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IoT-based Smart Home Monitoring and Automation System Using Android Application

Labony Akter[1], Khadiza Akter[1], Md. Nazmus Sakib[1], Jargis Ahmed[1]

1 Department of CSE, Green University of Bangladesh (GUB), Dhaka, Bangladesh

*Corresponding author's email:
jargis@cse.green.edu.bd

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Abstract

Internet of Things (IoT) devices are connected to the Internet and provide a variety of scopes in different projects and research domains. Smart home monitoring and automation largely depend on the usage of IoT devices. The concept of a smart home is now widely popular and a necessity in modern busy urban life. As most homeowner has to work at a distant workplace, it is a quite cumbersome job to monitor their household activity. In this paper, we address this issue and develop a prototype smart home system. The system contains IoT devices that are responsible for continuously sensing the home environment and sending the data to the Microcontroller. The microcontroller receives data and generates automated actions. We also connected the smart home system to a mobile Android application using the internet via a WiFi module. Thus, the homeowner can observe the current status of the home and will get a notification of the urgent situations in the application. We described the hardware requirement, software requirement, and connectivity of the devices. We ran different tests and checked the performance of the IoT sensors that were used. The developed prototype performed as expected and the integration of the smart home and Android application was quite smooth for monitoring and taking automated actions.

Keywords: Internet of Things (IoT), Smart Home, Home Automation, Sensor, Application based Home Monitoring.

Highlights

- Development of a prototype smart home system using IoT devices.
- Integration with a mobile Android application for remote monitoring.
- Automated actions based on real-time data from sensors.
- Cost-effective solution for smart home monitoring and automation.

Acknowledgements

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1 Introduction

The usage of the Internet of Things (IoT) devices has become necessary and unavoidable in nearly every aspect of day-to-day life. IoT devices are connected to the internet and the information they collect, or sense can be sent to a central computing system [1] for decision-making, performing actions, creating alerts, etc. The interaction of IoT devices is free of human-to-human or human-to-computer intervention. Thus, making smart homes and automation is largely dependent on the IoT [2]. Again, we can think of monitoring and automation that can be done easily if we can develop a smartphone-based system. As the usage of smartphones or mobile devices is increasing in the mobile edge network, it indicates that computation resource management and offloading [3]–[5] of the sensed data is a must for smart homes.

Home automation systems face four main challenges, these are high cost of ownership, inflexibility, poor manageability, and difficulty in achieving security. Homeowners have to worry all the time when they are outside of their residences to perform their daily work. Their aged parents or children may be at home and cannot control the home environment according to the requirements. In this regard, the owner or the responsible person needs to monitor the home environment and control the utility devices to ensure the comfort and safety of their parents or children. Hence it is required to build a system where IoT devices help to sense the home environment and notify homeowners and they can take initiatives remotely to manage the sound home environment.

IoT has a vast application field to aid different kinds of people in many different ways, such as home automation, visually impaired person, traffic monitoring system, smart city, agriculture, etc. [2], [6], [7]. In the field of smart homes, the paper [8] only focused on the sensing home environment and if it is dark, then the light will turn on automatically. In the paper [9], multiple features have been implemented but real-time image-based security has not been strengthened. The papers [10], [11] implemented common features of home automation, although they did not implement a mobile app to monitor and get notifications directly on smart devices. Many important features like garden soil moisture measurement, fire detection, and taking required actions are still missing in these works.

In this paper, we described the development of a smart home monitoring and automation system with the help of IoT devices, a microcontroller, and an Android application. The homeowner can observe the condition of the home environment and take necessary actions. The actions include turning on and off the light, Fan, and AC through an Android application via the internet. If there is any gas leakage or fire in the house flame sensor senses or detects it quickly and sends a signal to the microcontroller. The microcontroller processes the signal and generates alarm and notification to the Android application. Similarly, the soil moisture sensor in the garden sends the data, and a notification will be sent to the application. This will be helpful when all the residents of the home go for a tour or to spend a vacation, then there will be no one to monitor the garden and the plants will be dying due to lack of water. Based on the notification, the owner can turn on the water pump by using the app and pressing a few buttons. This signal will be sent to the microcontroller, and it will initiate the water pump for watering the garden. To restrict an unauthorized person from entering the house, we developed a smart door lock system using a camera module. We need to save the face images of the home resident first. When people come in front of the camera it will capture an instant image and send it to the microcontroller. The microcontroller will compare this image with stored pictures and direct the servo motor to open the door if a match is found. If a stranger is in front of the door it will not open the door but will let the owner know via app notification that an unauthorized person is in front of the door. We have used Arduino Uno Microcontroller as a programming device. To control the home system, we added a WiFi module that can be connected via the internet and the owner can easily access it remotely.

We organize the rest of the paper as follows. In Section II, we described the contribution of the literary works. To build the system prototype, we described the description and architecture of the required components in Section III. In Section IV, we provide a few experimental demonstrations and results. Finally, Section V concludes the paper.

2 Literature Review

In this part, we explore some of the closely related work of Home Automation Systems using IoT devices. In the paper, [8] provided a system for controlling sensor data, such as light, and triggering a procedure in response to a requirement, such as turning on the lights when it gets dark. But if we need to turn on the light far from home, it will become a problem. The authors in the paper [12], focused on how computer technology can regulate home gadgets to save energy and give security, and how website-based access to home devices even if we are far away from home where WiFi is available. In [13] authors used a microcontroller, Arduino board, and the LabVIEW platform to develop a smart home system. The Arduino microcontroller board is used to link sensors and household gadgets. The home equipment was automatically controlled, managed, and connected in response to any commands issued by the homeowner. In 2018, Hossain, et al. [10] demonstrated a smart home automation system that separates devices that are connected via motion sensors, fog computing, servers, and switches, among other things. The home appliances are controlled by a computer in this setup. By sensing the motion sensor, they have been designed to control various household components. When a motion is detected by the sensor, the components are turned on and off automatically. They only focused on security issues and general-purpose home automation systems like fans, lights, and fire alarms on/off were not highlighted. In the paper, [9] focused on a smart home automation system that focuses on monitoring fans and lights, with additional security offered by collecting an image if any object is identified and sending it to the owner through email. This system is implemented using the ”Node MCU” module. For the elderly and handicapped, the proposed system will be beneficial, but will not be able to monitor far from home.

Consider a wireless sensor node to increase smart home automation, various electrical equipment was connected to a home automation system and automated with little or no user intervention such as the work done in [11]. The smart home system monitors and records numerous environmental variables, enabling home gadgets to function by the needs of the system user. The system was utilized to automate the process of appliances for the home. In paper [14] suggested a smart door system architecture, the system is adaptable and cost-effective, and a mobile Android application is utilized to notify a homeowner of door open occurrences in an office or home environment. The system's architecture includes a Raspberry Pi2 board for connecting to a web server that implements a RESTful API. The Raspberry Pi minicomputer is utilized, which can support a huge number of devices and can manage and monitor them all at the same time. On the Raspberry Pi, a local server is built. The system user will need smart devices such as a laptop or a smartphone with a User Interface (UI) [15]. But it is so costly to afford.

All these papers either implemented only how to control home devices or only implemented a smart door individually. Most of the work did not mention any proper Android application or remote controlling system which will make sure to get proper benefit from the smart home system. Considering the contribution and limitations of the existing works we are motivated to design and implement a home automation system using IoT sensors to sense the home environment. Based on the sensors data the appropriate notification will be sent to the owner, who can instruct the controller system to take the required actions.

3 System Architecture

Fig. 1 represents the block diagram of home automation using Arduino and IoT. We can observe the connection between sensors and WiFi modules with the microcontroller Arduino UNO. After getting power Arduino UNO takes the input signals from the switch, soil sensor, flame sensor, and ESP32-CAM. Then Arduino UNO processes all data and decides whether the Buzzer, Relay module and servo Motor will be turned on or off. An Arduino UNO is dedicated to performing a single task and running a single application at a time.

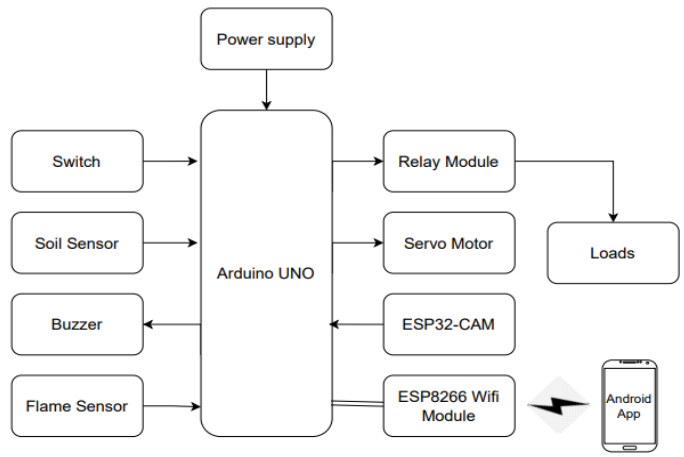


Fig 1. Smart home system components block diagram.

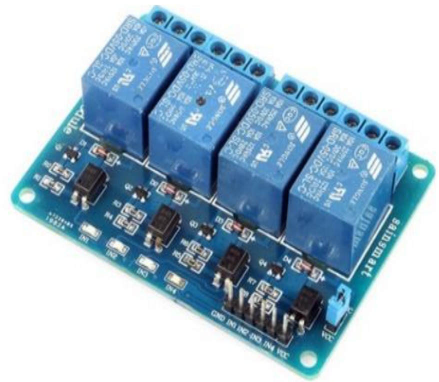
3.1 Hardware Requirements

Arduino Uno: The Arduino Uno is a microcontroller board designed by Arduino.cc and based on the Microchip ATmega328P chip (Fig. 2a. The board includes a variety of advanced and basic information/yield (I/O) sticks that can be used to connect to various development sheets (safeguards) and circuits. The board contains 6 basic pins and can be programmed with the Arduino IDE using a type B USB cable (Integrated Development Environment). It can be controlled by a USB connection or an external 9-volt battery.

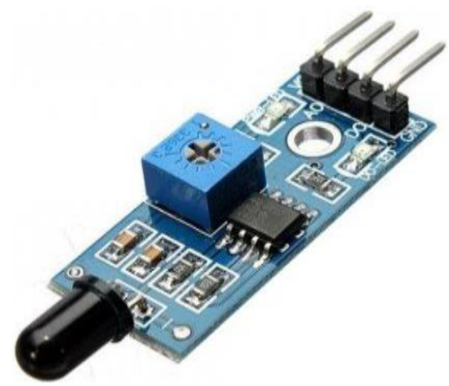
Relay Module: Relay module is used to control different devices based on the signal that comes from the microcontroller. This module can refresh incoming low-power signals to an enhanced signal. This module was highly used in telegraph circuits for long-distance communication. (Fig. 2b).

Flame Sensor: A flame sensor is a sensor that detects and responds to the presence of fire (Fig. 2c), making flare detection possible. Sounding an alarm, shutting off a fuel line (such as a propane or gaseous gasoline line), and

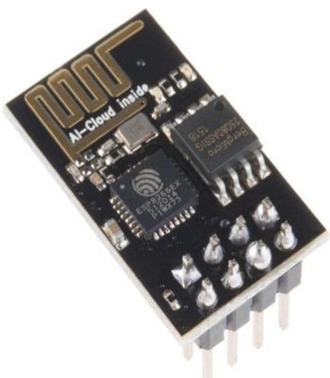
(a) Arduino uno



(b) Relay Module

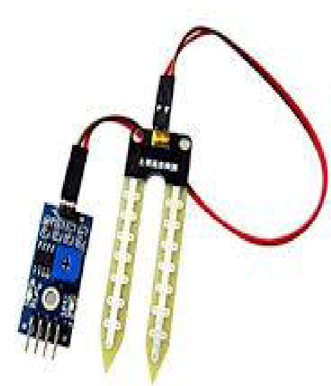


(c) Flame Sensor

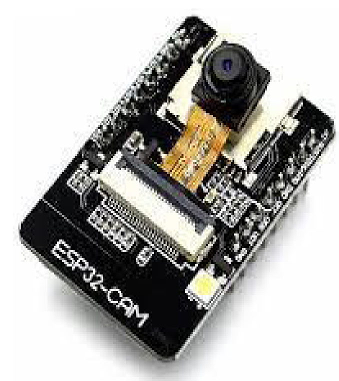


(d) Wi-Fi Module

(e) Servo Motor



(f) Soil Sensor



(g) ESP32-CAM

Fig 2. Required hardware components

putting in place a fire suppression system are all possible responses to a detected fire, depending on the situation. When used in modern heaters, their job is to ensure that the heater is working properly; they can also be used to turn off the start system, but they usually do little more than warn the administrator or control system. Fire identification can often respond directly and more precisely than a flame or heat locator due to the mechanics it utilizes to recognize the fire.

WiFi Module: The ESP8266, is a low-cost WiFi microprocessor (Fig. 2d) with built-in TCP/IP networking software and microcontroller capability. We need to use this module to connect the smart home microcontroller to the internet. Therefore, the homeowner connected to the internet from a long distance can easily get the update from the controller as a notification.

Servo Motor: A servo motor is really a rotation or continuous operator that has the capability to perfectly manage circular or linear direction, direction, and acceleration (Fig. 2e). It is created from either a compatible motor or a servo control sensor. It also needs a powerful microcontroller, which may be a selection made especially for servomotors. Even though the term servomotor is usually used to refer to a motor that's also suited for use with a closed-loop control scheme, this does not relate to the actual mechanism. Automation, CNC machines, and industrial automation applications are all using servo motors.

Soil Sensor: Soil moisture sensors (Fig. 2f) evaluate the volume moisture content of the soil. Humidity sensors indirectly moisture sensors measure the volumetric using another real estate of the soil as an indicator for the humidity level, such as resistance value, refractive index, or particle interplay, since direct spectrometric measurement of free-soil moisture usually requires the evacuation, drying, and trying to weigh of a specimen. The association here between the sample of large and soil moisture must always be validated, and it can differ focusing on ecological factors such as soil type, humidity, and electrical properties. Represented microwave energy, which is used for remotely sensed data in hydrologic and agribusiness, is affected by the soil water. Portable probing gadgets are useful for agricultural producers. Sensors that detect

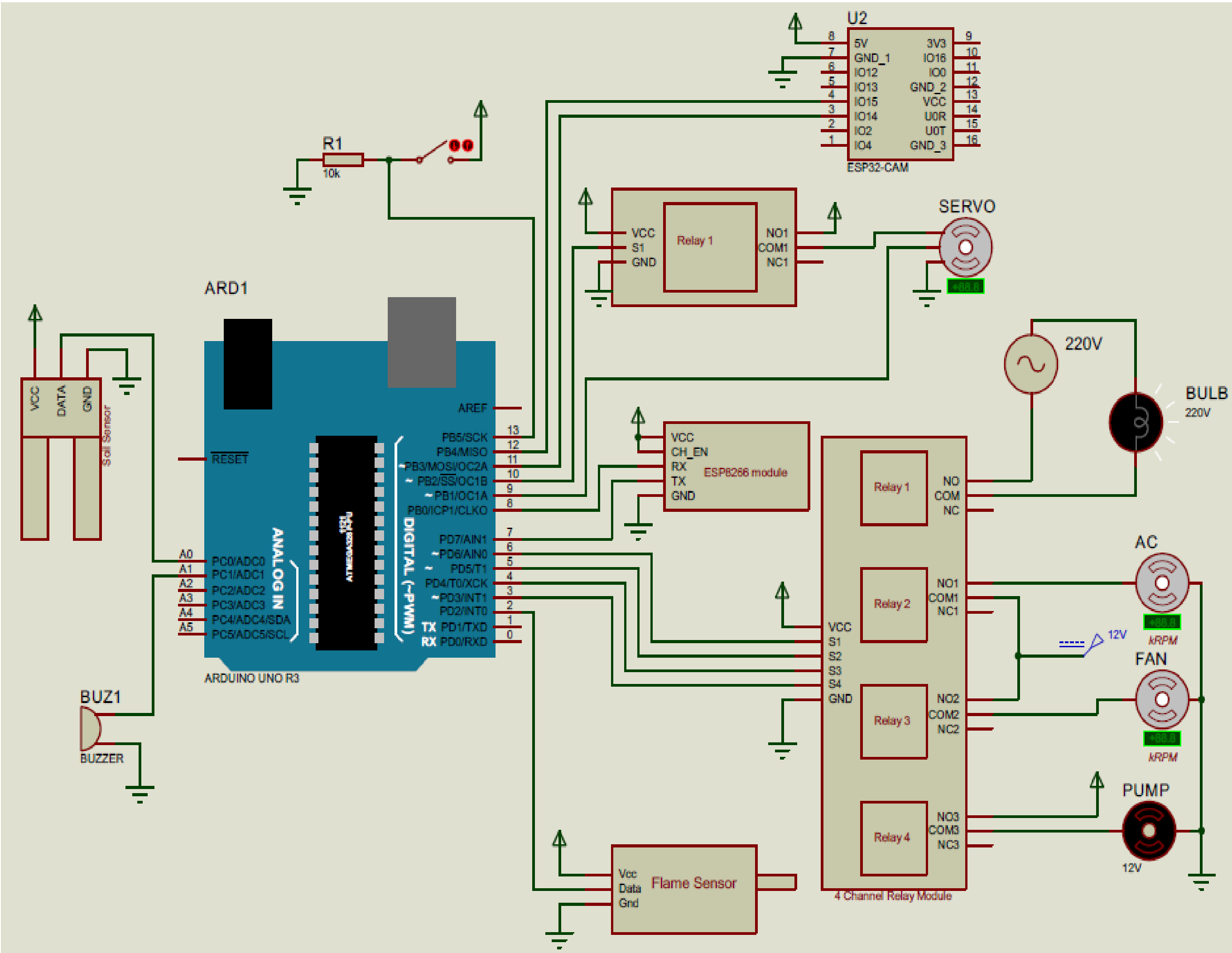


Fig 3. Prototype design of the system

the moisture level are typically known as natural moisture sensors. Soil water possibility sensors are a different variety are some of such sensors.

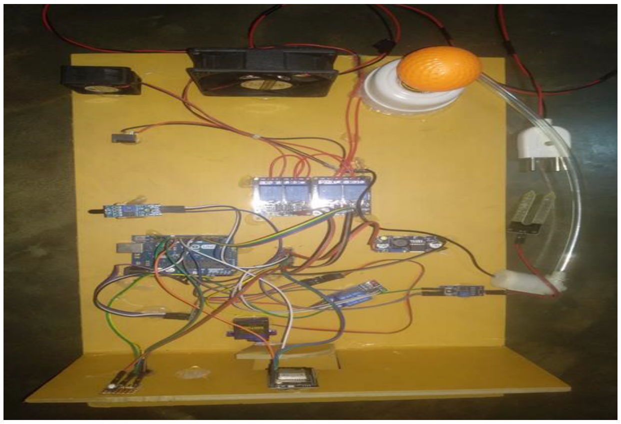
ESP32-CAM: The ESP32-CAM (Fig. 2f) is a microcontroller board with only a length of 2740mm. This might be connected to a camera system using an ESP32 module and a camera. The ESP32-CAM is suitable for a wide range of Internet of things. Smart home gadgets, industrial IoT control, wireless surveillance, QR wireless authentication, wireless indoor positioning signals, and other Internet of Things applications are all possible with it. It's a fantastic option for IoT applications.

Buzzer: Buzzer makes a buzzing sound to attract someone's attention with a mechanical/piezoelectric signal.

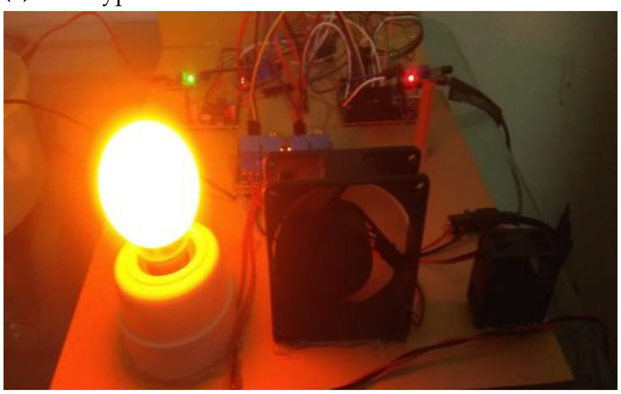
We also require connectors and wires to connect different components, IoT sensors, microcontrollers and a water pump for watering soil according to the circuit diagram in Fig. 3.

3.2 Software Requirements

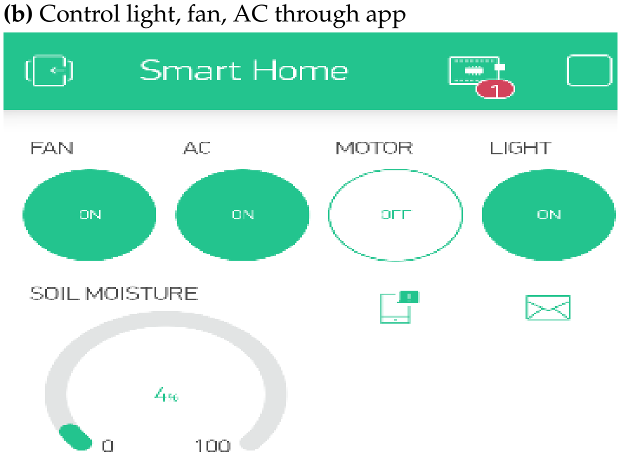
Arduino IDE: The Arduino IDE is a type of cross-platform application where C++ programming language covers 80% of the instructions. Programs are referred to as 'sketches.' Sketches must serve two purposes: one is "void setup()" and another is "void loop()". setup() function is the first and only thing that initializes the program and variables. The loop() function repeats until the power is turned off or a fresh sketch is loaded to the microcontroller. We also require an Android app called "Blynk" to create the user interface for the proposed system. To install the app, we need to use the Google Play Store to download and



(a) Prototype

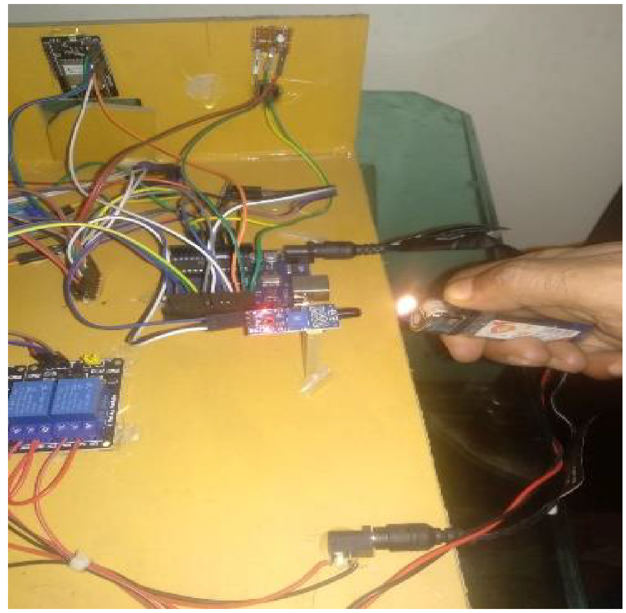


(b) Control light, fan, AC through app

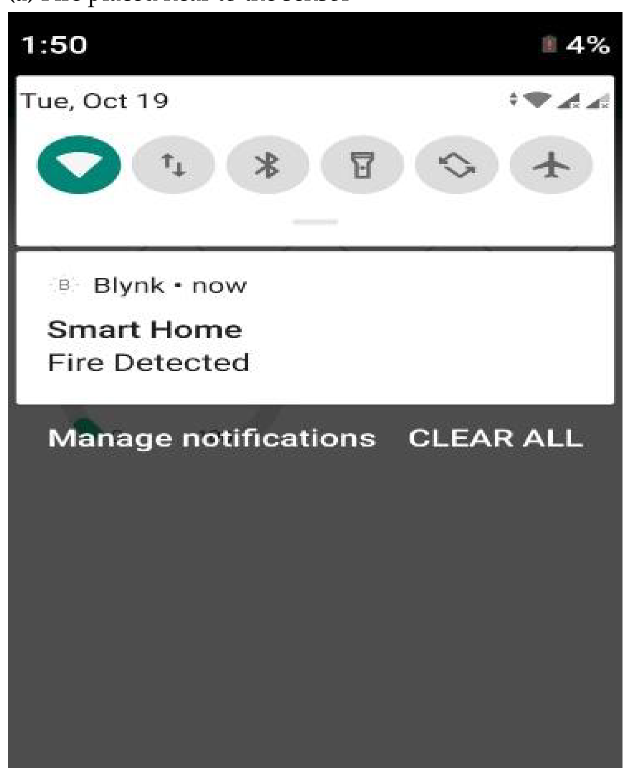


(c) Application interface to control light, fan, AC

Fig 4. The smart home prototype is controlled by the application



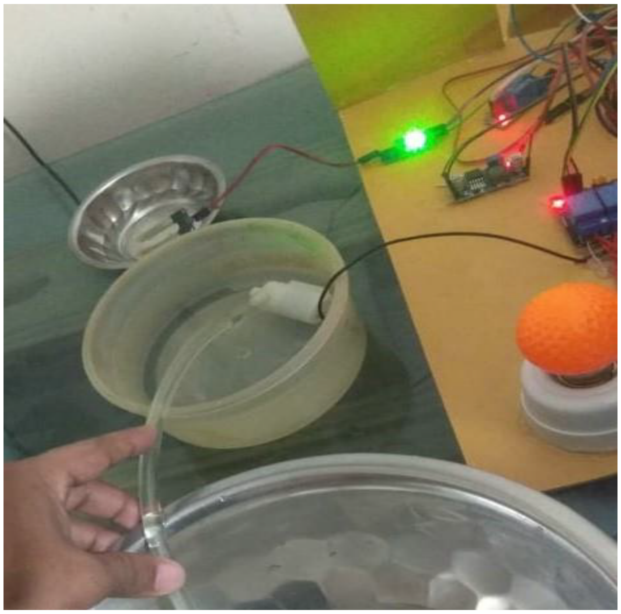
(a) Fire placed near to the sensor



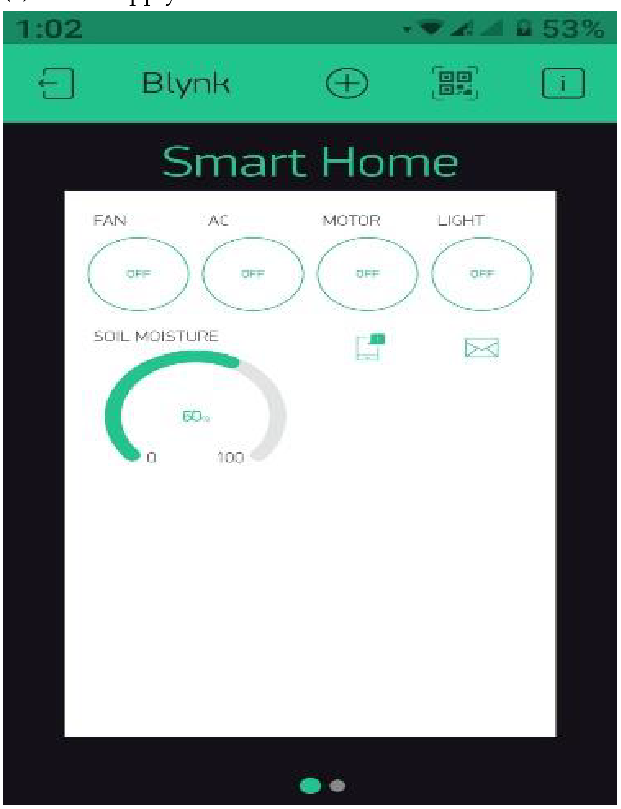
(b) Notification of fire detection in app

Fig 5. Fire alarm system with notification

install the app. After the application is installed, create a new account and log into it. A new project is created after logging in. The project is given a name, and Node is chosen as the hardware. MCU and connection type are selected as WiFi and a WiFi network is built. Blynk will then send a notification to the phone which we provided.



(a) Water supply for soil moisture



(b) Measurement of the soil moisture and motor turn on/off in apps

Fig 6. Smart irrigation System through application

The Blynk server hardware will be identified using this notification. For our prototype we used a four-channel relay module, hence, we need to add four buttons on the app screen from the sidebar and label them for different purposes. We need to personalize these buttons by giving them a name, which digital pin to connect, which device should be operated etc. As the relay module is physically connected to the digital pins, it will have an impact on the hardware connection. After completing all these steps, we finally will get the workable setup of the smart home app.

4 Results and Discussion

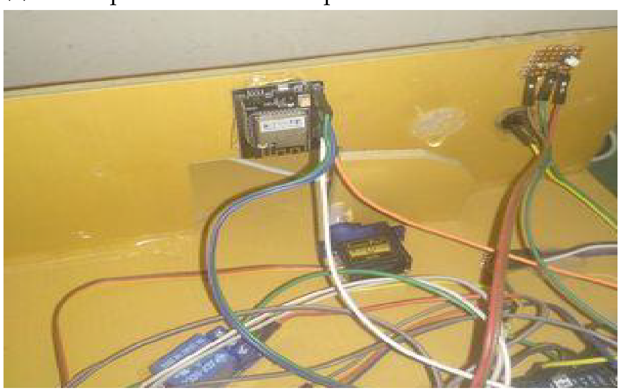
We described the required system IoT components and software in the previous section. Based on the discussion, we proposed IoT devices for sensing the home environment. The sensors send the data to the controller for processing. The controller connected with WiFi using the ESP8266 module sends the status and notifies the homeowner through the app.

In Fig. 4a, we can observe the prototype we have built and considered as our smart home environment. In Fig 4b, we turned on the light, and the app page shown in Fig. 4c is the user interface to control the light. The light bulb is connected to the microcontroller Arduino Uno through a 4-channel relay module. Using the app, the user can similarly turn on or off the Air conditioner (AC), fan, etc. When the user presses the turn on or off button in the app, the microcontroller gets a signal through the WiFi module. The microcontroller processes the signal and decides about turning on or off the light, fan, or AC. Hence homeowners can control their electric devices remotely when required. This will reduce the wastage of power and will save money.

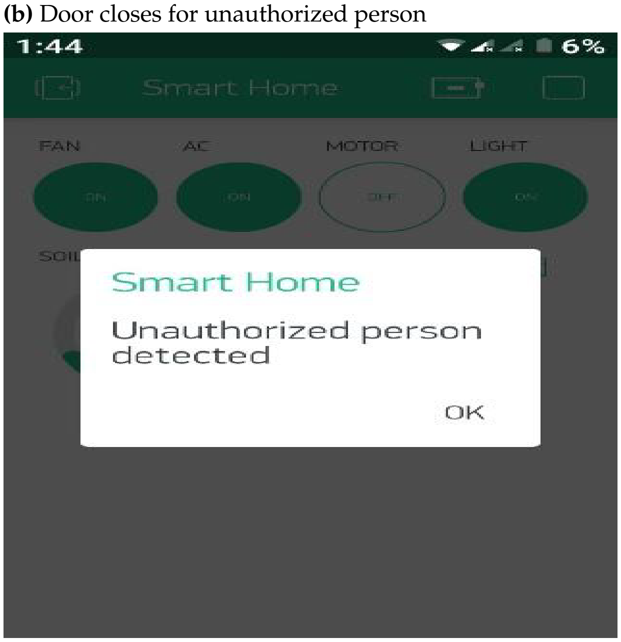
Fig. 5a shows how our system will detect fire using the flame sensor. The flame sensor contains three pins where two pins connect with +5v and ground, other pins connect with the microcontroller Arduino Uno's digital pin no. 2. When the flame sensor detects fire then it sends a signal to the microcontroller using digital pin 2. The microcontroller processes the signal and generates an alarm. At this time the buzzer will be beeping to alert the home resident. A notification will also be sent to the mobile application through the Wifi module. In Fig. 5b we can observe the response of fire detection in Android applications.

Fig. 6a shows how soil moisture sensor works. The soil moisture sensor contains three pins, two connected with +5v and ground, other pin connects with the microcontroller Arduino Uno's analog pin A0. When the soil moisture sensor measures the moisture of the soil, and then sends a signal to the microcontroller through analog pin A0, the microcontroller processes the signal and generates an alarm if the soil moisture is under 30% and a notification is sent to the mobile application. Fig. 6b shows the

(a) Door opens for authorized person



(b) Door closes for unauthorized person



(c) Detect unauthorized person in app

Fig 7. Smart door control system by face reorganization

moisture measurement of soil in the app. The user can easily check if the soil moisture level is below 30% or not. The user can turn on or off the motor using the mobile application as required. The microcontroller again gets a signal from the mobile application, processes the signal, and decides about turning on or off the motor.

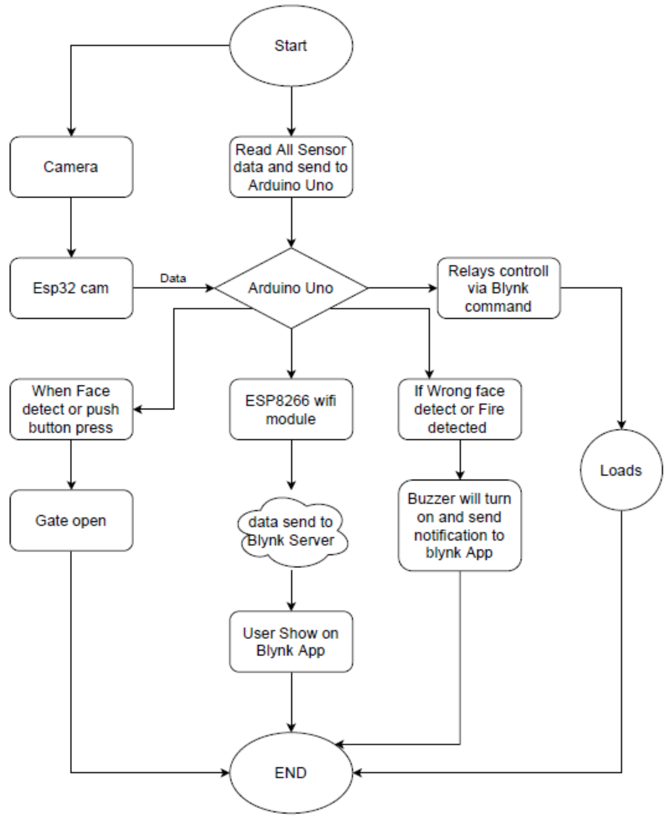


Fig 8. Flowchart of the face detection process

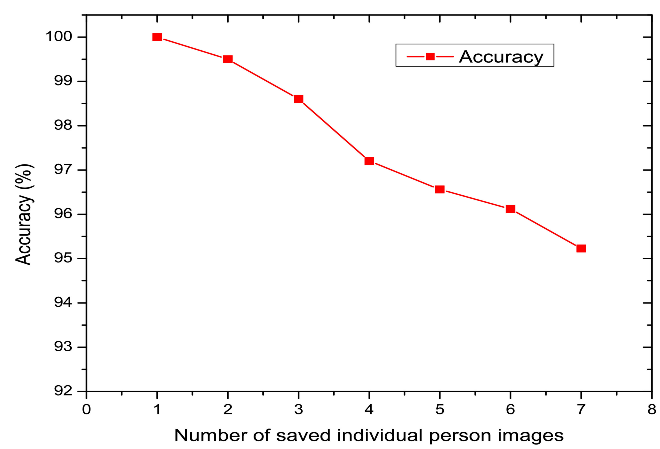


Fig 9. Face detection accuracy of the system

For face recognition, we use the camera module ESP32-CAM. In Fig. 7a, we can see that the door is open for authorized persons. The camera module contains a total of 16 pins, two pins are connected to the microcontroller Arduino Uno digital pins 11, and 12. When a person comes in front of the door, the camera module ESP32-CAM sends a signal to the microcontroller Arduino Uno. Arduino Uno processes the signal and matches the face image with the stored images from the database. If the person is known, then Arduino UNO will send the signal to the servo motor, and the servo motor will operate and open the door. If the person is not known, then Arduino UNO will send a notification to the user (Fig. 7b, Fig. 7c). Also, an alarm will be generated by turning the buzzer on. If the user feels safe as the person opposite the door is known to him/her but the image is not stored in the database, then he/she can also open the door from the inside by using a push button. The flowchart of the door control system is depicted in Fig. 8. The graph in Fig. 9, represents the accuracy percentage we can get from our system. We calculated the accuracy considering the following equation,

$$Accuracy = \frac{\text{No. of Correct Detection}}{\text{No. of Total Trial}} \times 100\% \quad (1)$$

where we divided the number of correctly detected trials by the total number of trials. We can observe that when the number of saved images is very low, the accuracy is nearly 100%. When we increase the number of saved images of different people the accuracy is getting lower, and it will continue to decrease accuracy.

Table 1. Sample table that spans one column.

Index	Items	Price (BDT)
1	Arduino UNO	750
2	Adaptor	350
3	Buck Module	200
4	Flame Sensor	150
5	ESP32-CAM	980
6	Relay Module	450
7	Buzzer	25
8	Soil Sensor	280
9	WiFi Module	260
10	Pump Motor	180
11	Servo Motor	220
12	Others	1000
	Total:	4845

In Table 1, we listed the required sensor devices and relevant devices, connectors, microcontrollers, etc. prices. In summary, we can say that the proposed smart home monitoring and automation system is quite effective as the home environment can be observed through the mobile app and any user can take the initiative to manage certain situations based on the sensed data using IoT.

5 Conclusion

In this paper, we have proposed and built a prototype of a smart home system. We have used different IoT devices and sensors to monitor the inside and outside of the home environment. The microcontroller decides which actions are required to take based on the sensed data of the IoT sensors generates a notification and sends it to an Android app used by the homeowner. The required devices, sensors, and other equipment are not highly priced. In the future, we aim to add artificial intelligence-based decision-making methods. Also, we are willing to add voice-based command interfaces.

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Labony Akter was a student at the Green University of Bangladesh (GUB). She was a student in the evening program at GUB. She completed her B.Sc. in the Summer 2021 semester. She has a good command of programming languages. Her main interest is in IoT, sensors, and hardware-based projects.

Khadiza Akter was a student at the Green University of Bangladesh (GUB). She was a student of the evening program at GUB. She completed her B.Sc. in the Summer 2021 semester. Her main interest is in IoT, sensors, and hardware-based projects.

Md. Nazmus Sakib was a student at the Green University of Bangladesh (GUB). He was a student of the evening program at GUB. He completed his B.Sc. in the Summer 2021 semester. His main interest is in IoT, sensors, and hardware-based projects. Currently, he is working in a private company.

Jargis Ahmed was born in Rajshahi, Bangladesh, in 1994. He received the Bachelor of Science, B.Sc., and Master of Science, M.Sc. in Computer Science and Engineering (CSE) from the University of Dhaka, Bangladesh, in 2017 and 2021 respectively. He has several publications in renowned conferences and journals. He has served as a Lecturer in the Department of CSE at Green University of Bangladesh (GUB) since 2018 and is currently working as an Assistant Professor and Program Coordinator. His research interests include the Internet of Things (IoT), Mobile Edge computing, Cloud Computing and 5G.