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Design and Fabrication of a Low-Cost System for Smart Home Applications

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***Abstract*—Smart systems and security got impressive attention and development in recent years, which have been appeared in the terms of smart homes, intelligent security, and the Internet of Things (IoT). Home automation comprises the controlling of the electrical appliances in the home wirelessly or automatically. Many different integrated circuits, sensors, modules, and embedded systems are available to be compatible to integrate with smart homes. In order to apply the concept of smart homes, many issues should be considered like as providing a user-friendly, reliable, secure, and cost-effective. In this paper, an effective and low-cost smart home system is designed and implemented based on the Arduino microcontroller boards with its compatible modules. The proposed work employed many types of sensors to carry out the tasks for the smart home for a couple of the essential segments, the first one is home security and the latter one is home automation. The antitheft home segment is based on the laser source directed on the light-dependent resistor and infrared sensor; once the thief tries to cut the laser or passes beside the sensor, the alarm will be switched on. The later segment aims to detect the fire occurring by the means of the flame sensor, gas leakage detection by the MQ-05 sensor, servo motor to opening/closing the garage door, LCD to display the status of the all-utilised sensors, and finally, the Bluetooth module to controlling the garage door wirelessly. To increase the system performance and reliability the Arduino Nano and the Arduino Leonardo board are utilised.**

Keywords*—: *Smart House; IoT; Infrared sensor; Bluetooth module; Arduino; MQ-05; Servo motor;

I. INTRODUCTION

Throughout the last century with the technology development, the term of the smart house and the intelligent security system have been appeared and started to gain the researchers' interest. The smart home signifies the control of the home appliances and equipment wirelessly or automated. There are several types of sensors, modules, shields, and microcontroller boards that can be employed for the construction of smart home systems [1]-[8].

Consequently, this technology comprises automatic lighting arrangements, temperature control, home facilities protection, smart security, and multiple other functions, as illustrated in Fig. 1. The smart home also, involves the subsystems for the applications of wireless communication, entertainment, security, convenience, and information management [9]-[13].

The smart home scheme is described as a group of interconnected sensors, actuators, interaction tools, and modules that are utilised to offer homeowner assistance and implementations such as the safety or the security, automation, amusement media, and energy controlling with little to no human involvement. But there is a high need for and ongoing requirement for smart home safety and security systems for an assortment of conditions, comprising the people's inclination to realise the safe in their own homes and to reduce an elevated rate of criminality [14]-[16].

In the configuration of the smart homes, numerous types of sensors can be employed for the purpose of protecting the homes against combustion, as gas infiltration is another undesirable circumstance. whereas, Liquefied petroleum gas (LPG) is considerable extremely utilised for concoction in the homes. The LPG is offered in cylinders and could explode if there is a leak. The residents of the homes and the other institutions are frequently unaware of the case of the gas infiltration. As a result, they might start a conflagration that explodes. Installing and utilising the gas leakage detection strategy is necessary to prevent this risky status. These days, there is a huge increase in criminality. Consequently, it is essential to install protection systems in homes [17], [18].

Many other researchers have reported in the literature on the utilising of the other type of the sensor like as the PIR sensor, water level sensor, soil moisture sensor, light intensity sensor, current sensor, voltage sensor, DC motors, and ultrasonic sensor. All of the previously mentioned sensors can be embedded with the modules and microcontrollers to create the completed smart home system [10]-[22].

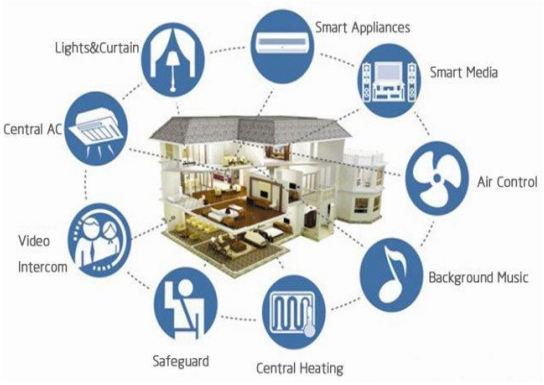

Fig. 1. Smart home applications.

The research contribution is summarized as a design of a low-cost system introduced for controlling the applications of the appliances of the smart home. The proposed system is including a couple of essential functional parts the first one is employed for security while the second one is employed for the safe of the home residents. The first part is made up of the

basis of the IR sensor, laser ray directed to Light Dependent Resistance (LDR) sensor, Bluetooth module with a programmed smart mobile phone App, and servo motor. The second part is made up on the basis of the gas sensor, flame sensor, humidity and temperature sensor, liquid crystal display, and alarm. Both parts utilised the Arduino as a brain for processing the sensors' data.

II. SMART HOME

The homes have been developed throughout antiquity, from the fire vaults toward the warm cells and even torches and candles, and ultimately the appearance of the most modern innovation that is the electricity, which has provided convenience for the house residents. Following that, the electronic components and embedded systems were studied to be utilised in the machines and the other appliances. Whereas through the programming procedures for the processor of the embedded systems several of the tasks can be done such as automatic hot/cold washing, switching On/Off the lights, and the security employments. Since the 1970s the embedded and integrated systems were widely utilised as well as emerged within the domestic functions of urban homes, this during the home automation manages to link between the electrical and electronic aspects toward the search of smart home system indispensable [23], [24]. Some of the applications for the smart home controlling and automation can be summarised as follows [25]-[32]:

- Monitoring the weather temperature and switching ON/OFF the air-conditioner or warming system.
- Detecting the cooking gas leakage and alerting the home residents by means of the alarm and sending a warning message via SMS.
- Monitoring the climate and closing the windows of the home in case of soppy weather.
- The smart control of turning ON/OFF the outdoor lighting for the house depending on the day or night situations.
- The smart control of turning ON/OFF the different of the home appliances through the mobile phone using Wi-Fi or Bluetooth technology or through the SMS service.
- Closing and opening the door of the home by means of RFID technology instead of the traditional locks.
- Use of movement detection sensors to defend the home against burglary.
- Open the firefighting pumps during the appearance of the fire.
- Applying smart irrigation for the garden based on the percentage of humidity in the garden soil.
- Employing solar cells to equip the home with electricity.

All of the mentioned above previously affords security and safety for home residents. Additionally, the mentioned applications can be utilised by companies and other institutions. Whereas all of these applications are done through the employment of several of the available electronic sensors, and their data can be managed and processed through the use of the available microcontrollers' boards such as Arduino, raspberry pi, pic microcontroller, and other types. Consequently, the Arduino is preferred to be utilised as compared with the other types due to the ease of dealing with it, low price, and open-source for both software and hardware. In recent years the new term Internet of Things (IoT) concept is expanding swiftly, where the researchers and amateurs are doing more of the smart home applications via this technology. All of the home controllable appliances can be combined within a Local Area Network (LAN) and the user manages these appliances remotely and sent or receive all the necessary data by the system's mainboard through the internet. Some of the various other technologies such as the wireless LAN, ZigBee (XBee), Bluetooth, etc., can be employed to connect the smart home sensors and modules wirelessly. Fig. 2 illustrate an example of the wireless communication between the home sensors, modules and the internet wirelessly [33], [34].

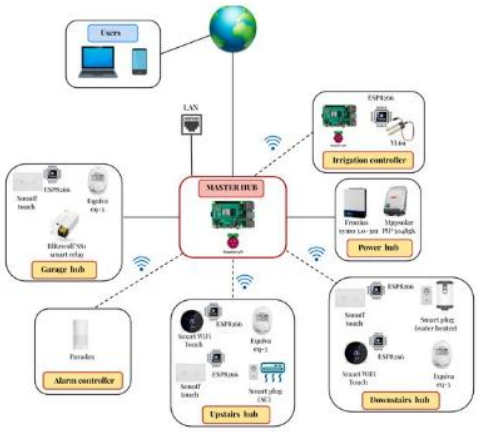

Fig. 2. Wireless communication between the modules and internet.

A. Advantage of the smart homes

There are many significant advantages that can be achieved through the implementation of smart homes, some of these advantages can be merged with the following points [35]-[42]:

- Manage and control all of the home appliances from the same place.
- Offers the flexibility for adding or removing the new appliances within the system.
- Enhance the protection for the home in terms of security.
- Provides the homeowners comfort through the remote control for the home functions.
- Power savings due to the only actual consumption.
- Optimising the goodness for the appliance; whereas the smart homes could further permit the optimum operation for the appliances.

B. Home security system

The security of the homes is not a new innovation, since the Stone Age, it has been declared. In that era, people have utilised all varieties of rock, trees, and arms to maintain the predators away. In recent years the ways of protecting one's royalty are continuously developed. Presently the individuals utilise the much extra complicated, secure, and less costly security devices to guarantee the perfect property's protection.

The automatic home security system is based on many of the electronic components or utilises the microcontrollers' boards to guarantee efficient protection for the homes against theft, Fig. 3 illustrates the block diagram for the basic and modern home security system [43], [44].

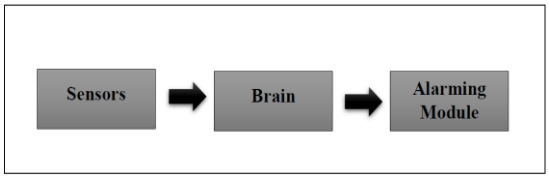

Fig. 3. General block diagram for the primary home security system

III. SYSTEM DESIGN AND BUILDING

Generally, the introduced system consists of pair of principal parts, the first is regarding the security of the home and the latter part is held for the automatic control (i.e., automation), both parts are based on Arduino microcontrollers and programmed by the means on the Arduino IDE [45]. The security of the home is constructed on the basis of the infrared (IR) sensor and the laser ray that is directed immediately on the LDR. The moment that, the thief crosses at the front of the IR sensor, the sensor directly return logic "1" to the Arduino Nano kit to switch ON the warning siren. Furthermore, if the thief tries to avoid the IR sensor, it will be facing the laser ray, once the ray is cut, the LDR resistance value will raise then the Arduino Nano performing the same mentioned procedure previously. The automating and the controlling process for the introduced configuration is based on the ATmega328P of the Arduino Nano and Arduino Leonardo microcontroller with multiple of sensors, like as the MQ-02 gas sensor, KY-026 fire detection sensor, as well as soil wetness sensor; the function of the mentioned sensors that utilised in this work is explained in Table I.

TABLE I. FUNCTIONS OF THE UTILISED SENSORS

Sensor	Task
Flame sensor	Utilised for the purpose of the conflagration detection. In the case of fire, Arduino will be switching ON the buzzer, switching ON the sprinkler that is represented by LED-1, and printing an alerting message on the LCD.
Gas sensor	Utilised for the purpose of the LPG detection in the home kitchen. In the case of a gas leak, Arduino will be switching ON the buzzer and printing a alerting message on the LCD.
DHT-11 sensor	Utilised for the purpose of the weather temperature and moisture measurement. The Arduino Leonardo will be print the temperature and humidity value on the LCD and switch ON the air conditioner that is represented by the LED-2.
Soil moisture sensor	Utilised for the purpose of the soil moisture measurement. In the case of the soil is dry the Arduino will be switching ON the water pump that is represented by LED-3 and prints a message on the LCD.

The Arduino Leonardo, 2x16 LCD, and DHT-11 sensor are utilised also to develop the system; the function of the LCD is to display the weather temperature and the humidity as well. In addition, the warning messages for the situation of the LPG leak and in the situation of the blaze detection will be appeared on the LCD. Finally, the HC-05 module that provides the wireless communication based on the Bluetooth technique with a special Android-based app and the small servo motor is also employed to controlling the garage door remotely. Figs. 4-6 respectively, illustrates the system flowchart, system block diagram, and the implemented prototype for the proposed smart home system.

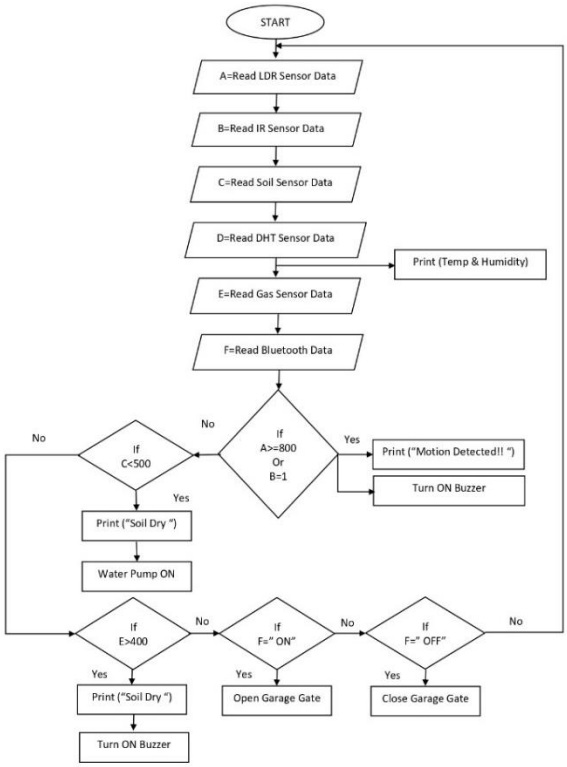

Fig. 4. Flowchart of the proposed

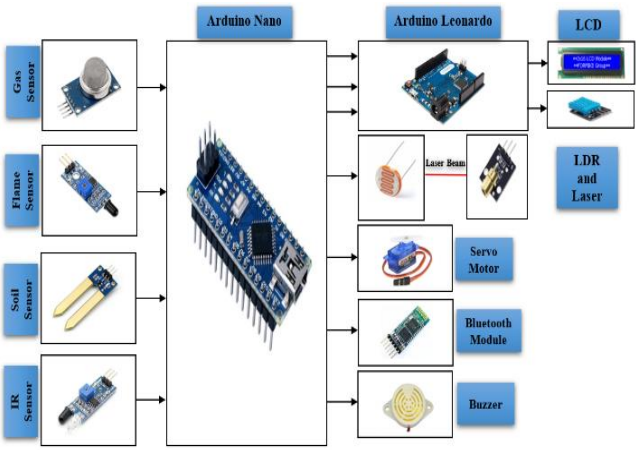

Fig. 5. Graphical block diagram for the proposed system

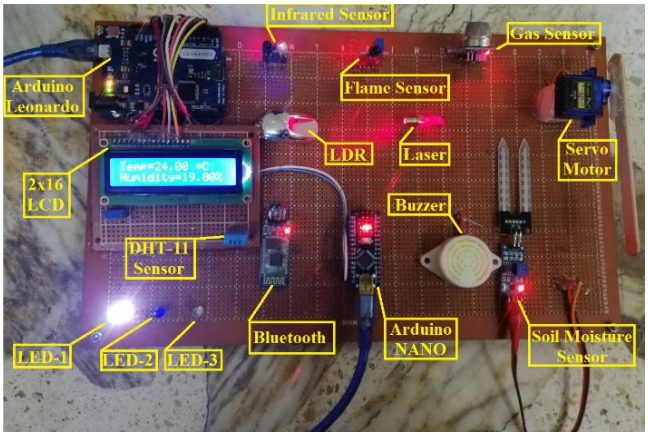

Fig. 6. The implemented prototype

The utilised Android app has been programmed within the "MIT App Inventor" online environment that was founded by Google, and managed by Massachusetts Institute of Technology. This platform dependent on the creation of the graphical user interface based on the visual programming language (i.e., blocks arrangement); which permits the users to drag/drop visual blocks to build the required app [46], [47]. Figs. 7 and 8, respectively, illustrates the blocks arrangement for the programmed android app within MIT environment and the installed app in the Android-based phone.

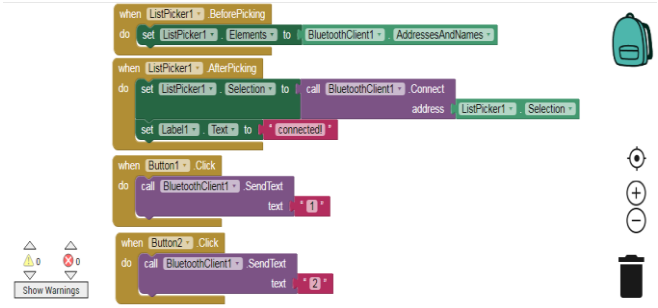

Fig. 7. Designed app code inside the MIT platform

Fig. 8. The user interface for programmed app inside Infinix mobile

Many of the essential proceedings should be considered for the purposes of operating and testing the implemented prototype, which is summarised by turning ON the system power supply in the first step. Consequently, a wireless communication between the Infinix smartphone and the Bluetooth module of the Arduino must be established for the purpose of testing the opening/closing of the garage gate wirelessly by the means of the programmed app. Several methods were applied to examine the system and the rendition of the sensors, as shown in Table II.

TABLE II. FUNCTIONAL EXAMINATION FOR THE UTILISED SENSORS

Sensor	Task
Flame	This sensor is checked by bringing it close to the fire, such as a lighter or any other source of fire
Gas	This sensor is practically tested by directly exposing it to LPG such as that in a lighter.
DHT-11	This sensor is practically tested by directly exposing it to heat and moisture. The moisture through damp cloth with water and heat through a lighter.
Infrared Sensor	This sensor is practically tested by placing a hand in front of it and paying attention to its operating lamp.
Soil Moisture Sensor	This sensor is practically tested by placing it in the soil once in dry soil and again in moist soil.

Figs. 9 and 10, respectively, shows the warning messages that emerged on the 2x16 LCD in the state of the fire and the case of the gas leak.

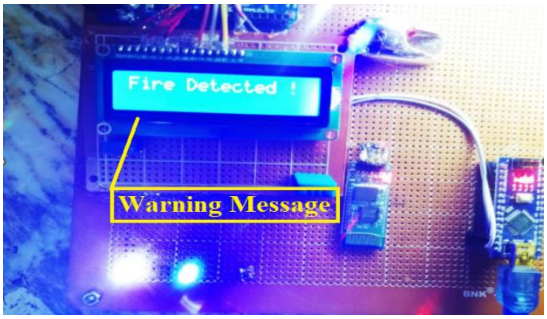

Fig. 9. Appeared message in case of fire detection

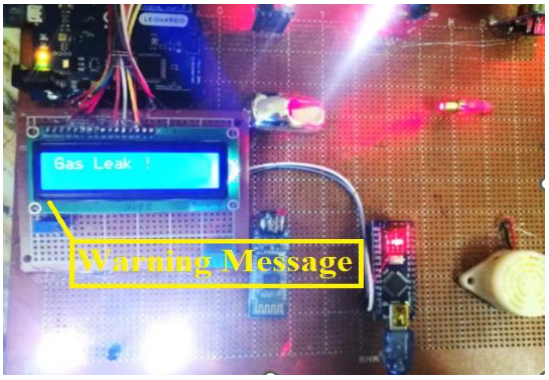

Fig. 10. Appeared message in case of gas leak

Some of the research articles are reviewed and summarized in Table III in order to compare the proposed work with those previously made in the literature.

TABLE III. COMPARISON OF THE PROPOSED WORK WITH PREVIOUS STUDIES

References	Specifications	Cost
Ref. [16]	Safety and Security Based on IoT	High; Due to the Requirement of Internet Connection
Ref. [25]	Safety and Security Based on IoT and GSM	High; Due to the Requirement of Internet Connection and the Presence of the GSM Shield
Ref. [48]	Safety and Security Based on GSM	High; Due to the Presence of the GSM Shield
Ref. [49]	Home Automation Based on IoT and XBee technologies	High; Due to the Requirement of Internet Connection and the Presence of the XBee Module
Ref. [50]	Home Security Based on IoT	High; Due to the Requirement of Internet Connection
This Work	Home Safety, Security, and Automation	Low, Due to the utilization of the Bluetooth technology

IV. CONCLUSION

The smart home is a basic concept that provides home residents with comfort, enhances security, and saves energy. This work studied the conception for the building of a low-cost smart home and automation framework. In this paper we have proposed an affordable design of a smart home utilising the Arduino Nano and the Arduino Leonardo microcontroller boards. The implemented system comprised a savvy garage gate which is wirelessly controlled through the smartphone, a couple of levels for the security to protect the home from stealing, and a safety system for detection of the blaze and LPG leakage. The implemented system was tested practically and a good rendition was acquired.

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