A Proposal of Low Cost Home Automation System Using IoT and Voice Recognition

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Abstract. Home Automation System is becoming more popular day by day due to its numerous benefits. This project proposes an idea in the design of low cost home automation system by using the Internet of Things (IoT) and voice recognition. The layout of the home divided into four areas and each area has own function and system. The Raspberry Pi 3 (RPi) Model B+ used as the main controller for the processing and transmitting the input data. IoT provided huge storage for data collection from sensors and home appliances. An Android application is developed to monitor the home environment and remotely control the home devices by using the button or voice. The speaker-independent recognition system by using Google Voice to Text on Android embedded in this project for physically challenged people to control the electrical appliances without moving. All the data will be stored in Firebase and can be retrieved at any time by the application and the RPi board. There is a side view of a prototype model with two floors and divided into four home areas. This Low-Cost Home Automation System using IoT and Voice Recognition is successfully achieved the project’s objective.

1. Introduction
Home is a place that people spend most of their time in it. Thus, home automated is developed to increase the comfort and quality of people’s life. The home automation is also known as domotics, and home automation system (HAS) called smart home or smart house [1-4]. The system will also include the security parts such as the fire alarm system, surveillance system, motion detection, and more. It is able automated and controlled all of the electronic appliances in home through remote control units, touch devices, electronic devices, and even the homeowner voice over the Internet. Hence, home automation is a step toward what is referred to as the Internet of Things (IoT) [7-8].

The “Internet of Things” phrase which is shortly known as IoT. It is one of the technologies which can be implemented for connecting, controlling and monitoring the smart devices over the Internet [5]. The goal of the IoT is not only focused on giving us the ability to control the things, but also allows the users to keep monitoring the status of the things. IoT based HAS typically involving climate control, light controls, smart door and so on.
About 650 million people or around 10% of the world’s population live with a disability based on the Disabled-World website [6]. The physically challenged person encountered a lot of problems in moving from one place to another. Therefore, this project proposes an IoT based HAS that consists of voice recognition for physically challenged people to control the electrical appliances. The main objective of this project is to develop a low cost home automation system using IoT and voice recognition. This project is addressed at the following: (i) develop a low cost home automation system ease of installation and configuration, (ii) develop an Android application user interface for the user to monitor and control the home appliances over the internet, and (iii) embed the voice recognition system for physically challenged people to control the home appliances.

2. System Model
The overall system architecture for low cost home automation system using IoT and voice recognition is divided into different block: remote control system, voice recognition system [10-13], home automation system architecture, and cloud connection system. The first block is the remote control system - Android App. It receives two types of input, user input control and voice command. The UI includes a home control, voice recognition, and monitoring system page that allow users to remotely control and monitor home appliances. Voice commands are received via smartphone microphone and then processed by the voice recognition system which shown in the remote control system block. Android Apps use the Google Speech to Text to process the voice commands. Once the conversion is complete, the voice output is uploaded to Firebase and processed by RPi to perform the operation. The next block is the home automation system architectures, the RPi3 B+ as the main board [9]. The green colour box indicates the input to the system and the yellow colour box indicates the output of the system. The final part of the overall system is the cloud connection system. Each data read by the sensor is progressed by the board and uploaded to Firebase via the board’s built-in Wi-Fi. The remote control system and HAS architecture are applied two-way wireless communication with the Firebase Real-time Database to update and retrieve the status of the home appliances. Figure 1 shows the model of home automation system block diagram.

![Figure 1. Home automation system block diagram](image)

2.1 Low Cost Home Automation System Architecture
The HAS architecture divided into several parts; automatic door system, automatic clothesline system, living room, kitchen, bathroom, and bedroom. Each area has its own function and household appliances as shown in Table 1.

Table 1. Home automation system functions

| Location            | Sensors                | Devices                                      |
|---------------------|------------------------|----------------------------------------------|
| Automatic door system | IR Sensor              | Door (Servo Motor)                           |
| Automatic clothesline system | Rain sensor module | Clothesline (DC motor)                       |
| Living room         | DHT11 Sensor           | 5mm Yellow LED and 5V DC Fan                 |
| Kitchen             | MQ2 Gas sensor         | 5mm Green LED, 3mm Kettle Green LED and Alarm (Buzzer) |
| Bathroom            |                        | 5mm Blue LED and Speaker                     |
| Bedroom             | LDR                    | 5mm White LED                                |

2.1.1 Automatic Door System. Figure 2 shows the sub-block diagram for Automatic Door System. The user input from the remote control system sent to Firebase and RPi retrieve it. An IR sensor for detecting obstacle and a servo motor for operating the door. The IR sensor has 3 pin interfaces. The left pin (OUT) is the output pin of the sensor which provides digital output (high or low). The centre pin is the ground (GND) pin and the last pin is for input voltage (VCC) connect to either +3.3V or +5V. The sensor contains a potentiometer to adjust the obstacle detection sensitivity range (2cm - 10cm). In this project, the obstacle detection range was set to approximately 5cm. TowerPro SG90 micro servo has 3 wiring which are GND, 5V and Signal. The maximum rotation angle of the servo motor is 180 degrees. In this project, 0 degrees is used as the initial door closing angle and rotated 90 degrees as to open the door.

RPi will keep to reading the door status from Firebase. When the door status is on, the servo motor will rotate 90 degrees to open the door and delay for 3 seconds to allow the people to enter the house before closing the door. If an object is detected after the completion of the time delay, the door will remain open and continue to delay more 3 seconds. Otherwise, when no object is detected, the door will close. The door status will always be uploaded to the Firebase.

2.1.2 Smart Power System (Living Room). Figure 3 shows the sub-block diagram for smart power system located in the living room area. The user input from the remote control system and the sensor value are sent to Firebase and RPi retrieve it. DHT11 sensor for detecting temperature and humidity of the room and a L298N motor driver connected with the 5V DC fan power on by 9V battery. The DHT11 sensor can sense the temperature from 0 to 50°C with +/- 2 accuracy and humidity range between 20% and 80%
with +/- 5% accuracy. The VCC pin of the sensor connected to the RPi’s 5V pin and GND pin connected to RPi’s GND. The OUT pin is connected to one of the GPIO pin in the RPi (GPIO 17) to get the sensor data. The sensor collects one reading every second.

![Figure 3. Sub-block diagram of smart power system](image)

**Figure 3.** Sub-block diagram of smart power system

**Figure 4.** Adjust the fan speed using python code

There was one 5V DC fan used in this smart power system. A L298N dual motor controller module 2A is implemented with RPi to control the speed of the fan. The motor driver can receive the external power source from 7V to 30V which used to supply the power to connected fan. The input ports are to provide the PWM signal for control the fan speed while the output pins are connected to the VCC and GND pin of the fan. The motor driver +12V pin is connected with the 9V battery to power on it and the GND pin of RPi and battery are linked together to common the GND.

Figure 4 shows the method of using the Python programming language to generate PWM to control the speed of the fan. GPIO 27 and GPIO 22 of the RPi are to give the signal to the fan. The ENA pin (GPIO 12) is used to enable the generate signal send to the output port. The OUT1 pin is connected to the positive pin of the fan and OUT2 pin is connected to the negative pin of the fan. Hence, to turn on the fan is required to set both input ports with LOW and HIGH signal respectively. To stop the fan by set both inputs pin with the same signal (LOW and LOW).

### 2.1.3 Smoke Detector System (Kitchen)

Figure 5 shows the MQ2 gas sensor and buzzer are implemented in this project for gas leakage and fire detecting in the kitchen. The gas sensor value is send to Firebase via RPi’s built-in WiFi. The buzzer is act as the alarm and be activated by the gas sensor when detected gas leakage.

![Figure 5. Sub-block diagram of smoke detector system](image)

MQ2 gas sensor is suitable for detecting of LPG, i-butane, propane, methane, alcohol, Hydrogen, smoke and carbon monoxide. In this project, the gases used for gas leakage detection are LPG and smoke. The analog output plays the essential role in this project by giving the concentration of surrounding gas present to RPi. However, this is analog output data type, it required an MCP3008 ADC to convert the analog output voltage into digital before send into RPi. ADC module contains 8 channels to read and
convert up to 8 devices analog output into digital. The pins at the right side of the ADC module are linked with SPI bus of RPi for sending the converted data into RPi.

2.1.4 Smart Lighting System (Bedroom). Figure 6 shows the sub-block diagram for Smart Lighting System located in the bedroom. The user input from the remote control system and the LDR sensor value are sent to Firebase and RPi retrieve it. The LDR is analog type output data and similar to the MQ2 gas sensor, it required an ADC to convert the analog output voltage into digital. The MCP3008 ADC module is shared for LDR with different channel. LDR is used to detect the presence or the level of the light. The 5mm white colour LED as the output for the smart lighting system. This benefit of the system is can reduce the energy and the money in electricity bill.

2.1.5 Automatic Clothesline System. Figure 7 shows the sub-block diagram for Automatic Clothesline System. The rain sensor as the input to detect the raindrop and the L298N motor driver is used to control the DC motor whether to draw back clothes to indoor or hang the clothes to outdoor. This system able to saves the manpower and the money on dryer the clothes.

The wiring connection for the Automatic Clothesline System is similar to the previous connection mentioned in the Smart Power System. It required 2 input pins, 2 output pins and 1 enable pin (IN3, IN4, OUT3, OUT4, and ENB). The input ports are to provide the signal for control the direction of the motor while the output pins are connected to the VCC and GND pin of the DC motor.

2.2 Remote Control System.
The instruction from the Android App UI is transmitted to the RPi3 B+ board for performing the action through the wireless medium such as Wi-Fi. This system allows the user to remotely control the home appliances that shown in figure 8 far away from the home via App as long as there has an Internet connection. In addition, the voice recognition system shown in the remote control system also enables the physically challenged person remotely to control the home appliances by using the voice command.

The speaker connected with RPi by using a 3.5mm audio jack cable also can be controlled by user input to play and stop the music. The connection of the door and fan which has been discussed in the previous section also can control by user via Android App. The Home Control page in the application is shown in figure 9. The user can click the bottom bar button to switch to another UI page. The voice recognition page is for physically challenged people to control the home electrical appliances displayed in Home Control UI page.
2.3 Voice Recognition System
The users can control the home devices via the App whereas the system has provided an alternative way for the physically challenged people by using voice command to perform the same action. Total 19 voice commands that can be recognized to perform the actions. The voice commands, actions, and the voice response for HAS are shown in Table 3.2.

2.4 Cloud Connection System
The Cloud Connection System is used to store, display and monitor the collected data. The data is saved for future analysis and send to the Android App and RPi. As shown in figure 10, Firebase Real-time Database as the platform between Remote Control System, Voice Recognition System and Home Automation System to wireless communication and transmission all sensors data, home device status, and translated text output in this project. The stored data can be viewed via the Firebase console and Android App.

The Python code is used to keep upload the sensor reading and retrieve the data from Firebase. Each data is declared to be sent into the specified child so that the data do not mix up and display in different field and child in the Firebase console. The Java code is written to read the data from the Firebase by declaring the child path. After retrieving the data from the Firebase, it will send the value to the specific text view box to display it. It can obviously see that the Firebase as a good platform to interact with the mobile.

3. Results and Discussion
The prototype of the project is successfully developed. There is a side view of a prototype model with two floors and divided into four home areas which are the living room, kitchen, bathroom, and bedroom. The clothesline that implements the Automatic Clothesline System was set up on the right-hand side of the prototype. Figure 11 displays the prototype for the low cost HAS.

Furthermore, the prototype is linked with the Android App and Firebase. The user not only can observe the data at the Firebase console, an Android App also able to monitor the data anytime anywhere as long as have a stable network connection. When the system has any abnormal condition, the RPi enables an alert system by sending the email to the user. User is able to control the door by using the Android App. The servo motor is used to operate the door and IR sensor to detect the object. The open door button is in the bottom left side in the Home Control page shown in figure 12.

When the user presses the door open switch, the servo motor will rotate 90 degrees to open the door. The door status will upload to the Firebase, “1” for open and “0” for close. When the IR sensor detects
an object, the output value is “0”, otherwise it is “1”. The RPi retrieve the door status from Firebase, and the door in the prototype is performed according to the status.

The Smart Power System is functional when the Auto Mode and Fan are turned ON. This can be viewed and controlled via the Home Control page in the Android App, as shown in the right side of figure 13. Smart Power System will adjust the fan speed based on the temperature reading that sensed by the DHT11 Temperature and Humidity sensor. The application also contains a Monitoring System page that displays the DHT11 sensor readings.

**Table 2. Voice Commands of the HAS**

| Location | Voice Commands | Actions | Voice Responses |
|----------|----------------|---------|-----------------|
| Living room | Ok home turns On/Off the living room light | Yellow LED On/Off | Sure living room light On/Off |
| | Ok home turns On/Off the living room fan | Fan On/Off | Sure living room fan On/Off |
| Kitchen | Ok home turns On/Off the kitchen light | Green LED On/Off | Sure kitchen light On/Off |
| | Ok home help me make some hot water | Kettle LED On after 3s Off | Sure (before On the kettle your hot water is ready after Off the kettle) |
| Bathroom | Ok home turns On/Off the bathroom light | Blue LED On/Off | Sure bathroom light On/Off |
| | Ok home plays some music | Music On | Sure music is now playing |
| | Ok home stop music | Music Off | Sure music is now stopping |
| Bedroom | Ok home turn On the bedroom light | White LED On | Sure bedroom light On |
| | Ok home adjusts the bedroom light to 50% | White LED 50% brightness | Sure bedroom light now 50% |
| | Ok home is tome to sleep | White LED Off | Sure bedroom light Off good night |
| Home | Ok home turns On/Off all the lights | All LEDs On/Off | Sure all lights On/Off |
| Door | Ok home open the door | Door open | Sure welcome home |
| | | After 3s close (if no detected object) | |
| Auto Mode | Ok home auto mode On/Off | Auto mode On/Off | Sure auto mode On/Off |
Figure 10. Sub-block Diagram of Cloud Connection System

Figure 11. Prototype for the Low Cost HAS

Figure 12. Automatic Door System UI

Figure 13. Smart Power System UI

Figure 14. Smart Power System Operation

When Auto Mode and Fan are turned on and temperature is greater and equal to 25°C means it is hot day, the system will automatically adjust the fan to high speed. RPi retrieve the data from the Firebase to perform the particular action in the prototype shows in Figure 14.
Figure 15 shows the MQ2 gas sensor is tested with the lighter for LPG and smoke detection to prove the gas sensor is able to detect gas leakage in the home. The gases concentration reading of LPG and smoke from the gas sensor is increasing when provide LPG gas from the lighter. When in clean air condition, the concentration of gases is very low around 0 to 2 ppm for each gas, however, the lighter provide the LPG gas into the sensor, the gas concentration reading is raised up until 532.04 ppm and 104.07 ppm for Smoke and LPG respectively. RPi will keep transmit the LPG and Smoke value into Firebase shows in figure 16. The Alarm is activated when the gas value over the threshold value. If one of the gas values exceeds the threshold value, the alert system is triggered and the RPi will send the email to the user.
The seekbar that displayed in the Home Control page allows users to adjust the brightness of the bedroom’s light when Auto Mode OFF via the Android App. The brightness can be adjusted to 50% and 100%. When Auto Mode ON and it is Day Mode, the bedroom’s light will automatically OFF to save power. The Day Mode is determined by the LDR value. Figure 17 displays the before and after adjusting the bedroom light when Auto Mode ON.

The child paths that store the light status and LDR readings are shown in figure 18. The Day Mode equal to “1” means it is morning, the bedroom light will automatically OFF and Firebase update the latest value to the application to display. The RPi will retrieve the latest data from the Firebase and perform the automatically OFF operation in the prototype when it is Day Mode.

Android App contains one Monitoring System page to display the Automatic Clothesline System status shown in figure 19. In this system, the clothesline operates based on the rain sensor module and the Day Mode status. When the rain sensor detected raindrop or it is night mode, the DC motor will turn on to keep the hanging clothes under the roof. In the other hand, when it is sunny day and morning, the clothes are hanged at the outdoor.

The status of the system will always upload into Firebase to allow the RPi retrieve it to perform action. Figure 20 shows different condition that will trigger the clothesline. Rain sensor value equal to “0”
means detected raindrop. The rain sensor module was placed on the side roof of the home. This system also will trigger the alert system to send the email to the user to notice about it is raining day and the clothes were kept inside under the roof.

This remote Control System total contains 3 page, namely Voice Recognition System page, Home Control page, and Monitoring System page. Each page contains its own features. The details of the button are shown in figure 21. The home devices status and voice output are uploaded into Firebase, and sensor values are retrieved from Firebase. It is obviously seen that the Remote Control System is fully relies on the network connection.

Voice Recognition System page contains a microphone button to press, as shown in figure 22. After pressing the button, it will pop up a Google Voice dialog and begin recording voice command. The physically challenged people can use this voice system to control home devices without moving. The speech is converted directly to text and displayed in the same page and then uploaded into Firebase. For instance, when the user says “ok home turn on all the lights”, the voice will convert to text and uploaded to the Firebase under the Voice path.

The Firebase Real-time Database as the Cloud Connection System used to communicate between Remote Control System and Home Automation System Architecture. The Home Devices parent is used to store all of the home appliances status, door status, and clothesline status. All sensor values are stored under the Sensor parent node. For the Voice parent is used to save the converted text output from the application. Firebase is used in this project as it is a platform that able to link with mobile and have a real-time database. In addition, all the data collected in Firebase can be view through the mobile application or Firebase console. Thus, the limited memory space of RPi can be avoided to save all the collected data for further analysis.

In this project, the overall system is completely dependent on the network connection. If RPi is not connected to a network, it is unable to execute the Python code that contains the process of sending and retrieving data from Firebase. For the Remote Control System, all of the data unable synchronized with the Firebase cause no display value or status due to no network issues.

4. Conclusion
The integration of hardware and software utilized in this project demonstrates the reliability and effectiveness of the development system as the Remote Control System is developed. The limitations of HAS is fully dependent on the network connection to synchronizes data. In addition, there is a Monitoring System page in the Remote Control System that is developed to provide the users with a vision. This page allows the user to get updated sensor readings. The sensors used in this project have been successfully programmed and are capable of detecting, acquiring and transmitting data. All collected data is uploaded to Firebase. The developed system allows users to wirelessly control and monitor the HAS.

Nonetheless, the system is becoming easier and convenient to monitor as all the data have been stored in Firebase and displayed in the application. As a result, users can view the data by browsing the Firebase
console or mobile application anywhere, as long as they have an internet connection. In addition, the system automatically sends an alert message via email when fire or rain is detected. The messages allow the user to take further actions for the scenarios. The last objective of the project was achieved by embedded a Voice Recognition System in the Remote Control System for physically challenged people to control the home electrical appliances. They need to mention “ok home” at the beginning of the voice command and then specify the action and specific home area. The voice is converted to text by using Google Speech to Text on Android and the text is uploaded to Firebase. RPi retrieves the text output and based on the matched output to perform the action. The voice response of the particular action is played by the connected speaker to the physically challenged people.

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