DESIGN A SMART HOME AUTOMATION SYSTEM

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Abstract. To make our life less complex and secure, the trendy solution nowadays is to use a Home Automation System (HAS). The HAS allows to control all the house appliances wirelessly. It offers a home security and emergency system as well as the ability to regulate various electrical appliances. It provides access to control the devices in the home and office. The smart home automated control system is an easy-to-use home automation system, where Android application is the bases for that. It is a portable system and easy to install, configure, run, and maintain. The HAS allows to control all the house appliances wirelessly. To control 10 to 16 devices a smartphone application is used, where Bluetooth technology and sensors are suggested to connect the system. This paper implemented a secure HAS by utilizing an Arduino microprocessor (AT Mega 2560) and an Android application (Remote XY). A Bluetooth module (HC-06) is establishing the communication between an Android mobile device and the Arduino, where the appliances are connected through its microprocessor. The examination of the system showed that it is properly worked and no fault alarm happens for face recognition or in controlling the different appliances.
Keywords: *Home Automation System (HAS), security systems, Integrated Development Environment (IDE), saving energy, Internet of Things (IoT), Arduino*

Introduction

Although life becomes difficult and more complicated, there are many innovations that try to make it easier. For example but not limited to, the Home Automation System is one of them. Automation is essential to human life in the fast-paced 21st century. It offers a home security and emergency system as well as the ability to regulate various electrical appliances used in the home. Home automation includes time and energy savings in addition to reducing human effort. The important objective of this intelligent system is to help handicapped and elderly people who will unable to control the appliances and alert them in critical situations. This system is an easy-to-use, it can be portable and constructed in a way that is easy to install, configure, run, and maintain (Chen et al., 2021; Angioletti et al., 2020; Majidzadeh Gorjani et al., 2020; Taiwo and Ezugwu, 2020). There are numerous incredible practical benefits to home automation, even while you might think of it as a cool method for homeowners to showoff, or a means to stay current with technology. The ability to operate all of your home equipment from a single location and maintain connectivity across all of your home's technologies via a single interface is a significant advancement in technology and home

management (Al-Ali and Al-Rousan, 2004). Smart home systems often have a tremendous amount of versatility when it comes to accepting new appliances, gadgets, and other types of technology. If you can successfully integrate these newcomers, your job as a homeowner will be made much easier, and you'll be able to keep updating to the most recent lifestyle technology. Another objective is to control the home's heating and cooling systems with the assistance of a programmed smart thermostat in order to use energy as efficiently as possible. Also, the person can program the Lights and motorized shades to switch ON and OFF automatically depending on the sun's rise and set. Or when anyone enters or leaves the room, so don't worry about wasting energy (Khan et al., 2020). Although of the benefits of smart homes, there are some challenges; more users can be connected to a home network and control all the devices if homeowners are careless about security PIN Bluetooth. As users add more devices to their homes, they become more vulnerable. Any device connected to Bluetooth can be an entry point for attackers to access other devices on the same network (Arthanat et al., 2020; Huraj et al., 2020).

The suggested smartphone application system is fully operated based on an Android application. It allows the users to control up to 16 devices including home appliances and sensors using Bluetooth technology. The system uses an Arduino microprocessor (AT Mega 2560) and an Android application (Remote-XY). The microprocessor is connected to household appliances, and a Bluetooth module (HC-06) is used to establish a connection between the Arduino and an Android mobile phone or tablet. This idea is both affordable and has a user-friendly interface for elderly and physically challenged individuals. The remainder of the article is structured as follows: (1) section 2 is the related work; (2) section 3 illustrates the hardware platform; (3) section 4 goes through software requirements; (4) section 5 give details about implementation and design; (5) section 6 presents testing and results, and; (6) section 7 concludes the work.

Related work

This section provides a brief survey of the existing energy-saving system proposed and the research papers related to smart home automation systems. Sriskanthan et al. (2002) presented a model using Bluetooth via PC for home automation. The network contains a remote, mobile host controller, and several client modules (home appliances). Through Bluetooth devices, the client modules communicate with the host controller. A Home Automation Protocol (HAP) is built on top of the Bluetooth software stack. The device controller is connected to electronic devices through the I2C Bus. The multi-device controller can be connected to the host controller, but the bad thing is that the system does not support mobile technology. A low-cost solution for home automation was designed by Piyare and Tazil (2011). It supported the operating system cell phones works on Symbian. But some issues like limited platform and range limitation are not solved. A low-cost Java-based automation system is designed and implemented by Al-Ali et al. (2004), but this issue is not achieved exactly. Soliman et al. (2017) created a device control system with the use of a web server. They had to deal with budgetary restrictions and server downtime issues.

Materials and Methods

Hardware platform

The proposed system consists of many components like Passive Infrared (PIR) sensor that detects the motion inside the room, whereas the Ambient Light Sensor (BH1750) detects the brightness of sunlight. Smoke and Gas sensors (MQ2) are used to detect smoke and gas leaking in the home. The DHT22 is a commonly used temperature and humidity sensor. And other important parts will be explained in the coming sections.

Arduino mega 2560

A microcontroller board called Arduino Mega is based on the ATmega 2560 as shown in *Figure 1*. It contains 54 digital input/output pins, 16 MHz crystal oscillator, analog inputs, UARTs (hardware serial ports), a power jack, a USB connection, and a reset button. You can use a USB connection or an external power source, where power source selection is done automatically. Either a battery or an AC-to-DC adapter (wall wart) can provide external (non-USB) power. Through the adapter, a 2.1 mm center-positive can be connected to the board's power port. An external supply between 6 and 20 volts can power the board. However, the 7 to 12-volt range is advised to prevent unstable or damaging occurrences (Brunete et al., 2021; Tural et al., 2021; Wollschlaeger and Kabitzsch, 2020; Zheng et al., 2020).

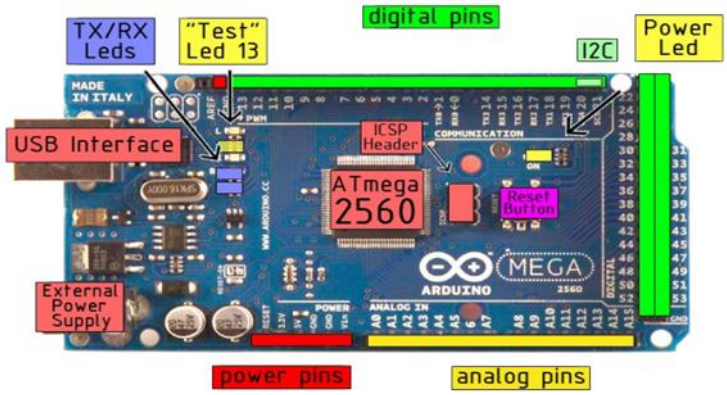

Figure 1. *Arduino board.*

Relay

It is an electrical switch that automatically flips from the off to the on position using an electromagnet as shown in *Figure 2*. Relays require only a little amount of power to activate them, but they can control devices that consume much more power. There are two components to a relay switch: input and output. A magnetic field is generated in the coil when a small voltage is applied to the input section. It is called the Operating Voltage (Arthanat et al., 2020). While contactors are placed in the output section, this mechanically connects or disconnects the device. Three contactors are often present: the Common (COM), the Normally Open (NO), and the Normally Closed (NC). The COM is connected to NC in the NO instance. The relay coil becomes engaged after the operational voltage is applied, and the COM switches contact to NO (Majidzadeh Gorjani et al., 2020).

Figure 2. *Relay stack.*

Bluetooth module (HC-06)

The HC-06 enables wireless data transmission over a short distance between two microcontrollers or systems. Bluetooth 2.0 communication protocol is dependent here and it can only act as a slave device. It is considered a more flexible and cheapest approach for sending wireless data and applied full duplex transmission. The speed of file transmission reaches 2.1Mbps. To avoid interference with other devices a technique called frequency hopping spread spectrum technique (FHSS) is used. The frequency range is 2.402 GHz to 2.480 GHz (Chen et al., 2020), as in *Figure 3*. A flexible module called the HC-06 can add two-way (full-duplex) wireless connectivity to the project. Any Bluetooth-enabled device, such as a phone or laptop, as well as two microcontrollers like Arduino, can be connected to this module. The abundance of Android apps already available (Arthanat et al., 2020) substantially aids this strategy. This HC-06 module has interacted with the UART interface. Data is sent to or received from the module through this interface. Since every microcontroller or PC has an RS232 port, the module can be immediately connected to them using the UART interface. *Figure 4* depicts a sample interface circuit for connecting the module to an Arduino. The UART interface is formed here and the module is connected to a +5V standard regulated power source as illustrated (Sriskanthan et al., 2002).

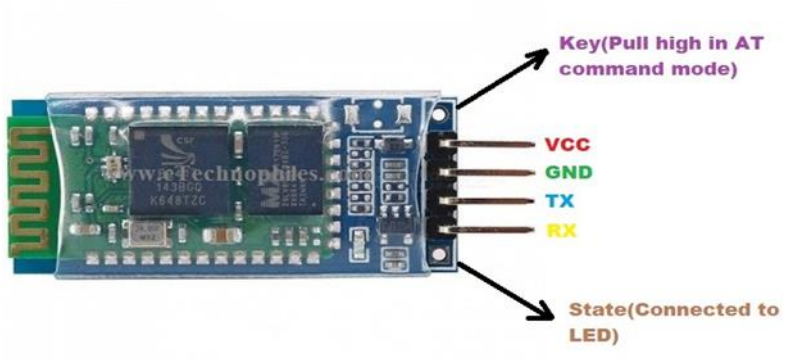

Figure 3. *Bluetooh module HC-06 pin-out.*

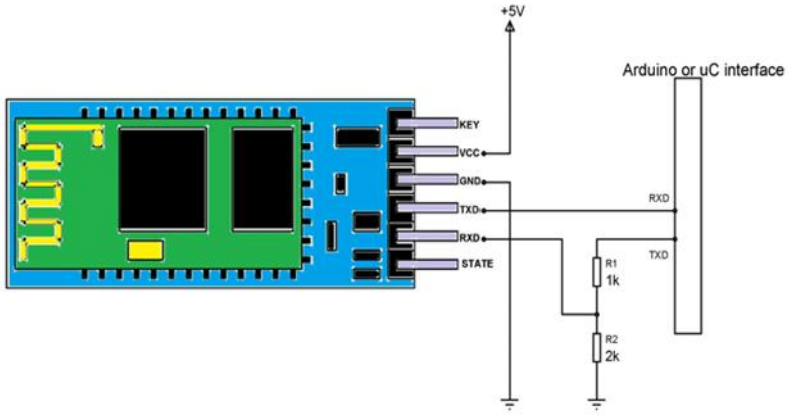

Figure 4. *Interface with Arduino.*

Graphic user interface

In this work, an Android application is created that may be used to turn on and off household appliances. The status of several system-connected appliances is displayed in the screenshots below, along with switches for turning them on and off. *Figure 5* depicts the proposed system's status after all appliances have been turned on. Using Remote-XY, it is simple to create and operate a mobile graphical user interface. The controller boards are for mobile or tablet control. The controller is the store of the interface structure because it can download the interface structure to the mobile application depending on it. The number of devices is not limited to any number, while one mobile application can manage all your devices (Latella et al., 2022). The graphical interface for any task can be developed using the online editor Remote-XY by placing the elements on the screen as shown in *Figure 6* (Hock et al., 2020). To implements your interface, the source code for the microcontroller can be gotten after the development of the graphical interface. The structure for interaction between your program with the controls and display comes from the source code. So, for the device you are developing, it will be simple to merge the control system into the task (Simeoni et al., 2021). Many devices can be managed using one mobile application with different graphical management interfaces (Khan et al., 2020).

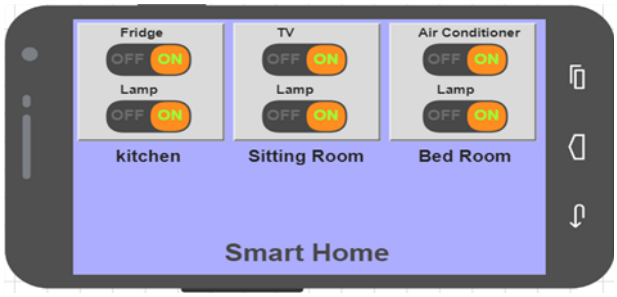

Figure 5. *Smart home application.*

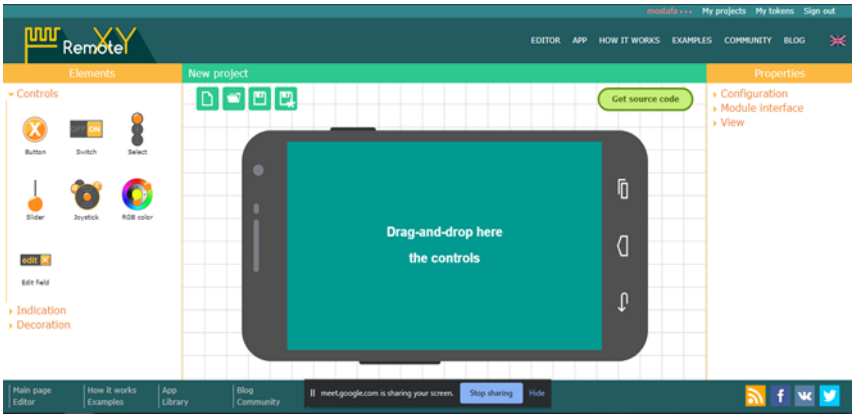

Figure 6. *Graphic user interface.*

ESP32-CAM

The ESP32-CAM, as illustrated in *Figure 7*, has a tiny footprint and a deep sleep current of up to 6mA has a very competitive compact camera module that can run independently. The ESP32 has 4 out of 39 digital pins as input only. A 12-bit ADC can support 18 channels, while an 8-bit DAC for 2-channel. It has 16 channels for PWM signal generation (Simeoni et al., 2021). The ports of the ESP32 are shown in *Figure 8*.

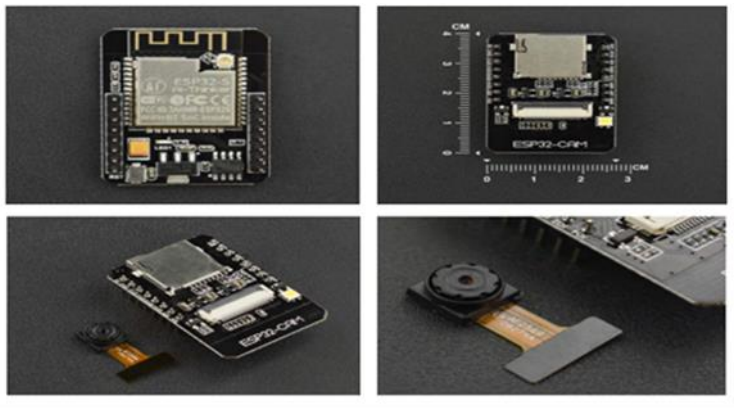

Figure 7. *ESP32-CAM.*

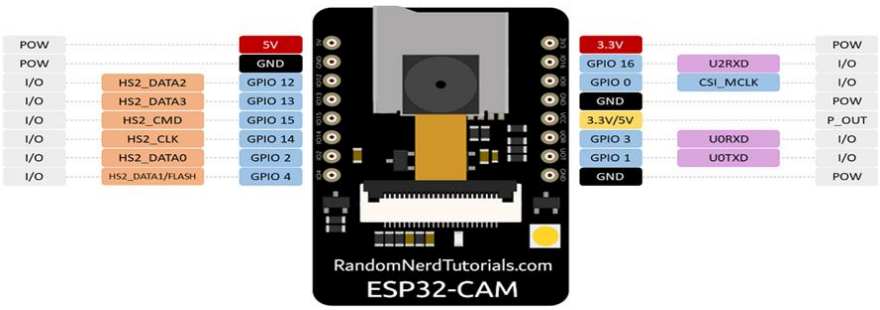

Figure 8. *ESP32 pin-out.*

Gas sensor

MQ2 is a Metal Oxide Semiconductor (MOS). Gas sensors are commonly used in the MQ sensor series as shown in *Figure 9*. Because the detection is based upon the change of resistance of the sensing material, As the Gas comes into contact with the substance;

it is also referred to as a chemiresistor. Between 200 and 10,000 ppm, it can detect alcohol, LPG smoke, methane, propane, hydrogen, and carbon monoxide.

Figure 9. *Gas sensor.*

Miniature 5V cooling fan and buzzer

It is a brushless DC fan with, a 5V operating voltage and 0.2A current, while the Buzzer Operating Voltage is 4-8V DC and the rated current is <30mA.

Software requirements

For Windows, MacOS, and Linux, the cross-platform application is the Integrated Development Environment (IDE) of Arduino. It is written in the programming language Java. It came from the IDE for the programming languages Wiring and Processing. The (GNU) General Public License governs the source code for the IDE (Piyare and Tazil, 2011). The Arduino IDE uses special rules of code structuring and supports C and C++ languages. To convert the executable code into a text file, IDE employs the program argued. This is done in hexadecimal encoding, where the loader program in the board's firmware is loaded into the Arduino board (Wollschlaeger and Kabitzsch, 2020).

Design and implementation

Hardware requirements

All the connections among the hardware components should be done as follows: (1) First of all the 12v and 5v as VCC supplied for both Arduino ATmega 2560 kit and the relay board respectively and GNDs are connected. After the Arduino programming process, the output pins are connected to the relay pins (*Figure 10*). Then LEDs are connected to the COM of the Relay pins, and When there is no input state, the COM is connected to NC. The relay coil is activated and the COM changes contact to NO when the working voltage is applied. The LEDs 1 to 6 will simulate the real device of the house like a fridge, lamp1, TV, lamp2, AC, and lamp 3 these LEDs will connect to relays 1 to 6 respectively. The Fan is connected to relay 7. (2) HC-06 should be connected to the Arduino as in *Figure 11*, where the RXD of HC-06 is connected to the TXD of Arduino and the TXD of HC-06 is connected to the RXD of Arduino. (3) Another connection to the Arduino is the Gas sensor where, VCC to 5v, A0 to A5, and the GNDs of both. (4) The VCC of camera ESP32-CAM connected to 5v of Arduino.

The GNDs of them are connected with RESET and GPIO as shown in Fig. 12. The RXD of ESP32-CAM is connected to the RXD of Arduino and the TXD of the ESP32-CAM with the TXD of Arduino as shown in *Figure 13*. Also there are 2 LEDs to indicate face recognize. The first one (YELLOW LED) is connected to GPIO12 for a known face and the second one (RED LED) is connected to GPIO13 for an unknown face. (5) Last but not least Arduino should be connected to pc and program the ESP32-CAM.

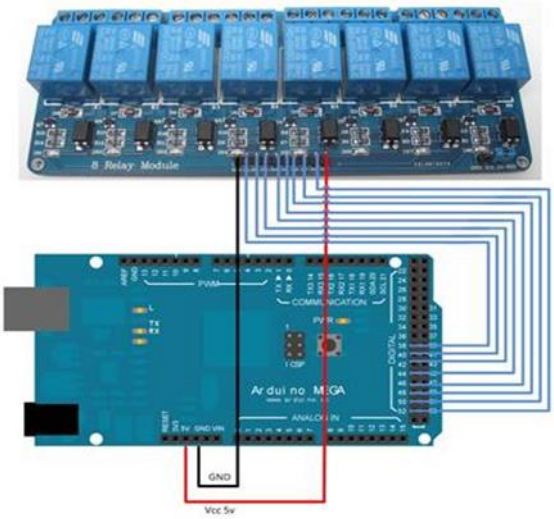

Figure 10. *Fully relay connected.*

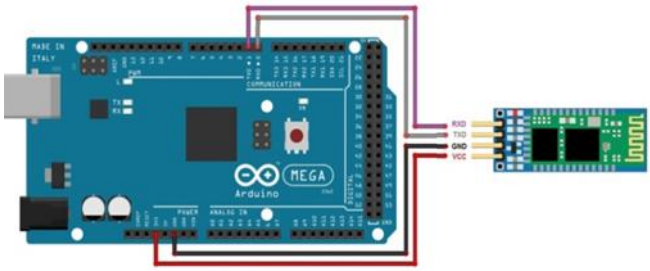

Figure 11. *Connect HC-06 to Arduino.*

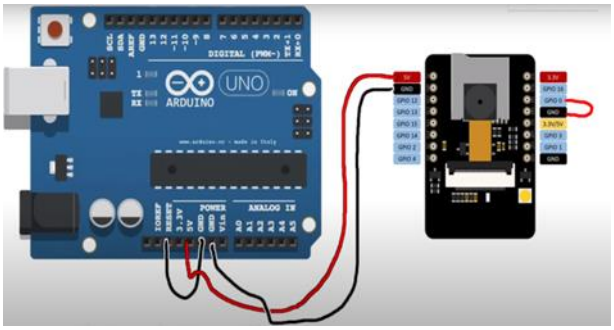

Figure 12. *Connect ESP32-CAM to Arduino.*

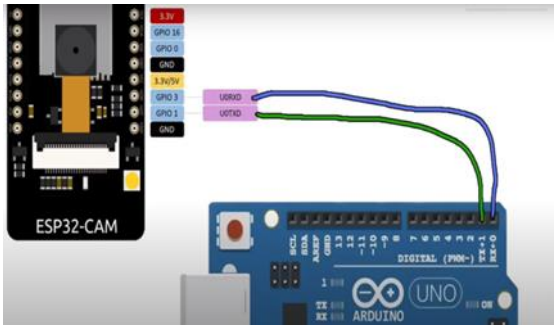

Figure 13. *Connect TX, RX.*

Software requirements

Using the Remote-XY library to complete the system as follows: (1) Properties section has many components for choosing, like the type of board, the type of connection Wi-Fi/Bluetooth (HC-05/06), the pins that work as TXD/RXD in the application, baud rate, and the number of pins for each element inside the GUI. The code should be opened through Arduino IDE before uploading the code. So, from the tool options choose Arduino Mega 2560 from (board) and ATmega 2560 from (processor) and USB connection port through COM11. (2) Through IDE, download ESP32-CAM library version 1.4.3 and setup should be done, where this step is important to Face Recognition. Using the (Enroll Face) to start a live stream window (a few sampling taking) to save the face for the authorized person (the man face in our proposed system).

Results and Discussion

First of all, face recognition is checked by applying a photo of a woman's face. So the red LED will be ON, as shown in *Figure 14*, while the yellow LED will be ON when the man's face is recognized. After the HC-06 Bluetooth model is connected to the Remote-XY application and starts changing switch positions in GUI, the different LEDs (referred to as real devices) are turned ON or OFF depending on that change, as shown in *Figure 15*.

Figure 14. *The Red LED refers to door locked.*

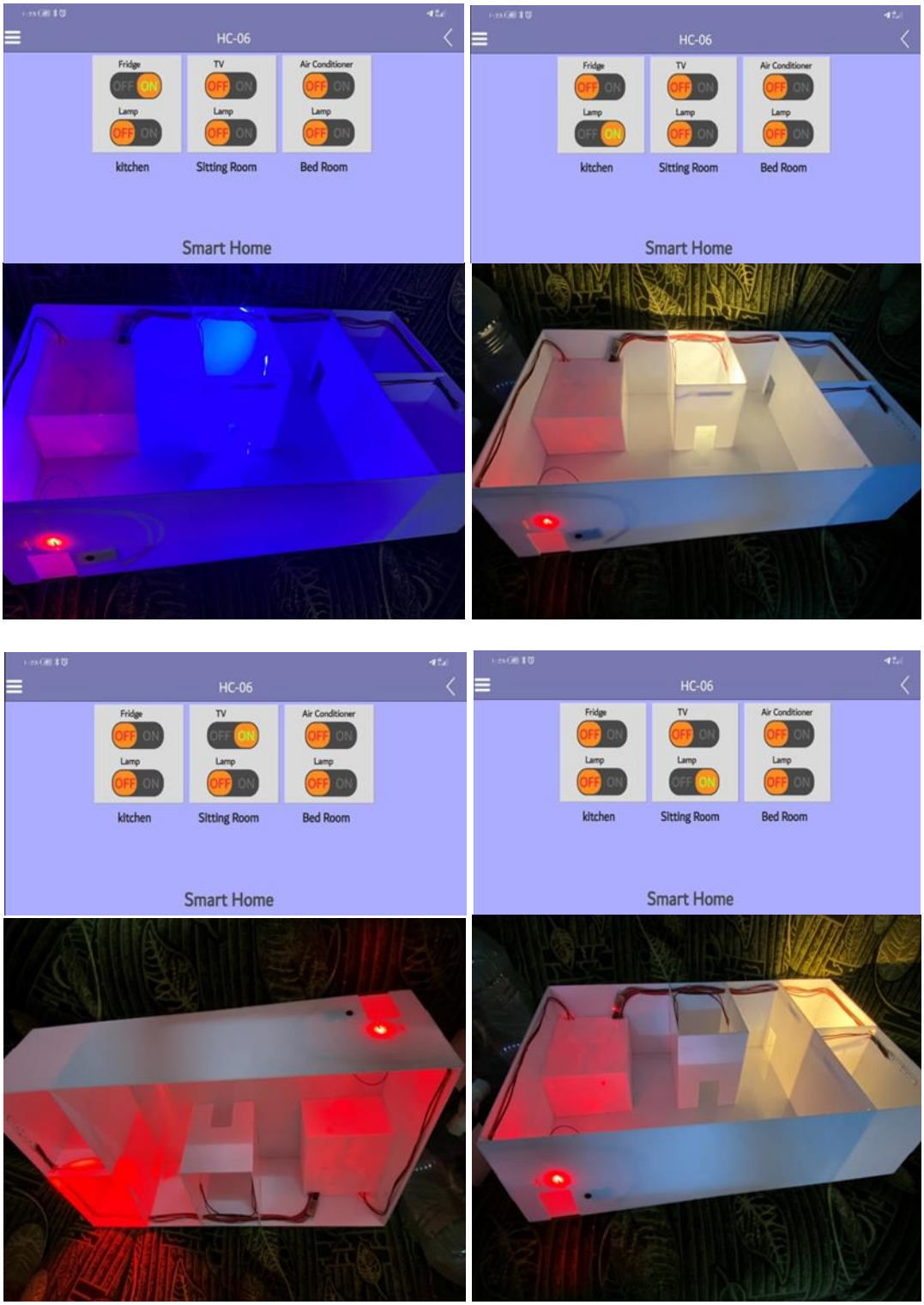

Figure 15. *The LEDs turned ON and OFF depending on switches positions.*

Conclusion

A secure home automation system is proposed using Bluetooth facility, applied through a mobile phone. The C Language is used to program Android, which is the best choice for HAS through connection with mobile phones and Bluetooth. Although it is

efficient and applicable for home applications, it is a low-cost simple design system. This method makes it easier for elderly or physically challenged people to operate household appliances and get emergency alerts.

Acknowledgement

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Conflict of interest

The authors declare that there is no conflict of interest involve in this research study.

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