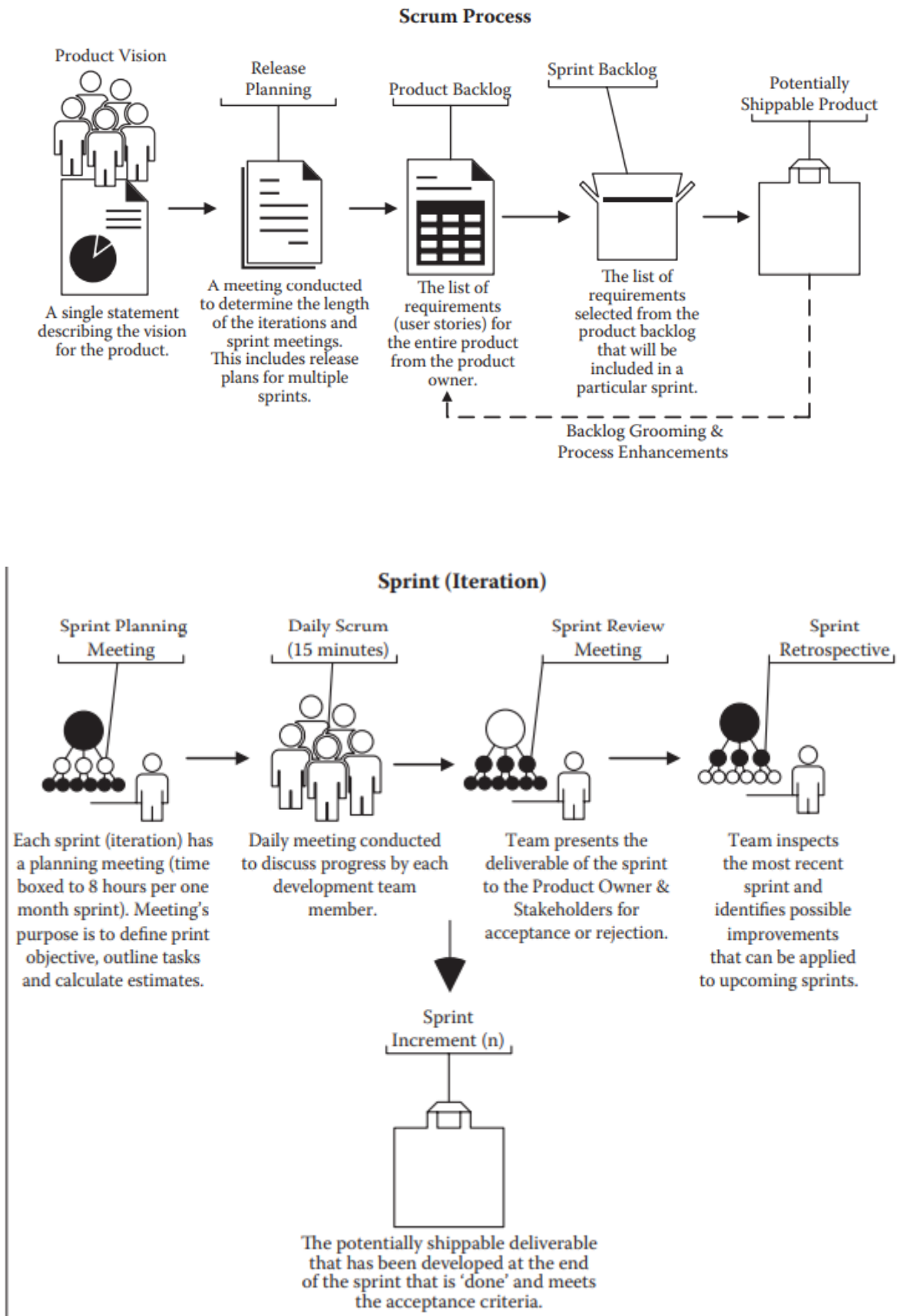


Figure 3: Scrum agile system development (Luís, 2019)

3.7.1 Why Scrum Agile System Development?

During the development of the system, this method allowed to improve the ability to manage changing priorities. This Method also enhances system quality, reduces system risk and cost not only that but also improve system visibility. The scrum models have 10 steps also called phases in scrum:

(i) Product Vision

In this step, the large items and useful points of interest are changed into epics and user stories. The product vision portrays a future state of the product and what issues it tries to resolve or what desire it tries to fulfill. Having a clear and motivating Item vision makes a difference in persuading and motivating individuals, just like the Scrum Group, the partners and clients (Digital, 2021). The user stories are changed from huge to littler things which can be put within the item excess. The s user stories can also be included within the item excess but cannot be included within the sprint backlog without changing over it to a user story (Gouveia, 2015). The conversation about why the owner who is Authority Aviation Civil du Burundi (AACB) needed the thermal camera was one of the aims which pushed to develop this system. The aim of this project is to have a digitalized system for the body temperature sampling that is able to generate reports.

(ii) The release planning

Another stage is to do the sprint backlog creation for which the scrum team must select the important user stories and make them into small assignments. The objective of release planning is to when different sets of usable usefulness or product is conveyed to the client. Scrum team to have an outline of the releases and conveyance plan for the product being created (Digital, 2021). For this second step, the solid stories and testimonials necessary for the development of the system are selected among the testimonies and stories of the existing system and also the wishes of how the desired system can work. The release plan for each sprint deliverable was prepared.

(iii) Product backlog

In Agile development, a product accumulation may be a prioritized list of deliverables (such as modern highlights) that ought to be actualized as portion of a extend or product

advancement. It's a decision-making artifact that makes a difference you appraise, refine, and prioritize everything you might at some point within the future need to total (Digital, 2021). To start with, an assignment board too called a Kanban board made with a part of cards was utilized. The cards indicated the points of interest around the tasks such as assignee, work points of interest, due date or the time term (Luís, 2019). The task board comprised of the following columns “Product backlog or the User stories”, and the “To Do” lists, “Work in Advance” and after that “Testing” and “Work Done” columns. The cards were moved from the cleared out to right of preference and based on the completion (Gouveia, 2015).

(iv) The sprint review meeting

The assignments completed are to be realized as a working system with full life cycle testing. The sprint survey is a casual assembly which the advancement group, the scrum master, the product proprietor and the partners has gone to. The group gives a demo on the product and was decide what are wrapped up and what aren't (Digital, 2021). The testing fetched can be minimized with the expansion of QA or having less users' stories, in any case, the primary one is the most excellent conceivable solution. Each sprint that's completed must be illustrated to the client for his acknowledgment and his perspective the complete solution (Gouveia, 2015).

(v) Potentially shippable product

When a product is potentially shippable at that point which means “that all the work that must be done for the right now actualized highlights has been done and in fact the item can be shipped” but it doesn't cruel that “the highlights actualized are profitable sufficient for the client to need a unused release” (Digital, 2021). The last mentioned is decided by the Item Proprietor. The result of this step is to examine what went well and what can be moved forward for another level. Moreover, you would like to examine the lessons learned and the pitfalls of any specific issues or problems. Then another sprint planning has to be commenced based on the knowledge that we have for the current processes and past projects (Gouveia, 2015).

(vi) Sprint planning meeting

The Scrum framework has several planning events (meetings) to establish the goals for each Sprint. A sprint planning meeting is when the group (counting the Scrum Master, Scrum product Director, and Scrum Group) meets to decide which excess things was taken care of

within the following sprint. The sprint planning Scrum ceremony could be a collaborative prepare that permits group individuals to have a say in when work happens (Digital.ai, 2021).

(vii) Daily scrum

A daily 15 minutes time-boxed meeting utilized for the advancement group individuals to talk about progress, problems. Day by day Scrums move forward communications, distinguish obstacles, advance fast decision-making, and subsequently dispense with the require for other gatherings (Digital, 2021). This daily scrum helped me to know what I completed since the last meeting I did with medical team and passengers, helped also the tomorrow's plan after meeting and helped to know if any problem occurred how to solve it.

(viii) Sprint review meeting

A meeting that's conducted at the conclusion of each Sprint to display the product increase to the product Owner and partners. Accumulation things are displayed for acknowledgment; in any case, these things can in reality be rejected by the Product Owner (Digital.ai, 2021). The meetings were conducted with the AACB chief to evaluate if the development of the project respect the requirements.

(ix) Sprint retrospective

A lessons learned meeting conducted at the conclusion of each Sprint. The meeting is based on the past Sprint and openings for change of future Sprints are talked about (Digital.ai, 2021). The meetings were planned to evaluate if what discussed in the previous meetings.

(x) Sprint increment (n)

Usually the potentially deliverable product increase created by the improvement group that has fulfill acknowledgment criteria (Digital, 2021).

So, the requirements or conceptual creation phase required an understanding of the body temperature measurement during pandemic emergencies activities, current practices and tools available for analysis.

The design of the system is the second phase after understanding how the system worked and understand what are requirements. As the agile system development work, the design was validated to allow me to continue with development.

Once the design validated the development of the system was the third phase. The Performance validation phase involves computation of the design and system refinement process. A refinement of the model is necessary to ensure if the model would be functioning effectively based on requirements. This process was repeated until the performance measure is satisfied. The design needs to be implemented and evaluated; therefore, real life cases could be used to calibrate the system:

- (a) The Conceptual Creation phase requires an understanding of the Thermal Camera based Continuous Body Temperature Measurement operation, current practices and tools available for analysis.
- (b) The Performance validation phase involved computation of the design and system refinement process. A refinement of the model is necessary to ensure the model would be functioning effectively based on requirements. This process was repeated until the performance measure is satisfied. The design needs to be implemented and evaluated; therefore, real life cases could be used to calibrate the system.
- (c) The Prototype of the system proposed, involved all parts and process in implementing the concept based on the design. To deploy this project, Arduino UNO Board and Raspberry Pi was used as microcontroller boards and Computer where codes was housed, MLX90640 Thermal Camera Assembly of the sensing part. Physical simulation shall also be presented thereafter.
- (d) The system that has been proposed “A thermal camera based continuous body temperature measurement during pandemic emergencies” is based on, MLX90640 thermal camera and Raspberry Pi technology.

3.8 System Requirements

3.8.1 Hardware Requirements

(i) MLX90640 IR far-infrared Thermal Camera

The MLX90640 is a far-infrared thermal camera as shown in Fig. 4 or a warm imaging camera, which identifies the temperature of the human body progressively and yields an infrared picture. MLX90640 is also called a cluster of 768 (32x24) thermal sensors that can identify

temperatures from -40 to 300°C with around 1°C precision and up to 64 FPS (Frames Per Second) (Rasool *et al.*, 2020).

The MLX90640 far-infrared thermal camera is shown in Fig. 4.



Figure 4: MLX90640 far-infrared thermal camera

(ii) Pi Camera Module

This proposed system used the Pi Camera module as shown in Fig. 5 which is a camera that was used to take pictures and high-definition video. The Pi camera module as shown in Fig. 5 was used for images capturing using python and save it to the specified directory.

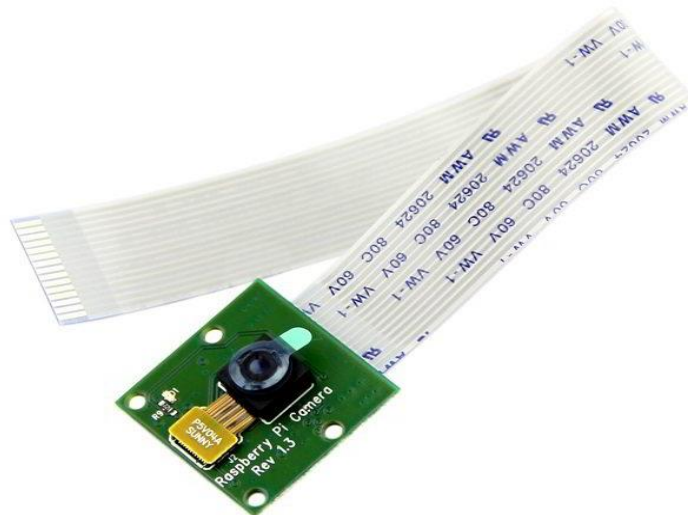


Figure 5: Pi camera module

(iii) Raspberry Pi

The MLX90640 was connected and configured in the raspberry Pi. Raspberry Pi is a little, incredible, modest, hackable and education-oriented PC board presented in 2012. It works

similarly as a standard PC, requiring a keyboard for command, a display unit and a power supply (Maksimović *et al.*, 2015).

The Raspberry Pi as shown in Fig. 6 is a moo fetched, credit-card measured computer that plugs into a computer screen or TV, and uses a standard keyboard and mouse. It could be a capable small device that empowers individuals of all ages to investigate computing, and to memorize how to program in languages like Scratch and Python.



Figure 6: Raspberry Pi

(iv) Buzzer

In this system, the buzzer alerted the in-charge person or medical team that there is a person who have a high temperature, the email contains the photo of the person and his temperature tested was sent immediately to the emergency medical team in order to check other symptoms.

The Buzzer is a sounding device that can change over audio signals into sound signals and its ordinarily powered by DC voltage. It is broadly utilized in alarming, computers, printers and electronic items as sound device. The buzzer is shown in Fig. 7.



Figure 7: Alarm module buzzer (Devices, 2019)

(v) Monitor

The screen or the monitor as shown in Fig. 8 was placed in a place where the medical team in charge of emergency cases at the airport decided to mount it for monitoring the thermal camera imaging by looking at the temperature values of each passenger entering or leaving the airport.



Figure 8: Screen monitor

3.8.2 Software Requirements

A thermal camera based continuous body temperature system offered the following features: Capturing of picture of the passengers, body temperature Sampling, alert system when a suspected high temperature is detected and email system was also configured for sending report when a high temperature is detected. These highlights are given by paid program as well as open-source program such Raspberry Pi, Python and MySQL as database.

(i) Python

For our case, the python open-source software is the chosen one. Python is a well-known general-purpose programming dialect that can be utilized for a wide assortment of applications (Halvorsen, 2018). It is simple to use and support all metadata standard and gives underpins management of different sorts of materials that incorporate recordings, image processing and Pi camera integration. Image processing has been used. Moreover, it has the usefulness of computerized messaging and computerized mail notifications.

3.9 System Architecture

The system's architecture is divided into three stages at MLX90640 Thermal Camera side whose Sampling of the body temperature phase, the MLX90640 Thermal Camera is designed to gather person or object temperature by the Supply chain management (SCM), transform the temperature into an liquid-crystal display (LCD), and alarm when the temperature exceeds a certain threshold (Zhang, 2018). To take advantage of the increased processing capability, a Pi camera connected to the Raspberry Pi was used for the second phase, which allowed a depiction of all 768 pixels of the MLX90640 at around 3 frames per second (fps). For MLX90640 Preparation on a Raspberry Pi, the MLX90640 thermal breakout board was viewed using the Adafruit library. The third phase was the software database for processing and sending emails to the person in-charge of body temperature sampling within a given time configured and analyze them. The SAP Cloud platform has been used for the backup of the information captured.

3.10 System Development

The developed system is a thermal camera based continuous body temperature measurement during pandemic emergencies system method. This point is arranged in a way to answer the questions raised on the problem by exploring the existing situation of COVID-19 at the study area and coming up with a design that caters for the need at the Airports and Hospitals, etc. This system's functionalities are split into two parts. The first part of the speed-up procedure is as follows: body temperature measurement activities such as face screening, monitoring, alarm etc. and the second part is based on sending report of body temperature measurement scan for a given time to the medical team's emails.

A thermal camera based continuous body temperature measurement is the system based on hardware and software phases. A set of hardware have been utilized in an unexpected way in existing system depending on the system prerequisites and objectives.

3.11 System Validation

After the implementation phase, the system was checked by the medical doctors and the Information Technology (IT) manager of Civil Aviation Authority of Burundi (AACB) whether it meets or does not meet the requirements as per their standards and regulations and finally approved.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results Presentation

4.1.1 Demographics Characteristics

The respondents of this study involved passengers and medical staff at the Melchior NDADAYE International Airport in Burundi. Table 1 shows that 65% of the respondents were male while 35 % were female. This result indicated that more respondents were male.

Table 1: Demographics characteristics

Gender	Respondents	Percentage (%)
Male	100	65
Female	54	35

4.1.2 Traveling Representation of Respondents

Figure 9 shows a number of travels made by respondents (passengers) in a year using Melchior NDADAYE International Airport in Burundi. The result shows that 29% of the respondents had travelled five times while 3% have travelled one time using the airport. These results entailed that the passengers body temperature should be taken at the airport.

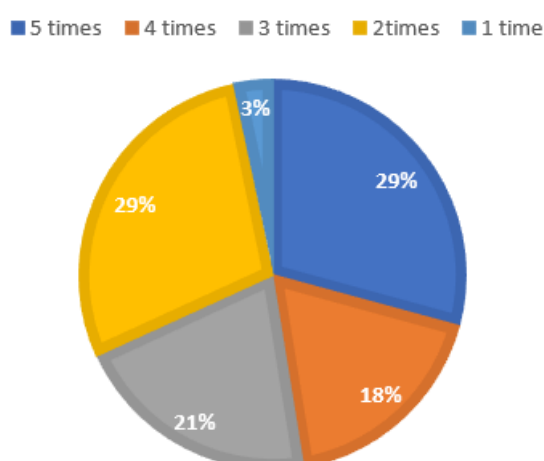


Figure 9: Travels of respondents

Furthermore, the study investigated whether the passengers' body temperature have been taken at the arrival terminal of the Melchior NDADAYE International airport. Figure 10 shows that

73% of respondents indicated that the sample of passengers' body temperature were taken at the arrival terminal. However, 27% of the respondents indicated that passengers' body temperature was not taken at the arrival terminal. These results entailed that the proper digital technology system has to be installed at the Airport to measure body temperature of all the arrival passengers for a few seconds.

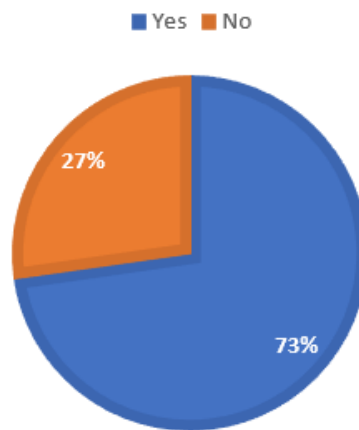


Figure 10: Passenger temperature sampling

4.1.3 Observed Challenges in Temperature Sampling

As shown in Fig. 11, 78% of respondents who arrived at the airport agreed to lineup for forehead temperature sampling while 22% of respondents said that to line up is a risk for them because some passengers can contaminate others.

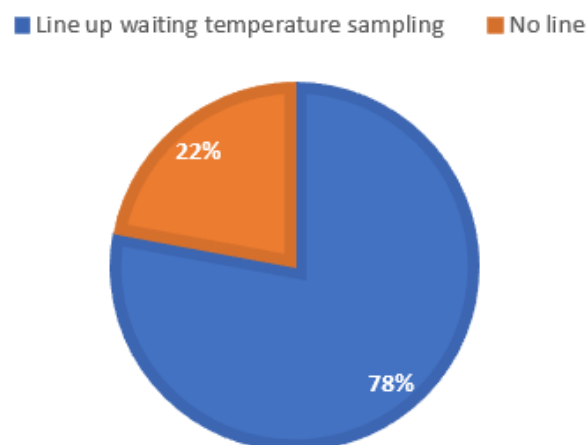


Figure 11: Methods used in temperature sampling

Figure 12 shows 64% of respondents indicated that the process of body temperature sampling for each passenger took 5 minutes while 10% of respondents agreed that the process was done in 2 minutes. These results imply that the current process of body temperature sampling for passengers at the airport consumes time. It also indicated the social distancing of one meter between one passenger and the other was sometimes not respected which triggered a big probability of passengers being contaminated.

Furthermore, the related works revealed that in other international airports where forehead temperature sampling was used, there were many challenges such as time consuming, not compatible to measure more than one passenger at once, temperature manual typing in daily reports generation which can encompass a lot of masquerades. Other challenges include risk of contamination between passengers is very high for forehead temperature sampling compared to other types of techniques used like thermal imaging cameras. Therefore, a thermal imaging camera is needed to minimize the time for temperature sampling. Imaging thermal camera is fast in report generation due to its automatic way of report generation.

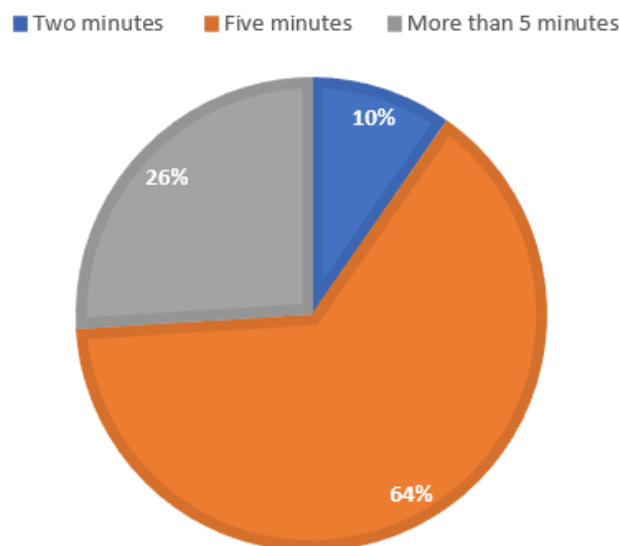


Figure 12: Passengers waiting time

4.1.4 Technique used for Temperature Sampling in the East African Community Region

The data obtained from interviewers when asked of the technique that other airports used to measure temperature in the human body showed that, forehead technique was the most techniques used for temperature body sampling to passengers at 87% while thermal camera was used at 13% in the airport of the East African community region (Fig. 13).

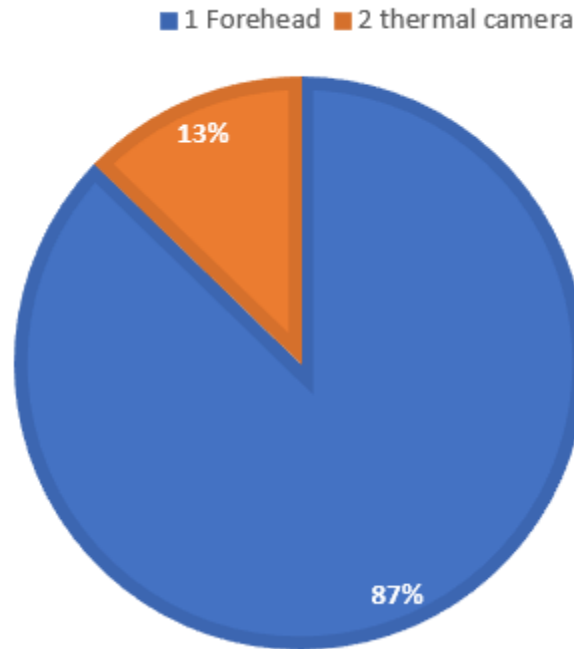


Figure 13: Technique used for temperature sampling in the East Africa community region

4.1.5 Importance of Thermal Camera in Temperature Sampling

The results from the obtained data in the above figures showed that Thermal cameras were used at low level in developing countries while in developed countries are commonly used. In pandemic situations like COVID-19, the thermal camera acted as an element of security (Erdem *et al.*, 2021). It took body temperature in real time without contact. Passengers were only requested to pass in the angle and be tested. As most pandemic diseases, require contact in contamination, this technique when used can bring advantages and reduce contamination risk and increase health security (Priest *et al.*, 2011).

4.2 System Requirements

The identified systems requirements are as shown in Table 2 and Table 3.

Table 2: Functional system requirements

Requirement	Description
Users, Adding, and Editing users' information	The system allows admin to perform users and information management task.
Generate Report	The software should be able to generate report weekly or any time needed.
Limitation of data storage	To avoid storage saturation, only data with high temperature have to be save
Visualization	The software shall allow visualization inform of all temperature and other data recorded.
Temperature sampling	The system provides an ability of capturing body temperature with no human interaction.
Time management	The system speeds up temperatures sampling processes.

Table 3: Non-functional system requirements

Requirement	Description
Power	The system should not work when there is no power source.
Availability	The system should not be available when developers are doing maintenance or if one of used hardware is failure stage.
Caption angle	The system should not provide results when passers pass out of the camera angle which is 145 degrees.
Camera placement	The system should not operate when cameras are exposed to high temperature.

4.3 System Design Results

This section presents the system architecture, use case diagram and flowchart diagram.

4.3.1 System Architecture

The system's architecture was divided into three stages at MLX90640 Thermal Camera side whose sampling of the body temperature phase, the MLX90640 Thermal Camera was designed to gather person or object temperature by the Supply chain management (SCM), transform the temperature into an liquid-crystal display (LCD), and alarm when the temperature exceeds a certain threshold (Zhang, 2018). To take advantage of the increased processing capability, a Pi camera connected to the Raspberry Pi was used for the second phase, which allowed a depiction of all 768 pixels of the MLX90640 at around three frames per second (fps). For MLX90640 Preparation on a Raspberry Pi, the MLX90640 thermal breakout board was read using the Adafruit library. The third phase was a software database for processing and sending emails to the person in-charge of body temperature sampling within a given time configured and analyze them. The SAP Cloud platform was used for the backup of the information captured.

4.3.2 Block Diagram

The block diagram for the developed system is as shown in Fig. 14.

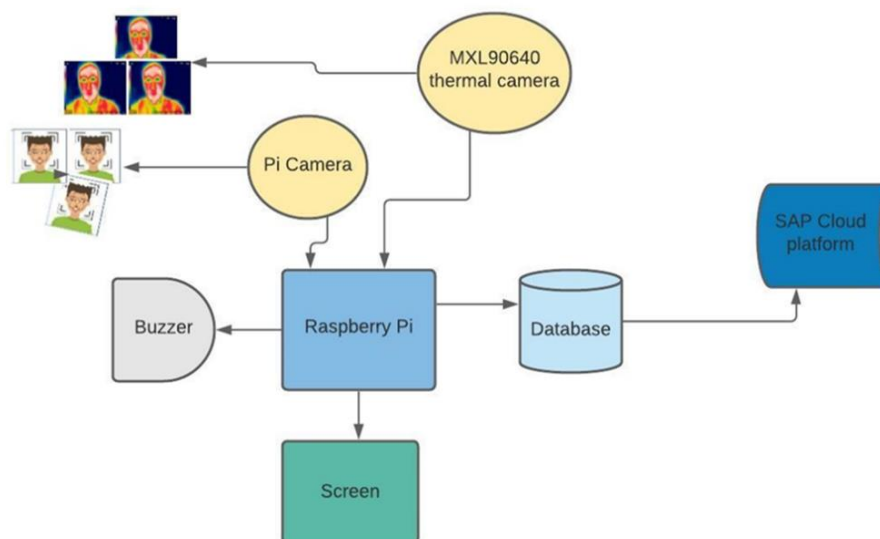


Figure 14: Block diagram

4.3.3 Flowchart Diagram

The developed system was working according to the flowchart diagram shown in the Fig. 15.

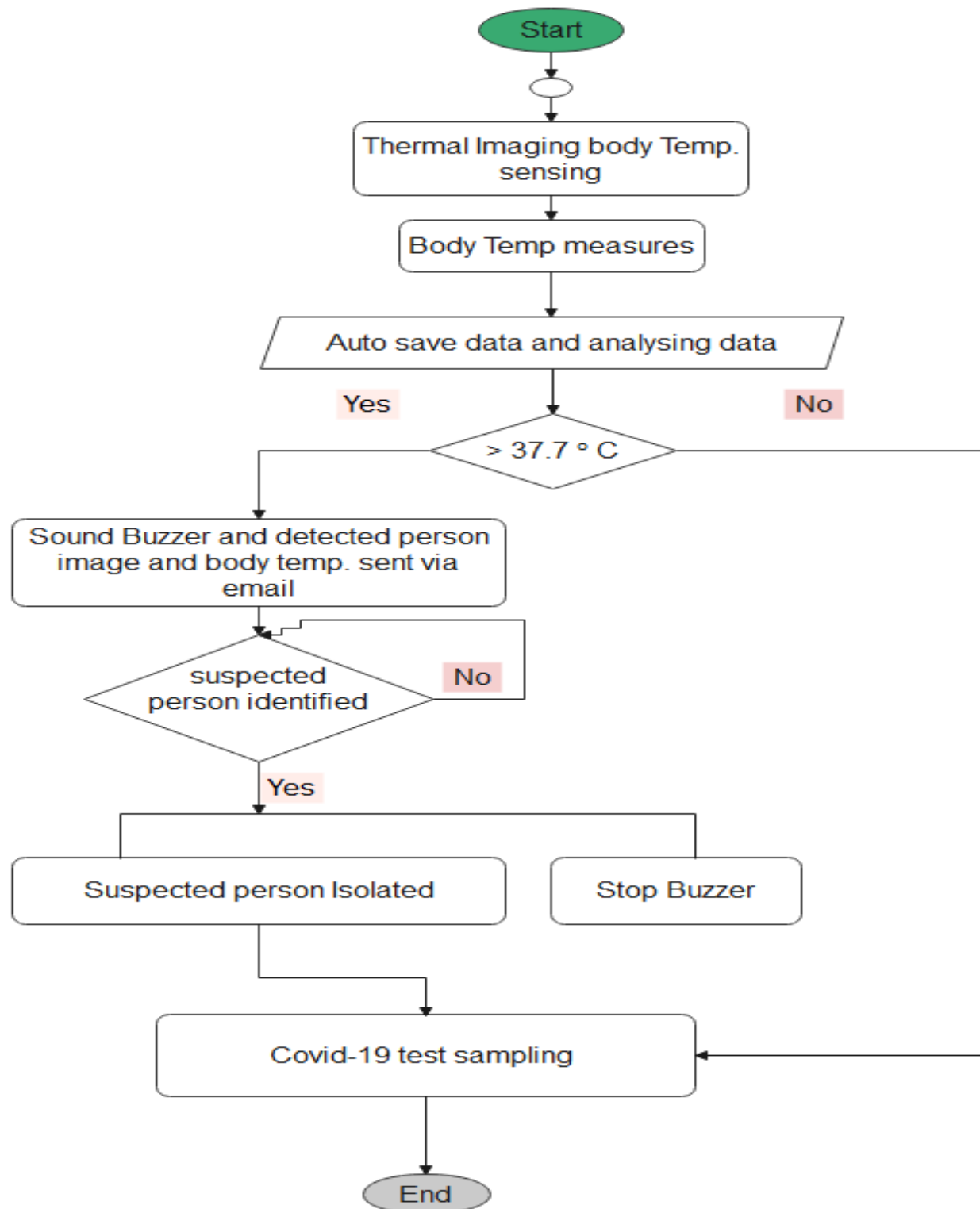


Figure 15: Flowchart diagram

4.3.4 Selection of Sensing Unit Components of the System

The system needs a lot of techniques where the difference of the existing system and developed system was shown that there was no automation of report generation and view, no time management in body temperature sampling, no social distance, no alert when a high temperature detected; that why this system has been developed which used a MLX90640 infrared thermal camera and Pi Camera for to sense the approaching passengers.

4.3.5 Database Design

The designed database for this system was supported by MySQL database management system and PHP scripts for interfaces connections. Figure 16 indicates the number of tables used and their associations in the application. The database of this system helped to store, retrieve and manipulate consistency data.



Figure 16: Database view in phpMyAdmin tool

4.4 System Development Results

The codes source for the developed system are shown in Appendix 3. The following figures demonstrate how different application interfaces were presented and how recorded data were displayed. Users to access data first have to register and to be able to login to the system.

(i) Login Window

Figure 17 presents a login window where users are required to type their usernames and passwords. Users are required to register to use the system. The user registration and management are done by a system administrator.

The login window is titled "Body Temperature Sampling". It features two input fields: "Username" with a person icon and "Password" with a lock icon. Below these fields is a "LOGIN" button with a right-pointing arrow.

Figure 17: Login window

Figure 18 shows the interface to displayed after known login. Admin can visualize if there are detected cases or not. Admin view human pictures and their measured body temperatures.

The home page interface is titled "Report View". It displays the date "2022-05-18" and the status "Today there were 1 no Cases." Below this, it states "The following are the 1 Persons whose Temperature was normal (non indication of Fever):". A large image of a person is shown, with the temperature "36.2" displayed below it. A "Generate PDF" button is located at the bottom right.

Figure 18: Home page interface

(ii) Users' roles

Figure 19 illustrates other roles where the system administrator can add to users to have access to the system.

The system administrator can be able to view all registered users with their assigned roles. The system administrator also has the rights to modify and delete users in the system. Authorized users to the system can view and generates various reports in pdf format (Fig. 20).

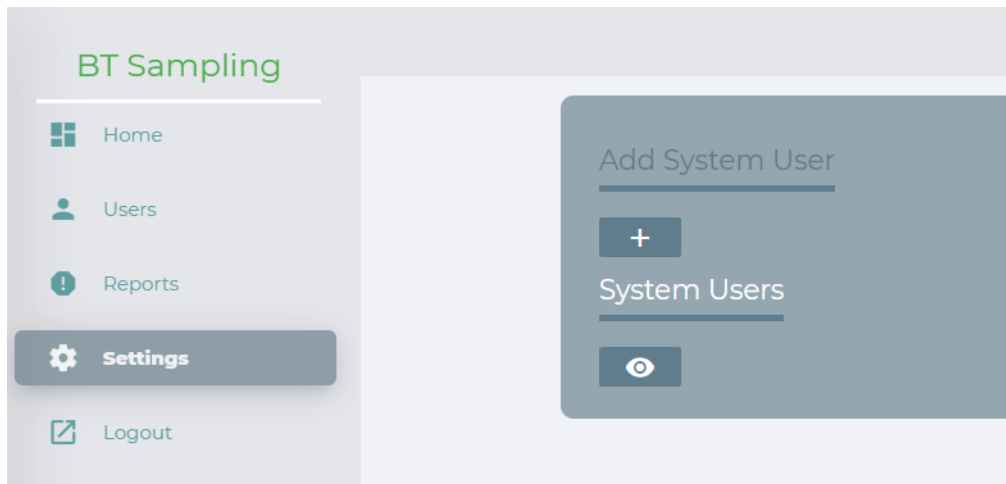


Figure 19: Addition and users' view

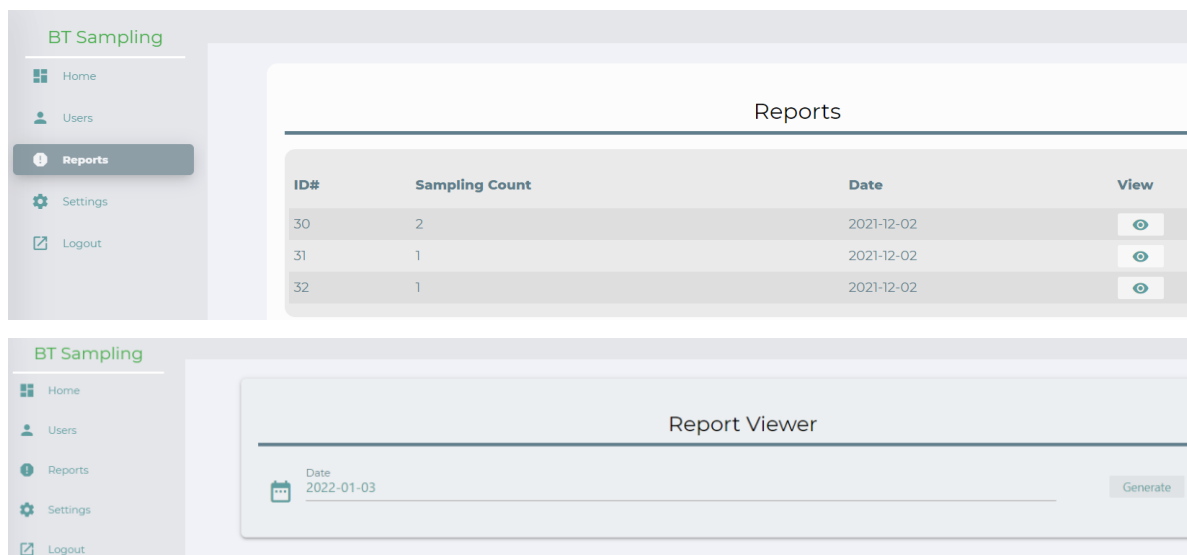


Figure 20: Report generation and view

(iii) Device's packaging

Figure 21 shows how different devices used in the proposed system have been connected and boxed to avoid disconnection and other inconvenience that can happen such as jumping wires and devices.

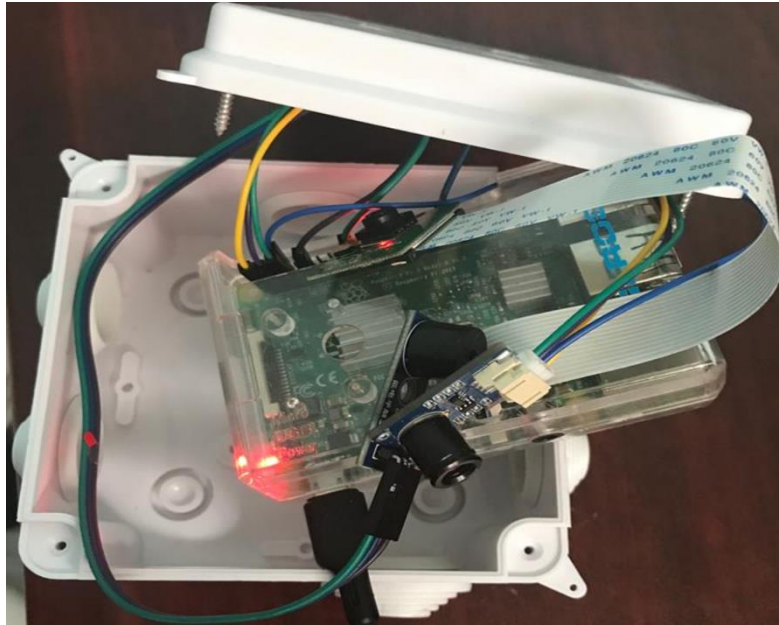


Figure 21: Device's packaging

(iv) Body Temperature Sampling

Figure 22 shows captured passengers' body temperature in system testing. The numbers in yellow color are the temperatures results from devices used in this system. When the body temperature sampled was less than 37.9 degrees Celsius, the system automatically indicated that there was no suspected case. These results mean that passengers are at normal body temperature unless the system provides an alert in the case temperature measured is more than 37.9 degrees Celsius.



Figure 22: Temperature sampling

4.4.1 System Testing and Validation

After the Thermal Camera Based Continuous Body Temperature Measurement System for Pandemic Emergencies design and implementation phase, each unit employed in the development of this system was put to the test to evaluate the way it performed and its compliance with the system requirements. The system was tested to provide capabilities to give out the body temperature, generation and view of the report in the user desk successfully. All components of the system work as per the design. The passengers sensed, the body temperature was shown up to the screen of monitoring, the report was generated and viewed automatically. The developed system has been recommended to be used at the airport and different public areas. The white box as well as the black box approaches were utilized during testing and validation of this system. The black box methodology whereby, the internal working of the developed system was tested, the python software has been used for simulating the body temperature sampling, buzzer and email alert when a high temperature was detected (Table 4).

Table 4: Test and validation results

System Requirement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Hardware is connected and working within the software	0	0	0	0	10
The system allows admin to perform users and information management task.	0	0	0	2	8
The software is able to generate report weekly or any time needed.	0	0	0	1	9
Only data with high temperature is saved to avoid storage saturation	0	0	0	3	7
The software allows visualization information of all temperature and other data recorded.	0	0	0	0	10
The system provides an ability of capturing body temperature with no human interaction.	0	0	0	0	10
The system speeds up temperatures sampling processes.	0	0	0	1	9

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Pandemic is a disease outbreak that spreads quickly over a wide area across many countries or continents and affects a large population. It has been observed that contactless infrared thermal camera for body temperature plays a significant importance to avoid propagation of disease during pandemic periods. As contact is one the best ways to induce contamination to many people, a lot of measures haven been taken in many countries for instance in COVID-19 pandemic period in order to prevent its propagations.

In medicine, high body temperature is a symptom which can show that human life is not in a good state. It is also the first symptom to be checked before recommending passengers to do the COVID-19 test. Most thermometer tools are not contactless with a lot of limitations such as time consuming, lineup of passengers, hard writing of reports, absence of alarm in case high temperature has been detected, not respecting social distance etc. In order to check temperature, the users are taking the thermometer in hand and pointing it to the forehead of travelers or patient.

The developed system came to respond to those limitations listed above and contributed more to human life security. Temperature of passenger to airport has to be sampled without contact, or line in real time. This system through its options gives the possibility to admins to generate report, to produce an alarm when high temperatures are detected which were absent in the existing systems. It has been an answer for time management, minimization of errors when writing reports. The developed system has been liked by passengers and administration at different borders and the airport of Burundi.

5.2 Recommendations

5.2.1 Implications to the Policy Makers

It is recommended to the policy makers such as Ministry of the Interior, community Development and Public Security, Burundi Airport Authority, Immigration Officers and Border Policy makers, to use this system properly at the NDADAYE airport and at the borders

in Burundi. The officers should direct passengers to pass in front of the camera and not passing behind it and as well as should ensure the camera is not exposed it to the sun or fire.

5.2.2 Implication to the Practitioners

- (i) System administrators to make sure that the implemented system is always powered using electricity.
- (ii) Airport staff to respect the conditions by instructing passengers to pass through the corridors where the system is installed.
- (iii) System administrators are required to prepare training for end users to be familiarized with the proper use and interpretation of samples.

5.2.3 Future Research

The future research is to add more features to the developed systems to be more robust.

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APPENDICES

Appendix 1: Interview guide

Section A: Questions for Passengers

1. Do you like to travel?
2. How many travels by year?
3. Have you been measured temperature when arrived to the Airport?
4. If yes, which types of technique used among these a) forehead thermometer b) thermal Imaging camera?
5. For forehead technique at what distance the airport employee was stood up?
6. Did you see where they are using a thermal imaging camera?
7. If yes, did you know the importance of the thermal imaging camera?
8. As you know that the use of contact equipment's is one of the factors of contamination of COVID, are you satisfied of the method which used here at Melchior NDADAYE International Airport for temperature sampling?
9. If many of you arrived, do you have to line up to be tested one after the other?
10. How long it took for temperature sampling?
11. Since the instructions tell us to keep our distance during this period of the COVID pandemic, you are not afraid that you may have spread the pandemic when taking the temperature?
12. If there is a plan to devolve a digital system that takes the temperature of passengers entering the airport, is that going to decrease the time spent at the airport for testing?

Section B: Questions for Medical STAFF

1. Do you know a thermal imaging camera?
2. If you know a thermal imaging camera system, have you ever used it?
3. Do you see the importance of the digitalization of the temperature sampling using this system said above?
4. Is it important to Minimize the use of printed matter for temperature sampling?
5. As you know that the use of contact equipment is one of the factors of contamination of the COVID, you are not afraid of being contaminated as the equipment used for temperature samples does not respect the distance of one meter (1m) here at Melchior NDADAYE International Airport?

6. If there are many passengers arriving, do you have to have them lined up to take the temperature one after the other?
7. If yes, passengers do not spend a lot of waiting time on line?
8. Is it easy to write a daily / weekly / monthly report of temperature samples manually?
9. Since the instructions tell us to keep our distance during this period of the COVID pandemic, you are not afraid that you could not be contaminated or that you may have spread the pandemic when taking the temperature?
10. If there is a plan to devolve a digital system that takes the temperature of passengers entering the airport and others who work at the airport, is that going to decrease the time spent at the airport for COVID testing?

Thank you for your valuable time!

Appendix 2: Internship Offer letter

REPUBLIQUE DU BURUNDI
Ministère du Commerce, du Transport,
de l'Industrie et du Tourisme.



DIRECTION GENERALE

Bujumbura, le 18.02.2021

To : Libère NKUNZIMANA
Nelson Mandela African Institution
Of Science and Technology

Our Ref: 729/DG/02.10/2021

Dear Sir,

Re : Internship place request

Reference is made to your correspondence dated on December 11th, 2020 requesting for an internship place within our institution

Burundi Civil Aviation Authority hereby informs you that internship is granted to you for six months as requested, starting from June, 3rd to December 2nd 2021.

The Head of IT Unit who is below copied will be in charge of the trainee during this period.


Emmanuel HABIMANA
DIRECTOR GENERAL
BURUNDI CIVIL AVIATION AUTHORITY

CC:

- Dina Machuve,PHD
- Director Of Finance & Administration /BCAA
- Head of IT Unit/BCAA

B.P 694 Bujumbura-Burundi Tél : +257 22203102 (Secrétariat); +257 22203100 (Standard Info);
Fax: +257 22223428. Email: aacb@aach.bi ; aacbburundi@yahoo.fr; aacbburundi@gmail.com
site web: www.aacb.bi

Appendix 3: Programming codes

a. Database

```
<?php
class Database
{
    private static $dbName = 'libere' ;
    private static $dbHost = 'localhost' ;
    private static $dbUsername = 'root';
    private static $dbUserPassword = '';

    private static $cont = null;

    public function __construct() {
        die('Init function is not allowed');
    }

    public static function connect()
    {
        // One connection through whole application
        if ( null == self::$cont )
        {
            try
            {
                self::$cont = new PDO( "mysql:host=".self::$dbHost.";". "dbname=".self::$dbName, self::$dbUsername, self::$dbUserPassword);
            }
            catch(PDOException $e)
            {
                die($e->getMessage());
            }
        }
        return self::$cont;
    }

    public static function disconnect()
    {
        self::$cont = null;
    }
}
?>
```

b. Functions

```
<?php
include 'password.php';

use PHPMailer\PHPMailer\PHPMailer;
use PHPMailer\PHPMailer\SMTP;
use PHPMailer\PHPMailer\Exception;
//SECURE SESSION START FUNCTION
function sec_session_start()
{
    $session_name = 'agri_business'; // Set a custom session name
    $secure = false; // Set to true if using https.
    $httponly = true; // This stops javascript being able to access the session id.
    ini_set('session.use_only_cookies', 1); // Forces sessions to only use cookies.
    $cookieParams = session_get_cookie_params(); // Gets current cookies params.
    session_set_cookie_params($cookieParams["lifetime"], $cookieParams["path"], $cookieParams["domain"], $secure, $httponly);
    session_name($session_name); // Sets the session name to the one set above.
    session_start(); // Start the php session
}

function active($current_page)
{
    $url_array = explode('/', $_SERVER['REQUEST_URI']);
    $url = end($url_array);
    if ($current_page == $url) {
        echo 'activee'; //class name in css
    }
}

//SECURE LOGIN FUNCTION
function login($username, $password, $mysqli)
{
    $user_id = $name = $mail = $level = $db_password = $adm_no = "";
    if ($stmt = $mysqli->prepare("SELECT * from users where name = ?")) {
        $stmt->execute([$username]);
        $check = $stmt->fetch();
        print_r($check);
        if (!empty($check)) {
            // echo $check['password'];
            if (password_verify($password, $check['password'])) {
                if ($check['status'] == 1) {
```



```

        if ($check['status'] == 1) {
            // echo "imooooo";
            $ip_address = $_SERVER['REMOTE_ADDR'];
            $user_browser = $_SERVER['HTTP_USER_AGENT'];
            $_SESSION['user_id'] = $check['id'];
            $username = preg_replace("/[^a-zA-Z0-9_\-]/", "", $check['name']);
            $_SESSION['user_name'] = $username;
            $_SESSION['level'] = $check['role_id'];
            $_SESSION['login_string'] = password_hash($check['password'] . $check['id'] . $username . $ip_address . $user_browser, PASSWORD_BCRYPT);
            $return_code = $check['role_id'];
            return $return_code;
        }
    } else {
        $_SESSION['error_msg'] = "Wrong Password";
        return 333;
    }
} else {

    // No user exists.
    $_SESSION['error_msg'] = "User Does not Exist";
    return 333;
}
}
}

function login_check($mysqli)
{
    // Check if all session variables are set

    if (isset($_SESSION['user_id'], $_SESSION['user_name'], $_SESSION['login_string'])) {
        $gID = $_SESSION['user_id'];
        // echo $_SESSION['login_string'];
        $login_string = $_SESSION['login_string'];
        $username = $_SESSION['user_name'];
        $ip_address = $_SERVER['REMOTE_ADDR']; // Get the IP address of the user.
        $user_browser = $_SERVER['HTTP_USER_AGENT'];
        if ($stmt = $mysqli->prepare("SELECT * from users where name = ? LIMIT 1")) {
            $stmt->execute(array($username));
            $check = $stmt->fetch();
            // print_r($check);

```

```

        if (!empty($check)) { // If the user exists
            $login_check = $check['password'] . $check['id'] . $username . $ip_address . $user_browser;
            if (password_verify($login_check, $login_string)) {
                // echo "verified";
                return true;
            } else {
                return false;
            }
        } else {
            return false;
        }
    } else {
        // Not logged in
        return false;
    }
} else {
    // Not logged in
    return false;
}
}

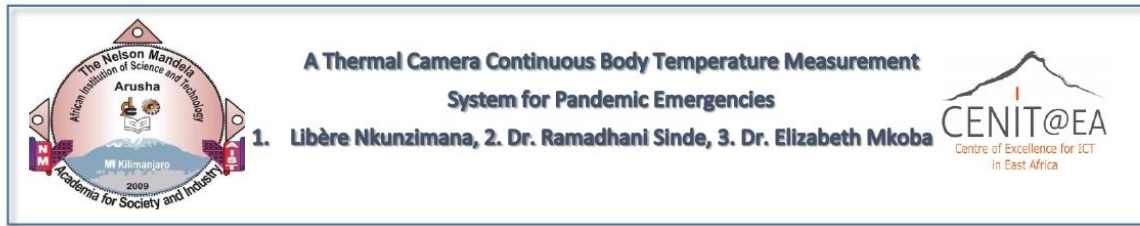
function cus_login_check($mysqli)
{
    // Check if all session variables are set
    if (isset($_SESSION['user_id'], $_SESSION['username'], $_SESSION['login_string'])) {
        $user_id = $_SESSION['user_id'];
        $login_string = $_SESSION['login_string'];
        $username = $_SESSION['username'];
        $adm_no = $_SESSION['admission_no'];
        $ip_address = $_SERVER['REMOTE_ADDR']; // Get the IP address of the user.
        $user_browser = $_SERVER['HTTP_USER_AGENT']; // Get the user-agent string of the user.

        if ($stmt = $mysqli->prepare("SELECT kamchatka FROM customers WHERE kosovo = ? LIMIT 1")) {
            $stmt->bind_param('i', $user_id); // Bind "$user_id" to parameter.
            $stmt->execute(); // Execute the prepared query.
            $stmt->store_result();

            if ($stmt->num_rows == 1) { // If the user exists
                $stmt->bind_result($db_password); // get variables from result.
            }
        }
    }
}

```

Appendix 4: Poster Presentation



Introduction

The goal of this study was to create a continuous body temperature measurement system based on thermal cameras for pandemic crises at Melchior NDADAYE International Airport. The system has functions that maximize time, minimize the usage of stationary equipment, sample temperatures without physical touch, and automatically regenerate temperature sampling reports. The medical staff and the volume of people going through this airport make it impossible to quickly take the temperatures of every passenger.

Problem Statement

The majority of temperature detection techniques currently in use are manual, rely on human input, and have a number of limitations include query mistakes, facial detection issues that make dressing reports difficult, and the inability to read the temperatures of several people. Due to used equipment that require close proximity when performing tests, it is challenging to detect the body temperature in a short amount of time, and it is quite simple to be contaminated.

Tools



Figure 1: MLX90640



Figure 3: Pi camera



Figure 2: Raspberry Pi



Figure 4: Buzzer



Figure 5: Monitor

Results

Through its options, the developed system offers administrators the ability to produce reports and alarms when excessive temperatures are detected, both of which were not possible with the prior system. It has been a solution for time management, reducing errors in report writing, and boosting health security.

Conclusion

The developed system came to respond the existing limitations and contributed more to human life security. Temperature of passenger to airport has to sampled without contact, or line in real time. Through its options, this system allows administrators the ability to create reports and to create alarms when excessive temperatures are detected, both of which were not possible with the previous system. It has proven a solution for time management and reducing errors in report writing.