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Design and development of arduino-based automation home system using the internet of things

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ABSTRACT

The home automation system described in this paper is low-cost, dependable, and versatile. It uses an Arduino microcontroller and Bluetooth internet protocol (IP) connectivity to allow authorized users to remotely access and control devices. The suggested system employs the internet of things (IoT), which is server-independent, to manage human-desired appliances ranging from industrial machinery to consumer products. In this project, we have taken a Bluetooth module that is programmed through an Arduino Nano to control various devices auto-switching of mechanical devices and monitoring of water level within a range of 130 m using an Android application. This is done to show the effectiveness and viability of this system. Each bulb was switched on/off remotely using a mobile phone successfully. The operation of the water pump attached to the source bucket were controlled from the phone while in manual mode and controlled by an ultrasonic sensor while in automatic mode. It enables remote control of a number of devices, including lights and pumps, and decision-making based on sensor feedback.

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1. INTRODUCTION

Home automation enables us to access and manage house appliances from any location on Earth using a mobile smartphone. The term "home automation" may be applied to specific programmable devices like thermostats and sprinklers, but it is more appropriately used to describe homes in which almost all of the appliances-including lights, fans, electrical outlets, and heating, cooling, and ventilation systems-are connected to a remotely programmable network [1]. This might also include any alarm systems, all the doors, windows, locks, smoke sensors, security cameras, and any other sensors that might be attached to them from the perspective of home safety [2], [3], asserted that in a building management system, the idea of home automation aids minimization or elimination of occurrence and consequences of fire outbreaks, loss of properties. As presented in the study of [4], the idea of smart home automation is not new, several methods had been used to design a good home automation system, wired-network mechanisms were the first method used in the early days to design and implement home automation. Several researchers have worked on home automation systems with a variety of difficulties. According to [3], [5], [6] described the few prominent

challenges of existing home automation systems are; switching time delay, lack of restart mechanism, unreliable security for the communication of connected devices, high-cost design and high-power consumption. In some existing designs of home automation, control of turbo machinery device is not included which is an essential unit for energy conservation. Pau and Salerno [7], analysed the utilization of high-end computer or wired network for the installation and configuration of the home automation system attracts high expenses.

Venkatesan and Ramachandraiah [8], there is rapid change in technology that always aims to serve mankind, and the expectation for living a simple yet advanced life continues to rise. The internet has become an essential part of people's social and educational lives, without which they are helpless [9], state that, the internet of things (IoT) devices not only control but also keep an eye on the many mechanicals, electrical, and electronic systems utilized in different kinds of infrastructure. One user controls these devices that are connected to the cloud server, which then transmits or notifies every authorized user who is connected to the network. Through various network infrastructures, a variety of electronics and electrical items are connected and can be remotely managed. There is rapid change in wireless technology several connectivity devices are available in the market which solves the purpose of communicating medium with the device and the micro-controller. Chaurasia and Jain [10], proposed wireless networking technologies such as Z-wave, Zigbee, Bluetooth, ESP 8266 Wi-Fi module, GSM module, Arduino Uno interfaced with Raspberry Pi and Node MCU. Though, Bluetooth and ESP 8266 Wifi module are widely used for a short-range home automation system [11], since they have high processing power, good response time, reliable data protection, very cheap module. In this project, we used a Bluetooth module that was programmed by Arduino to manage a number of pieces of equipment, including the automatic switching of mechanical devices and the monitoring of water levels up to 130 m away.

This research is organized as follows; Section 2 presents the literature review. Section 3 presents describe the method used in this project. Section 4 presents the results and discussion, and Section 5 conclusion and future works for the realization of effective automated and home systems using IoT

2. LITERATURE REVIEW

The development and application of wireless home automation has been the subject of numerous studies in the past. Some of the studies are based on comparative analysis, smart home design and implementation, and solution proposals for problems with previously employed technologies. Some people have also conducted comparative, descriptive, and experimental research studies that use a variety of techniques to set up wired and wireless communication networks for the home automation system [12].

The first wireless home automation system was created in 1893 to enable remote control of a television, and due to its numerous advantages, people began constructing home automation systems in the early 2,000 s [13]. As presented in Table 1 about 40.3 million of smart home have been developed in USA and this makes USA to in the first position on the ranking of top 10 countries with numerous smart homes as at year 2019. However, as reported in the analytical research work on the rapid development of smart home automation system in Africa, conducted by [14], Africa is at initial stage of the development of smart home automation and throughout the African Region, Nairobi in Kenya has largest percentage of smart home while South-Africa and Ethiopia have also engaged in the development smart home system including some other African countries like Nigeria, Ivory Coast, Rwanda, Tunisia, Ghana, Egypt, Senegal, and Morocco. Santosh *et al.* [13], reported that throughout the world the estimated market value for a full automated house was US$5.77 billion in 2013 and the predicted value for the year 2020 was US$12.81 billion.

Using the International Electrical Commission (IEC) 61,499 function block standard for a distributed control system [15], created an incredible home automation system. The study was primarily concerned with developing and putting into practice an architectural solution for high reconfigurability, scalability, and flexibility control in the home automation design as a replacement for the conventional system. Wireless sensors were used as the smart home system's infrastructure to create an internet of things (IoT) based network. To assess the system's performance, there was, however, no outcome [16].

Kumar and Qadeer [17], a wireless network can be created between various hardware components using universal plug and play (UPnP) devices, X-10-based devices, infrared devices, Bluetooth devices, IP-based devices, or radio networks. Subsequently, [18] described a number of popular techniques for establishing wireless communication between devices, including Bluetooth, Wi-Fi, Zigbee, and Z-Wave. Zigbee was highlighted by the author as a wireless communication technology that uses little power and can support more than five devices. Danbatta and Varol [18] the Zigbee-based communication network has several significant limitations, including limited connectivity over short distances, a high switching delay, and poor product interoperability across different manufacturers. even though Z-wave technology. Azis [19], Chaurasia and jain [10], and other sources, the use of GSM devices, which are susceptible to system failure if

the GSM is misplaced, is the system's main flaw. A webApp-based wireless home automation system was constructed by [7] utilizing an Arduino AT Mega board with Node MCU and an integrated Wi-Fi ESP 2866 module. HTML and PHP were used to create a webapp that allows users to view and operate appliances. The website has additional features like usernames and passwords that allow for data authentication. With the help of the Android Blynk App, [20] created an advanced user interface that the Node microcontroller can use to receive actuation signals and send them to a web server that users may access from anywhere in the world. The system's shortcomings include its inability to support simultaneous connections from several users. Data user identity security and data authentication were not considered in the design. The system forbids local connections to the server (without the use of data).

Table 1. Top 10 countries in the world that have highest number of smart homes [13]

Rank (number of smart homes)	Country	Number of smart home (millions)	percentage of smart home (% of total home)
1	USA	41.2	31
2	China	18.6	5
3	Japan	6.9	14.9
4	Germany	7.1	16.3
5	UK	4.9	20.7
6	South-Korea	5	22
7	India	3.2	<1.1
8	Australia	2.1	18.12
9	Brazil	1.9	2.1
10	Russia	1	2.0

3. METHOD

In this study, we depict the major application area of IoT in Figure. 1 as background in this design, in addition, more devices that were require to make a whole system architecture were included. Its user interface, which is restricted to text only and is not user-friendly for everyone, especially elderly persons for basic elements of the IoT environment [6], [21] created Android application is created by using the Eclipse software that will be installed in the Android mobile. It has four relays and each relay will be on/off using corresponding on and off buttons to control the appliances.

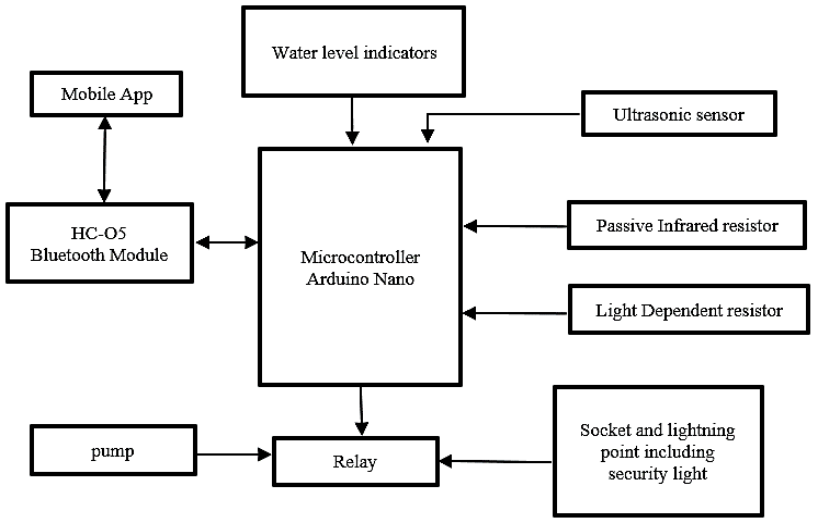


Figure 1. Block diagram for the system architecture

3.1. System design

In the system, smartphones, laptops or tablets acting as wireless controllers are connected through Bluetooth in order to control and monitor the appliances and water level. As presented in Figure 2 Arduino board was used as the microcontroller unit to trigger and communicate the status of household appliances to the smartphone over the Bluetooth network. The microcontroller receives a signal from sensors that capture measurements in their environment. Electrical outlets with relay circuits acting as connection points for home

appliances such as fans, air conditioners, television, radio, and refrigerators are connected to the microcontroller. The relay module acting as a connection point affect the signal of the Arduino board on home appliances. Home appliances are on/off by the microcontroller based on the signal received from the mobile App. Furthermore, the Arduino Nano board was also configured with E-plum in order to retain the state of appliances after any power interruption. In the water level system, there are two modes of operation; automatic control and remote control. In the automatic operation, an ultrasonic sensor was used to turn off/on the pumping machine when water reaches or falls within a range of certain levels. For the remote control, the mechanism of water level system can be controlled at any instance of time using the mobile phone.

A friendly user interface (using a mobile app) was designed with MIT inventor for the remote control of appliances. On the user interface, the water level system can be set to operate in automatic mode or controlled remotely. Figure 2 shows an activity flow chart that captures data flow within the overall system architecture.

The circuit is comprised of relay module connected with Arduino board, ultrasonic sensor, passive infrared sensor (PIR) sensor, and light-dependent resistor (LDR). The ultrasonic sensor was used to ascertain behavior of water level system in the auto-mode. The Arduino board receives a signal from the sensor, which turns the pumping device on and off. The microcontroller unit has three indicators to show the status and track the water system's levels. The power supply circuit as shown in Figure 3 was used to energize the circuit. Sub-components in this area are Arduino board in Figure 3(a) and 4-pins relay module shown in Figure 3(b). As shown in Figure 4 the relay module was used to control the switching operations of electric outlets and bulbs. The LDR was used to save energy consumption in security light and ultrasonic sensor control operation of the pumping machine for the automatic mode operation of the water level system.

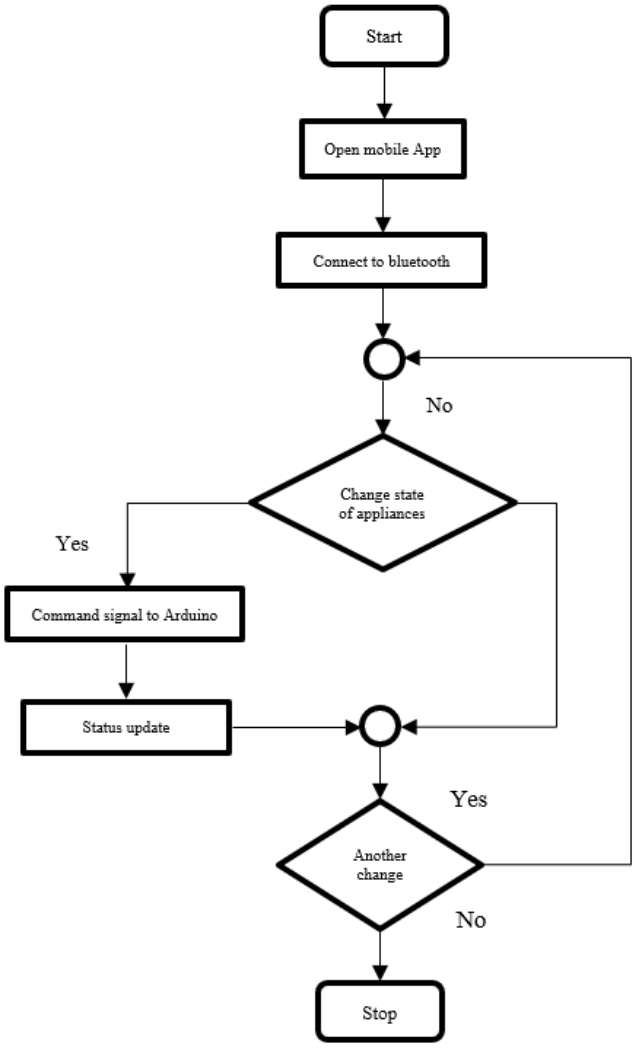


Figure 2. Activity flow chart for the system

(a) (b)

Figure 3. Major switching control components of home automation system (a) Arduino board and (b) 4-pins relay module

3.1.1. Hardware description

Figure 4 shows the major switching control components of home automation system. The model used for this project involves the utilization of E-plum of an Arduino board with other components interacting over a bluetooth network. It comprises of six (6) major hardware components or devices, they are Arduino nano, relay module, power supply, Bluetooth module (HC-05), water pump and sensors finally water level indicators.

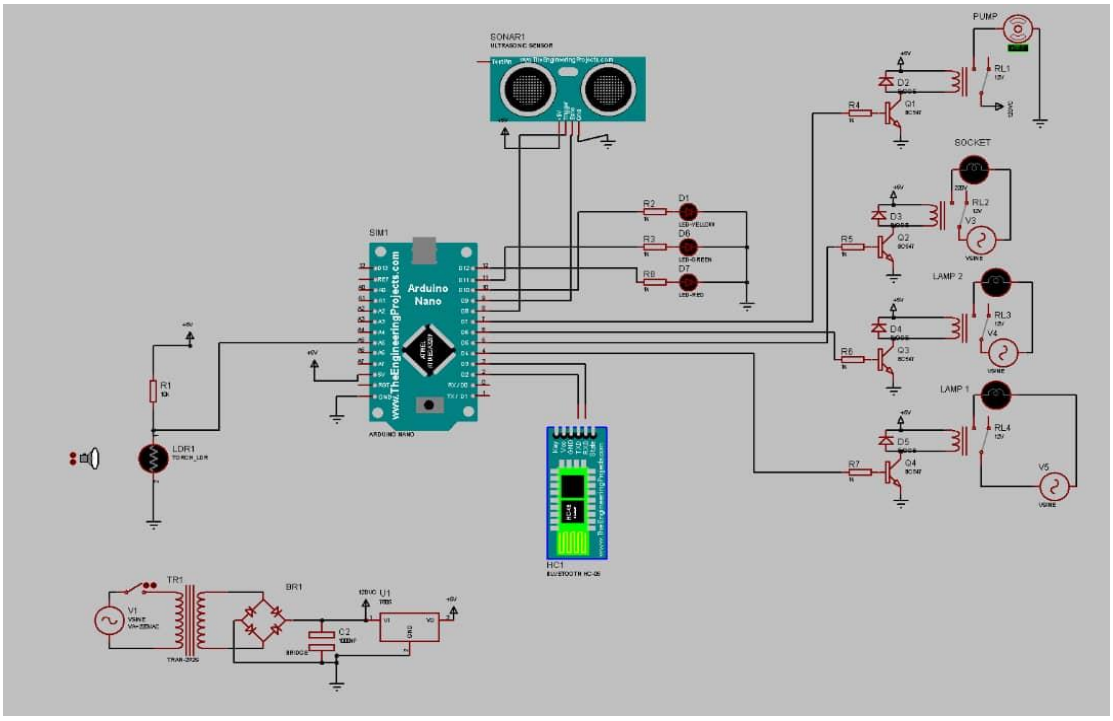


Figure 4. Circuit diagram of the system architecture including power supply circuit

A. Arduino nano

Based on the ATmega328, the Arduino Nano is a compact, comprehensive, and breadboard-friendly board (Arduino Nano 3.x). It is an AVR microcontroller board that, although it comes in a different package, essentially performs the same functions as the Arduino Duemilanove [22]. It only lacks a DC power jack and uses a mini-B USB cable rather than a conventional one to operate. It has a 5 V working voltage, 32 kB of flash memory (of which 2 kB are used by the bootloader), a 16 MHz clock speed, 1 kB of EEPROM, and a 19 mA power consumption. It has eight analog-in connections and 22 digital I/O pins, six of which are PWM. The Arduino Nano board was chosen in part because it may be utilized for sensor collection and portable electronics.

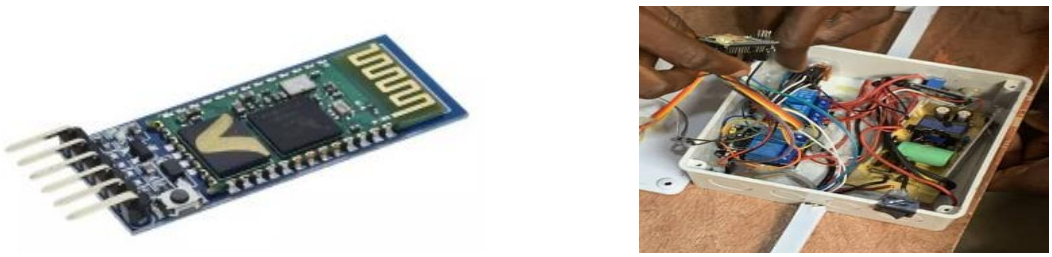
B. Relay module

A power relay module is an integrated circuit on board that acts as an electrical switch working based on the mechanism of electromagnetic flux. By turning on the electromagnet with a separate low-power

signal from a microcontroller, the electromagnetic flux is created. The electromagnetic flux pulls to either open or close an electric circuit when it is energized. Majumder *et al.* [23], relays are suitable for applications that involve a high range of voltages. Another benefit of using relays is that require very low power to energize their coils. The relay module was used in the project work to open or close contact that initializes the operation for activating or deactivating appliances and other components.

C. Bluetooth module (HC-05)

The HC-05 Bluetooth module was created for transparent wireless serial connection setup and is a simple-to-use Bluetooth serial port profile (SPP) module. The Bluetooth module enables wireless serial communication over a network between hardware devices. It is simple to use to interface PCs, smart phones, or microcontrollers. Figure 5 is components of wireless control network in the home automation system. It is a tiny chip, as depicted in Figure 5(a). Users use the Bluetooth communication network to send data from their phones to the microcontroller. The relay module is an integrated circuit as shown in Figure 5(b).



(a) (b)

Figure 5. Components of wireless control network in home automation system
(a) Bluetooth module (b) Relay with power supply board

D. Power supply

An electrical device known as a power supply provides electricity to an electric load. A power supply's primary function is to convert electric current from a source (such as the electric power grid, an outlet, or an energy storage device) to the proper voltage, current, and frequency so that the load can be energized. As a result, a supplier may also be called an electric power converter. The controller receives the output from the solar panel array and uses it to adjust a number of factors before feeding it to an electric motor, which in turn powers a water pump.

E. Water pump

The water pump in usage is a turbo-mechanical device that can raise water pressure to move it from one place to another [24]. The pump that is used to transfer water from the reservoir to the tank has a working pressure of roughly 20 psi. An IoT-based intelligent monitoring solution for solar water pumping plants. The monitoring system was created by changing the controller and adding a suitable feedback mechanism to keep the temperature constant as suggested in [25]. These pumps can deliver water to places that aren't serviced by electricity cables. Typically, these locations rely on human or animal power, which cannot adequately provide the crop water requirement. Solar water pumps are environmentally and socially responsible.

F. Sensors and water level indicators

The HC-SR04 ultrasonic sensor is a sensor that measures distance. When an object or obstacle is in its path, the ultrasound that is emitted by the device at a frequency of 40,000 Hz (40 KHz) will bounce back to the module. The distance can be calculated using the sound's speed and travel time [26]–[29]. A PIR, commonly referred to as a motion sensor, is an electronic gadget that detects motion by detecting heat energy in the environment using two pyroelectric sensors.

3.2. Hardware programming and application software design

To achieve optimized and efficient home automation system, each part of the system has a certain level of programming to improve flexibility of the system. In the software design and hardware configuration, the software development environments used for the hardware and application programming include MIT inventor, proteus, and Arduino integrated development environment (IDE). The instruction set for each Arduino component was written with Arduino IDE as presented in the appendix section, the circuit design and simulation were done with proteus and the android application was designed and configured with MIT inventor software [28]. The various sections of the overall developed mobile communication-based home automation system are as follows.

3.2.1. The main control unit

The Arduino nano interfaced with relay modules as shown in Figure 6 acts as the main controllers in the system to activate or deactivate all appliances. A relay module was attached to the Arduino board to accommodate home appliances to the wireless network system. Each component was assigned a variable in the program as presented in appendix section to improve flexibility of the system. The Arduino board sends actuating signal to appliances based on user's command and also receives signal from the appliances to update their status on the android mobile application. For the water level system, there are two modes of operation; Automatic operation mode and manual operation mode. In the automatic mode, pumping machine is energized or de-energized based the signal that the microcontroller received from the ultrasonic sensor.

Figure 6. Control unit or the system

4. RESULTS AND DISCUSSION

The range for the bluetooth connection was checked with different devices. A mobile phone can connect to the bluetooth network in less than 5 seconds, and the connection range of the system is within 0-100 meters, according to the test results. Furthermore, it was observed that the connection speed is within 2-3 Mbps. The operation of automatic control of the system was observed to know the performance of the ultrasonic when water reaches a level that is 100 mm and 40 mm to the sensor. While checking for the reliability of the ultrasonic sensor, the bucket (reservoir) was empty and then fully filled to examine the operation of the pump under influence of the sensor. In the automatic mode; as water approaches 40 mm to the sensor, the pump quickly goes off in order to stop pumping water from the first bucket (reservoir) to the second bucket (tank) and when the sensor detects a drop in water level to about 350 mm, the pump is energized to start pumping water from the reservoir to the tank.

To check the performance of the mobile application design and hardware response on remote mode, the operation and performance of the pump were tested for different levels of water in the storage. When the water storage was empty, it was de-energized from the mobile application to verify that its operation did not conflict with the automatic operation mode. Finally, to test the performance of the entire system, a prototype that contains water level system and electric bulbs and electrical outlets was built as shown in Figure 7. Each bulb can be switched on/off remotely using a mobile phone. The operation of the water pump attached to the source bucket can be either controlled from the phone while in manual mode or controlled by an ultrasonic sensor while in automatic mode.

Figure 7. Experimental bed and result

5. CONCLUSION

A prototype of a mobile communication-based home automation system was designed and developed with Arduino microcontroller interfaced with relay modules and a Bluetooth module. The hardware was programmed with Arduino IDE and its circuit was simulated with proteus software while the software part of the system (android application) was designed with MIT inventor software. A power supply circuit was designed and implemented while designing and implementing the Arduino microcontroller circuit for the wireless control and monitor of water level system and household devices. A Bluetooth network was established to allow data communication between Arduino board and mobile phone. Also, all hardware devices excluding the power supply were integrated on a single switching board as a proof of concept that home appliances and components of the water level system could be controlled and monitored remotely with the mobile phone. some of the potential areas for future work in relation to the performances of Arduino-based automation home systems using the IoT are the introduction of energy efficiency, artificial intelligence and cloud computing integration.

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