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IMPLEMENTATION OF SMART HOUSE DIGITAL APPLICATIONS FOR SAFETY AND HEALTH

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Abstract

This paper aims to present the design and development of low-cost smart home digital applications for safety and health purposes. Some of these applications are integrated with and compatible to smart mobile applications to achieve a convenient environment. This implementation can be realized using an appropriate smart sensing device in addition to wireless communication units to implement and improve the control and management of the proposed systems. The implementation of such systems will help realize an automated building that is integrated with – up-to-date smart technologies for convenient and secure daily activities. Some applications can also be implemented for health care by monitoring critical symptoms, such as blood pressure and pulse rate. High performance with fast response has been achieved using the proposed systems.

Keywords: Applications, Health, Smart, Safety, Smart mobile.

1. Introduction

Microcontrollers are mainly used to achieve flexible and efficient control systems and can be implemented using different types of microcontrollers, such as 8051, STMicroelectronics, PIC16 and PIC18C microcontrollers, dsPIC33, and Arduino controller. This paper presents several applications that have been implemented using the PIC16F and Arduino controllers. These controllers are selected to implement the presented applications due to their advantages over others, such as low cost, high speed, commercially available ranges, low power consumption, and suitable number of input/output ports [1, 2]. An example of commercially used controllers is the Arduino Mega module microcontroller board based on the ATmega1280 processor. Figure 1 illustrates the structure of Arduino Mega, in which the main components are digital input/output pins, pulse width modulation outputs, hardware serial ports, a 16 MHz crystal oscillator, and a USB connection.

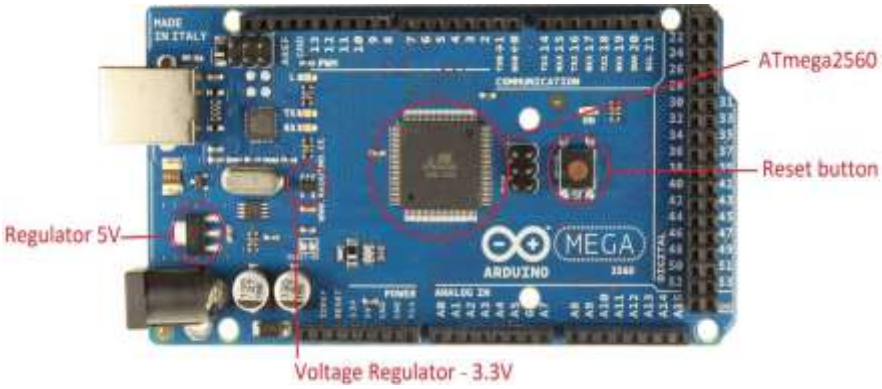

Fig. 1. Arduino Mega.

Such applications can include, integrate, and link with other tools to provide flexible control, such as MATLAB and LabVIEW [3]. They can also be extended to measure and monitor devices. These devices offer the required flexibility to carry measurement and monitoring tasks in many fields and various industries. These applications can be user friendly through the use of graphical programming to provide customized needs. They can also be implemented to achieve security and protection. Such applications can include an intelligent parking system that can manage and organize the parking area with the aid of smart technology tools to achieve security and flexibility. The use of image processing technologies and an Arduino controller can successfully realize a car identity recognition system that can satisfy the need of car parking systems [4].

A smart home design aims to offer utmost relaxation and comfort even when using a toilet in addition to health-related matters. An intelligent toilet can perform a comprehensive and valuable health examination as a user sits. The proposed system can conduct electrocardiogram and bispectral index (BIS) measurements using dry electrodes embedded in a toilet seat. The monitoring of body composition using BIS has been performed using the same electrodes. The results show the high potential of the presented intelligent toilet to increase the quality of medical care. This care is a concern for elderly people staying at home for keeping track of crucial health and nutrition factors [5]. A study has proposed

the measurement of a bioimpedance of a human body to accrue data about the changes in the body during different life activities. The results derived the amount of water in the body, which is valuable information for many athletes [6].

2. Proposed Applications

Smart house applications and services can perform unlimited functions and tasks, such as a smart parking system that can manage and protect residences' cars in the parking area. The parking region can be controlled and regulated with smart technologies and equipment. Additional image recognition technologies can be used to integrate the signal and image processing technologies with the control systems based on Arduino controller [4].

Monitoring, measurement, and instrumentation can also be implanted to enhance the productivity and reduce the overall cost. National Instrument Laboratory VI Engineering Workbench (LabVIEW), modular measurement, and control hardware can be utilized to obtain a satisfactory control and professional design where the system can be remotely monitored using several virtual instruments. After that, data can be stored analysed in contrast to conventional tools. It also provides a safer system for customers [3].

The design of Bluetooth video surveillance devices are illustrated in [7]. It Also has been implemented and tested in real applications. The design is important, especially for portable wireless video surveillance devices. The proposed design based on embedded system with Bluetooth hardware aims to implement a video surveillance device to realize video data transmission between the video server and client.

The availability of different engineering simulation tools can also help implement some smart house applications. The reason is that most updated versions of these tools can be integrated with many other tools and peripherals [8].

The main application to be thoroughly described in this paper includes a gas leakage warning system, a pulse rate and remote control and monitor of the blood pressure based microcontroller, a fingerprint-based security system, and an air quality monitoring system.

2.1. Gas leakage warning system

In 1910, the Liquefied petroleum gas (LPG) was produced by Dr. Walter Snelling. Nowadays, LPG is utilized in homes for cooking purposes [9]. LPG is expensive in comparison with other types of fuels, i.e., fuel wood. Nevertheless, it is still much popular for personal usages due to its low negative impacts on the environment because it is relatively much cleaner [10, 11]. LPG is composed of different components, such as propane (C_3H_8) and butane (C_4H_{10}) in addition to a small concentration of other hydrocarbons subjected to the source and the production of LPG. The use of LPG is not limited to cooking only. Given the versatile nature of LPG, its usage includes local fuel, industrial fuel, automobile fuel, heating, and illumination. As a result, the demand for LPG is continuously increasing.

The issue of gas leakage is concerned due to its fatal effects. These dangerous effects can result in financial losses and serious human injuries. Accidents due to gas leakage may lead to death due to the explosion of gas cylinders. These

explosions mostly occur due to external interference, corrosion, construction defects, material failure, old valves, worn out regulators, and lack of awareness using gas cylinders. A warning system is proposed to avoid the dangers of gas leaks. The proposed system is an intelligent, automatic, and highly sensitive system for detecting the leakage of cooking gas. The proposed system aims to minimize the injuries and losses that may happen due to gas leakage.

The main concept of the implemented system is to sense leaked cooking gas that is mixed with the surrounding air. When the leakage reaches a dangerous pre-set limit, the system generates a series of warning signals to prevent possible explosion. The forms of the warning signals include visual, audio, or text message, which can be utilized by the general public for safety.

The system is activated once a small amount of LPG gas is detected by the sensor. As leakage occurs and is detected, the buzzer is activated, and the knob of the gas supply is automatically closed. The homeowner and the fire station are notified through the system if the LPG gas leakage has reached a critical level. The adaption of this system can enable the integration of the automated building with today's smart devices to achieve secure and convenient living. Testing of the developed devices shows a good performance and a fast response to gas leakage. The general flow of proposed device operation is illustrated in Fig. 2.

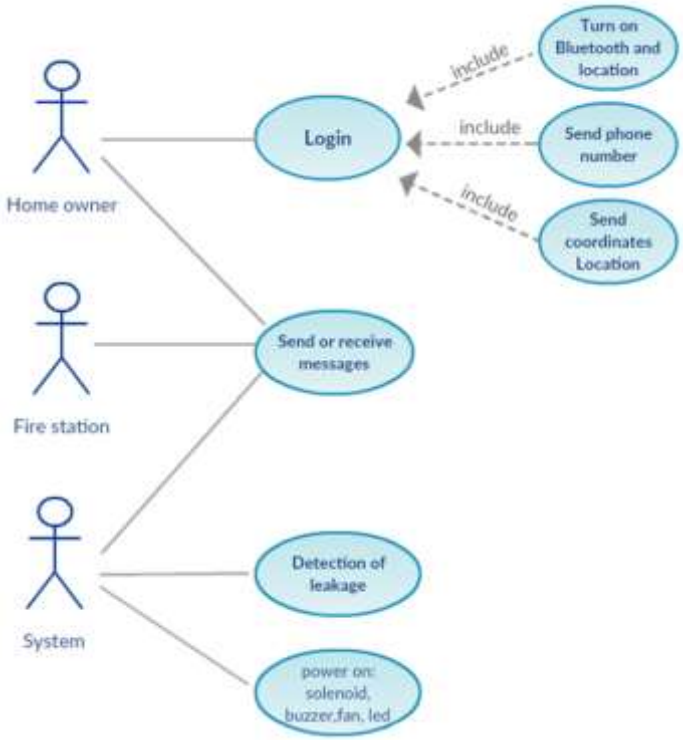

Fig. 2. Functionality flow of the gas leakage warning system.

An efficient and fast response controller is used for the real-time measurement of LPG to implement the system prototype effectively. When a gas leak is

detected, the microcontroller activates the output port to automatically close the regulator valve for preventing further leakage from the gas cylinder. Meanwhile, the audio buzzer is activated to alert people about the danger. The house owner and the fire station receive a text message about the incident. The general block diagram of proposed system is presented in Fig. 3.

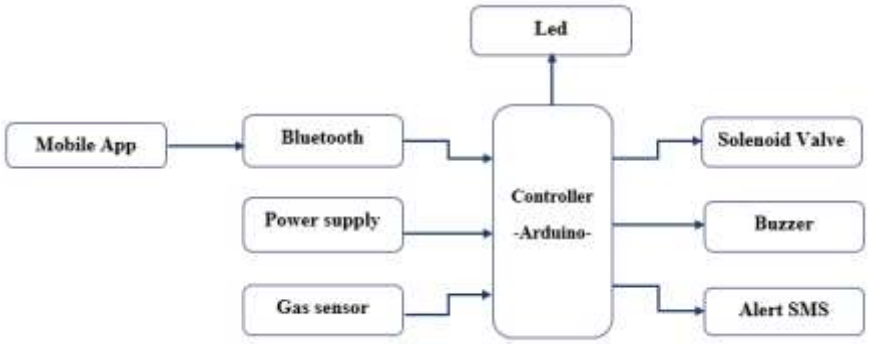

Fig. 3. Block diagram of the gas leak system.

The developed system mainly consists of the sensing part that is fixed near the gas cylinder area. The other part is mounted on the gas cylinder before the gas regulator. The main components of the implemented design include power supply, Bluetooth module, solenoid valve, led, buzzer, gas sensor, and the Arduino controller. The completed implemented prototype of the proposed application is shown in Fig. 4.

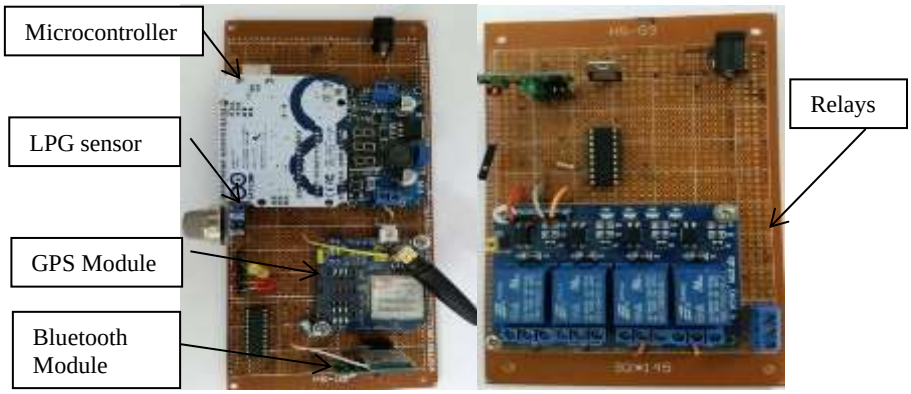

Fig. 4. Implemented system prototype.

The system is implemented using Bluetooth for system communication. However, it can also be developed by replacing Bluetooth with a WiFi module, which makes it more compatible to communicate with many IoT devices. The current use of Bluetooth is due to budget restriction.

2.2. Pulse rate and blood pressure monitoring systems

Heart attack, high heart rate, and high blood pressure are crucial issues and they may lead to death. This fact highlights the need to propose a system that alarms

rescuers immediately if the pulse rate or blood pressure is not normal, which is implemented mainly for swimmers and infants. As a result, they can decide the required aid in time for saving lives. The proposed system is shown in Fig. 5 [12]. This application is monitoring the pulse and blood pressure of a swimmer or a new born. Posteriorly, the system sends a text alert short message to the server, which automatically appears on the rescuers' mobile screen [12].

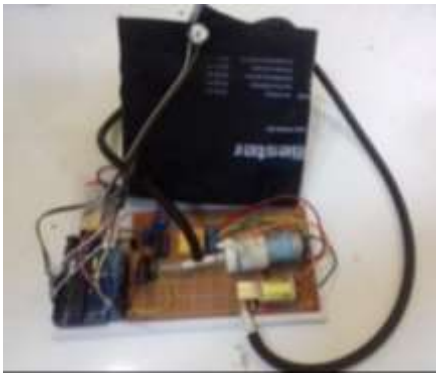

Fig. 5. Pulse and blood pressure monitoring device [12].

A non-invasive wireless blood pressure remote monitoring instrument based on microcontroller and Bluetooth transmission kit is designed and developed, as shown in Fig. 6 [13]. The presented application is based on the measurement of a real-time blood pressure signal by the aid of optical measurement circuit. The measurement is based on plethysmography technique and conducted continuously for a long period. The captured measured signal is amplified and fed to the microcontroller for processing to activate the appropriate input port. A proper algorithm is developed to capture and analyse the measurement of blood pressure data, which are then transferred via Bluetooth port to the stationary computer. The measurement of blood pressure is based on measuring the numerical reading of systolic and diastolic blood pressure remotely, which is then recorded and displayed on the liquid crystal display (LCD), as shown in Fig. 6. The results of the proposed system show satisfactory operation with acceptable accuracy of measurement of blood pressure compared with commercially available measurement devices [13].

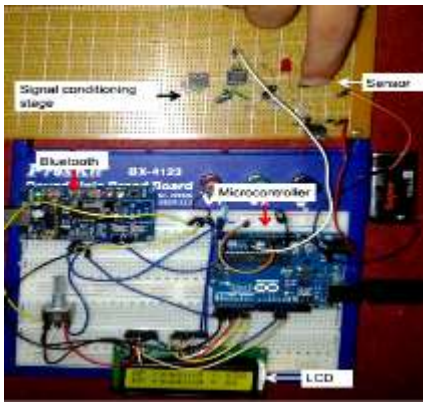

Fig. 6. Non-invasive blood pressure remote monitoring device [13].

2.3. Remote heart rate monitoring system based on wireless Bluetooth

This application proposes the design and implementation of a new heart rate remote monitoring device using a microcontroller. The proposed system uses wireless Bluetooth signals to transmit and display the accrued measured heart rate precisely on the laptop. The captured signal is the number of beats per minute of the heart that is continuously monitored to identify any deviations of the normal heart rate levels, as shown in Fig. 7 [13].

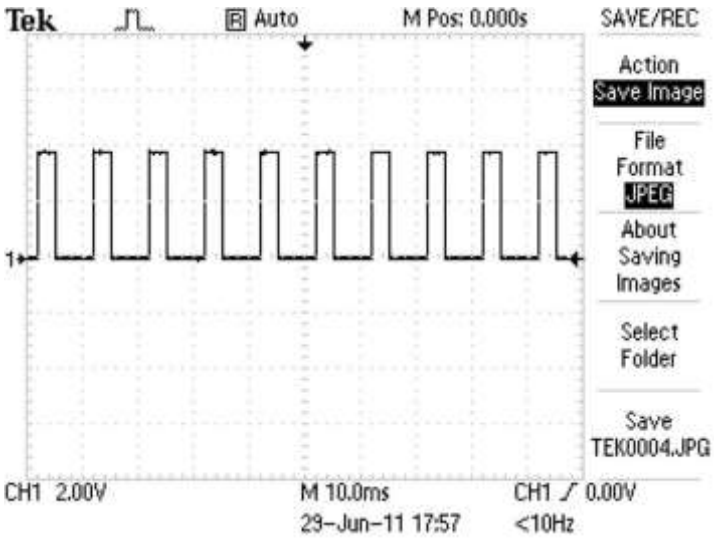

Fig. 7. Output signal of the pulse detection circuit using an optical sensor [13].

The implemented system is divided into two parts. The first part is the integrated pulse rate measurement circuit, which monitors the pulses on the fingertip. This part includes the extraction of the signal and amplification. The second part is the microcontroller, which mainly processes the captured signal via wireless Bluetooth module [2], as shown in Fig. 8.

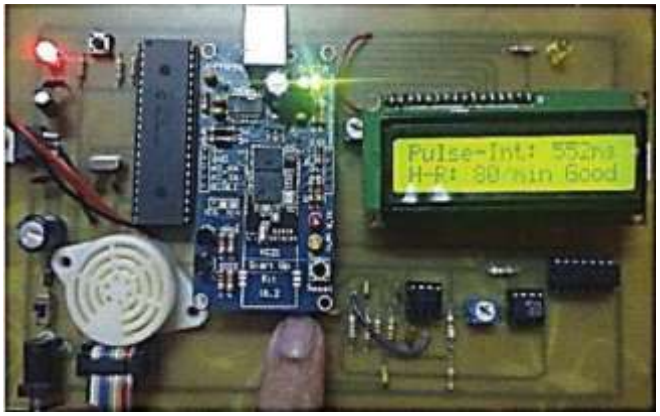

Fig. 8. Heart rate remote monitoring device [2].

2.4. Fingerprint-based security system

Security plays a key role in offices, institution, libraries, and laboratories. It continually prevents unauthorized people to obtain private data. Different technologies can be used to secure places, such as passwords, identification cards, and personal identification number verification techniques. The password technology has disadvantages, such as the password can be hacked and a card may be lost or stolen and used by unauthorized people and exploited for negative purposes. The most secured system that can distinguish between registered legitimate users and imposters is fingerprint recognition or iris scan because a person's fingerprint and iris never match those of others. The fingerprint is also unique and cannot be imitated.

In this design, a security technique based on fingerprint is proposed. Instructions will be shown on the LCD to proceed and login to the system. At the first stage, the visitor should scan the finger in the fingerprint module. If the user is registered, then the door will open automatically. If the user is not registered, then the door will not open. Figure 9 illustrates the block diagram of the proposed system.

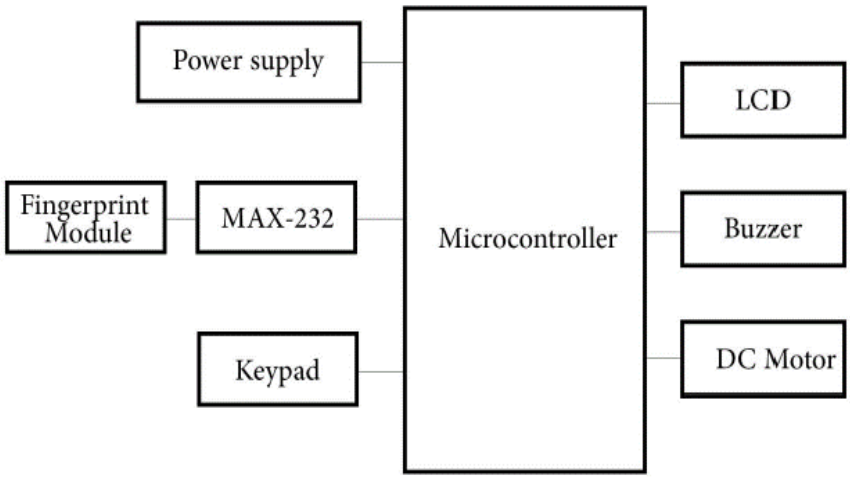

Fig. 9. Block diagram of the fingerprint security-based system.

The general functionality flow of the proposed security system is shown in Fig. 10.

2.5. Sensor network for air pollution detection

Air quality monitoring system is extremely substantial given that un clean air directly impacts human health. Therefore, a sensor network is introduced. The system can provide a low-power and a low-cost mobile sensing for participatory air quality monitoring. The design of an air pollution detector is successfully implemented and evaluated. The system is small in size and is thus considered a portable measurement system. The block diagram of the proposed monitoring system is shown in Fig. 11.

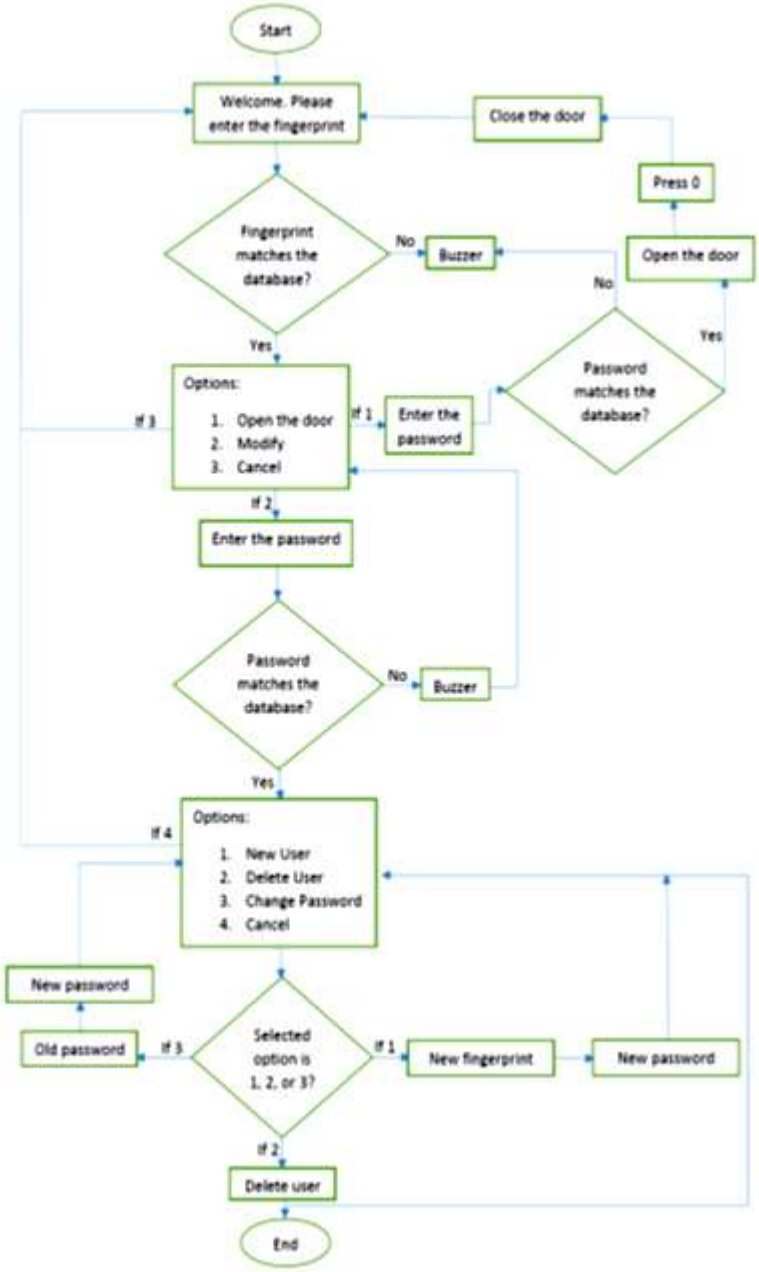

Fig. 10. Flowchart of the proposed security system.

Suitable sensing components are used to monitor the major sources of air pollution. The used sensor network includes ultraviolet (UV) sensor, dust quantity sensor, temperature sensor, and gas sensor to detect unhealthy components, such as carbon monoxide and carbon dioxide (CO_2). The results and locations will be transmitted in real time to a developed Android mobile application. The implemented proposed air pollution detection system is shown in Fig. 12.

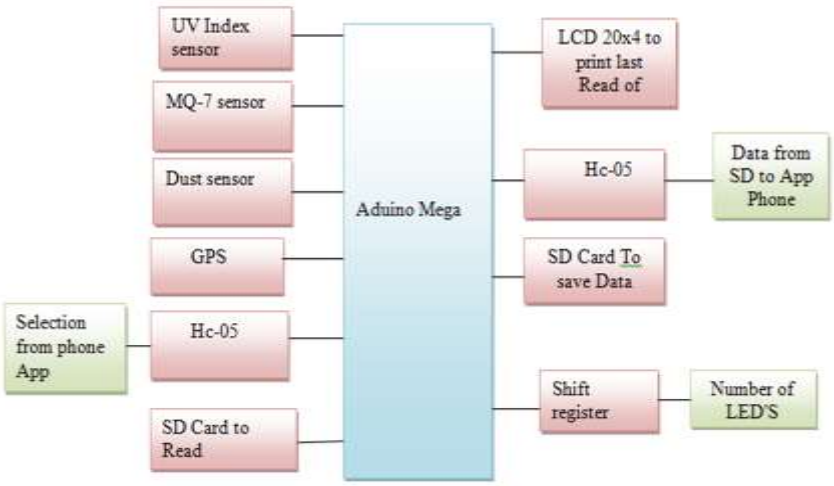

Fig. 11. Block diagram of the proposed monitoring system.

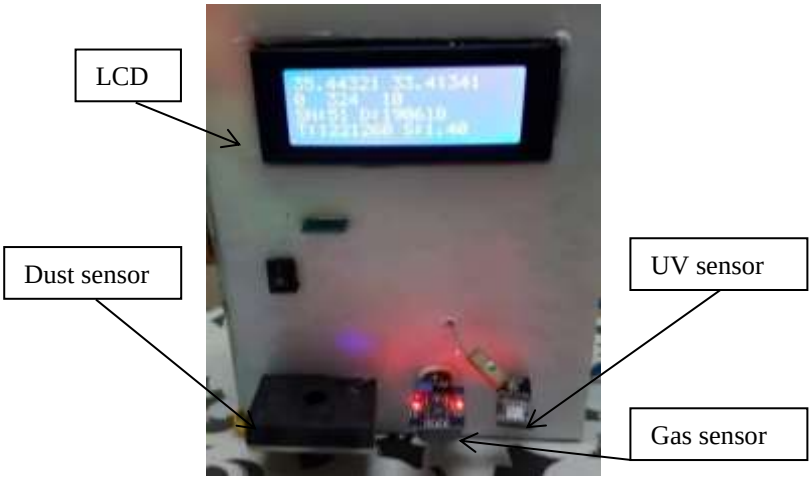

Fig. 12. Implemented air pollution detection system.

The data on the LCD screen in Fig. 12 are the GPS location, dust, CO_2, UV, serial number of each reading followed by the date the reading was captured, time in hour–minute–second format, and wind speed.

The proposed system aims to keep people safe by avoiding UV radiations, poisonous gases, and dust particles. The system can also identify concentration quantities, trends, and areas affected by pollutants by providing users with up-to-date information on air quality. The data will help avoid the risk of exposure to poor air quality, which reduces the potential unhealthy effects in a region.

2.6. Managing illumination using renewable energy and IoT

Renewable energy has attracted the interest of researchers due to sustainability and low cost in the long term. This application exploits the benefits of renewable energy

to design a smart area lighting system, which is controlled by the Internet of things (IoT). Smart area lights are equipped with a microcontroller, sensors, batteries, and photovoltaic modules. The proposed system will be monitored by the IoT. It also senses the objects in the area and transmits a signal to the monitoring unit, which is controlled by the IoT. Moreover, if one of the lights is not working appropriately, then the proposed system notifies the maintenance via the IoT. The proposed system senses and monitors the area with respect to congestion. The color of the smart pavement will be controlled using the IoT system.

2.6.1. Design and methods

The block diagram of the proposed smart lighting system is shown in Fig. 13. The system consists of a microcontroller module, which regulates the entire sensing and controlling activity for the system, a group of sensors for sensing various parameters, a voltage regulation circuit for regulating the input voltage for the LED module, and an IoT module for wireless communication.

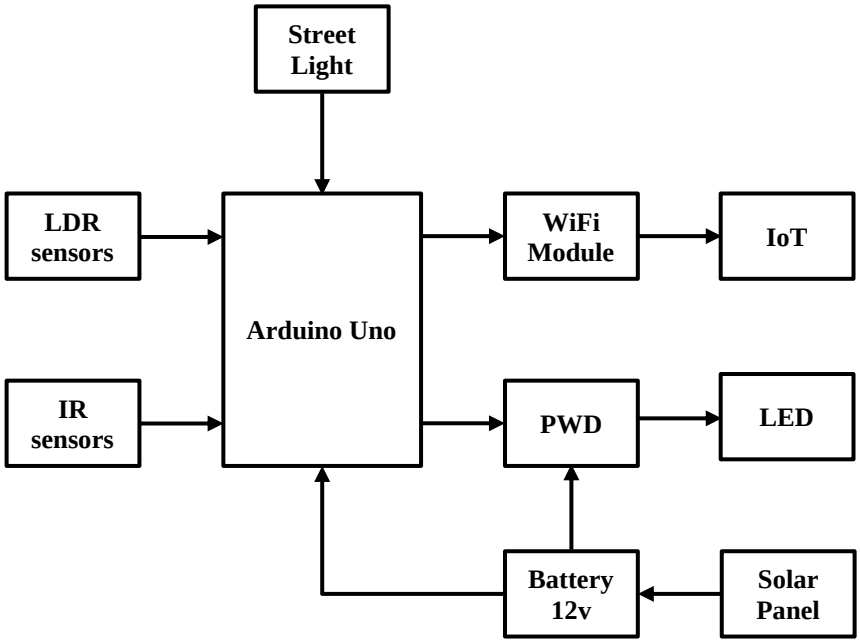

Fig. 13. Proposed smart lighting system

Each lighting pole is connected to the infra red (IR) sensor to make a sequence along the way, as shown in Fig. 14. The IoT controls and sends the signal to all other lights. Each lighting pole has an IR sensor, Arduino, sensor data, and unique identifier protocol (UID). All lighting poles are connected to each other with a special program on the computer using the IoT. In case of missing information from the sensor data, the Arduino directly sends a special message reporting a damage using the UID for that lighting pole with its location.

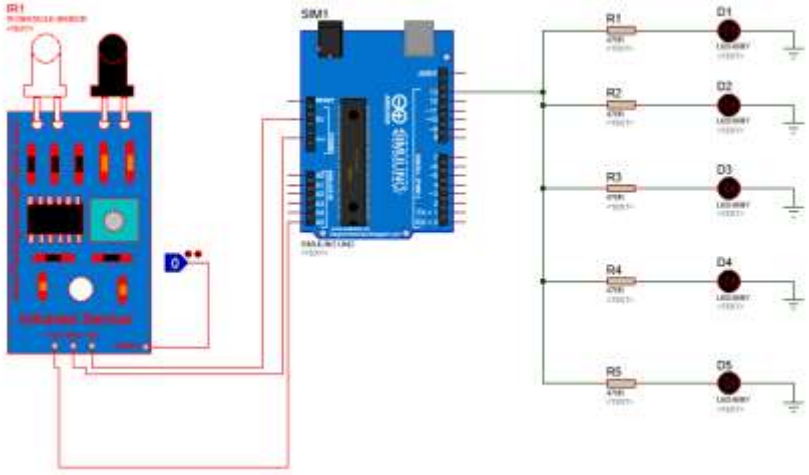

Fig. 14. Implemented proposed system circuit.

2.6.2. System impact

Existing reserves of fossil fuels are limited and have environmental impact. Thus, the traditional grid transitions toward a distributed hybrid energy generation system that mainly relies on renewable energy sources.

However, a smart grid is a combination of information and communication sensing systems that create various applications. These applications can help achieve efficiency and save consumption. These solutions can be applied in every part of a grid, such as smart homes, smartphones, smart street lights, and traffic lights. This research utilizes the advantage of using renewable energy to design a smart area/street, which is controlled by IoT. The idea of this research is to design a lighting system for areas or roads by using renewable energy and IoT to control the lights effectively.

2.7. Solar panel cleaning system

The affecting factors of the reduction in the efficiency of the solar panels should be considered to reserve solar power source and obtain the greatest possible efficiency. The most important factors are dust and dirt that produce a barrier to solar radiation on solar panels. Many ways can be used to clean solar panels, including cleaning with water, brushing (including brushing only), and hand-cleaning methods by hand. However, this system is different because it uses spray water on parts of the solar panel. The accumulation of dust on the brush forms granules, such as stone working on scratching the cell and thus damaging it.

Manual cleaning methods for solar panels are costly and time consuming. Thus, a system in automatic operation is demanded. A portable automated cleaning system for photovoltaic panels has been proposed. The proposed system can clean all parts of the solar panel and enables walking on the solar panel horizontally and vertically [14, 15].

In the current system, a cleaning system based on Arduino microcontrollers is designed to automatically clean the solar panels. A tool is designed on the basis of the standard array size. This system offers an effective and scalable solution for removing dirt and dust. In terms of daily energy generation, the presented automatic-cleaning scheme provides approximately 30% more energy output than the dust accumulated by PV module.

2.7.1. Cleaning mechanism

The cleaning machine covers all parts of the painting with water by horizontally moving from the beginning of the painting to the end and is estimated by the continuous movement for a period determined by the user according to the amount of accumulated dust. The sprayer sprays water onto the panel. The spraying mechanism consists of a water spray attached to a DC motor that moves from the beginning of the cell to the end of the cell. It cleans all the parts of the solar panel, as shown in Fig. 15.

2.7.2. System findings

After the proposed design is implemented, the system is experimented, and the system main features are summarized as follows.

- The weight of the solar panel cleaning system equals 7 kg.
- The dimensions and size of the system depend on the dimensions of the solar panel to be cleaned.
- The system can be sufficiently flexible and is thus suitable for all solar panels with different dimensions.
- The electrical power consumed by the solar panel cleaning system is

P = 2.2 A×12 V = 26.4 watts

If the system is placed on a solar panel of a type of (TSM-PD14) 325 watts per hour, then the cleaning system will consume approximately 8.12% of the total energy generated from the tested solar panel as follows:

$$100\% - \left[\frac{325-26.4}{325} \times 100\%\right] = 8.12\%$$

Fig. 15. Implemented solar panel cleaning system.

This method of cleaning is economical and simple. It does not require a lot of periodic maintenance. The cell is cleaned completely unless dirt is firmly attached to the surface of the cell, which then requires the presence of high-pressure water.

This paper has presented the development of some low-cost smart applications for safety and health purposes. These applications help achieve a digital smart house. The proposed applications are successfully integrated with smartphone applications to provide a convenient environment to end users. Moreover, many of these applications can be integrated with the IoT technology. Furthermore, some of the presented applications are implemented using Bluetooth modules for communication due to budget restriction. The Bluetooth should be replaced by a WiFi module to ensure compatibility of these applications to communicate with many IoT devices. The replacement with WiFi modules for the devices' communications also reduces the possible distance limitation associated with Bluetooth technology and ensures flexibility of the systems.

2.8. Development of an electronic stethoscope with a wireless system

The stethoscope is a device that is widely used in clinical application due to its effectiveness in monitoring heart and respiratory sounds. Physicians have been using the stethoscope for nearly two centuries for listening to patients' internal organs, such as the heart and lungs. A wireless technology based on analysis of heart sound becomes one new approach to diagnose cardiovascular diseases because of their annual rapid increase [16].

The main objective is to develop and design a low cost, user-friendly electronic stethoscope with a wireless transmission system. Moreover, an LCD displays the beat per minute. Global system for mobile (GSM) is also used to send the patient's heartbeat details when the doctor is far from the patient, especially in rural areas. Figure 16 shows the block diagram of the device.

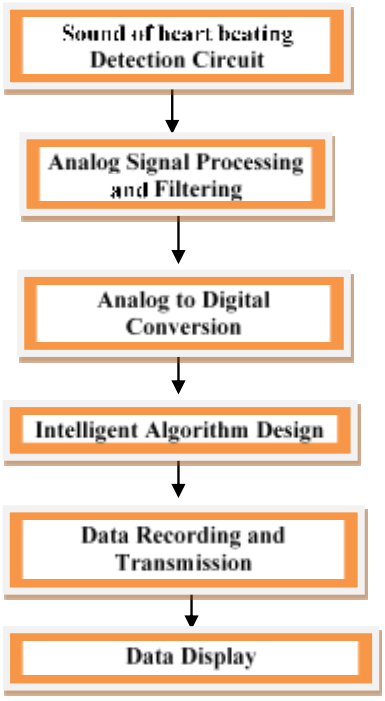

Fig. 16. Block diagram of the device.

2.8.1. Hardware implementation

The hardware of this device consists of the following parts: a chest piece, a condenser microphone (placed inside the chest piece to detect heart sound and then transform it into electrical signals), an LM386 operational amplifier (to amplify the weak electrical signals produced by the condenser microphone), filter circuit Arduino Uno, Arduino LCD keypad shield, and global system for communication GSM. The complete device is shown in Fig. 17.

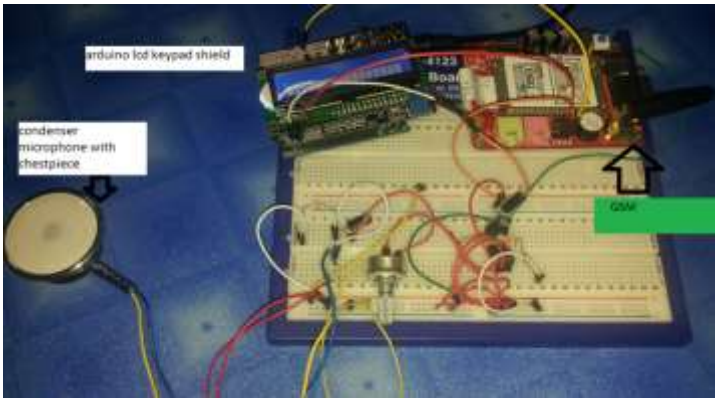

Fig. 17. Developed electronic stethoscope prototype.

2.8.2. Testing results

Testing of the proposed device reveals that it achieves the main task of monitoring heart and respiratory sounds satisfactorily. The device detects the heart sound. The signal of the heart sound is displayed on the oscilloscope. The heartbeat per minute is calculated and displayed on the LCD. The data are transmitted via a wireless module. Figure 17 shows the complete design of the electronic stethoscope with a wireless transmission system. It includes a diaphragm of a traditional stethoscope with a condenser microphone for heart sound detection. An amplification circuit is included to amplify the signal from the heart. Arduino Uno microcontroller's LCD displays current heartbeat per minute and transmits the data by using the SIEMENS TC35 GSM module. Figure 18 shows the result of the heart rate displayed on the LCD screen.

Fig. 18 Heartbeat per minute display on LCD.

The results show that the developed electronic stethoscope successfully detects the heartbeat and processes the signal for display and transmission purposes. This device can reduce the problems of the traditional stethoscope because it minimizes the possibility of disease transmission from patients to medical professionals by using wireless systems.

3. Conclusions

The development of low-cost and smartphone-friendly digital applications adopted for safety and health purposes in a smart house has been presented. The implementation of these applications is realized using smart sensing devices and wireless communication units. The group of proposed applications aims to realize control and management systems with the new technology and mobile phone apps to achieve a smart house. An automated building, which is integrated with today's smart technologies, is realized to achieve a convenient and secured daily living. The testing results of the proposed applications show a satisfactory performance and a good response. These applications can be used anywhere to achieve the target.

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Abbreviations

DC	Direct Current
GPS	Global Positioning System
GSM	Global System For Communication
IoT	Internet of Things
IR	Infra Red
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
PV	Photovoltaic
UID	Unique Identifier Protocol
UV	Ultra Violet
WiFi	Wireless Fidelity

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