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Research Article

Future Directions and Recommendations for the Design and Development of Smart Home Control and Management Systems

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Abstract

The smart home and management system in this study are powered by D.C. batteries. The battery can run for two to three days before running out of power when it is fully charged. The research title and the maximum temperature are shown on the LCD when the system is powered on. Additionally, it will indicate that no one is inside the residence. If you press the push button to enter the house, it will display on the Liquid Crystal Display (LCD) that you are welcome and the number of people in the house will increase by the number of people that enter the house. You can choose the number of people you want to enter the house. If you choose the maximum to be 12, the door will not open again until someone presses the exit button from the house and exits the house before another person will be able to enter the house. There is a fan in the house that is used to cool the temperature of the house if it is hot, and you can choose when you want the fan to turn on automatically by selecting the maximum temperature. If you choose the maximum temperature to be 30 °C, the fan will not operate until that temperature is reached. And if everyone leaves the house, both the fan and light will automatically switch off since no one is inside the house. There is a light in front of the house for security reasons. If it is dark at night, it will automatically turn on. This light is controlled by the second LDR outside the house. If the LDR senses the presence of light, the bulb outside the house will switch off during the day and if it senses the presence of dark, that is, at night, it will turn on itself for security purposes. The first LDR is inside the house. It will turn on the lights in the house if someone enters. Until everyone has left the house, the light won't turn off. Additionally, this study goes into great detail about the smart home management system's future directions and suggestions.

Keywords: *Recommendations, Future directions, LCD, Smart House, Infrared sensor, Microcontroller.*

I. INTRODUCTION

The terms "smart home" and "intelligent security system" have developed throughout the past century as a result of technological advancement and have begun to catch researchers' attention. A smart house is one that can remotely or automatically regulate its devices and appliances. For the creation of smart home systems, a variety of sensors, modules, shields, and microcontroller boards can be used [1]–[8]. Therefore, as shown in Fig. 1, this technology includes numerous other features such as smart security, home facility protection, temperature control, intelligent lighting arrangements, and many others. The subsystems for wireless communication, entertainment, security, convenience, and information management are also included in a smart home [9]–[13]. A system of interconnected sensors, actuators, interaction tools, and modules is referred to as a "smart home" and is used to provide homeowners with support and applications such as safety and security, automation, entertainment media, and energy control with little to no human

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participation. But smart home safety and security systems are highly necessary and constantly needed for a variety of reasons, including people's propensity to feel protected in their own houses and to lower a high rate of criminality [14]–[16]. Numerous sensor types can be used in the construction of smart homes to safeguard them against combustion, as gas infiltration is another unwanted situation. Liquefied petroleum gas (LPG) is a popular cooking fuel in contrast. Since LPG is sold in cylinders, a leak might cause an explosion. A gas infiltration case is usually unknown to the occupants of the residences and other institutions. They might consequently ignite a conflagration that bursts. To avoid this dangerous situation, the gas leakage detection strategy must be installed and used [51–53]. There has been a significant rise in crime recently [54]. As a result, installing protection systems in homes is crucial [17,18]. The use of different types of sensors, such as PIR sensors, water level sensors, soil moisture sensors, light intensity sensors, current sensors, voltage sensors, DC motors, and ultrasonic sensors, has been discussed extensively by many other researchers [55]. To build a complete smart home system, all of the sensors stated above can be incorporated with modules and microcontrollers [10]-[22]. The research's contribution might be summed up as the introduction of a low-cost system for managing applications for smart home gadgets. The suggested system has a few crucial functional components. The first is used for security, and the second is used for the occupants' safety in the residence. The IR sensor, laser beam directed at a Light Dependent Resistance (LDR) sensor, Bluetooth module with programmed smart phone App, and servo motor make up the first component. The gas sensor, flame sensor, temperature and humidity sensors, liquid crystal display, and alarm make up the second component. The Arduino served as the processing engine for the sensor data in both components [56].

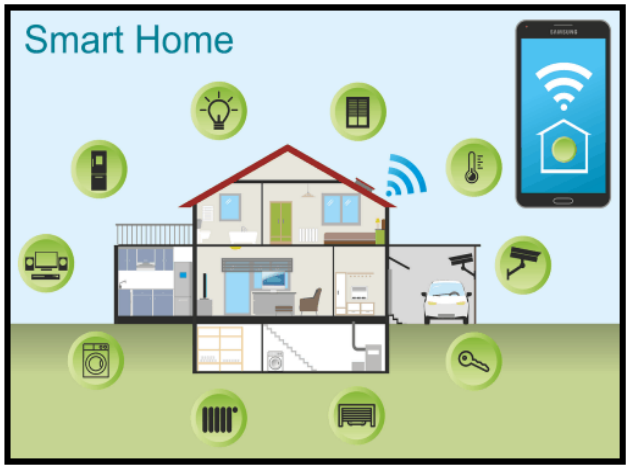


Fig. 1. A simple smart home

II. SMART HOME

From fire vaults to warm cells to torches and candles, and finally to the arrival of the most contemporary invention, namely electricity, homes have been created throughout antiquity, which has offered convenience for the home's occupants. After that, it was explored how to use embedded systems and electronic parts in machinery and other appliances. While programming instructions for the CPU of embedded systems can be used to complete a number of functions, such automatic hot and cold washing, turning on/off lights [57], and security employment. Since the 1970s, embedded and integrated systems have gained popularity and started to appear in urban households' domestic operations. In order to find necessary smart home systems, home automation is able to link between electrical and electronic features [23], [24]. Here are a few examples of smart home automation and control applications [25-32].

1. Keeping an eye on the weather and controlling the heating or cooling system.
2. Identifying a leak in the cooking gas and advising the residents of the house via an alarm and an SMS.
3. Keeping an eye on the weather and, in case of rain, closing the windows of the house.
4. The clever control that determines whether to switch on or off the exterior lighting for the house depending on the time of day or night.
5. The intelligent control of turning ON/OFF various home appliances via a mobile phone using Wi-Fi, Bluetooth, or an SMS service.
6. Utilizing RFID [58, 59] technology to unlock and close the front door of the house rather than traditional locks.
7. Utilizing movement detection sensors to protect a house against burglary [60].
8. When the fire first appears, turn on the firefighting pumps.
9. Using intelligent irrigation to water the garden based on the amount of humidity in the soil.
10. Electricity for the home is produced using solar cells [61, 62].

The items previously mentioned all offer residents of homes security and safety. The aforementioned applications can also be used by businesses and other entities. While each of these applications makes use of a variety of electronic sensors, their data may be managed and processed by using a variety of microcontroller boards, including Arduino,

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Raspberry Pi, PIC microcontroller, and others. Due to its simplicity of use, low cost, and open-source nature for both software and hardware, the Arduino is therefore more frequently used than other varieties. The "Internet of Things" (IoT) [63] concept has been rapidly developing in recent years, and more amateurs and researchers are using this technology to develop smart home applications. The user handles these appliances remotely and sends or receives all necessary data through the system's mainboard through the internet by combining all of the home programmable equipment into a Local Area Network (LAN). Smart home sensors and modules can be wirelessly connected via a number of other technologies, including wireless LAN, ZigBee, Bluetooth, etc. Figure 2 shows an illustration of wireless communication between modules, sensors, and the internet in a home [33, 34].

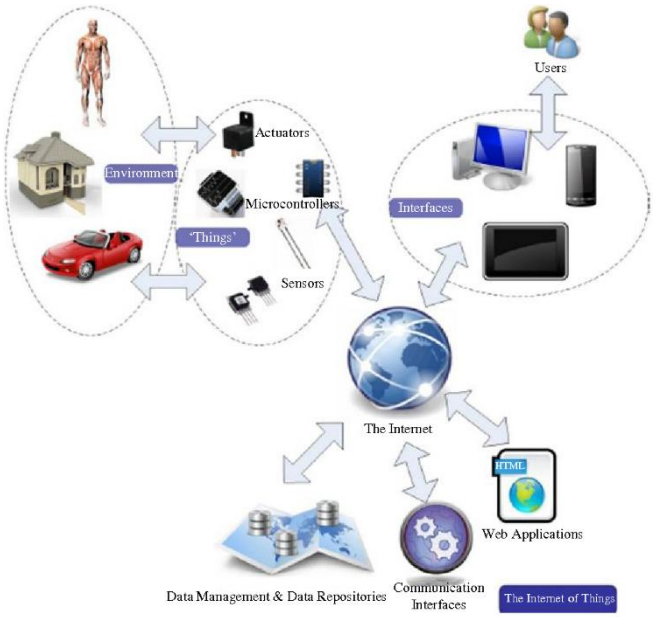


Fig. 2. Wireless communication between the modules and internet

A. Benefit from smart homes.

Smart home adoption has a number of noteworthy benefits that can be realized. Some of these benefits can be combined with the ensuing arguments [35–42].

1. From one location, manage and control all of your home appliances.
2. It gives users the option to add or remove new appliances from the system as needed.
3. Improve the security of the house's defense [64–67].
4. Through the use of a remote control, it offers the homeowners comfort for their house operations.
5. Savings on energy because only real consumption is used.
6. Increasing the equipment's usefulness, but smart homes might enable even more effective appliance operation.

B. System for securing a home

Home security is not a recent development; it has been acknowledged since the Stone Age. People then used a variety of rocks, trees, and weapons to ward off predators [68]. The methods for safeguarding one's royalty have been progressively improved in recent years. Nowadays, people utilize considerably more sophisticated, safe, and affordable security measures to guarantee the ideal property's security. To ensure effective protection for homes against burglary, the automatic home security system is built on various electrical components or makes use of microcontroller boards[43, 44].

III. SYSTEM DESIGN AND CONSTRUCTION

The newly launched system typically consists of two major components. The first section relates to the safety of the house, while the second is reserved for automatic control (i.e., automation). The Arduino IDE is used to program both components, which are based on Arduino microcontrollers [45]. The infrared (IR) sensor and the laser beam that is pointed directly at the LDR serve as the foundation for the home's security system. The IR sensor immediately sends logic "1" to the Arduino Nano kit to turn ON the warning siren the instant the thief walks in front of it. Additionally, the thief will be facing the laser beam if it tries to avoid the IR sensor. When the ray is broken, the LDR resistance value increases, and the Arduino Nano then follows the previously described procedure. The ATmega328P of the Arduino Nano and Arduino Leonardo microcontrollers with multiple sensors, such as the MQ-02 gas sensor, KY-026 fire detection sensor, as well as soil wetness sensor, are the foundation for the automation and controlling process for the introduced configuration. Table I describes the functions of the aforementioned sensors that are used in this work.

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Sensor	Task
Flame sensor	It serves as a tool for configuration detection. Arduino will activate the buzzer, the sprinkler represented by LED 1, and print a warning message on the LCD in the event of a fire.
Gas sensor	It is used in the home kitchen for LPG detection purposes. The Arduino will activate the buzzer and print warning messages on the LCD in the event of a gas leak.
DHT-11 sensor	Used to measure weather conditions such as temperature and moisture. The LCD will display the temperature and humidity values, and the LED-2-designated air conditioner will be turned on by the Arduino.
Soil moisture sensor	Used to measure the moisture content of soil. The Arduino will turn on the water pump, which is symbolized by LED-3, and print a message on the LCD if the soil is dry.

The system is also developed using the Arduino Leonardo, 2x16 LCD, and DHT-11 sensors; the LCD's purpose is to display the weather's temperature and humidity. Additionally, the LCD will display warning messages for the LPG leak and fire detection situations. Finally, the HC-05 module, which enables Bluetooth-based wireless communication with a unique Android app and a small servo motor, is also used to remotely control the garage door [69]. The employed Android application was created in the "MIT App Inventor" online environment, which was established by Google and is run by the Massachusetts Institute of Technology. This platform relies on the development of a graphical user interface based on a visual programming language (i.e., block arrangement), which enables users to drag and drop visual blocks to create the necessary software [46–50].

IV. MATERIAL AND METHODS

4.1. Materials

Table II: Below are the materials used in this research

S/N	Names of components	Number used
1	LDRs	2
2	Lights	2
3	Liquid crystal display	1
4	Microcontroller	1
5	Buzzer	1
6	IR Sensor	1
7	Switch Button	1
8	Light Emitting Diode	1
9	Battery	3
10	Connections	29
11	Fan	1

4.2. Methods

The microcontroller PIC16F8877A serves as the brain of the research, which offers relay with necessary information when the temperature is very high above the setting point to activate the DC fan in order to prevent the battery from unnecessary discharge. In cooperation with the DHT11 temperature/humidity sensor, it is used to monitor the temperature level in the premises while the LCD is used to display the corresponding temperature inside the room and also the number of people inside the house. Also, DC 12v bulbs are controlled by an LDR sensor during the day and night periods in order to control the waste of power consumption. The outside light is used at night for security reasons. However, the major components mentioned work in cooperation to form the system with the microcontroller. The automatic door, which is controlled or operated by the push buttons, is used to control the number of people who will enter and exit the house with the help of an IR sensor, which is used in the system.

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4.2.1. Connection of the Microcontroller to LCD

The liquid crystal display pins are connected to the microcontroller, which is the brain of the whole research.

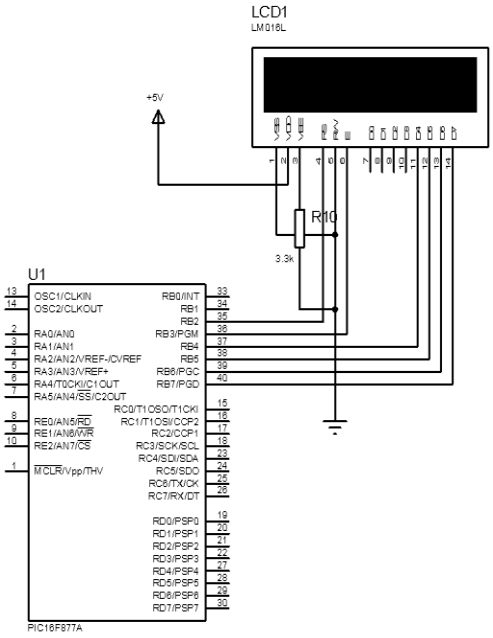


Fig. 3. LCD interfaced to PIC16F877A

4.2.2. DHT11 temperature/humidity sensor unit

The DHT11 acts as a temperature and humidity sensor. It gives an output of 10mV/C and is capable of producing a voltage from 10mV to 1.5V that corresponds to temperatures from 0 C to 50 C and 0-80%.

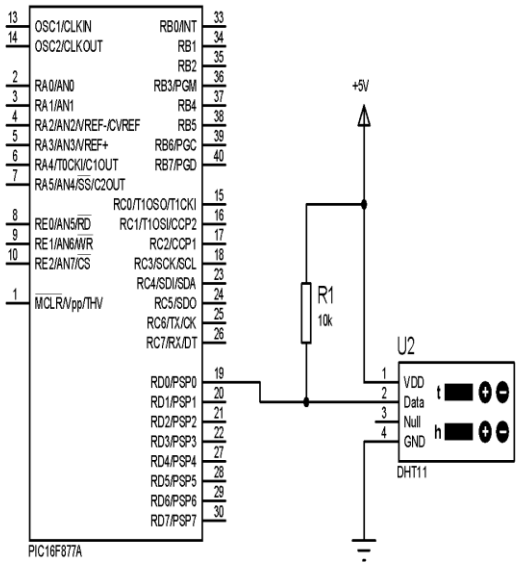


Fig. 4. Connection of DHT11 to microcontroller

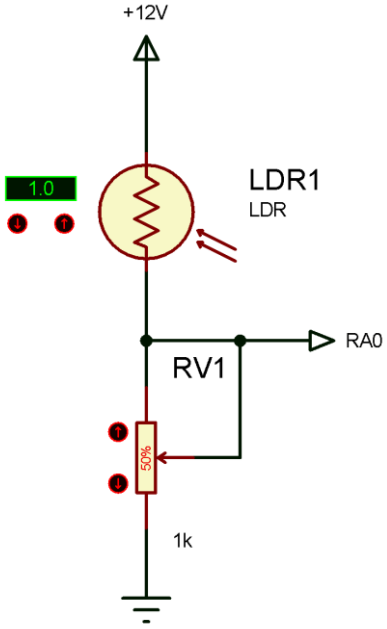


Fig. 5. Infrared Sensing Unit

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4.2.3. DC FAN/LIGHT Control Unit

The unit serves to control the DC fan and light system using a BD139 transistor. The circuit of this unit is shown in the figure below.

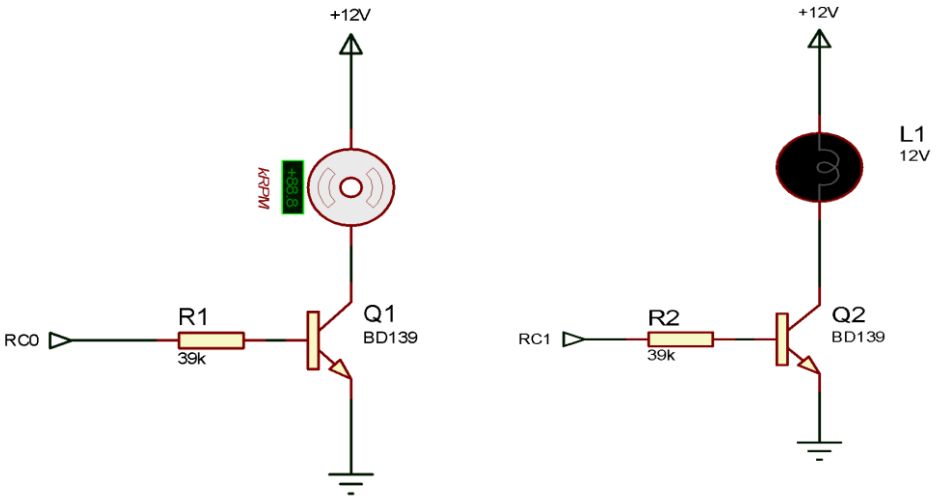


Fig. 6. DC fan/light transistor

4.2.4. Door control unit

The arrangement of the circuit as below is the actuator part, which uses the BC547 transistors to enable the actual door control to open and close due to movement of the motor clockwise and anticlockwise when a visitor arrives.

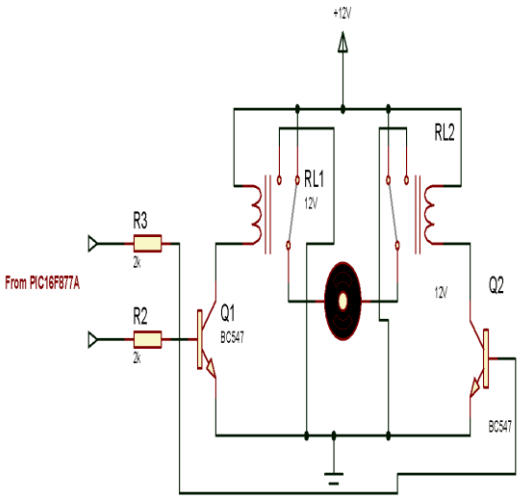


Fig. 7. Door control circuit

4.2.5. Alarming unit

This unit is used for alarming. When the limit is exceeded, it will sound an alarm showing that the number of people that are required to enter the house has reached its limit.

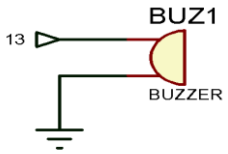


Fig. 8. Alarming unit

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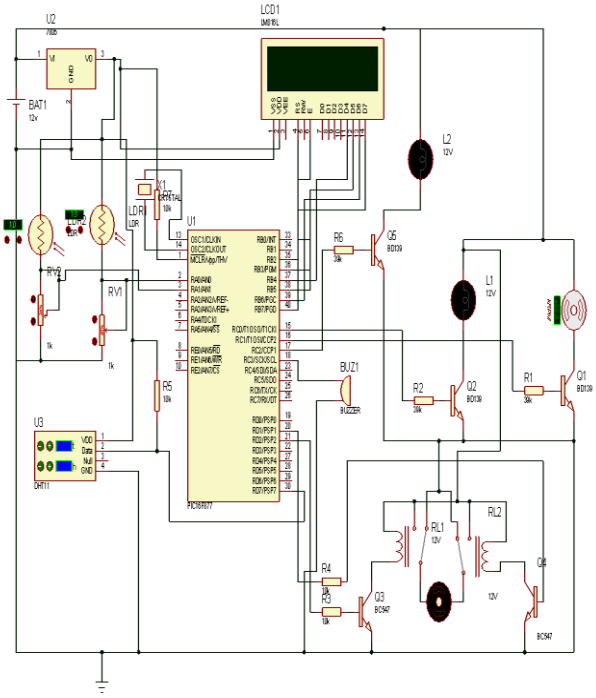


Fig. 9(a). Complete circuit diagram

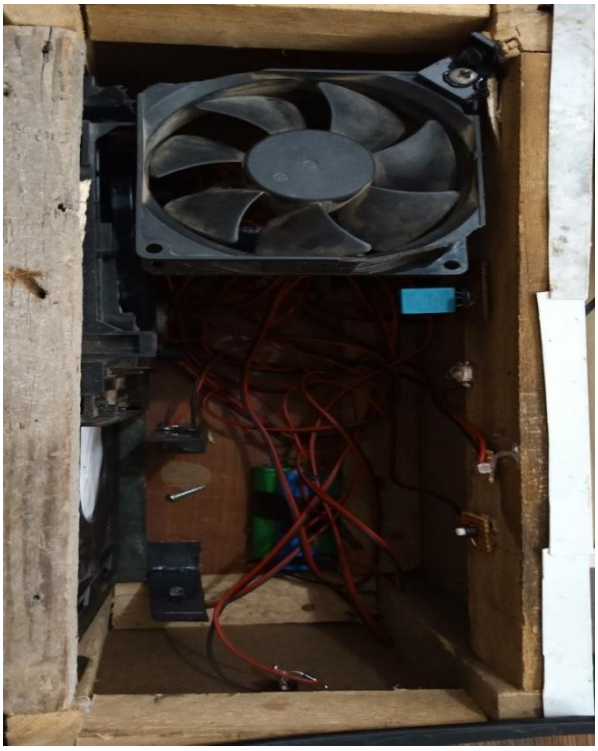


Fig. 9(b): Implementation of the System

V. RESULTS

The images below are the pictures of the results obtained from the implemented system.

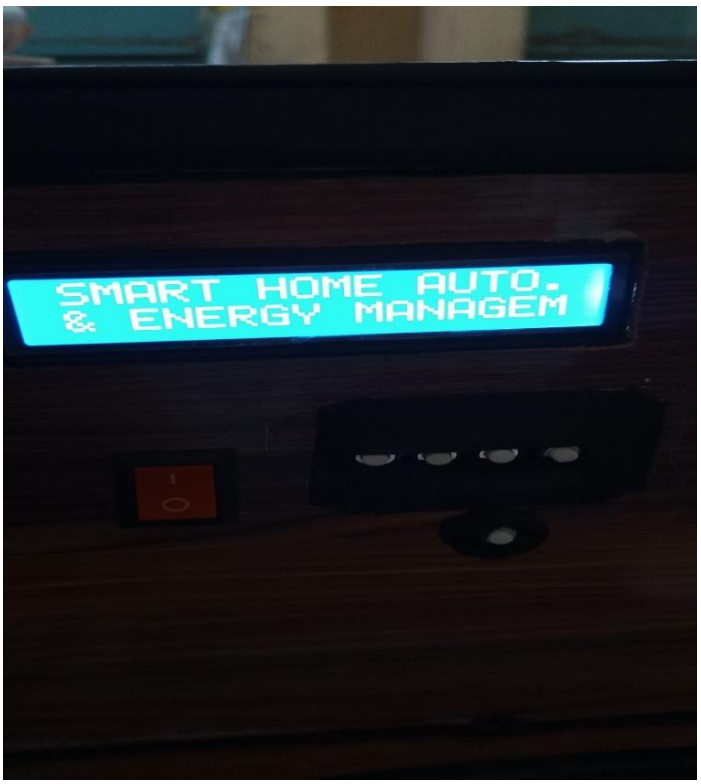


Fig. 10. Implementation of the Circuit Display the Title of the research



Fig. 11. The whole system implementation

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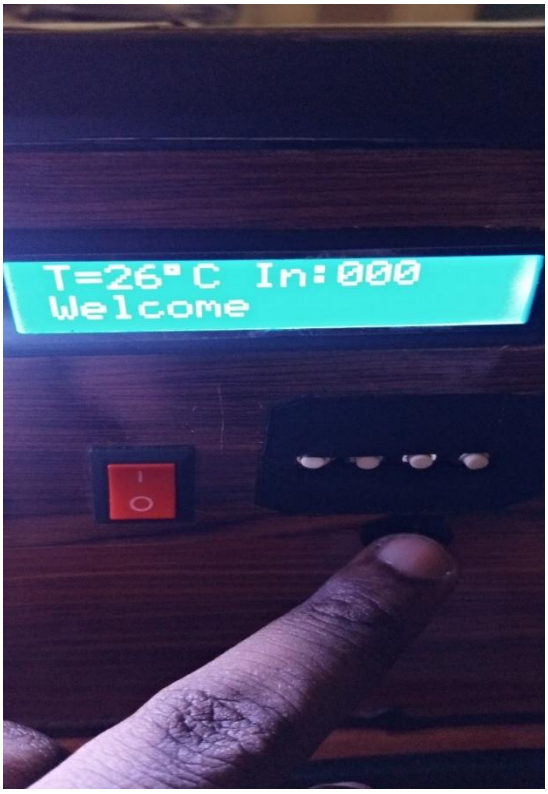


Fig. 12. Implemented Circuit Displaying the Process of Pressing the Entrance Door

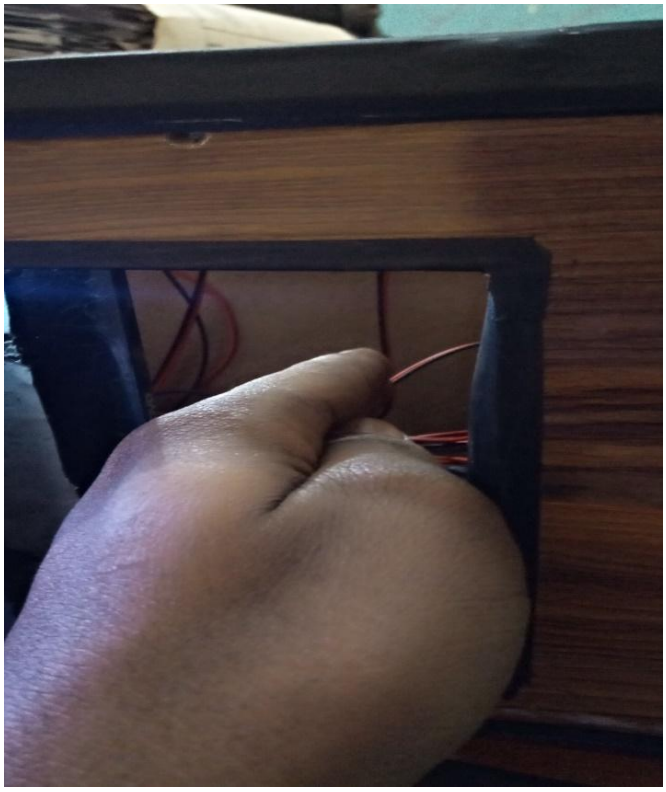


Fig. 13. The Process of entering the door

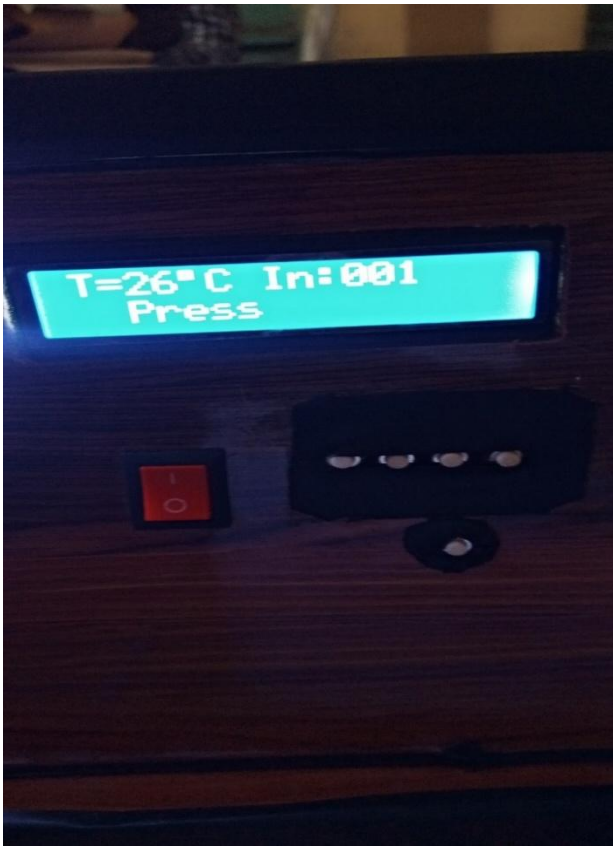


Fig. 14. System displaying one person is inside the house

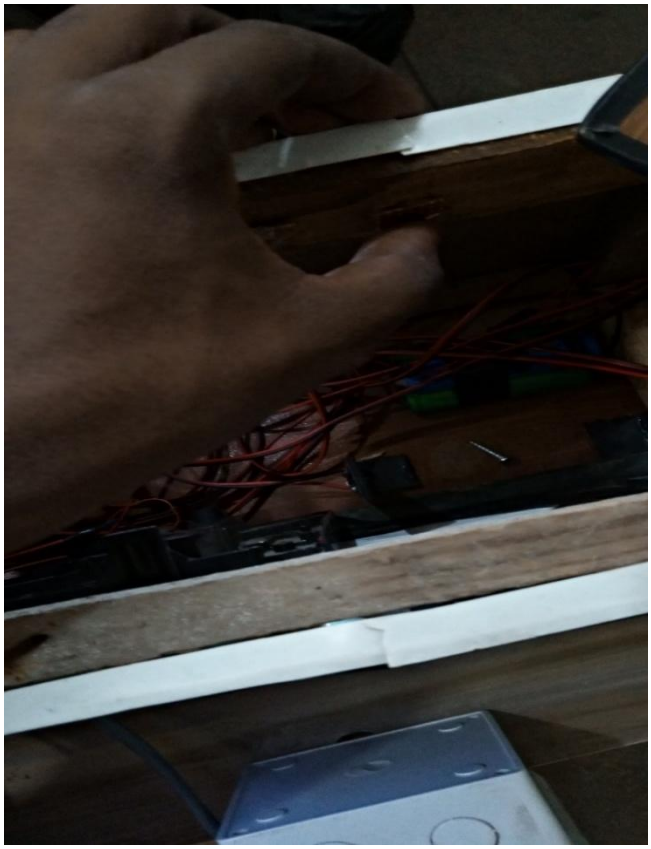


Fig. 15. The process of pressing exit button from the house

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Fig. 16. The process of leaving the house through the door

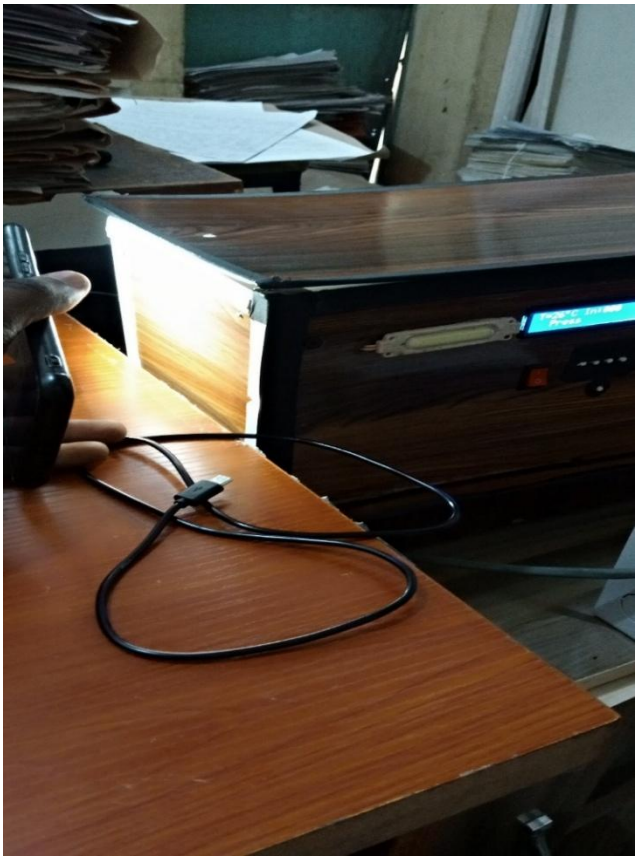


Fig. 17. The outside LDR that is used to control the front light of the house will go off during day light. That is, if the research is exposed to light, the front light will not come on until it sees dark the LDR.

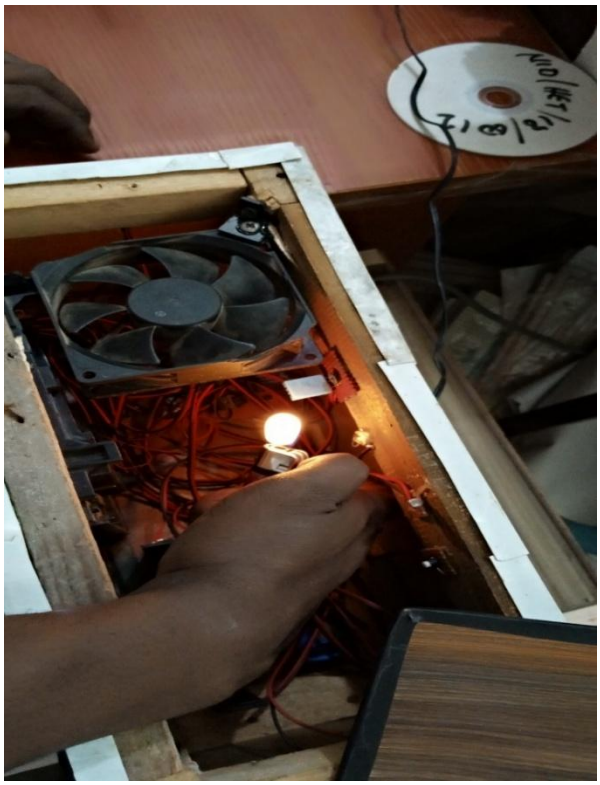


Fig. 18. The DHT-11 sensor is used to monitor the temperature and humidity of the house. If the temperature exceeds the maximum temperature set, the fan will turn on by itself with the help of the DHT-11 sensor.

VI. FUTURE DIRECTION

Future Directions: Future smart home systems will focus on greater integration, intelligence through AI, and enhanced security and privacy. Key future directions include more intuitive user interfaces, seamless device interoperability via technologies like 5G and IPv6, and AI driven personalization to anticipate resident needs for improved convenience, safety, and energy efficiency. Enhanced intelligence and automation

i. AI and machine learning: Future systems will use AI to learn user habits and preferences, enabling them to proactively adjust settings for comfort and energy savings without direct commands.
ii. Predictive maintenance and health monitoring: AI can analyze data from sensors to predict equipment failure or monitor residents' health, sending alerts for potential issues or emergencies.
iii. Advanced human-computer interaction: Expect more natural and intuitive control methods like gesture recognition, voice commands, and systems that can sense the presence and state of residents through a variety of sensors.

Greater integration and interoperability

i. 5G and IPv6: Advanced network technologies are providing the foundation for a truly interconnected home where all devices can communicate seamlessly and reliably.
ii. Interoperable standards: The future will see greater compatibility between different brands and devices, moving beyond proprietary systems to a more unified ecosystem.

Robust security and privacy

i. Advanced threat detection: Systems will use AI and deep learning to detect potential threats and take appropriate security measures, ensuring occupant safety.
ii. Enhanced privacy controls: As more data is collected, future development will focus on stronger encryption, user control over data, and transparent data usage policies to maintain user privacy.

Improved sustainability and efficiency

i. Energy management: Smart homes will optimize energy use by learning inhabitant schedules and preferences, intelligently controlling lighting, heating, and cooling to reduce waste.
ii. ii. Resource monitoring: Systems will become more sophisticated in monitoring and managing other resources, such as water consumption [71].

VII. CONCLUSION

One of the main tenets of the smart home is that it uses less energy, improves security, and makes tenants' lives more comfortable. This study looked at the planning and development of an inexpensive framework for smart home automation. In this study, research articles on inexpensive smart house designs utilizing the Arduino Nano and Arduino Leonardo microcontroller boards were examined. A smart gate door controller is designed to monitor the house appliances in order to reduce waste of power [70], provide security and control the number of people that will have access to the house [71-78].

VIII. CORE RECOMMENDATIONS FOR SYSTEM DEVELOPMENT

i. **Select Proper Sensors and Actuators:** Pair microcontrollers (such as Arduino or ESP8266/ESP32) with precise environmental sensors (like DHT-11 for temperature and humidity) and reliable relay or LDR modules for lighting and climate control.
ii. **Optimize Multi-Protocol Connectivity:** Combine Wi-Fi, Zigbee, Z-Wave, and Bluetooth Low Energy (BLE) to balance range, power consumption, and mesh reliability.
iii. **Prioritize Energy Management:** Build automated demand response (DRED) and real-time power monitoring to shed non-essential loads during peak tariffs or low-battery states.
iv. **Keep Interfaces User-Centric:** Design lightweight dashboards (via React Native, local LCD displays, or voice assistants) that minimize CPU overhead and lower the learning curve for non-technical users.
v. **Incorporate Edge-First Processing:** Keep critical security and safety loops (gas, flame, and motion triggers) running locally on the gateway rather than relying strictly on external cloud servers [79].

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