International Journal of Advanced Technology and Engineering Exploration, Vol 9(94)
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
http://dx.doi.org/10.19101/IJATEE.2021.875573

Case Study

IoT based smart fan controller and fire prevention in computer laboratory

Kevin Iriho*, Neema Mduma and Dina Machuve
School of Computation and Communications Sciences and Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

Received: 01-March-2022; Revised: 24-September-2022; Accepted: 26-September-2022

Abstract
Computer laboratory plays the role of key elements with high interest for different categories of populations. Event of fire, smoke, heat, and water leakage when occurs could cause a big loss for business continuity. This paper presents a developed system for the internet of things (IoT) based smart fan controller and fire prevention in the computer laboratory. The aim was to develop an automated computer laboratory that would control and monitor the computer laboratory environment from the incident of fire, heat, smoke, and water leakage. The system was created using three nodes and a single database. The first node used a flame sensor which detects fire and activates a fire extinguisher automatically. The second node used a digital humidity and temperature sensor (DHT), along with an ultrasonic sensor, which was used to manage a fan controller and activate the controller when the temperature is high and a person is present. Thirdly, smoke and water sensors were used to detect the presence of smoke and water leakage. Microcontrollers, access points, and software are used to accomplish the development of this system. Different actions of warning users were done. Triggering buzzers and sending emails were done whereas fire, smoke, and water leakage are detected. The email was also sent to the users registered in the system when there was a temperature of more than 25.

Keywords
Flame sensors, DHT22 sensors, Ultrasonic sensors, ESp8266, ESP32 WROOM-32D and BUZZER.

1.Introduction
Nowadays, automation system integrated with the internet of things (IoT) has been the key interest with the rapid growth of technology. Everyone wants to use automated devices for several reasons. These automated devices are able of transferring data from various devices to provide a solution [1]. Home automation means controlling electronic and electrical devices along with other manually operated things such as doors, and windows without human interaction [2]. Moreover, smart home (SH) technology does not simply turn devices on and off [3], it can monitor the internal environment and the activities that are being undertaken whilst the house is occupied. About the result, SH offers different technologies. It can monitor the activities of the occupant and devices operate in set predefined patterns independently, as the user requirements. To create an effective SH system, it is necessary to select the proper tools, devices, and technology to be developed and make them work coherently[4].

Significantly, the concept of IoT makes the connection of several devices such as computers, mobile phones, internet equipment, electronic device, and other things all together to be able to use the device for communication and work cooperatively.

The assumption that recognizes IoT is that it allows a person to be disconnected from a location, which ensures that an individual can access the devices without the need to be in a particular place to deal with a specific device [5]. Different IoT based devices or appliances are used to reduce the wastage of time by allowing the user to operate their devices from any distance without any delay [6]. SH and IoT can promote home safety, health, and monitoring [7]. The advancement of automation technology makes human life easier, more comfortable, and less demanding in all sectors [8]. The home automation system also includes a security system for safety and security [9]. IoT devices constitute a large number of devices and sensors that can monitor and control different physical quantities [10]. The key challenges in SH are intelligent decision-making, secure identification, and authentication of the IoT devices, continuous connectivity, data security, and privacy

*Author for correspondence

issues [11]. Detection and prevention of fire is a detrimental work that can bring risks of loss of lives when extinguishment is done by an extinguisher person [12]. Then, the computer lab is equipped with electronic equipment which possesses the risk of overheating when used continuously. Event of fire, smoke, heat, and water leakage when occurs could cause a big loss for business continuity. Indeed, IT equipment and other materials used for data recording or storage can be damaged when they are exposed to sustained elevated temperatures. The degree of such damage depends upon the exposure of materials for data recording and storage [13]. However, all incidents which occurs in computers facilities can cause a significant damage and a high consequential loss even where fire is quite small [14]. This paper present automated computer laboratory that would control and monitor computer laboratory environment from incident of fire, heat, smoke and water leakage.

In the last decades, the automation system was limited to industries since it required significant investments[15]. This led automation to become the key interest technology to many people who want to use automated devices in their daily activities.

According to Jensen and Nygaard [16], the information communications technology (ICT) room needs to be equipped with smoke detectors and aspiration detectors and an installation of a fire alarm system based on early detection. For this inconvenience, fire protection is a basic safety issue for all categories of buildings. The criteria for effective fire suppression and the characteristics of extinguishing systems in insulated areas depend on the combination of factors [17]. Water and chemical-based methods are the traditional fire extinguishing techniques why there is an urgent need to develop an extinguisher that can overcome the problem of residues and wastage of water[18]. The best solution and alternative to these traditional methods are sound waves. According to Li et al. [19], when the temperature is increasing, it also increases the occurrence of the outdoor environment in temperature. The ventilation fan with smart features, which uses a microcontroller to create an automation function is the best solution for the ventilation system [20]. The voice recognition using the Filipino language was used to automatically control the electric fan speed from speed no.1 to speed no. 4[21]. In this study, an IoT based laboratory automated was developed to control fire, temperature, water, and smoke. In case the fire is detected, the alarm will be triggered, an email will be sent to subscribers and the fire extinguisher will be turned off automatically.

This paper is organized as follows. Literature review has been discussed in section 2. In section 3, materials and methods have been discussed. Results and discussion have been discussed in section 4. Finally concluding remarks have been presented in section 5.

2.Literature review

Different works have already been made using IoT technology to automate devices for the protection and detection of fire, smoke, heat, and water leakage. This technology offers user interoperability and connectivity between devices, systems, and networks. It involves collecting and analyzing data from sensors [22]. Three protocols of wireless communication were widely used in home automation such as ZigBee, Wi-Fi, and z-wave [23]. The main purpose of home automation aimed to bring control of our everyday home life [24]. A project related to an automatic smart kitchen using a microcontroller had been done. It was designed to discharge heat and smoke in the kitchen and control the speed of the air blower [25]. Furthermore, a system for smart kitchen fire prevention system that protected gas stoves to cook was developed [26]. It used a flame detector, temperature sensor, gas sensor, gas shutoff device, line reporting system, and alarm sound to warn users. A project related to a digital smart fan module was implemented for monitoring fan speed following room temperature and the presence of a person [27]. This project was done to reduce energy consumption. Then, electricity is important in our daily life. To resolve this challenge, a developed system of smart fan controllers which uses electricity to work was developed [28]. The system included an ultrasonic sensor with wireless enabled IT that activated and deactivated the on/off operation based on detecting human presence. The main purpose of this system was to reduce energy consumption. Dzulkefli et al. [20] realized an innovative prototype design of an electric fan with smart characteristics. This electric fan used a microcontroller to produce an automation function. It also had unique double feature designs, such as using 2 fans, 2 light-emitting diodes, and 2 sensors. Onibonoje et al. [29] realized a project which aimed to control the speed of the fan automatically using Arduino, temperature, and humidity sensors. Fan speed needed to be manually controlled every time. By using this idea, the speed of the fan would be automatically adjusted according to the surrounding environment. Widyaningrum and

Pramudita [30] realized an automatic lamp and fan controller project based on microcontroller where automatic lamp system required sensors to detect the light using a dependent resistor sensor. Khoa et al. [31] designed a smart light system with a passive infrared sensor, light and other sensors, and actuators to open the light and dim light with remote control using the network that can be programmed and designed using a microcontroller. Alharthy et al. [32] realized an IoT based secured smart door access to provide smart monitoring and controlling the visitors, the thieves, and the homeowner. This system was performed to monitor the appliances for smart permission. Feng and Liu [33] described different aspects which could be used for protection against computer fire such as decision making, intelligent dispatching host system, fire alarm processing system, digital recording system, fire geographic system, global positioning system (GPS), precise positioning, and image monitoring system. Sassani et al. [34] designed a fire notification system that used a cloud-based system with sensors to detect fire to alert users through the internet using a single Application (App) with raspberry pi programmed using the python language and utilized google application for programming interface (API) for location detection. Hariveena et al. [35], in their study about fire identification in homes, said that it was important to prevent property loss due to both natural and triggered fire event. Fire would come anywhere and any moment but the existence of fire alarm keeps family safe. Alqourabah et al. [36], in his system about house combustion, He said that, the main concern for builder, designer and property resident was to implement a fire detection system to detect a fire using integrated sensor and give alarm to the property owners and emergency services.

3.Materials and methods

3.1System development approach

Prototyping is the process used for quickly building a model of a software system which is used as a communication tool to assess the information needs of the user [37]. Prototyping methodology offers quality improvement and cost reduction in all branches of product development; it has gained popularity only in the software sector of the creative industry [38] and is now as fundamental to software development as it has been to systems development in other engineering fields [39].

Indeed, among different types of prototyping methodology, the evolutionary focus is on gathering a correct and consistent set of requirements [40]. The process lends strength to building quality software using the ongoing clarification of existing requirements and the discovery of previously missing or unknown requirements. Then, the evolutionary development method assumes that a prototype is built and delivered to the user for experimentation [41]. The prototype is modified in close cooperation between the end user and the analyst in a step-by-step fashion to incorporate the experiences of the experimentation. *Figure 1* below shows the evolutionary prototyping methodology cycle.

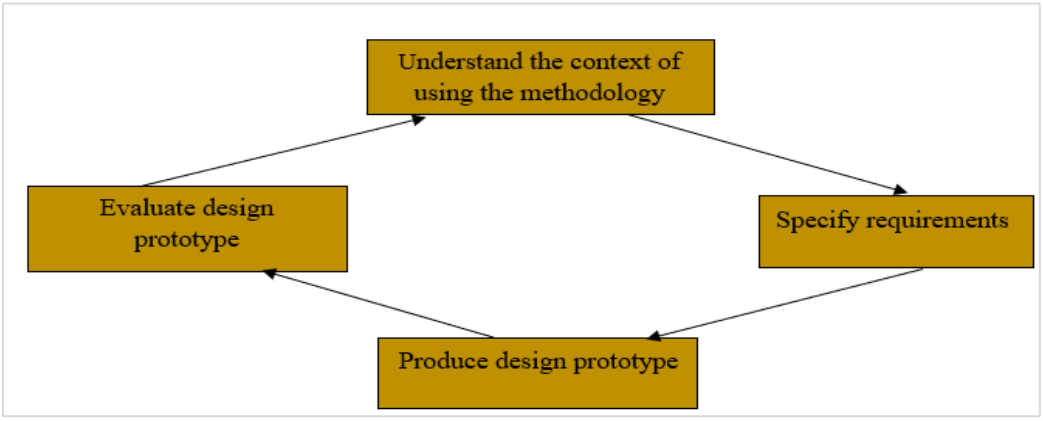


Figure 1 Prototype development life cycle

Evolutionary was selected because the implementation is commenced when the requirements are best understood, unlike rapid prototyping where the implementation starts with the least understood requirements.

3.2System requirements

During the development of this project, software requirements and hardware requirements have been used to accomplish the realization of that system.

3.2.1Software development tools and programming languages

Software development tool performs the same task as an application or program. To understand the concept of application programming interfaces, we need to understand a couple of important software engineering principles first [42]. It can be used by developers when they want to create, maintain, test, build, debug, fix and support a software application or product. Integrated development environments (IDEs) can aid in the integration of tools to facilitate the software development process and will succeed in doing so to the extent that the community of tools [43]. Developers can be influenced to develop tools in ways that increase the likelihood of their interoperation. Like other tools, it is used by users when they want to streamline and automate different software development tasks. In this project, different software tools have been used. They have used among other things following his performance, analysis, testing, verification debugging, and building application [44]. Programming language as a command instruction and other syntax was used to create a software program. This language allows programmers to write high-level code that can be compiled into the low-level language which is recognized by computer software. Embedded software is the key contributor to embedded system performance and power consumption. Program execution tends to spend most of the time in a small fraction of code [45].

Different software has been used in developing this system such as Sublime text editor as a text editor which is widely used by developers to create programs or applications. Xampp is an open-source cross-platform web server used by different servers and languages such as apache hypertext transfer protocol (HTTP) server, MariaDB, and script languages like Hypertext Processor (PHP) and Perl. It is available on Windows, macOS, and Linux systems. It has been used for the storage of data recorded from sensors. Arduino IDE which is an open source text editor like notepad was used in the programming of microcontrollers. The IDE mainly contains two basic parts: Editor and compiler former is used for compiling and uploading the code into the given Arduino module. This environment supports C and C ++ languages [46].

3.2.2Hardware tools

Hardware design and reconfiguration are easier and faster to prototype in a computer simulation [47]. In this paper, we present a design of IoT based smart fan controller and fire prevention in a computer laboratory which will be used to detect temperature, humidity, smoke, water leakage, and fire using sensors such as flame sensors, smoke sensors, and water sensors ultrasonic sensors. Flame sensors are used to detect the flame of the fire, smoke sensors detect smoke produced before the spreading of fire, temperature and humidity sensors are used to measure the temperature and the humidity of the environment, and ultrasonic sensors measure the distance between sensors and objects or persons. These sensors provide data to microcontrollers which contribute to triggering different actions of sending an email or pushing a sound. Technical details of each sensor and microcontroller used are provided as follows.

3.2.2.1Nodemcu ESP8266

Nodemcu ESP8266 is open-source firmware (*Figure 2*). It is integrated with Wi-Fi from the Espressif system and hardware which is based on the ESP-12 module. It was used to post data uploaded by sensors to a database hosted on a webserver and it allows to control the action of warning users when fire, smoke, heat, and water leakage are detected or open automatically fan or fire extinguisher in case of any threat such as temperature more than 25℃ or fire is detected.

The *Figure 2-8* has been taken from Google.

Figure 2 ESP8266

3.2.2.2Buzzer

The buzzer is an actuator used to push a sound in a place where is placed to send an alarm (*Figure 3*). It was used for triggering a sound to warn the users in case of smoke, water, and fire detection.

Figure 3 Buzzer

3.2.2.3MQ2 sensor

MQ2 sensor detects gas or smoke in the place where is placed (*Figure 4*). It can be used also for sensing the concentration of gases such as propane, methane, liquefied petroleum gas (LPG), and hydrogen. It works in the concentration range between 200 and 10000ppm (part per million). It was used to detect the presence of smoke and warn the users by the action of sending an email and triggering a buzzer in case of smoke detection.

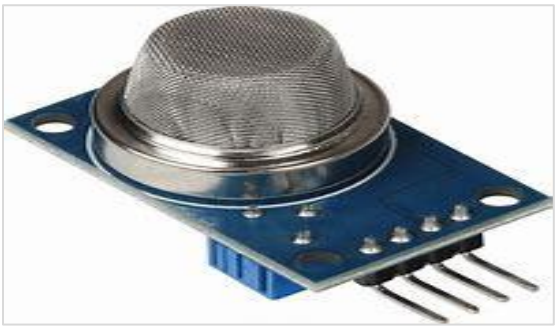


Figure 4 MQ2 sensor

3.2.2.4Flame sensor

The flame sensor is an electronic device which is used to detect a fire at the location where it'll be placed (*Figure 5*). It was to detect the presence of fire and allow prevention actions such as sending email, triggering the sound of a buzzer, and opening a fire extinguisher.

Figure 5 Flame sensor

3.2.2.5Water sensor

Water sensors detect the presence of water when it is placed in a location where it will be placed(*Figure 6*). It can be used to detect the water level, the volume, and the absence of water. It was used to detect the presence of water when it reaches the sensor and trigger actions of prevention such as triggering the sound of a buzzer and warning the users by sending an email.

Figure 6 Water sensor

3.2.2.6Ultrasonic sensor

An ultrasonic sensor (*Figure 7*) is an electronic device which is used tomeasure a target object by emitting ultrasonic sound waves and converting the reflected sound into an electrical signal. The measurement range is up 11m. It is used as a primary proximity sensor. An ultrasonic sensor was used for human presence detection based on distance measurement.

Figure 7 Ultrasonic sensor

3.2.2.7DHT22

DHT22 is calibrated with the final signal (*Figure 8*). It is used for humidity sensing and temperature sensing technology assuring its reliability and stability. DHT22 was used to control fan-based room temperature.

Figure 8 DHT22 sensor

3.3Architecture design

The design of this developed system is composed of three nodes that communicate separately.

3.3.1Architecture design of node 1

The first node is composed of two sensors, one microcontroller (ESP8266), one actuator (buzzer),

one fan, one switch relay, one print circuit board (PCB), and different wires (*Figure 9*). The sensors which composed this node are temperature sensors (DHT22) and ultrasonic sensors. They have been used to allow turning on the fan automatically in case there is a high temperature and when there is a person inside the computer laboratory. The data from these two sensors were recorded and inserted into a database hosted on the web server, *Table 1* shows how data are organized in a database.

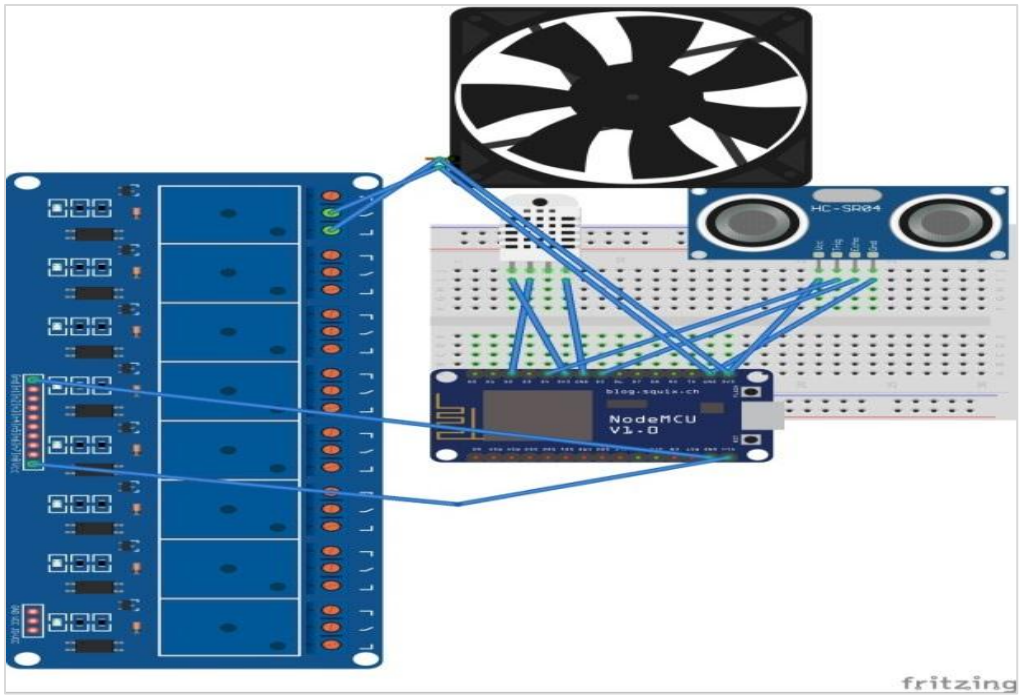


Figure 9 System architecture fan module

Table 1 node 1 data insertion structure

Id	Types of DHT sense	Types of ultrasonic sense	Temperature value	Humidity value	Distance	Date	Time
1 ….. n	ASARAM2	US-015	Value1 ….. Value n	Value1 …… Value n	Value 1 ….. Value n	Date of Data insertion …. N	Time of data insertion … n

3.3.2 Architecture design of node 2

The second node is composed of two sensors, and one microcontroller (ESP32-WROOM-32D). The sensors used were smoke sensor (MQ2) and water sensor (*Figure 10*). The sensors used are smoke sensor (MQ2) and water sensor. The functionality of those two sensors was to detect smoke and water leakage in the computer laboratory. The data from these two sensors were recorded and inserted into a database hosted on the web server, *Table 2* shows how data are organized in the database.

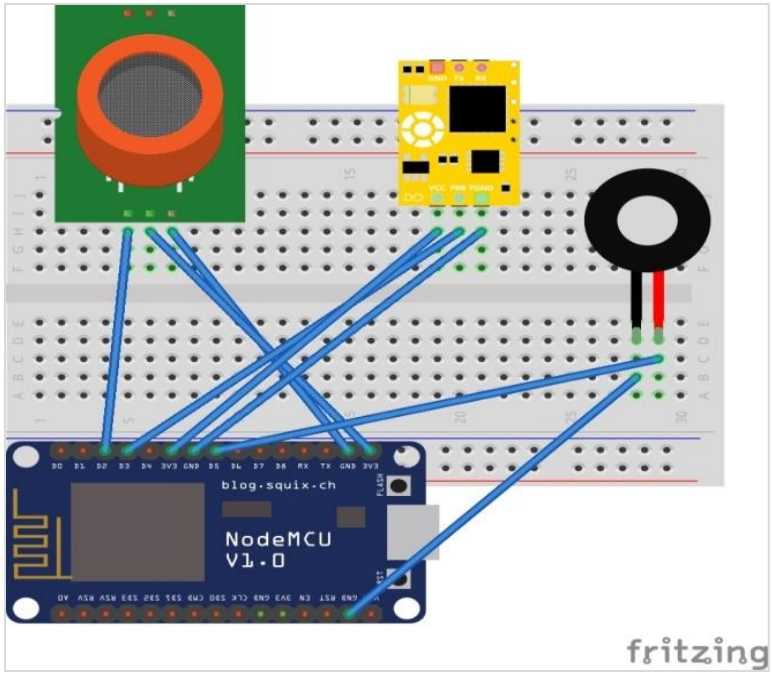


Figure 10 System architecture of smoke detection and water leakage detection

Table 2 Structure of data insertion of node 2

Id	Types of smoke sense	Types of water sensor	Smoke value	Water value	Date	Time
1 ….. n	MQ2	MH	Value 1 ….. Value n	Value1 …… Value n	Date of data insertion ….. n	Time of data insertion ….. n

3.3.3 Architecture design of node 3

The third node was composed of one sensor, one solenoid valve, one fire extinguisher, one microcontroller, one switch relay, one actuator, and different wires (*Figure 11*). It has been used to detect the presence of fire. *Table 3* shows how data are organized in the database.

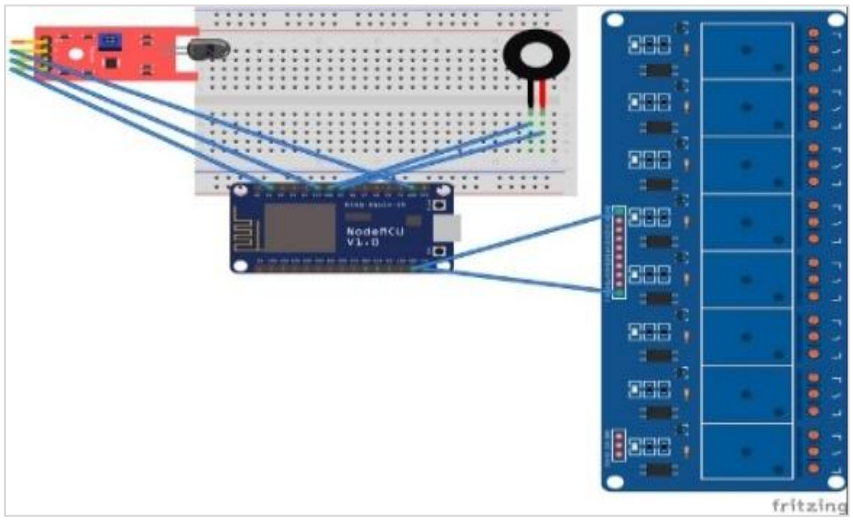


Figure 11 System architecture of fire detection and prevention

Table 3 Structure of data insertion of node 3

Id	Types of flame sensor	Flame sensor value	Date	Time
1	MH	Value1	Date of data insertion	Time of data insertion
……		…..	……	…..
N		Value n	n	n

3.4 Context diagram

A context diagram is defined as the level 0 data flow diagram which establishes the relationship between the systems with the external entities. The context diagram consists of the highest level of data flow chart diagram is presented in *Figure 12*. It shows how this developed automated computer laboratory works.

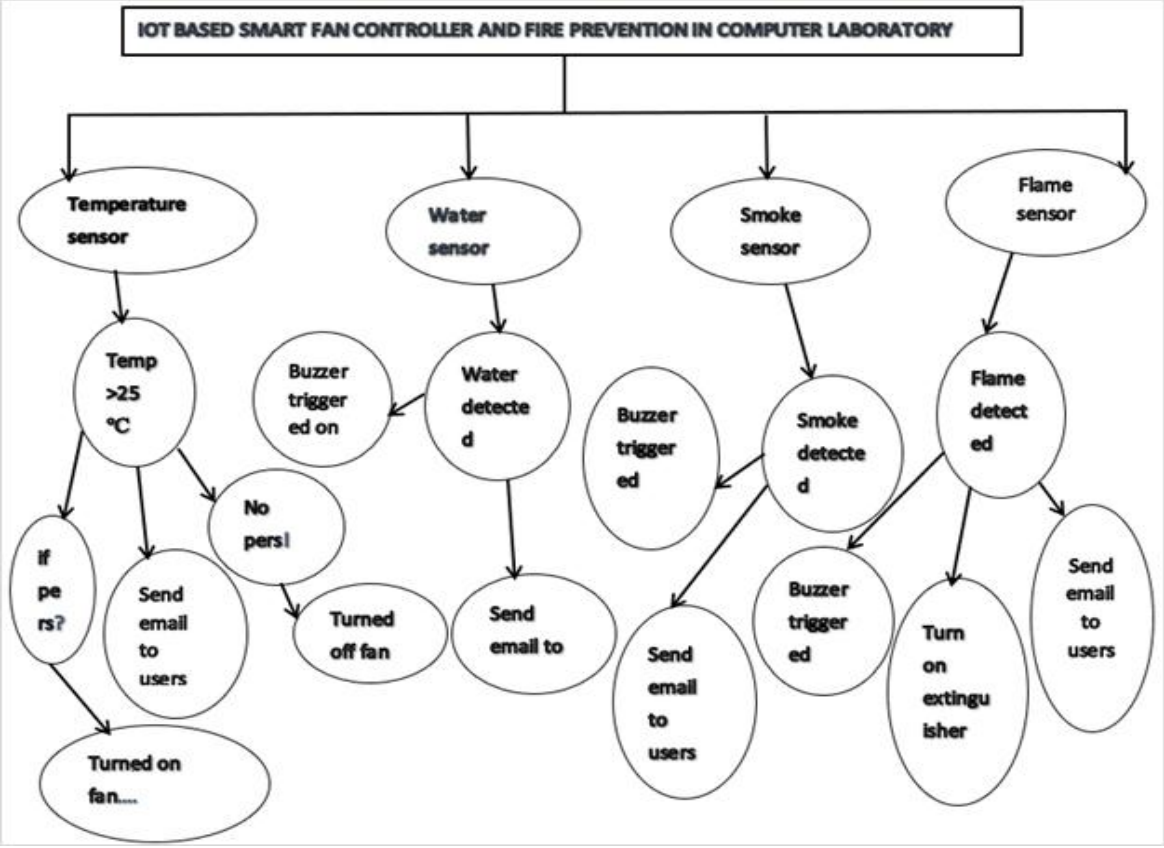


Figure 12 Flow chart diagram

4. Results and discussion

This section presents results obtained when conducting this study to answer the formulated research questions.

4.1Assessment of findings

4.1.1Demographic assessments

This study aimed at interviewing 80 individuals based on their cluster. However, 64 individuals accepted to respond to our questionnaires. Results showed that 57.81% of females were interested in the interview compared to 42.19% of males. This gender balance was important as far as the sample was concerned.

To meet the gender balance, this study was challenged by a number of females who showed interest in using computer laboratory. This study shows that 57.81% of female students used a computer laboratory that 42.19% of male students as presented in *Figure 13.*

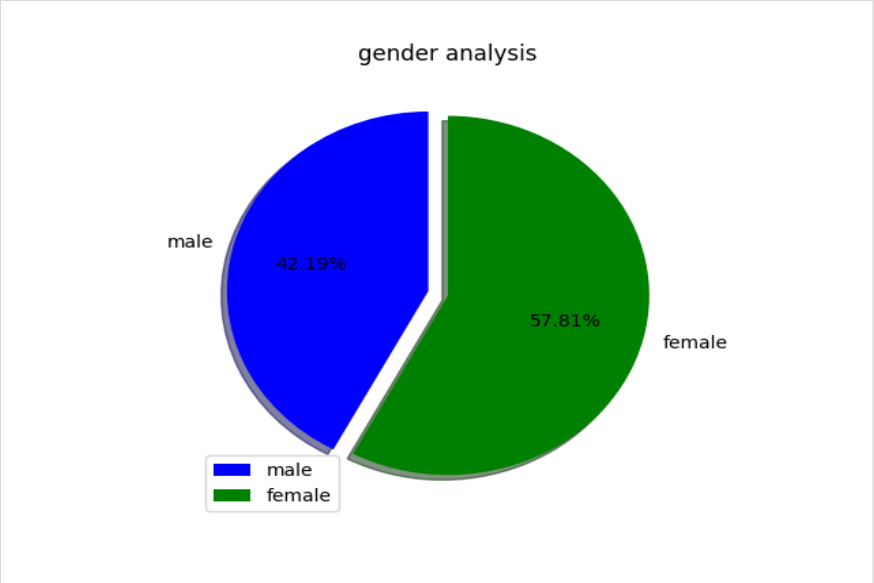


Figure 13 gender information

4.1.2Main source of a house fire

The study aimed to understand the main cause of fire in the house, out of 52 respondents 16 said electrical appliances due to overloading which damages the cable and generates short circuits, 3 said that the cause could be the heating system when you put cooking devices near the heating system.15 said the candles, 8 said smoking and 10 said old and inadequate wire could be also the cause of fire in a house. *Figure 14* shows the proportion of the main cause of fire in the house.

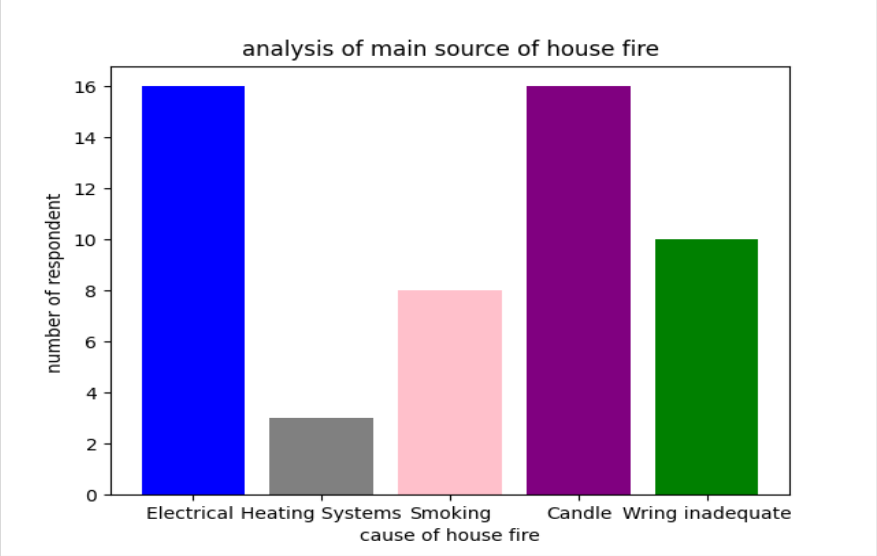


Figure 14 Main source of house fire analysis

4.1.3Computer equipment in East African laboratories

According to the documentation surveyed during the development of this study, it showed that 80% of computer laboratories are equipped with desktops and 20% are equipped with laptop computers. Several computer laboratories are equipped with either laptop computers or desktop computers. To monitor these devices, there is a need for an IoT based smart fan controller and fire prevention in the computer laboratory which is not yet implemented. *Figure 15* shows a representation of computer laboratory equipment proportions.

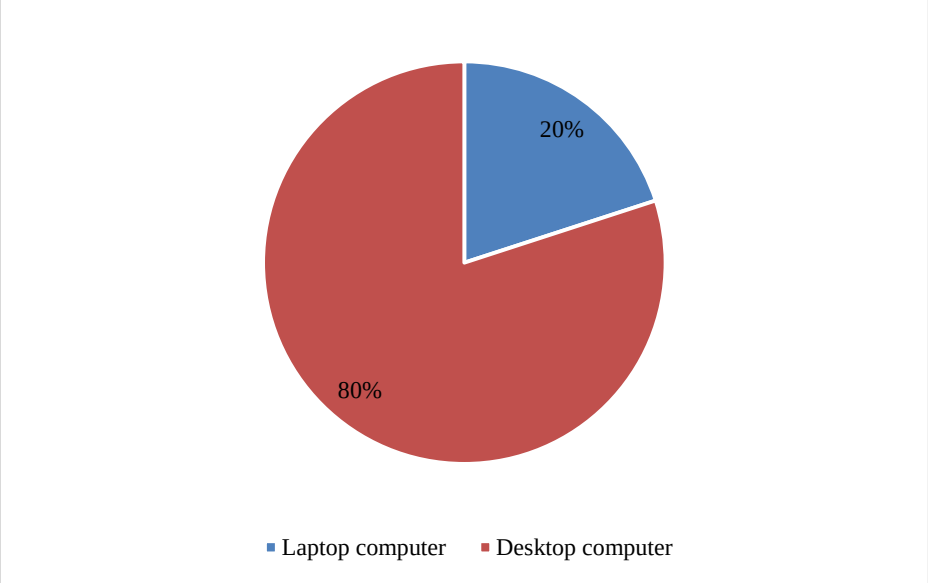


Figure 15 Security in computer lab analysis

4.1.4Internet access and devices connected

IoT based smart fan controllers and fire prevention in computer laboratory use the internet to access data and automation of devices. Among the respondents who participated in the survey, 40 have a connection to the internet through their smartphones and 24 have no access to the internet as represented in *Figure 16*. Following this, it was concluded that the majority of the respondents have an internet connection which allows this study to have a good impact on society.

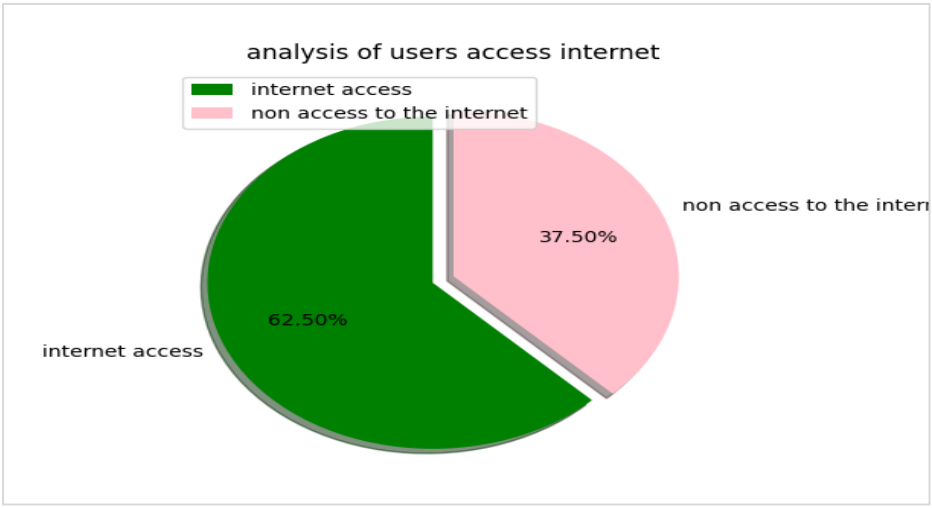


Figure 16 Analysis of user's access to the internet

4.2Results for developed system

In this section, we present data from the study's findings, as well as the methodology that was used to develop this IoT based smart fan and fire prevention in a computer laboratory System.

4.2.1Analysis of developed system

The developed system allows the users to register and access different values or data recorded from sensors. Mobile applications (*Figure 17*) and web-based applications have been developed to allow the user of the system to access the data recorded from the sensors from anywhere they are via their smartphone, laptop, or desktop computer. To access those data, the application and database are hosted on the web server and data are accessed when there is the

internet. The developed system includes different functionalities such as user registration (*Figure 18*) and user authentication (*Figure 19*) which allow the users to redirect to other pages. Data recorded from the sensor and inserted in the database are visualized via mobile application or web-based application.

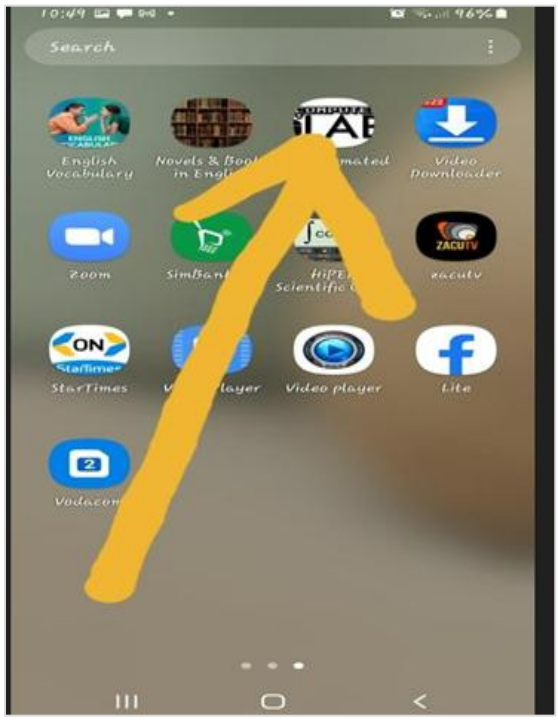


Figure 17 Lab automated mobile app

Figure 18 lab automated user registration

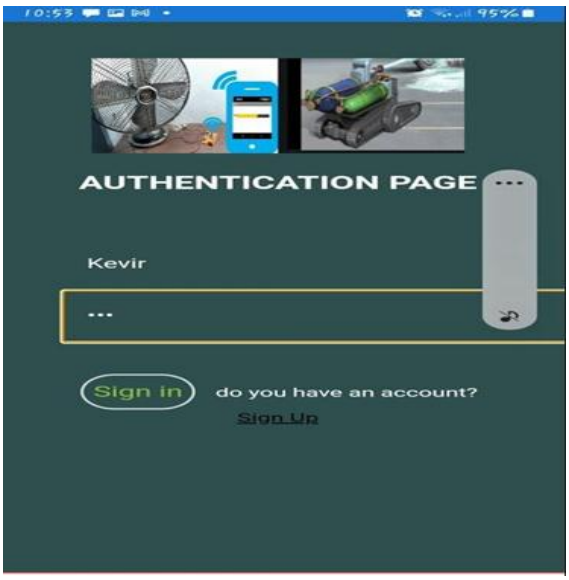


Figure 19 Lab automated user authentication

4.2.2Simulation and testing of design prototype

Simulation and testing were realized from the different prototypes. Data recorded from sensors that composed these prototypes are inserted in databases and allow for different actions of protection and prevention.

4.2.2.1Smart fan controller module

IoT based smart fan controller module (*Figure 20*) was developed for monitoring and controlling fans based on room temperature of more than 25℃ and the presence of the person. The values obtained from the two sensors used in the developed system are used to record and sent data to the database (*Figure 21*) and ThingSpeak cloud (*Figure 20*). The action of sending an email when the temperature is more than 25℃ is done to all users registered in the system using Equation 1.

If temp > 25℃ {-buzzer is triggered on
- Fan is opened automatically
} (1)

4.2.2.2Smoke and water detection module

Smoke detectors are important for the safety of buildings. Smoke detectors detect and warn the owners and the users of the building automatically in case there is the presence of smoke. Indeed, smoke leads to disease and harms nearly every organ of the body. Smoke can cause different diseases such as cancer, heart disease, stroke, lung, etc….

As it is important to use smoke detection for the safety of the house, it is also important to use a water detector because it detects water leakage in the house which is the cause of short circuits and causes loss of lives and equipment or property. The developed IoT

based for smoke detection and water leakage (*Figure 22)* was developed to control and monitor water leakage and smoke spreading in computer laboratory as presented in equation 2. The value from the sensors MQ2 sensor and water sensor were recorded and inserted into the database (*Figure 23*). The value from those sensors will allow the detection of smoke and water leakage and warn the users of the computer laboratory. The action of sending emails to the users in case there is the detection of smoke or water leakage is based on data inserted in the database Equation 2.

If smoke_value > 200ppm or water_value >480ppm
{- buzzer triggered on
-Email sent to all users} (2)

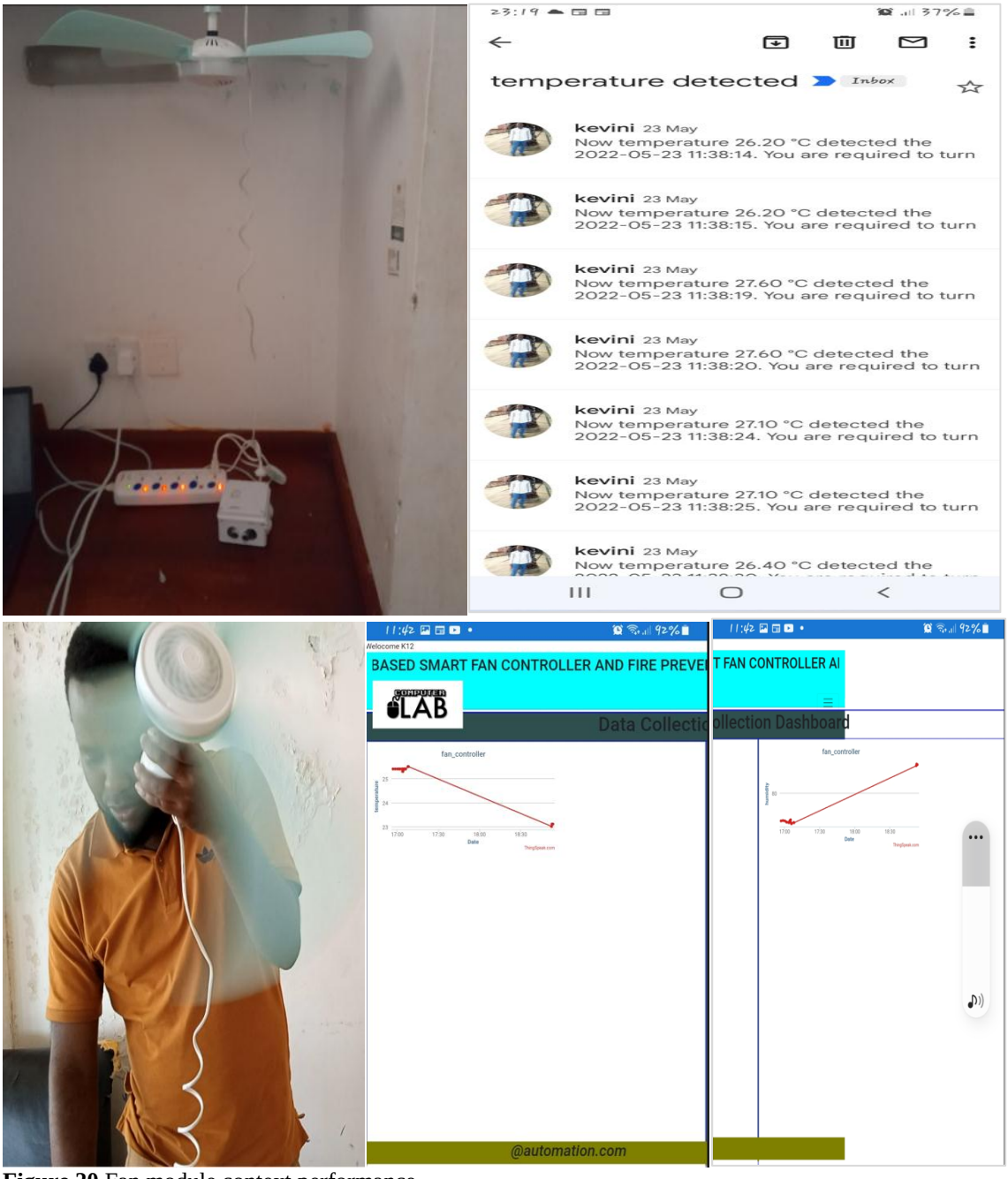
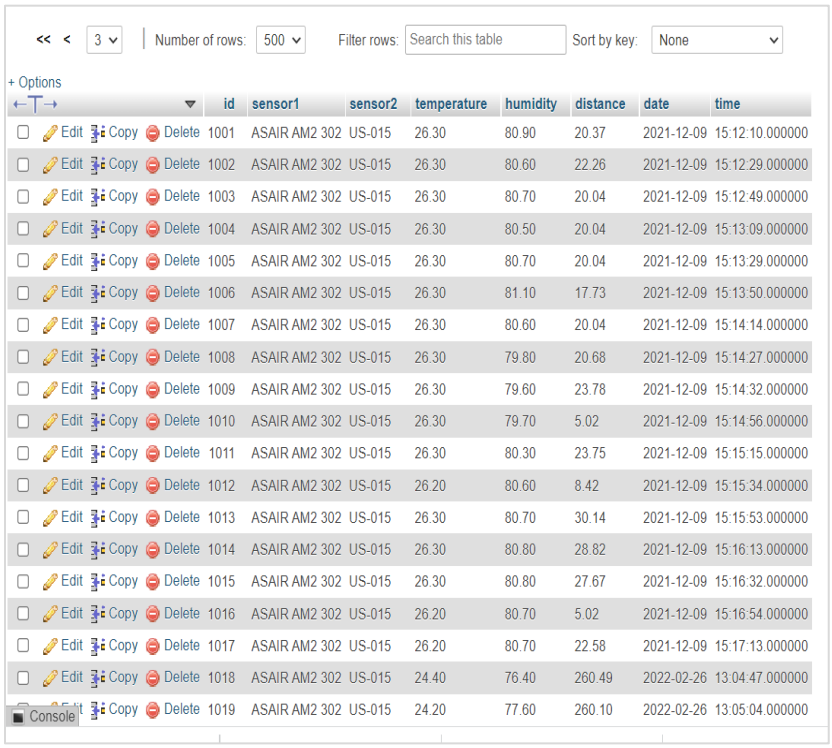


Figure 20 Fan module context performance



<< < 3 | Number of rows: 500 | Filter rows: Search this table | Sort by key: None

+ Options

	id	sensor1	sensor2	temperature	humidity	distance	date	time
Edit Copy Delete	1001	ASAIR AM2 302	US-015	26.30	80.90	20.37	2021-12-09	15:12:10.000000
Edit Copy Delete	1002	ASAIR AM2 302	US-015	26.30	80.60	22.26	2021-12-09	15:12:29.000000
Edit Copy Delete	1003	ASAIR AM2 302	US-015	26.30	80.70	20.04	2021-12-09	15:12:49.000000
Edit Copy Delete	1004	ASAIR AM2 302	US-015	26.30	80.50	20.04	2021-12-09	15:13:09.000000
Edit Copy Delete	1005	ASAIR AM2 302	US-015	26.30	80.70	20.04	2021-12-09	15:13:29.000000
Edit Copy Delete	1006	ASAIR AM2 302	US-015	26.30	81.10	17.73	2021-12-09	15:13:50.000000
Edit Copy Delete	1007	ASAIR AM2 302	US-015	26.30	80.60	20.04	2021-12-09	15:14:14.000000
Edit Copy Delete	1008	ASAIR AM2 302	US-015	26.30	79.80	20.68	2021-12-09	15:14:27.000000
Edit Copy Delete	1009	ASAIR AM2 302	US-015	26.30	79.60	23.78	2021-12-09	15:14:32.000000
Edit Copy Delete	1010	ASAIR AM2 302	US-015	26.30	79.70	5.02	2021-12-09	15:14:56.000000
Edit Copy Delete	1011	ASAIR AM2 302	US-015	26.30	80.30	23.75	2021-12-09	15:15:15.000000
Edit Copy Delete	1012	ASAIR AM2 302	US-015	26.20	80.60	8.42	2021-12-09	15:15:34.000000
Edit Copy Delete	1013	ASAIR AM2 302	US-015	26.30	80.70	30.14	2021-12-09	15:15:53.000000
Edit Copy Delete	1014	ASAIR AM2 302	US-015	26.30	80.80	28.82	2021-12-09	15:16:13.000000
Edit Copy Delete	1015	ASAIR AM2 302	US-015	26.30	80.80	27.67	2021-12-09	15:16:32.000000
Edit Copy Delete	1016	ASAIR AM2 302	US-015	26.20	80.70	5.02	2021-12-09	15:16:54.000000
Edit Copy Delete	1017	ASAIR AM2 302	US-015	26.20	80.70	22.58	2021-12-09	15:17:13.000000
Edit Copy Delete	1018	ASAIR AM2 302	US-015	24.40	76.40	260.49	2022-02-26	13:04:47.000000
Edit Copy Delete	1019	ASAIR AM2 302	US-015	24.20	77.60	260.10	2022-02-26	13:05.04.000000

Console

Figure 21 Data recorded and inserted in the database from DHT22 and Ultrasonic sensor

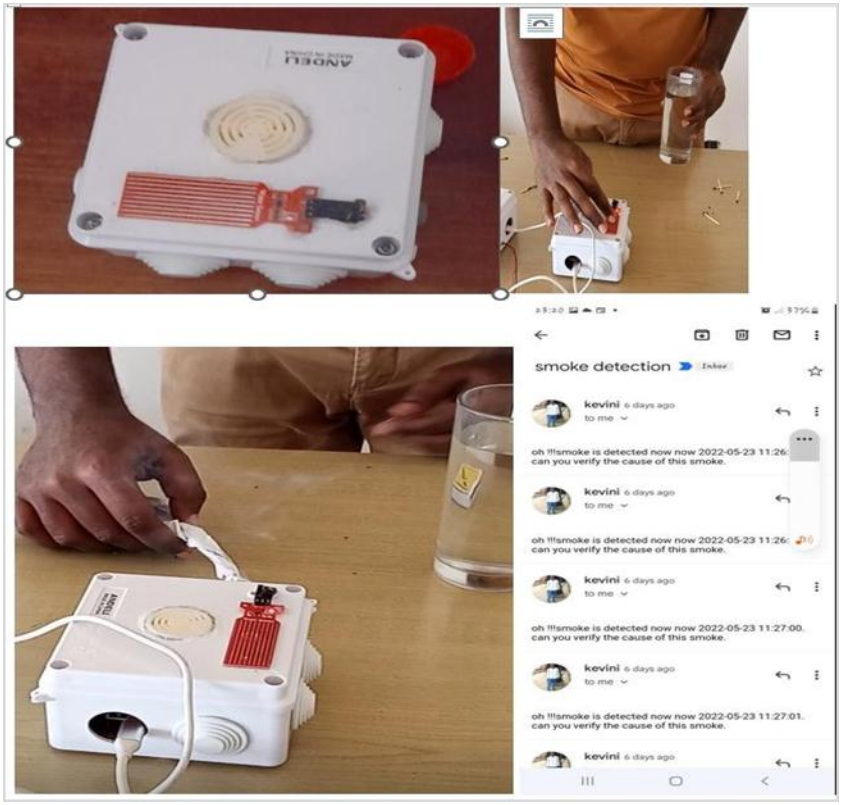
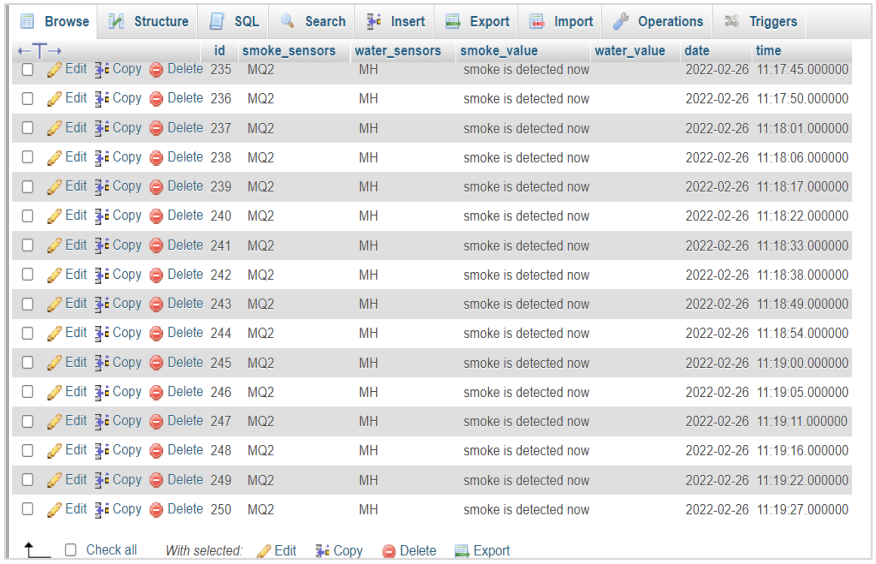


Figure 22 Smoke detection and water detection prototype



Browse | Structure | SQL | Search | Insert | Export | Import | Operations | Triggers

	id	smoke_sensors	water_sensors	smoke_value	water_value	date	time
Edit Copy Delete	235	MQ2	MH	smoke is detected now		2022-02-26	11:17:45.000000
Edit Copy Delete	236	MQ2	MH	smoke is detected now		2022-02-26	11:17:50.000000
Edit Copy Delete	237	MQ2	MH	smoke is detected now		2022-02-26	11:18:01.000000
Edit Copy Delete	238	MQ2	MH	smoke is detected now		2022-02-26	11:18:06.000000
Edit Copy Delete	239	MQ2	MH	smoke is detected now		2022-02-26	11:18:17.000000
Edit Copy Delete	240	MQ2	MH	smoke is detected now		2022-02-26	11:18:22.000000
Edit Copy Delete	241	MQ2	MH	smoke is detected now		2022-02-26	11:18:33.000000
Edit Copy Delete	242	MQ2	MH	smoke is detected now		2022-02-26	11:18:38.000000
Edit Copy Delete	243	MQ2	MH	smoke is detected now		2022-02-26	11:18:49.000000
Edit Copy Delete	244	MQ2	MH	smoke is detected now		2022-02-26	11:18:54.000000
Edit Copy Delete	245	MQ2	MH	smoke is detected now		2022-02-26	11:19:00.000000
Edit Copy Delete	246	MQ2	MH	smoke is detected now		2022-02-26	11:19:05.000000
Edit Copy Delete	247	MQ2	MH	smoke is detected now		2022-02-26	11:19:11.000000
Edit Copy Delete	248	MQ2	MH	smoke is detected now		2022-02-26	11:19:16.000000
Edit Copy Delete	249	MQ2	MH	smoke is detected now		2022-02-26	11:19:22.000000
Edit Copy Delete	250	MQ2	MH	smoke is detected now		2022-02-26	11:19:27.000000

Check all With selected: Edit Copy Delete Export

Figure 23 Insertion of smoke and water detections in database

4.2.2.3Fire detection and prevention module

When a fire occurs in the computer laboratory, there is a lot of loss to business continuity, either as a result of equipment loss, data loss, and loss of lives. The IoT based fire prevention in computer laboratory system (*Figure 24*) was developed to detect the presence of fire in the computer laboratory and perform necessary steps. To make this system effective, the flame sensor was used to detect fire in the computer laboratory and an actuator (buzzer) was used to trigger an alarm each time fire is detected as presented in equation 3. Then, once a fire is detected, a message is sent which shows that fire is detected, the information is sent to the database figure and an email is sent to the users. The email sent to the users (*Figure 24*) comes from the data stored in the database (*Figure 25*) and the action of triggering the fire extinguisher is automatically taken in real time as at the same information is stored in the database Equation 3.

If flame_value > 0{buzzer triggered on
Email sent to all users

Fire extinguisher triggered on}(3)

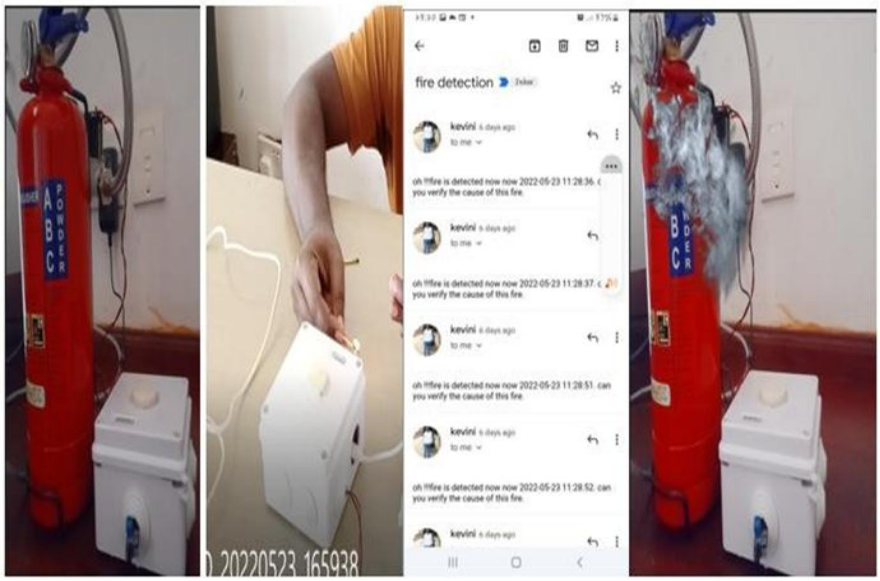
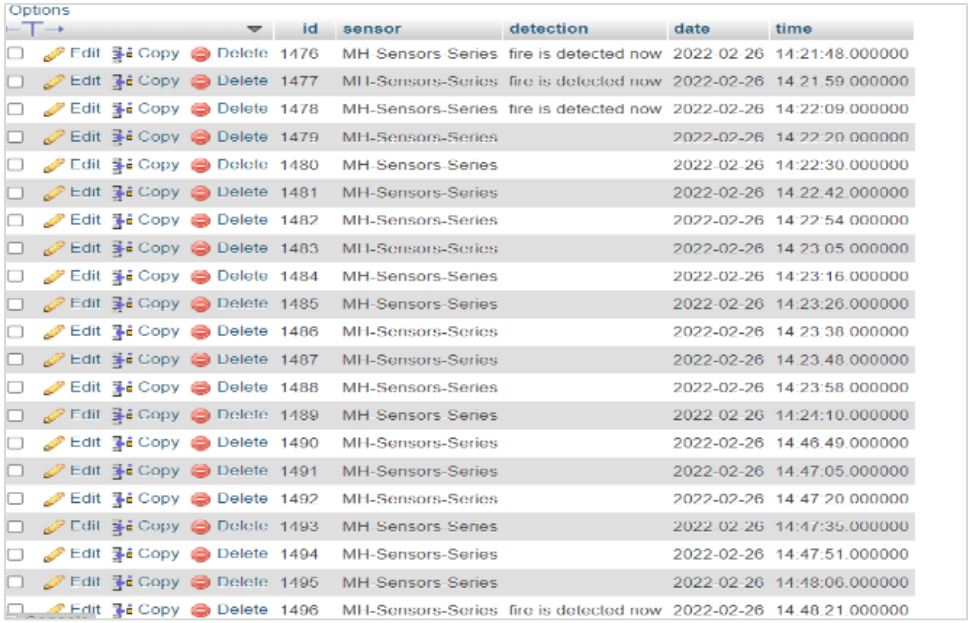


Figure 24 Fire detection and prevention prototype



Options

	id	sensor	detection	date	time
Edit Copy Delete	1476	MH Sensors Series	fire is detected now	2022 02 26	14:21:48.000000
Edit Copy Delete	1477	MH-Sensors-Series	fire is detected now	2022-02-26	14 21 59 000000
Edit Copy Delete	1478	MH-Sensors-Series	fire is detected now	2022-02-26	14:22:09.000000
Edit Copy Delete	1479	MH-Sensors-Series		2022-02-26	14 22 20 000000
Edit Copy Delete	1480	MH Sensors Series		2022 02 26	14:22:30.000000
Edit Copy Delete	1481	MH-Sensors-Series		2022-02-26	14 22 42 000000
Edit Copy Delete	1482	MH-Sensors-Series		2022-02-26	14 22 54 000000
Edit Copy Delete	1483	MH-Sensors-Series		2022-02-26	14 23 05 000000
Edit Copy Delete	1484	MH-Sensors-Series		2022-02-26	14:23:16.000000
Edit Copy Delete	1485	MH-Sensors-Series		2022-02-26	14:23:26.000000
Edit Copy Delete	1486	MH-Sensors-Series		2022-02-26	14 23 38 000000
Edit Copy Delete	1487	MH-Sensors-Series		2022-02-26	14 23 48 000000
Edit Copy Delete	1488	MH-Sensors-Series		2022-02-26	14 23 58 000000
Edit Copy Delete	1489	MH Sensors Series		2022 02 26	14:24:10.000000
Edit Copy Delete	1490	MH-Sensors-Series		2022-02-26	14 46 49 000000
Edit Copy Delete	1491	MH-Sensors-Series		2022-02-26	14:47:05.000000
Edit Copy Delete	1492	MH-Sensors-Series		2022-02-26	14 47 20 000000
Edit Copy Delete	1493	MH Sensors Series		2022 02 26	14:47:35.000000
Edit Copy Delete	1494	MH-Sensors-Series		2022-02-26	14:47:51.000000
Edit Copy Delete	1495	MH Sensors Series		2022 02 26	14:48:06.000000
Edit Copy Delete	1496	MH-Sensors-Series	fire is detected now	2022-02-26	14 48 21 000000

Figure 25 Insertion of data from fire detection

5. Conclusion and future work

This developed system describes the analysis and the results from the research carried out in computer rooms of East Africa Community headquarters in Arusha city and two computer laboratories of two secondary schools north of Bujumbura in Burundi. The developed IoT based smart fan controller and fire prevention in computer laboratory are to warn and trigger action of prevention for the user of the computer laboratory in case there is the detection of fire, smoke, water, and high temperature. The system has different modules such as user registration and user authentication. To access different functions of the system, the user must be registered first. The developed system presents different actions of automatic prevention such as:

- When the water sensor senses water leakage reaching near the power supply, an alarm is triggered automatically, and an email is sent to all users.
- When the water sensor senses water leakage reaching near the power supply, an alarm is triggered automatically, and an email is sent to all users.
- When smoke is detected, an alarm is triggered automatically, and an email is sent to all users.
- When there is a high temperature in the computer room, the fan is turned on automatically but only when there is the presence of a person.

A complete list of abbreviations is shown in *Appendix I.*

Acknowledgment

We would like to thank the Center of Excellence ICT in East Africa (CENIT@EA), the Nelson Mandela African Institution for Science and Technology, and the industry supervisor Dr. Kamugisha Kazaura.

Conflicts of interest

The authors have no conflicts of interest to declare.

Author's contribution statements

Kevin Iriho: Data collection, analysis, and interpretation of results, paper writing design, and conception of prototypes, design and conception of web and mobile applications. **Neema Mduma:** Supervision, Investigation on challenges, Writing – review and editing. **Dina Machuve:** Supervision, Investigation on challenges, Writing – review and editing.

References

[1] Roy PP, Kumar P, Chang V. A hybrid classifier combination for home automation using EEG signals. Neural Computing and Applications. 2020; 32(20):16135-47.

[2] Kshirsagar S, Sachdev S, Singh N, Tiwari A, Sahu S. IoT enabled gesture-controlled home automation for disabled and elderly. In fourth international conference on computing methodologies and communication 2020 (pp. 821-6). IEEE.

[3] Ricquebourg V, Menga D, Durand D, Marhic B, Delahoche L, Loge C. The smart home concept: our immediate future. In 1st IEEE international conference on e-learning in industrial electronics 2006 (pp. 23-8). IEEE.

[4] Suesaowaluk P. Home automation system based mobile application. In 2nd world symposium on artificial intelligence 2020 (pp. 97-102). IEEE.
[5] Alani S, Mahmood SN, Attaallah SZ, Mhmood HS, Khudhur ZA, Dhannoon AA. IoT based implemented comparison analysis of two well-known network platforms for smart home automation. International Journal of Electrical and Computer Engineering. 2021; 11(1):442-50.
[6] Garg R, Gupta S. A review on internet of thing for home automation. International Journal of Engineering Research & Technology. 2020; 8(10):80-3.
[7] Arthanat S, Chang H, Wilcox J. Determinants of information communication and smart home automation technology adoption for aging-in-place. Journal of Enabling Technologies. 2020; 14(2):73-86.
[8] Abdulraheem AS, Salih AA, Abdulla AI, Sadeeq MA, Salim NO, Abdullah H, et al. Home automation system based on IoT. Technology Reports of Kansai University. 2020; 62(5):2453-64.
[9] Islam R, Rahman MW, Rubaiat R, Hasan MM, Reza MM, Rahman MM. LoRa and server-based home automation using the internet of things (IoT). Journal of King Saud University-Computer and Information Sciences. 2022; 34(6):3703-12.
[10] Jaihar J, Lingayat N, Vijaybhai PS, Venkatesh G, Upla KP. Smart home automation using machine learning algorithms. In international conference for emerging technology 2020 (pp. 1-4). IEEE.
[11] Majeed R, Abdullah NA, Ashraf I, Zikria YB, Mushtaq MF, Umer M. An intelligent, secure, and smart home automation system. Scientific Programming. 2020.
[12] Rashid H, Ahmed IU, Ullah A, Newaz MF, Robin MS, Reza ST. Multiple sensors based fire extinguisher robot based on DTMF, bluetooth and GSM technology with multiple mode of operation. In international workshop on computational intelligence 2016 (pp. 41-6). IEEE.
[13] Hamidovic H, CIA II. Fire protection of computer rooms-legal obligations and best practices. ISACA Journal. 2014; 4:1-3.
[14] Johnson PF. Fire detection in computer facilities: 25 years on. Fire Technology. 2010; 46(4):803-20.
[15] Dhumatkar A, Bhiogade S, Rajpal S, Renge D, Kale P. Automatic fire fighting robot. International Journal of Recent Research in Mathematics Computer Science and Information Technology. 2015; 2(1):42-6.
[16] Jensen G, Nygaard S. Fire prevention requirements for ICT rooms, best practice document. UNINETT Led Working Group on Physical Infrastructure. 2013.
[17] Kuznetsov G, Kopylov N, Sushkina E, Zhdanova A. Adaptation of fire-fighting systems to localization of fires in the premises. Energies. 2022; 15(2):1-23.
[18] Jain S, Ranjan A, Fatima M. Performance evaluation of sonic fire fighting system. In 7th international conference on advanced computing and communication systems 2021 (pp. 1510-4). IEEE.
[19] Li X, Chow KH, Zhu Y, Lin Y. Evaluating the impacts of high-temperature outdoor working environments on construction labor productivity in China: a case study of rebar workers. Building and Environment. 2016; 95:42-52.
[20] Dzulkefli NN, Abdullah R, Jaafar AN, Shafie R, Yassin IM, Rizman ZI, et al. Design an automatic temperature control system based on PIC controller for smart ventilation fan. Journal of Fundamental and Applied Sciences. 2017; 9(3S):779-90.
[21] Dioses JJL. AndroiDuino-Fan: a speech recognition fan-speed control system utilizing filipino voice commands. International Journal of Advanced Trends in Computer Science and Engineering. 2020; 9(3).
[22] Syed IQ. Architectural pattern for implementing data quality monitoring and reporting framework. International Journal of Computer Trends and Technology. 2020; 68(2):46-53.
[23] Danbatta SJ, Varol A. Comparison of Zigbee, Z-wave, Wi-Fi, and bluetooth wireless technologies used in home automation. In 7th international symposium on digital forensics and security 2019 (pp. 1-5). IEEE.
[24] Ivanova N, Gugleva V, Dobreva M, Pehlivanov I, Stefanov S, Andonova V. Silver nanoparticles as multi-functional drug delivery systems. London, UK: Intechopen; 2018.
[25] Hadi NA, Hasan MH, Hashim NM, Salleh A, Salam AA, Hasan Z. Automatic smart kitchen system using microcontroller". International Journal for Advance Research in Engineering and Technology. 2015; 3(VI):30-4.
[26] Hsu WL, Jhuang JY, Huang CS, Liang CK, Shiau YC. Application of internet of things in a kitchen fire prevention system. Applied Sciences. 2019; 9(17):1-22.
[27] Bind A, Ashtankar K, Chahare M. An IOT based smart fan module. IJIRT. 2020; 6(11):95-8.
[28] PD GokuL, VS Arun, Mani S. IOT based energy conserving smart fan. International Research Journal of Modernization in Engineering Technology and Science. 2020; 2(9):1204-7.
[29] Onibonoje MO, Bokoro PN, Nwulu NI, Gbadamosi SL. An IoT-based approach to real-time conditioning and control in a server room. In international artificial intelligence and data processing symposium (IDAP) 2019 (pp. 1-6). IEEE.
[30] Widyaningrum VT, Pramudita YD. Automatic lamp and fan control based on microcontroller. In journal of physics: conference series 2018 (pp. 1-6). IOP Publishing.
[31] Khoa TA, Nhu LM, Son HH, Trong NM, Phuc CH, Phuong NT, et al. Designing efficient smart home management with IoT smart lighting: a case study. Wireless Communications and Mobile Computing. 2020.
[32] Alharthy ES, Alwahaibi SA, Al-malki RA. Secured smart door access using IoT. International Journal of Engineering Research & Technology. 2019; 7(4):1-3.
[33] Feng X, Liu F. Research on computer realization of building fire safety assessment. In journal of physics: conference series 2021 (p. 1-5). IOP Publishing.

[34] Sassani BA, Jamil N, Villapol M, Abbas MM, Tirumala SS. FireNot–an IoT based fire alerting system: design and implementation. Journal of Ambient Intelligence and Smart Environments. 2020; 12(6):475-89.
[35] Hariveena C, Anitha K, Ramesh P. IoT-based fire detection and prevention system. In IOP conference series: materials science and engineering 2020 (pp. 1-5). IOP Publishing.
[36] Alqourabah H, Muneer A, Fati SM. A smart fire detection system using IoT technology with automatic water sprinkler. International Journal of Electrical & Computer Engineering. 2021; 11(4):2994-3002.
[37] Carey JM. Prototyping: alternative systems development methodology. Information and Software Technology. 1990; 32(2):119-26.
[38] Horvath I. Theoretical framework for comprehensive abstract prototyping methodology. In international conference on engineering design, Denmark 2011 (pp. 15-9).
[39] Zant RF. Hands-on prototyping in system analysis and design. Issues in Information Systems. 2005; 6(1):10-4.
[40] Carter RA, Antón AI, Dagnino A, Williams L. Evolving beyond requirements creep: a risk-based evolutionary prototyping model. In proceedings fifth IEEE international symposium on requirements engineering 2001 (pp. 94-101). IEEE.
[41] Tavolato P, Vincena K. A prototyping methodology and its tool. In approaches to prototyping 1984 (pp. 434-46). Springer, Berlin, Heidelberg.
[42] De SCR, Redmiles D, Cheng LT, Millen D, Patterson J. How a good software practice thwarts collaboration: the multiple roles of APIs in software development. In proceedings of the 12th ACM SIGSOFT twelfth international symposium on foundations of software engineering 2004 (pp. 221-30).
[43] Wiegand J. Eclipse: a platform for integrating development tools. IBM Systems Journal. 2004; 43(2):371-83.
[44] Dhlamini J, Nhamu I, Kaihepa A. Intelligent risk management tools for software development. In proceedings of the 2009 annual conference of the southern african computer lecturers' association 2009 (pp. 33-40).
[45] Suresh DC, Najjar WA, Vahid F, Villarreal JR, Stitt G. Profiling tools for hardware/software partitioning of embedded applications. In proceedings of the 2003 ACM SIGPLAN conference on language, compiler, and tool for embedded systems 2003 (pp. 189-98).
[46] Fezari M, Al DA. Integrated development environment "IDE" for Arduino. WSN Applications. 2018:1-12.
[47] Mcneal R, Belkhayat M. Standard tools for hardware-in-the-loop (HIL) modeling and simulation. In electric ship technologies symposium 2007 (pp. 130-7). IEEE.

Kevin Iriho was born at Rugazi commune, Bubanza Province of Burundi. He earned a Master's degree in Embedded and Mobile Systems, specializing in Embedded Systems at the Nelson Mandela African Institution of Science and Technology. He has a background in network engineering obtained at Lake Tanganyika University. His interest lies in Information Communication Technology Security, Smart Agriculture, and Transport Automation.
Email: kevini@nm-aist.ac.tz

Neema Mduma is a lecturer at the Nelson Mandela African Institution of Science and Technology (NM- AIST) in Tanzania. She got her PhD and MSc degrees in Information, Communication Sciences, and Engineering from NM-AIST in 2020 and 2016 respectively. During her PhD, she developed a machine learning model called BakiShule which aimed at preventing students from dropping out of school. Neema's efforts toward women in science have been recognized through an award from L'Oréal UNESCO in 2020. Her research interests are Artificial Intelligence, Machine Learning, and Data Science.
Email: neema.mduma@nm-aist.ac.tz

Dina Machuve is a Senior Lecturer and Researcher at the Nelson Mandela African Institution of Science and Technology (NM-AIST) in Tanzania. She holds a PhD in Information, Communication Science, and Engineering from NM-AIST (2016), an MSc in Electrical Engineering from Tennessee Technological University, (2008), and a BSc in Electrical Engineering from the University of Dar Es Salaam (2001). Her research interests are Data Science and Agriculture Informatics in schools.
Email: dina.machuve@nm-aist.ac.tz

Appendix I

S. No.	Abbreviations	Description
1	API	Application for Programming Interface
2	App	Application
3	CENIT@EA	Centre of Excellence for ICT in East Africa
4	DHT	Digital Temperature and Humidity
5	GPS	Global Positioning System
6	HTTP	Hypertext Transfer Protocol
7	ICT	Information and Communications Technology
8	IDE	Integrated Development Environment
9	IoT	Internet of Things
10	LPG	Liquefied Petroleum Gas
11	PCB	Printed Circuit Board
12	PHP	Hypertext Processor
13	ppm	Part Per Million
14	SH	Smart Home