Interactive IoT-Based Speech-Controlled Home Automation System

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***Abstract*- Globally, the use of modern technology for home automation alongside its benefits continues to grow. Although several home automation systems have been implemented, there is still a huge need for efficient approach to assist home owners to perform smart home automation that will ensure convenience, good control, safety and savings for them. This paper presents the development of an interactive Internet of Things (IoT) based Speech-Controlled Home Automation system using Google Assistant, which is an interactive home automation, or commonly known as smart house system. The proposed system will enable users to control their home electrical appliances remotely with voice-based speech recognition through a mobile devices using a Google infrastructure known as Google Assistant. Experimental studies are conducted and different results are achieved on the proposed voice controlled home automation system using different scenarios such as noisy versus quiet environments, empty versus fully furnished room, distance and room sizes. The maximum performance of 100% accuracy rates are achieved in some of the different scenarios.**

Keywords *— Home Automation, Google Assistant, Internet of Things (IoT), voice/speech control, mobile device*

I. INTRODUCTION

As the uses of technology in different human endeavors continue to be applauded because their contribution to improved efficiency, the acceptability of home automation continues to increase [1,2]. With technology being so enhanced and smart services being of popular use, people have become more comfortable and their expectations have changed [3]. Lately, humans became more interested in the use of technology using touch of one button or even using speech via their smart phone or smart devices to ensure convenience, good control, safety and savings [4, 5]. This can however be connected to the fact that we live in an era dominated by modern technology, more precisely hardware automation. Automation is known as the technology by which a process or procedure is performed with minimal human assistance, while home automation in its simplest definition is a building automation for a home [6]. The system can be used to control most of the home electronics with examples such as the lighting, room temperature (heating ventilation and air conditioning), entertainment systems and security features such as access control and alarm systems [7]. Although the electricity usage cost in the homes can be reduced by turning off the home appliances manually when not used, safety, convenience and ease of control might sometimes be difficult for people such as the elderly and disabled. The use of home automation system for the control of home electrical appliances such as lighting, heating, ventilation, air conditioning and security provides financial savings, safety, convenience and ease of control.

Wireless Fidelity (Wi-Fi) has found good application in the monitoring and controlling of devices and appliances remotely. The use of Wi-Fi is generally for remote monitoring and control. Home devices, when remotely monitored and controlled via Internet is a part of Internet of things (IoT). IoT in its simplest form is when different devices such as smart phones and computers are connected over the internet with other systems and devices in order to exchange data. Systems that are considered to be modern generally consists of switches and sensors connected to a central hub called a gateway from which the system is controlled with a user interface that is interacted either with a mobile phone software, tablet, computers or a web interface, often but not always via internet cloud services. Google assistance is an artificial intelligence (AI) powered virtual assistance and can be used for a number of functionalities such as home automation, searching the internet and the scheduling of events and alarms through texts via alphanumeric keyboard or keypad and natural voice or speech via device microphone to engage in two-way conversations [8]. As machines or rather technology becomes more "intelligent", they are able to perform more and more tasks that were previously not possible without the interaction of a human, thus opening up many possibilities. This paper presents the development of an interactive Internet of Things (IoT) based Speech-Controlled Home Automation system using Google assistant.

The remaining parts of this paper are as follow. Section II presents a survey of the related works to the study conducted in this paper. Section III presents the methodology while Section IV discusses the system developed and experiment considering the users' responses on different test scenarios and the discussions of findings. The conclusion of the study is presented in Section V.

II. LITERATURE SURVEY

Several home automation systems have been proposed in the literature and they systems can be cable-based or wireless-based. A cable-based home automation system using Arduino and Raspberry-pi are presented in [9]. According to [10], cable system could be problematic if not well-designed and planned with proper installation during the physical construction of the buildings where they are installed. While considering the buildings that are already in existence before the installation of the systems, there could be significant increase in the cost of implementation. Wireless-based systems, such as Bluetooth, Wi-Fi and IOT, on the other hand can be of great use for home automation [11]. With the advancement of wireless technologies such as Wi-Fi and cloud networks in the recent years, their use every day and everywhere continues to increase among people [12].

Patchava et al. [13] utilized Raspberry-pi connected camera and motion sensors for a home surveillance and automation system using a web user interface. The smart house security is however the main interest in [13]. Srinath et al [14] provided insightful fundamental details regarding the implementation and core usage of Google Assistant in the modern home automation industry.

An intelligent home navigation system (IHNS) was proposed facilitate the movement of both elderly and disabled in [15]. The system proposed utilized an automated voice-based home navigation system that comprises of a wheelchair, navigation module and voice module. It basically made use of a speech recognition module, a line follower module for navigation and it had predefined voice commands for different rooms and predefined routes used to navigate to those rooms. A collision avoidance system was also incorporated into the system.

An intelligent access control system was developed using voice recognition chip in [16]. The supporting software used are modules for the voice training and recognition.

III. System Overview

This section describes the overview of the system proposed in this paper. The methodology, system architecture, a detailed system design describing the different components used in the development of the system and the functional flow are also presented in this section. The block diagram showing the basic functioning of the proposed interactive Internet of Things (IoT) based Speech-Controlled Home Automation system using Google assistant.

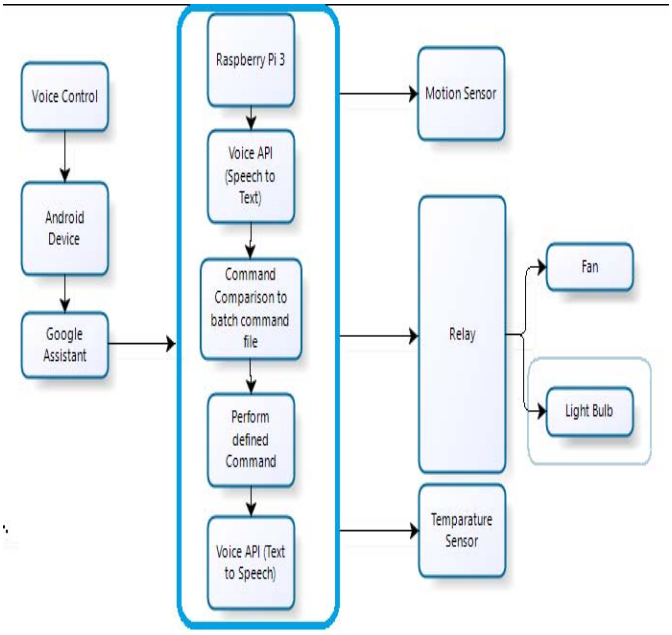

Fig. 1: Detailed System Design

A. Detailed System Design

Different components are used in the design of the system proposed in this paper. The components include Raspberry Pi, Google Assistant and Logitech Webcam C170

Raspberry Pi

Raspberry Pi electronic board was used and it was selected due to the fact of the great processing capabilities it possesses that corresponds to that of a personal computer. Raspberry Pi has found application in the building of several electronic devices such as tablets, laptops, phones, robots and smart mirrors. The board supports wireless internet out of the box, containing built-in Wi-Fi and Bluetooth and these functionalities are very handy and as a result enable direct connectivity to different internet cloud infrastructures such as Google cloud infrastructure over the internet. It as well allows wireless audio streaming from the Pi into an external speaker. The board also contain 4 USB 2.0 ports used to connect a Webcam to capture video. The board used a Raspbian operating system which is solidly built on Linux platform, the board contain a CPU of the following capacity 1.2GHz quad-core 64 ARM cortex A53, memory of 1 GB LPDR2-900 SDRAM.

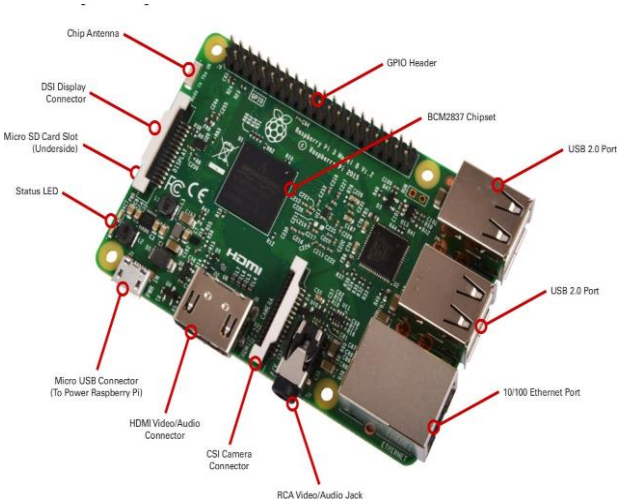

Fig. 2: Raspberry PI 3 Model B

Google Assistant

Google Assistant SDK provides the functionality of adding word detection, voice control, natural language understanding and Google's smarts to a device such as Raspberry Pi. The device accepts the input command (a spoken audio command), and then sends it to the Google Assistant. The received spoken response from the assistant in addition to the raw text utterance. Speech Recognition and Natural Language Processing, concept used by Google assistant was used. The use of speech recognition have grown over the years due to its usefulness and usability feature. Thanks to the popular smart voice-based products such as Amazon Echo and Google Home (Android Things). Google assistant consist of the capability to interphase the "Phases/sentences" as command into lesser single board computer such as Raspberry-Pi. The Google Assistant is installed on the Raspberry Pi using the python embedded Google Assistant SDK. The speech recognition is solidly performed on the Google big data infrastructure hosted on the Google cloud platform. The Google Assistant services come with following pre-built features:

1. Hand free activation – ability to activate a device by saying "Ok Google, or Hey Google".
2. Playback and the capturing of audio.
3. The management of conversation state.
4. The management of the timer and alarm.

The services can be deployed using different platforms apart from Python, such as Node.js, C++, Go, or Java which support gRPC (open source remote procedure call (RPC) framework). However, for the design, Python was chosen.

Logitech Webcam C170

The proposed system contains a USB Logitech webcam C170 that contain 720 pixels /30 frame rate, fixed focus, and a built-in microphone. The mentioned features smoothly allow the system to use the built-in microphone as a mechanism to accept audio requests from a user and furthermore the webcam is used to perform real-time video streaming.

Fig. 3: Logitech Webcam C170

B. System Architecture

A voice command is given by the user stating what the system should do. This is captured using the microphone of an android device. This is then converted to text by the Google voice application program interface (API). The converted text is then compared with the defined commands in the command configuration file to see if there are any match. If there is match, the bash command associated with voice command is then executed.

The proposed system utilizes the customization of Google assistant to remotely monitor and control home appliances. Google assistant python SDK is installed on Raspberry Pi and resulting in a real-time access to Google infrastructure such as Google API's and Google search engine.

In the process of Google Assistant command's execution, several script library are being called respectively on the Raspberry Pi to perform activities such motion control, electric appliance control and video stream. The scripts execution such turning on electric appliances such temperature, motion sensors, camera, and light bulbs are developed using Python and installed on the Raspberry Pi suite. The mobile application which is android is developed using Android Studio that uses JAVA as a programming language. Android studio will cater for the user interface and

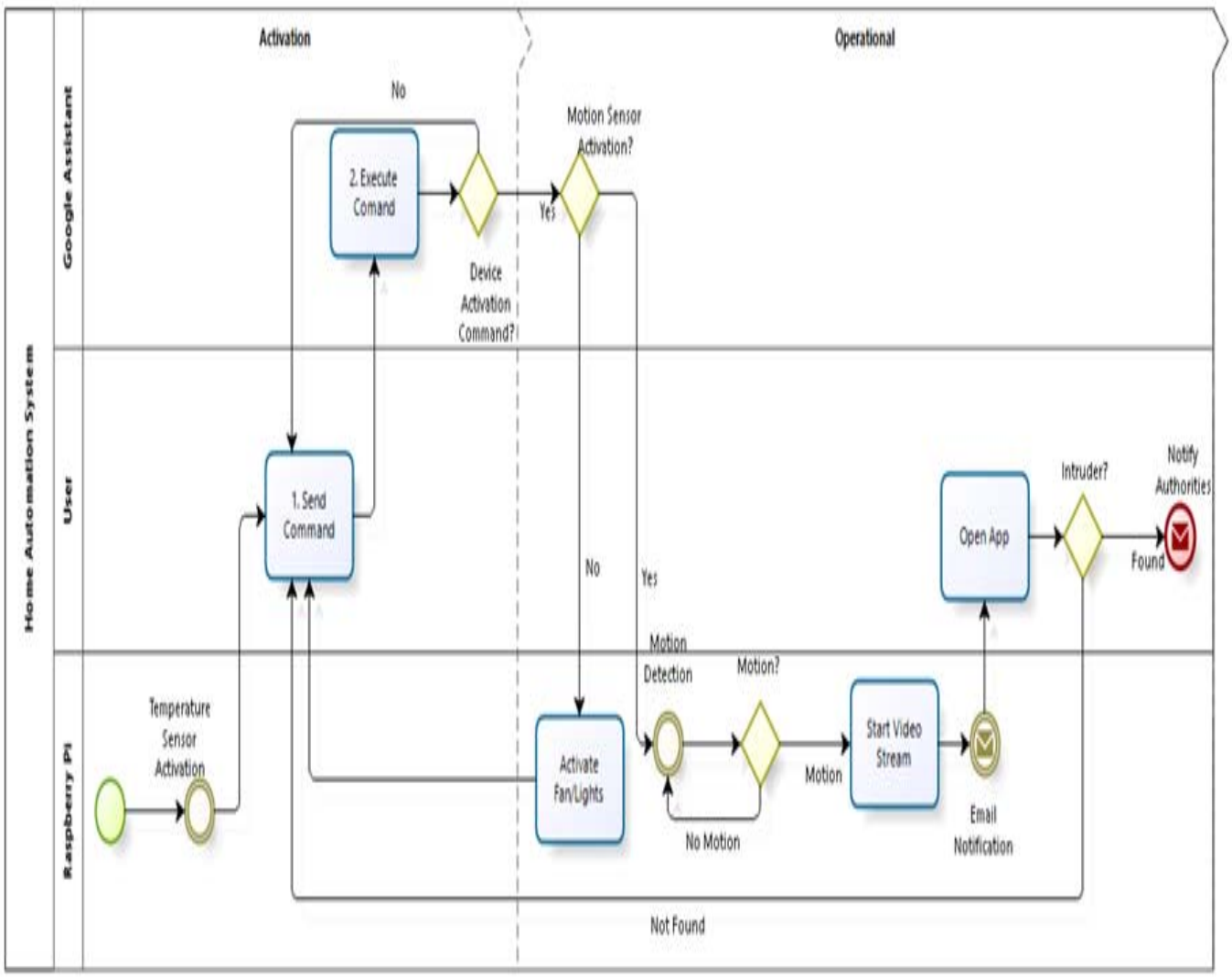

Fig. 4: Functional Flow of the Proposed System

The voice command will trigger home appliances such as bedroom light, sitting room light and outside light. The Google assistant acts as central control unit to ensure the activation and the deactivation of motion sensor. The motion sensor used for the detection of a moving person will automatically activate a live video streaming to the app and send an email notification of the captured photo with a timestamp. The hardware component includes a temperature sensor integrated with Liquid Crystal Display (LCD) for demonstration of changes in temperature readings within the room. Google assistant will provide a trigger value to the temperature sensor, based when the temperature sensor reaches the certain value, it then displays the results in automatically activating a fan on/off. The incoming voice command will be provided on the mobile's Google assistant, the android app provides the functionality for the user to view the video streaming and the incoming email/WhatsApp notification.

The combination of some methodologies are applied in this study. The functional flow of the proposed system is shown in Fig. 4 and Table 1 presents a detailed explanation of the different elements and their description.

TABLE I. TABLE EXPLAINING FUNCTIONAL FLOW

Element Name	Element Description
Temperature Sensor Activation	Temperature Sensor gets activated to obtain temperature readings to display
1. Send Command	Send command by Voice to Google Assistant
2.Execute Command	Command Execution
Device Activation Command?	Check if the command received is for the activation of a device
Motion Sensor Activation?	Check if the received command is a trigger to activate Motion Sensor
3 Activate Fan/Lights	Activate Fan if Fan Activation is received else turn Lights on
Motion Detection	Motion detector checks if there is any motion within the room
Motion?	Verify if there is motion detected
4. Start Video Stream	Start a recording a video
Email Notification	Notify the user that there is movement within the room
5. Open App	Open mobile App to view video feed and notifications
Intruder?	Verify if there is an intruder
Notify User	Call authorities for help

IV. SYSTEM DEVELOPMENT, EXPERIMENT & DISCUSSION

A. Developed software applications

The below shows where the user will have to create their profile/register so that they will have an account in order to use with the design system. User will populate all their details and select the register option

When trying to register using an email address that has already been registered on the app you will receive an error notifying you that that specific email address already exists (see Fig. 5and Fig. 6).

The next thing the user would see once they have successfully created their profile would be the login screen, a screen they will use when they need to access their account (see Fig. 7). In the instance where when you are trying to login and you have a space somewhere in your email address you will receive the below error (see Fig. 8).

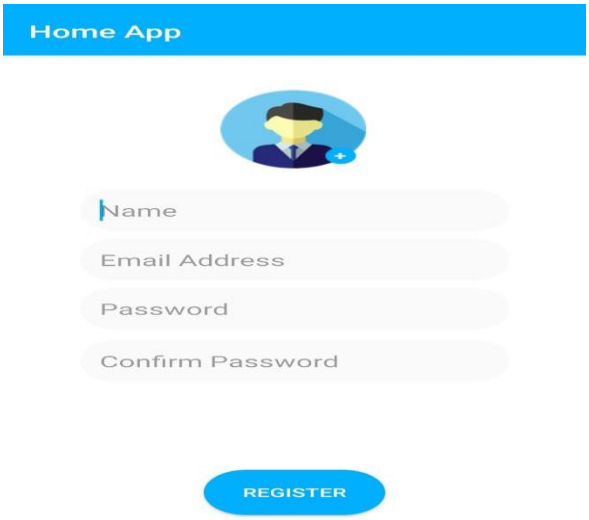

Fig 5: Registration screen

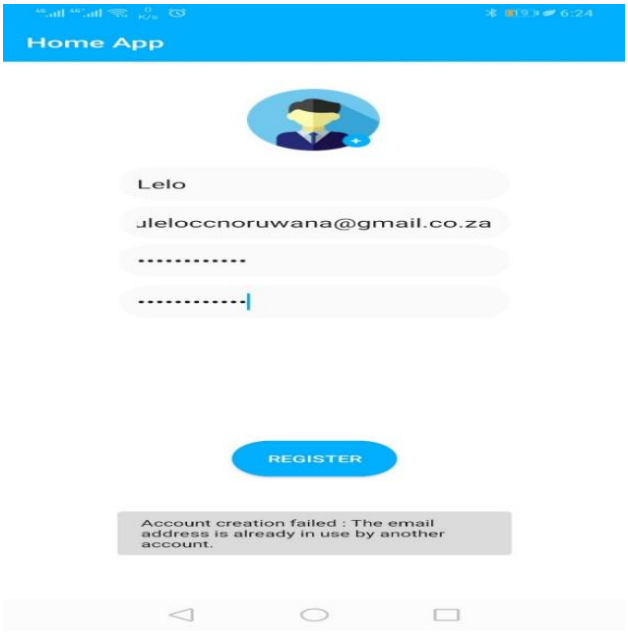

Fig 6: Unsuccessful Registration screen

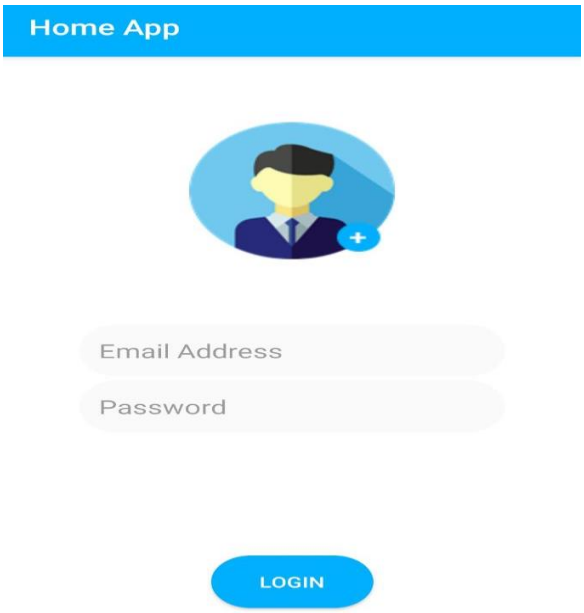

Fig.7: Login screen

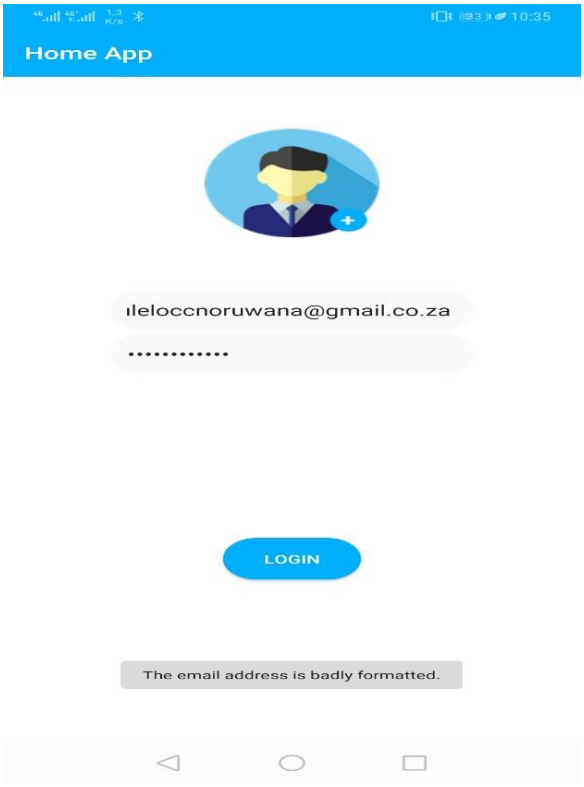

Fig. 8 : Unsuccessful Login screen

The video live streaming is achieved using a specific at the URL http:///192.168.43.175:8081/ and the live stream is real time. The prototype of the designed product is shown in Fig. 9 to Fig. 10.

Fig.9: Prototype of the system Designed

Fig.10: Prototype of the system Designed

B. Testing functionality

Fig. 11 shows the testing of the WhatsApp feature for the system when an intruder has been detected.

Fig.11: WhatsApp functionality

When the WhatsApp text comes through as shown in Fig. 11, and an email with the photo captured when the intruder was detected will also be received (see Fig. 12).

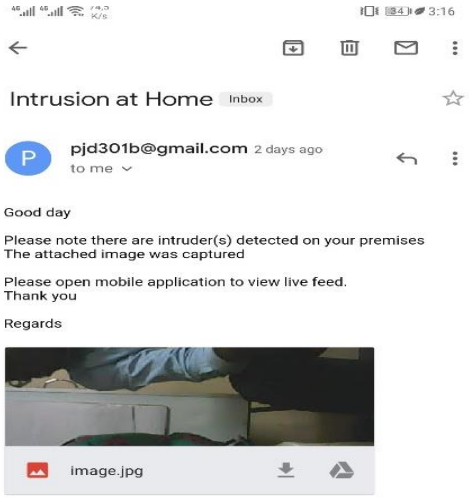

Fig.12: E-Mail functionality

The image that is attached on the mail will have a time-stamp, to further see what is happening you can just login to the app to check the live streaming (see Fig.13).

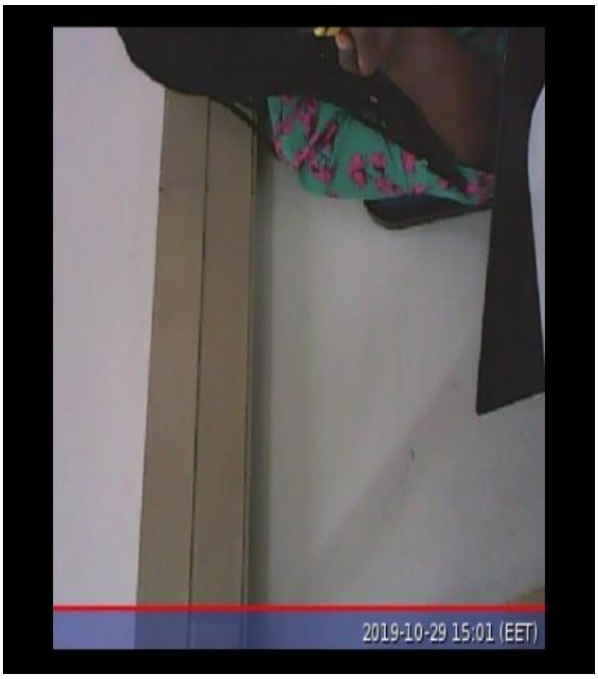

Fig.13: Time-Stamped Image functionality

C. Appliance Control

The proposed system is used to control two basic home appliances namely the light bulb and fan. It was also used to switch on the motion sensor needed for security purposes. The LCD is used to display the temperature readings recorded from the temperature sensors to determine the temperature of the room.

The bulb has only 3 states to be controlled, namely the

- On state
- Off state
- Switching on the lights for a certain time (depends on the user)

The fan 3 states to be controlled, namely:

- On state
- Off state
- Switching on the fan for a certain time (depends on the user)

This motion sensor has two states, namely to activate it if you want to arm the security feature and to deactivate when you are disarming. During the disarming state, people can come in and out as they please but you can still check what happens through the live streaming on your mobile application.

The commands applied when using Google Assistant are:

- To turn on/off lights and fan:

"Turn on/off kitchen lights", "turn on/off lights/fan"

- To activate/deactivate the motion sensor:

"Activate motion sensor"

- To turn on lights/fan for a varied time:

"Switch on fan/lights for 5secs"

Fig. 14 shows the LCD displaying the temperature and humidity in the room.

Fig.14: LCD Showing Temperature and Humidity

Table 2: Results Obtained from the Test Scenarios Conducted

TEST SCENARIOS	FACTORS	OUTPUT ACCURACY
Amplitude of voice	Normal Conversation	100%
	Whisper	20%
Distance from microphone	Distance <= 1 meter	80%
	Distance >= 2 meter	40%
Environment	Noisy	40%
	Quiet	80%
	Empty	20%
	Fully Furnished	100%
	Empty room with rug carpet and few furniture.	60%
	Empty room with tiles/wooden flooring with few furniture.	40%
Room Temperature	Warm/Hot	80%
	Cool/Cold	40%
Room Temperature and Humidity	Warm with high humidity	100%
	Warm with low humidity	60%
Room	With open windows (Windy)	60%
	With closed windows (Not windy)	40%
Rom Sizes	Small room	80%
	Large room	60%
Position of Sensor	Height < 8meter	20%
	Height > 8meter	80%
Fluency in English	Native language	100%
	Non-native language	60%

D. Results and Discussions

Different test scenarios of the proposed system are investigated in this study. Table 2 summaries all the results obtained from the test scenarios conducted Table d.

The proposed interactive Internet of Things (IoT) based Speech-Controlled Home Automation system using Google assistant is tested in different environments mainly a noisy and a quite one. Between the two environments this study show a better accuracy performance of 80% is achieved when used in a quite environment as compared to an accuracy rate of 40% achieved in a noisy environment.

Another test scenario is carried out in this study to check the performance of the proposed system is carried out in an room and a fully furnished room. An empty room normally has a lot of echoing involved because it is unable to convert echoes from the space. The reflected sound waves have nothing to absorb the energy and slow it down but in a more fully furnished room the level of the echo is better controlled since reverberation occurs less. The furniture in the room acts as absorbing material hence making the sound clearer and without an echo. A better accuracy performance of 100% is achieved when in a fully furnished room when compared to an accuracy rate of 20% achieved in an empty environment.
Another test scenario investigated is the distance in which the user held the smart device. In most cases an accuracy value of 80% is achieved if the device is less than or equal to one meter and an accuracy value of 40% is achieved if the device is greater than or equal to two meters. An accuracy value of 100% is achieved if the voice is of normal conversation and an accuracy value of 20% is achieved if the voice is a form of whisper.

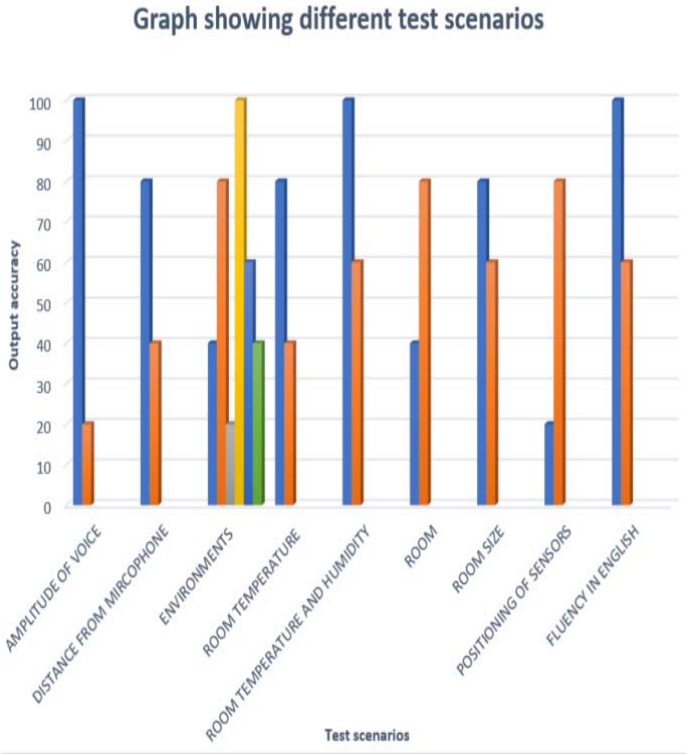

Fig.15: Results Obtained from the Test Scenarios Conducted

Generally, it has been said that sound is affected by temperature and humidity. An accuracy value of 80% is achieved if the room is warm and an accuracy value of 40% is achieved if the room is cold. An accuracy value of 100% is achieved if the room is warm with low humidity and an accuracy value of 60% is achieved if the room is warm with high humidity.
A scenario where the windows are opened and it is windy is also considered. This is to investigate the effect of wind on the performance of the proposed system. An accuracy value of 80% is achieved if the windows of the room is closed when it is windy and an accuracy value of 40% is achieved if the windows of the room is opened when it is windy.

When investigating the performance of motion sensor that is used for security purposes. An accuracy value of 80% is achieved if the positioning of the sensor has the height greater than 8 meters and an accuracy value of 20% is achieved if the positioning of the sensor has the height lesser than 8 meters.

V. Conclusion

An interactive Internet of Things (IoT) based Speech-Controlled Home Automation system using Google Assistant, has been implemented in this paper. The proposed system enabled users to control their home electrical appliances remotely with voice-based speech recognition through a mobile devices using a Google infrastructure known as Google Assistant. The proposed home automation system for the home electrical appliances such as lighting, heating, ventilation, air conditioning and security provides financial savings, safety, convenience and ease of control. Experimental studies conducted on the proposed voice controlled home automation system using different scenarios such as noisy versus quiet environments, empty versus fully furnished room, distance and room sizes achieved the maximum performance of 100% accuracy rates in some of the investigated scenarios. In the future, the use of commands based on South Africa native languages shall be investigated for voice controlled home automation system

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