Smart Home Apps Design for Users with Physical Disabilities

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Abstract

Conventional wall switches located in different parts of a house to control various electrical and electronic appliances are posing problems to home users with physical disabilities, senior citizens and bed-ridden patients. This project has identified several requirements and designed a suitable mobile apps to help this group of users. An Android prototype of this apps was developed together with Arduino node MCU ESP8266 hardware device which is equipped with Wi-Fi. The prototyping model is used as the methodology and the prototype has been tested with a group of randomly selected users. The users' feedback was obtained which indicate the pros and cons of the prototype. Overall users were satisfied with the design and functions of the mobile apps.

***Keywords*:** Smart Home, Home Automation, Disabled People, Senior Citizens, Bed-Ridden Patients, Arduino, Esp8266, Android, Firebase, Physical Disablities, Prototype, Mobile Apps.

1. Introduction

" … And help each other in righteousness and piety, and help not one another in sin and transgression and remain fearing Allah. Undoubtedly, the torment of Allah is severe"

(Quran 5: 2 (a part of))

From the given verse above, it is clear that Islam urges their followers to help each other. Moreover, helping people with disabilities, senior citizens and bedridden patients are more meaningful to them.

The advancement of advanced technology today has enabled people's life to become easier and has improved people's living standards which made conventional home controlling system is not that suitable anymore to be used. This is where the conventional home controlling system can be modified by turning it into a smart home controlling system which is a good idea. Smart home is a term refers to modern homes where electric/electronic home appliances connected to Internet can be automatically monitored and controlled remotely through smartphone with Internet connectivity from any location and at anytime using mobile app (Davies E. I., 2019). As conventional wall switches located in different parts of a house, manual operations needed to switch on or off switches to control various appliances which are impossible and troublesome to keep track of appliances running and control all electric/electronic appliance manually. This makes conventional home controlling system fail in providing people a flexibility to control electric/electronic appliance in home anywhere and anytime. In order to

make peoples‘ daily life become easier and convenient in controlling home system, a simple home controlling system application have been developed where it will be used by normal home user to control and operate on/off home device remotely through android smartphone.

This is because smartphone has become one of the top and popular devices which are important in people’s life being used to do many things. In the present-day smart home controlling system is getting popular and it is widely used in a lot of houses worldwide and becoming essential for the purpose of improving living condition. The android application will help home user to control on/off device in home remotely anywhere and anytime through smart phone. By having Internet connectivity, accessing and control on/off device in home easily can be controlled remotely using Android smartphone application which do not necessarily require user to be at home all the time to control the on/off device in home. Android smartphone will be used to control and operate all electric/ electronic home appliance through android application which will communicate with microcontroller Nodemcu /esp8266 module that will control and send information about the device over Internet connectivity to smartphone. This smart home controlling system application allows authorized home owners to remotely control connected devices at home through Internet connection. Then the android application will provide a graphical user interface (GUI) for accessing and controlling home devices through phone.

A study conducted by (Harris, 2010) found that people with disabilities would like to use advanced technology to improve their self-reliance in and out of the house, but high costs have deprived them from doing so. For instance, light activated with motion sensor switch would cost more than MYR500 per unit as at now. For bedridden people, which have difficulty to move, this type of control is useless.

2. Problem Statement

As conventional wall switches located in different parts of a house and need manual operations to switch on or off these switches to control various appliances can be quite difficult and troublesome.

Moreover, with the device located on different parts of house, it gets virtually impossible and troublesome to keep track of appliances that are running and to control all electric/electronic home appliance manually. This makes the conventional way of home controlling system fail to provide people more flexibility and convenience to control the electric/electronic appliance in home anywhere and anytime. Therefore, a simple, cheap and useful device and smart home apps should be designed to help this group of people.

Smart Home Controlling System Application was developed to provide a way to change manual control of on/off of home devices into a convenience and an efficient way by using an Android application. Home appliances can be controlled anywhere at any time if there is an Internet connection. It will also help the home owner to manage their electricity bill more efficiently.

3. Related Works

The existing of smart home controlling systems are remote controlling (Bluetooth (Asadullah & Ullah, 2017), radio frequency (Tian, Long, & Liao, 2018), infrared (H., T., R., T., & T., 2019)), mobile (SMS) (Awl & Karim, 2018), and web-browser (K & S, 2015).

Asadullah & Ullah, (2017) suggested system has more features than conservative home automation systems such as an ultrasonic sensor is used for water level detection and soil moisture sensor is use for automatic plant irrigation system.

Tian, Long, & Liao, (2018) designed a smart home system based on WSN. Firstly, by presents the architecture, node structure and characteristics of WSN. Then, defines the design process and method of the smart home system using Basic-RF wireless sensor network.

H., T., R., T., & T., (2019) offered a remote control that is used to control some appliances, thus achieving a simple low cost home automation system. IR remote enables remote control of device like TV, Air Conditioning, Washing machine, light, fan, so forth.

Awl & Karim, (2018) proposed a cost-efficient security, safety, and home automation system. The proposed system lets property security/protection by using PIR sensor, Arduino and GMS module. The system also delivers remotely controlling electrical devices at home through text messaging, smartphone app, and IR control.

K & S, (2015) present a Home Automation System (HAS) using Intel Galileo that employs the integration of cloud networking, wireless communication. HAS provides the user with remote control of various lights, fans, and appliances within their home and storing the data in the cloud. In addition, the system will automatically change on the basis of sensors' data.

Analysis on existing system which control home appliances through radio frequency or Bluetooth has problem which is speed or distance limitations. Problems faced by mobile application via SMS is to send controlling signals SMS, uses more time and cost of sending these signals to devices, and over that increases the cost of the system. Through web browser, it is not always possible to open a browser for accessing devices each time. The time efficiency is thus affected using web browser. Every time to check the device status or to send a signal, one must open it and if there are any changes in setting the thresholds of the devices it is more time and cost consuming.

4. Smart Home App Design

The significance of this study is to provide an easy and convenient methods in controlling electric/electronic home appliances compared to conventional way of home controlling system. This is where people can use this smart home controlling system application in the future to be able to control electric/electronic home appliances using smartphone which will ease mind and body as it only needs a few click from application and do not need to necessarily go to the switch manually anymore and if in case of forgetting to turn on/off the switch when not in the house. Beside that, by having the application it will help people to save a lot of time and give flexibility to operate home appliances as it can be controlled through the application at anytime and anywhere as long as has Internet connectivity. For example, air-conditioner can be switched on earlier at least 30 minutes before arriving at home during hot weather by clicking button from the application. Furthermore, by developing smart home controlling system with relatively low-cost design, simple interface and ease of installation made the android application can be used by normal user without the need of highly sophisticated IT knowledge to operate it in the future. Moreover, it also will help people to lower billing cost and enhance energy efficiency as electric/electronic home appliances can be controlled and operated more efficiently if having the application, that can make people's life easier.

The scope of this project is targeted on users with physical disabilities that use conventional home controlling system where all electric/electronic home appliances being control and operated manually. In order to develop a suitable and effective android application in the future that will help home user to have better way of home controlling system, the study is focusing on finding and identifying the suitable requirement tools that can be used for the development of smart home controlling system application. In addition, not all home users have knowledge on IT which the project will be focusing on to building a simple and easy smart home controlling system application which everyone can use easily to control home appliances remotely. Therefore, another scope is to be able developing a prototype for controlling home appliances wirelessly via android application run on android smartphone that provides the features of switch mode successfully. Besides that, it is important to make sure the process involve in develop the project follow the time schedule and well-planned to avoid cannot be finish on time within given time.

The limitation of project is when the application does not support smart phone with other platform such as iOS where application only will be developed to be used in android smartphone. Another constraint is when the project must be completed on given scheduled time. In addition, not all home user has knowledge on IT which the project will be focusing on to build a simple and easy smart home controlling system using android application which everyone can use, it is easily to control home appliances remotely and not develop the application that is difficult to operate. Therefore, another constraint is to be able develope a prototype for controlling home appliances wirelessly via android application run on android smartphone that provides the features of switch mode successfully. Android devices with lower API version may not supported the android application. Besides the Nodemcu only being used to create small project as it is not powerful as using computer and limited amount of device can only being tested as it only uses develop a prototype which resemble the real system. Home appliance such as small lamp and fan will be used for test purpose in developing and testing the application which to provide the functionality to control home device or appliance remotely like the real situation in home. Another limitation is to find suitable software and hardware that is going to be used to develop the prototype of smart home controlling system using android application and to make sure all the software and hardware that are going to be used can function and communicate with each other without having problem. The need of Internet connectivity for connecting android smart phone to home device or appliance also is one of the limitations of the project as without Internet connection, the application cannot function.

The rest of this sub-section will explain the overall design of the smart home. This includes smart home, controlling design, Android smartphone, Android app, Home Appliance, Remote, iOS, Wi-fi, Nodemcu v3, 4 Channel relays module and people with physical disability.

4.1 Smart Home

The term 'smart home' is used to describe a house that contains a communication network that connects different appliances and allows them to be remotely controlled, monitored and accessed, according to the Department of Trade and Industry. Smart devices connect to the Internet and many have smartphone apps allowing you to access and control them remotely over Wi-Fi. It’s becoming easier to connect an entire home too. Broadband is faster, more reliable and more affordable than ever before. The improved signal range of Wi-Fi routers means that a single router can offer wireless coverage across more rooms in our homes, allowing more devices to be connected. A home equipped with lighting, heating, and electronic devices which are connected to Internet can be controlled remotely by smartphone or computer

from any Internet-connected place in the world using a mobile or other networked device (Stevens, 2018). Figure 1 shows the smart home concept by (Techsore, 2002).

Figure 1: Smart Home Concept (Techsore, 2019)

4.2 Controlling Design

A control system is a system, which provides the desired response by controlling the output (Donald Christiansen, 2005) that manages, controls, commands, directs or regulates the behavior of other devices or systems to achieve desired results.

4.3 Android Smartphone

Android smartphone is a phone which has advanced computational abilities in it such as with a touch screen interface, multiple connectivity options, Internet browsing capabilities, support for video playback and a camera and operating system name Android running in them.

4.4 Android App

An Android application is a software application running on the Android platform because the Android platform is built for mobile devices on the Android OS. Android code is written using Java and it also uses the Java core libraries. In a other words Android app is an application which runs on mobile phones and makes life easy for human beings (Quora, 2019).

4.5 Home Appliance

An appliance, home devices or machines, usually electrical that are in home that does a particular job in home.

4.6 Remote

Denoting a device which can only be accessed by means of a network.

4.7 iOS

Apple's mobile operating system iOS runs the iPhone, iPad, and iPod Touch devices. Originally known as the iPhone OS, the name was changed with the introduction of the iPad. It uses a multi-touch interface in which simple gestures operate the device, such as swiping your finger across the screen to move to the next page or pinching your fingers to zoom out. There are more than 2 million iOS apps available for download in the Apple App Store, the most popular app store of any mobile device. Operating system used for mobile devices were manufactured by Apple Inc. (Nations, 2019).

4.8 Wi-fi

A facility allowing computers, smartphones, or other devices to connect to the Internet or communicate with one another wirlessly within a particular area.

4.9 Nodemcu v3

It is an open-source firmware and development kit that plays a vital role in designing own IoT product using a few Lua script lines. The module is mainly based on ESP8266 that is a low-cost Wi-Fi microchip incorporating both a full TCP/IP stack and microcontroller capability. It is introduced by manufacturer Espressif Systems – A manufacturer based in Shanghai, China. Arduino Modules and Microcontrollers have always been a great choice to incorporate automation into the relevant project. But these modules come with a little drawback as they don’t feature a built-in WiFi capability, subsequently, we need to add external WiFi protocol into these devices to make them compatible with the Internet channel. This is where NodeMCU V3 comes handy that incorporates a built-in WiFi support, giving an easy pathway to design IoT applications as per your technical requirements. (Aqeel, 2018).

4.10 4 Channel Relays Module

A relay is an electrically operated switch. Relays are used when we want to control many circuits by one signal. So, by using relay, we can turn on/off a circuit electrically. Relay is controlled by small current and can switch ON and OFF larger current. When no voltage applied to the coil, COM terminal will be connected to NC (normally closed) terminal. And when the voltage is applied to the coil, electromagnetic field produced that attract the Armature, and COM and NO (normally open) terminal gets connected, that allows a much larger current to flow (Aqeel, 2018).

4.11 People with Pysical Disability

Physical disability of people is a restriction on the physical functions of a person, mobility, agility or stamina. This include and not limited to senior citizens and bed-ridden patients that have limited ability to move around in a house.

5. Methodology

The smart home controlling system application is developed using prototyping model (Gehani, 1982). Prototyping model is an early sample implementation of system, model, or release of a product built to test a concept or process or to act as something to be replicated or learned from. By using prototyping methodology will help to evaluate an idea of developing a smart home controlling system using android application better as it allows to design a working prototype of the project. Besides, errors can be detected much quicker using available feedback leading to better solutions and better understanding of the project being developed and at the same time documentation and prototype can be done simultaneously. Figure 2 shows the methodology model that is used in this paper.

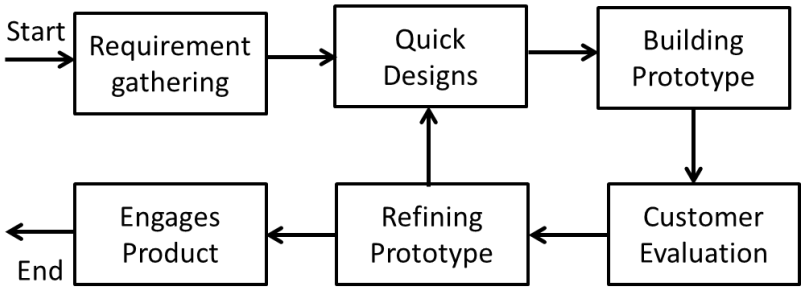

Figure 2: Methodology Model

The steps carried out in the prototyping model are:

5.1 Requirements gathering and analysis

Requirements analysis and requirements of project are defined in details. Brainstorming, search and reading articles and research papers from the Internet and discussion have been done in order to gather requirements of the project and doing analysis on requirements needed for the project. Objectives of smart home controlling system application will be identified first to know the purpose of developing the project and to ensure that the project do not deviate and is able to achieve the objectives beside providing solutions to the problems and why the project is being developed. Then, software and hardware required for development of project were identified so that the project prototype development can begin and all hardware and software that will be used are compatible, which is important to develop the project that will satisfy the needs of user. Hardware involved: Nodemcu v3, solderless breadboard, jumper cable, relay module, power supply module, jumper wire, lamp, 5V brushless DC fan, usb cable, android and smart phone. For software, Arduino ide 1.8.9, library for Nodemcu and firebase, MIT app inventor2 software were needed to develop the application to control home system and firebase will be used to store data for application.

5.2 Quick design

After the requirements are known, preliminary design or quick design for the project is created to give an idea on how the project will look like to helps start the process of developing prototype. At this process the design is not done in details which only includee important aspects that need to be used in the project for only the draft design. Besides, online software like fritzing will be used to help in design layout of circuit.

Figure 3 and Figure 4 show the network connectivity design and hardware connectivity design using fritzing, respectively. It is important to produce the design of the prototype before the actual prototype has been developed.

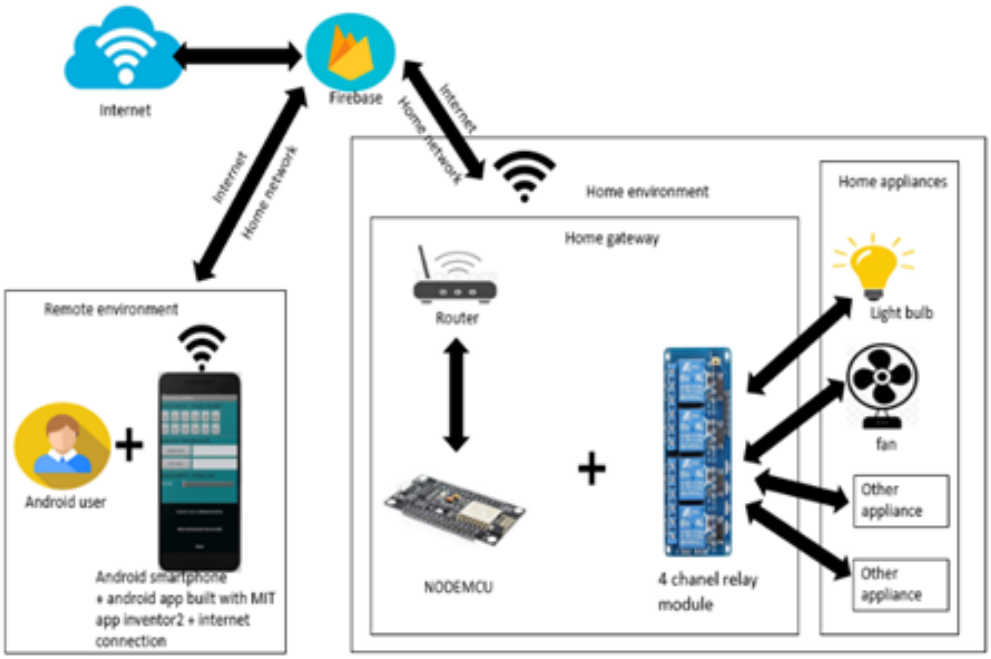

Figure 3: Network Connectivity Design

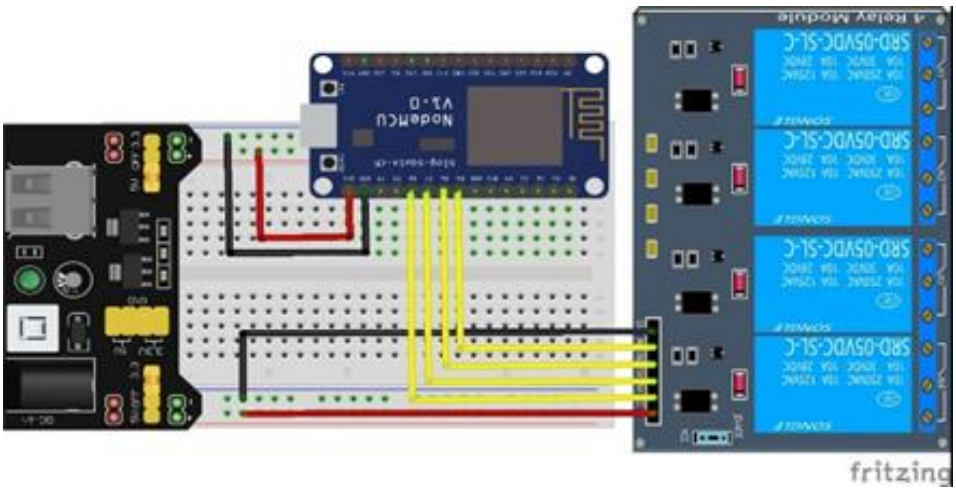

Figure 4: Hardware Connectivity Design Using Fritzing

5.3 Build prototype

Information gathered and quick design that has been created is then modified to build the initial prototype, which represents the working model of the project.

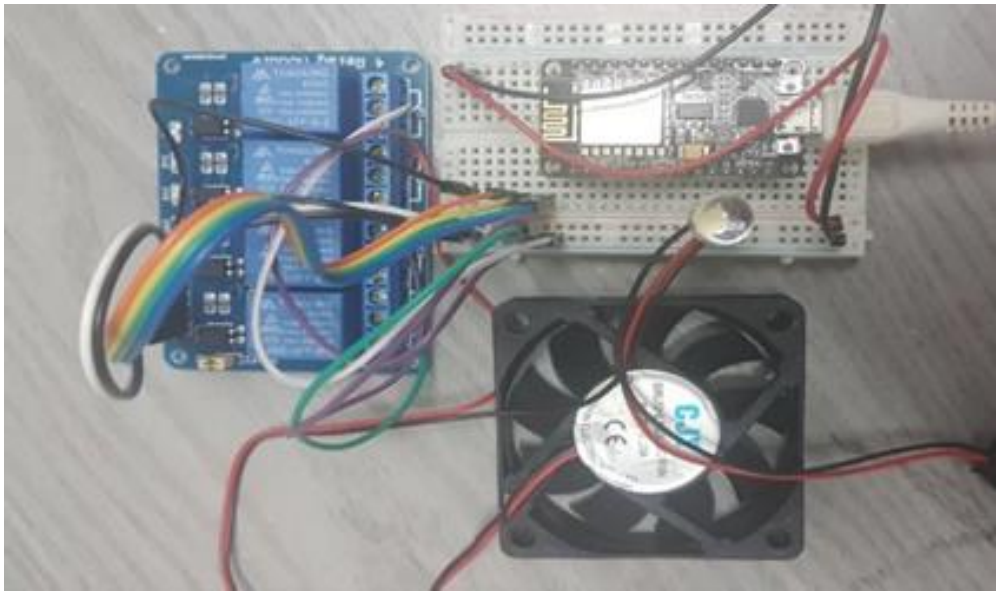

Figure 5: Prototype of Hardware Connectivity

Figure 6: Prototype of Android Apps Main Screen

Figure 5 and 6 show the prototype of the hardware connectivity and the prototype of the android app, respectively. Because the project involved the hardware, the connectivity of all hardware

need to be completed. In addition, the development of app need to be guided by the connected hardware.

5.4 User evaluation

Next, the proposed project is presented to user for evaluation of the prototype to evaluate its strengths and weaknesses such as what is to be added, removed and what is missing. Comments and suggestions are collected to make improvement and changes in the project prototype. User evaluation that have been conducted is about the User Acceptance Test (UAT). It is done using questionnaire through Google form and the respondents have been shown a demo of the application before they answered the questionnaire. There are 30 randomly selected respondents participated in the study where 20 of the respondents are female students and the rest of 10 respondents are male students. 38 questions have been asked through Google form which were divided into two parts, section A for demographic and background information and section B questionnaire is measured using USE Questionnaire (Usefulness, Satisfaction and Ease of Use). Besides, there will be 3 section in this part for Evaluation of Smart Home Controlling System Application. In Section B, respondents need to rate the system based on scale 1-Strongly Agree, 2-Disagree, 3-Slightly Disagree, 4-Neutral, 5-Slightly Agree, 6-Agree, 7-Strongly Agree. There will be 13 multiple choice questions in Section A and 25 scale questions in Section B and respondents are required to answer all questions in the questionnaire. The choice of n = 30 for a boundary between small and large samples is a rule of thumb, only. There is a large number of books that quote (around) this value, for example Robert V. Hogg in their book of Probability and Statistical Inference (7e) says "greater than 25 or 30" (Robert V. Hogg, 2014).

5.5 Refining and enhance prototype

Once the user evaluates the prototype and if still does not meet the needs, the current prototype is refined according to the requirements. New prototype is developed with the additional information provided by user. New prototype is evaluated just like the previous prototype. This process continues until all requirements specified by the user are met. Once the user is satisfied with the developed prototype, an android application of smart home controlling system is developed based on the final prototype.

5.6 Engineer product

Once requirements are completely met, the user accepts the final prototype. It is evaluated thoroughly followed by the routine maintenance on regular basis for preventing large-scale failures and minimizing downtime.

5.7 Closing

Once all the development process involves developing smart home controlling system application and documentation completed, the project will be close.

6. Smart Home Android App

There are five main functions of the smart home apps. To secure the system from being used by an unauthorized user, the user needs to register (Figure 7) and that is verified by the system. User need to provide their details such as his/her full name, email address and valid phone number. This phone number is used to verify the user identity. A four-digit code will be sent to user through short messaging service (SMS) and the user needs to key in the code to be verified by the system. User password is also required with at least eight characters long combination of lower and uppercase letters, numbers and special characters. Users can change their password from time to time and they can also click "forget password" if they have forgotten their password. System will send a link to their email and users can reset their password through this link. Once new password has been created the users can use their email address and password to login to the system. The system will verify the username and password in the firebase database and if it is matching the user will be granted to access and use the apps to manage and control their smart home devices.

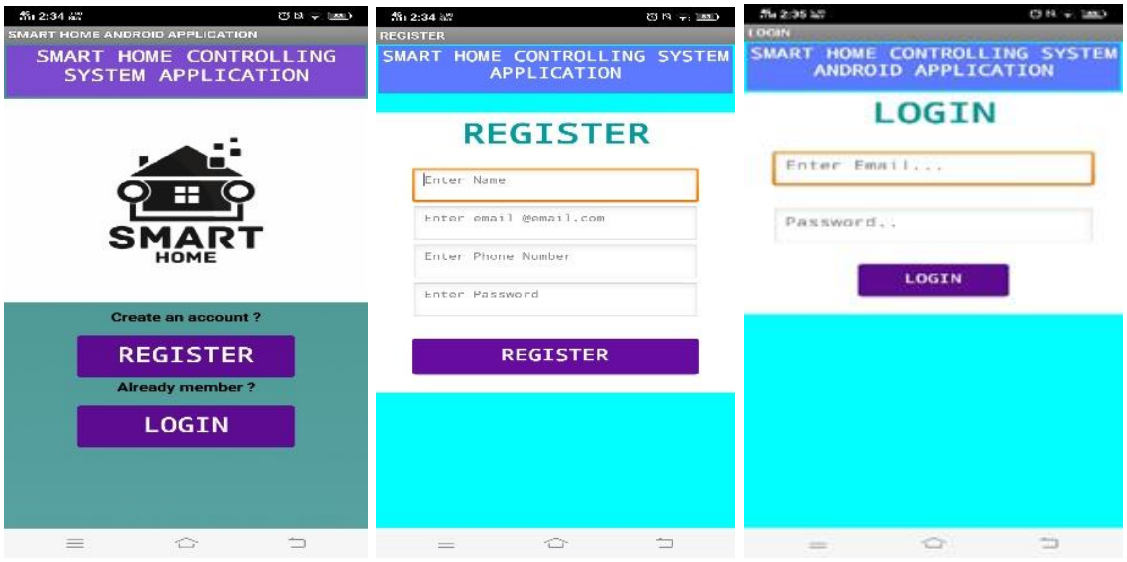

Figure 7: User Registration and Login Screens

Once the users have successfully login to the system, they can manage and control the home devices or appliances as shown in Figure 8.

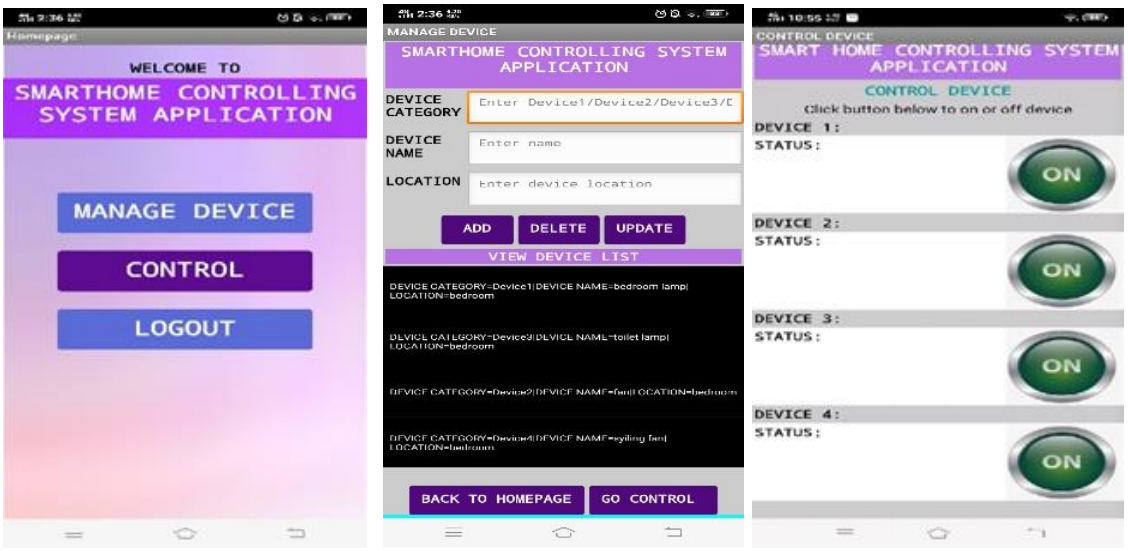

Figure 8: Screens to Manage and Control the devices

For “Manage Device”, users can add/delete/update/view device that they want to control. The devices can be grouped into certain categories, for instance, “bedroom 1”, “kitchen”, etc. Lastly, for “Control Device”, user can switch on/off the devices by tapping on the on/off buttons.

7. Future Works

For the future works, the application will be designed to be able to control more home devices that can be controlled through. In additon, the application in the future will be designed to become more flexible and can be used to control many home devices without having any problem. Moreover, the app will be designed to be simple and ease to use. Besides, it is important to make sure the application is always functional and able to recover quickly when there is error in the application. On other words, the error handling will be improved.

8. Conclusion

From the data that have been analyzed, the Smart Home Controlling System Application can help people including people with disabilities to have convenient and easy daily life in controlling on/off device through the use of the application. As mentioned before, from 30 respondent that participated in the study, most of them give good positive feedback after using the proposed app.

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