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Development of a Secure Intelligent Home Automation System Using Arduino

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Abstract

This article presents an intelligent home that integrates advanced technologies to offer the user optimum levels of comfort, safety and energy efficiency. The main aim is to create an interconnected, automated home environment capable of meeting the needs of its occupants intuitively and efficiently. To achieve this, various components will be installed, such as temperature and movement sensors, control devices, automatic watering, security systems and energy management systems. The aim is to demonstrate the benefits and potential of smart homes, marking an important step towards the future of connected living. In this project, we have built a prototype of a real smart home, controlled and monitored, using the microcontroller. The system includes several functionalities, such as automatic watering, smoke detection, motion detection, lighting control, secure door opening, etc. The object of this work is to design a home automation system that allows the control of home appliances in a simple and less expensive way, to provide comfort, safety and energy savings. The results show that the system works properly, it allows the control of several functions at the same time, simple to realize with low cost and remote control.

Keywords: Smart Home Control, Microcontroller Arduino, IOT sensors, IOT actuators

1. Introduction

In recent years, the Internet of Things (IoT) has become one of the most essential technologies of the 21st century. Connected objects, also known as IoT, have invaded every aspect of our daily lives. Whether in industry 4.0, healthcare, smart buildings, or even at home with home automation, which offers several technologies and currencies to manage heating, lighting, etc. no one can escape their presence (Gong, 2016). A home automation system focuses on automating the control of home electronics. Whether the user is inside or outside the home, home automation enables automatic control of home elements. Home automation mainly comprises centralized control of lighting, temperature, appliances and other systems, to improve comfort, convenience, efficiency and security (Alsakran and al.,

2020). The connected home offers a number of advantages, including greater day-to-day comfort, with centralized access and control of household equipment (Robles & Kim, 2010). As a result, recurring daily tasks are easier to manage, more convenient and less time-consuming. It offers a certain level of security (Yavuz and al., 2007) and energy savings, for example, as soon as the water meter is connected; the slightest leak in the domestic network pipes is reported (Biswal and al., 2015). The connected home is the perfect solution for people with reduced mobility, such as the elderly. Indeed, this technology is a real revolution, highly effective in keeping these categories of users at home by securing their movements and preventing domestic accidents they could fall victim to, thanks to motion detectors that switch on lights, warning systems, light signals and much more.

The aim of this document is to present an intelligent home that integrates advanced technologies to offer optimum levels of comfort, safety and energy efficiency. The objective is to provide assistance to its occupants, particularly the elderly and those with reduced mobility, in all situations of daily life. It integrates techniques for controlling, automating and programming the home environment. In this project, we decided to combine home security, by locking and unlocking doors with a password, monitoring fires with a smoke sensor and triggering an alarm in the event of a fire. Daily comfort, by automatically switching on the lights as soon as someone is present and according to the intensity of the light, by triggering a fan as soon as the room temperature exceeds a precise threshold, and by triggering the water pump for automatic watering after detecting dry soil using a soil moisture detector. And last but not least, energy saving, which is summed up in the control of lights, which will reduce electricity consumption, and watering when necessary, which will save water resources.

To achieve this, we will be installing several automatic systems in the house, including a house access management system, automatic and remote-controlled light control systems, a fire detection system, as well as an automatic watering system for the garden based on soil conditions, an additional option compared with other smart homes already developed, and finally supervision by sending an e-mail to the owner in the event of a fire. The design of the various systems is based on the use of the Arduino Uno microcontroller, various sensors and actuators.

2. Literature Review

This section briefly presents the most relevant publications on the subject in chronological order. The authors of (Bangali & Shaligram, 2013) gave an overview of a home system that consists of sensors, a GSM module, a microcontroller, relays to regulate the gadget and a buzzer to provide security, enabling homeowners to receive alert messages when away from home. In addition, the authors of (Komninos and al., 2014) outlined various IoT-based smart home applications. Subsequently, they outlined several challenges associated with the use of IoT in smart home devices, such as protection, information management, communication-related issues, etc. Smart homes offer many benefits, including improved living comfort, increased safety and health for residents, energy savings and easier communication between residents (Ghazal & AI-Khatib, 2015). An overview of smart homes and their main components is provided by (Asadullah & Raza, 2016). It gives an overview of security

studies carried out to address safety-related issues in smart homes and proposed some possible solutions. The study conducted by (Abdul Kareem Kasim, 2017) outlines a robust and flexible home automation device that exploits the Internet of Things and the Arduino microcontroller. This system uses WiFi and IP connectivity to allow authorized users to control devices. The system controls household devices such as fans and lamps, rather than a server. The system developed by (Halgurd & Bakhtiar,2018) regulates smart home security using the GSM network, a Bluetooth module for a Smartphone application, and an IR module for infrared (IR) control. A smart security device was designed by (Ayon & shahadat, 2019), using Arduino and a GSM module to effectively detect home intrusions. In addition to the GSM module, they used a servomotor, buzzer, light-based resistance sensor and light-emitting diode to set up the system. The system worked using the Arduino microcontroller to effectively control the hardware and trigger a light, sound and send an SMS to the owners. The smart home is presented as an extension of domestic building automation (Raza and al., 2020). The first steps involved the computerization and control of systems such as lighting, heating, ventilation, air conditioning and security that enhance human well-being. Recently, a wide range of home appliances using Wi-Fi for remote monitoring has been introduced. The widespread use of Smarthome systems, the result of technological development, has helped to improve living standards. Many functions can be performed without having to be present in the home at all times, as alarm and video surveillance systems can be monitored and controlled remotely using a smartphone or tablet (Okafor and al., 2022). Recent security devices from (Nayak & Dass, 2023) and (Abiodun & Okpe, 2024) are implemented using the Arduino Uno microcontroller, an ultrasonic sensor and a GSM module to effectively control intruders and send SMS alerts to homeowners in the event of intrusion, facilitated by the Internet of Things network. The devices are both simple and extremely effective, as they can detect any intruder in the home and trigger an SMS alert. The various home automation systems presented focus more on security and the use of a few sensors and actuators, but the system we are proposing brings together several functionalities for security, comfort by adding automatic watering and energy saving using several sensors and actuators and the Arduino Uno microcontroller.

3. Component Description

The schematic diagram of the smart home automation system is shown below (Figure 1). All components are connected by Arduino board; this system can work in AC and DC, because it uses hybrid power supply. The Arduino board is used to get the values of physical conditions for example the temperature sensor reads the temperature values and the smoke sensor detects the smoke and sounds the buzzer.

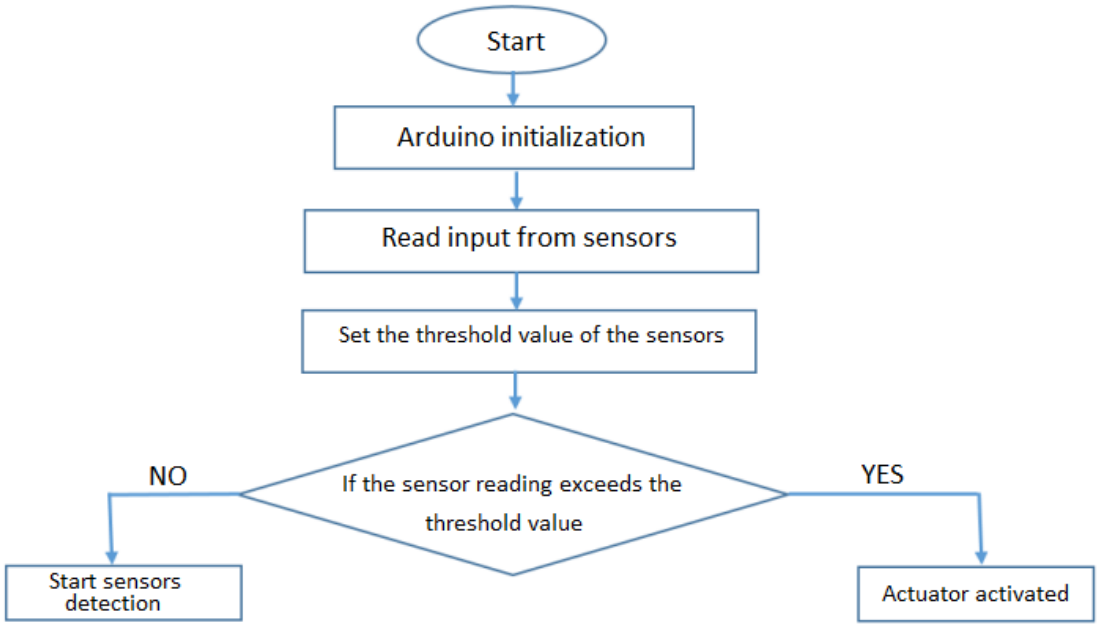

Figure 1. Flowchart for smart home automation system

3.1 Arduino Uno

Arduino is an open-source project that provides a platform for prototyping interactive objects, consisting of an electronic Board and a programming environment. The fundamental aim of Arduino is to combine the performance of programming with that of electronics. The major advantage of programmed electronics lies in the considerable simplification of electronic schematics, resulting in lower production costs and a reduction in the workload involved in designing electronic boards. The electronic board is not equipped with any type of connector other than the USB port, so it uses a different module (Wi-Fi, Bluetooth, memory card reader, etc.), which makes it inexpensive, extremely adaptable to different projects and economical from an energy point of view (see Figure 2) (Arduino, 2024).

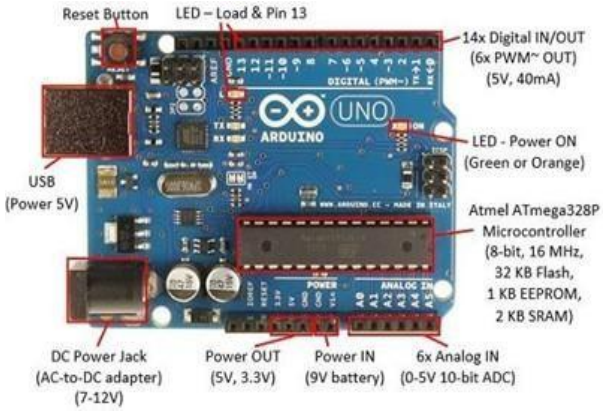

Figure 2: Arduino Uno board

The Arduino Uno board, shown in Figure 2, is extremely user-friendly and easy to use. It offers simple integration and compatibility with different operating systems, making it accessible to a wide range of users. It can be programmed directly by connecting it to a computer running Windows, Mac or Linux.

3.2 The Sensors

3.2.1 Temperature and Humidity Sensor

We used the DHT11 temperature and humidity sensor for our project (Figure 3). This sensor is capable of measuring temperatures in the range 0 to +50°C with an accuracy of +/- 2°C, as well as relative humidity levels from 20% to 80% with an accuracy of +/- 5%. It takes one measurement every second. The DHT11 sensor consists of a resistive humidity sensor and an integrated microcontroller that takes measurements, converts them and transmits them.

Figure 3. Temperature and humidity sensor DHT11

Features of the DHT11:

- Power supply: 5V.
- Consumption: 0.5 mA nominal / 2.5 mA maximum.
- Temperature measurement range: 0°C to 50°C ± 2°C.
- Humidity measurement range: 20-90%RH ±5%RH.
- Measurement period: 2s.
- Dimensions: 12*15.5*5.5mm.

3.2.2 Soil Moisture Sensor

This moisture sensor is designed to measure the state of the soil and has an ideal application in the creation of connected objects that indicate whether a plant needs water. Using this sensor, we can assess soil moisture by detecting changes in the electrical conductivity of the soil (soil resistance increases with drought) (Figure 4) (Yeow and al., 2018).

Figure 4. Soil moisture sensor

The sensor consists of two main parts. Firstly, the sensor fork is fitted with two electrodesthat allow us to measure soil moisture by detecting changes in resistance between them. Thisfork is inserted vertically into the soil, whether in a flower pot or a garden. Secondly, the sensor's electronic board plays an essential role. It includes a conditioning circuit for the fork's resistive sensor, as well as circuits for processing and converting the analogue signal into a digital signal. This board generates a digital signal proportional to the humidity measured by the sensor, which is then transmitted to the Arduino board or other processing device.

3.2.3 Flame Sensor

The flame sensor KY-026 is an electronic module specially designed to detect the presence of flames or sources of intense heat. It is commonly used in electronic projects and safety systems to detect the start of fires (Figure 5).

Figure 5. Flame sensor

The flame sensor KY-026 works by using a photoreceptor capable of detecting theinfrared light emitted by a flame. When the sensor detects the presence of a flame, it generates a digital output indicating the presence of the flame. This output can then be used to trigger various actions or alerts, such as activating a fire alarm or automatically shutting down potentially dangerous equipment. It consists of:

- Digital output: If a flame is detected, a signal is emitted here.
- Analogue output: Direct measured value of the detection unit.

3.2.4 Photoresistor

A photoresistor is an electronic component whose resistivity varies according to the amount of incident light: the lighter it receives, the lower its resistivity (Figure 6).

Figure 6. Photoresistor

With Arduino, it's possible to exploit variations in photoresistor to detect and measure ambient brightness. This makes it possible to create projects that react to light, such as automatic lighting systems, sun-tracking devices, brightness indicators, or even security systems that activate according to the presence or absence of light.

Photoresistor features:

- Luminous resistance at 10 Lux: 18 - 50 K ohm i.e. 18000 to 50000 ohm
- Resistance in the dark (0 Lux): 2 M ohm (±20%)
- Power dissipation (25°C): 100 mW Max voltage (25°C): 150 Volts DC (direct current)
- Operating temperature: -30°C to +70°C
- Response time: 30 ms

3.2.5 Ultrasonic Sensor HC-SR04

The HC-SR04 sensor uses ultrasonic technology to accurately measure distance to an object. It offers a wide non-contact detection range and guarantees stable, accurate measurements. Unlike other sensors that can be affected by sunlight or dark materials, the HC-SR04 sensor is unaffected by these factors. In short, this sensor is a reliable choice for measuring distance in a variety of applications (Figure 7).

Figure 7. Ultrasonic transducer

Ultrasonic transducer technical data:

- Dimensions: 45 mm x 20 mm x 15 mm
- Measurement range: 2 cm to 400 cm
- Measurement resolution: 0.3 cm
- Effective measuring angle: 15°
- Trigger input pulse width: 10µs

3.2.6 IR Remote Control

An infrared remote control is a device used to remotely control electronic devices using infrared signals. With Arduino, you can create a system for receiving and decoding infrared signals from a standard infrared remote control, enabling you to control specific actions or functions (Figure 8).

Figure 8. IR remote

Technical specifications:

- Operating frequency: 38 kHz
- Remote control range: up to 8m
- Operating voltage:3V
- Operating current: <20mA
- Dimension: 86x40x7mm

To use an infrared remote control with Arduino, you'll need an infrared receiver, such as the TSOP infrared receiver module, and an infrared decoding library, such as the IR remote library.

3.2.7 IR Receiver

The use of infrared is widespread in the field of remote control. With the Infrared receiver module, an Arduino board can exploit the signals of any infrared remote control by implementing the appropriate decoder (Figure 9).

Figure 9. IR receiver

Features:

- Power supply: 2.5 - 5V
- Digital interface
- Optimum modulation frequency: 38Khz

- Distance 18 metres.

3.3 Actuators

3.3.1 An I2C LCD Display

An LCD (Liquid Crystal Display) is a device that displays characters while consuming relatively little electricity, which is why it's found in many electronic projects and on all types of devices (Figure 10).

Figure 10. LCD

I2C LCD display features:

- Dimensions: 82 x 35 x 18 mm
- Weight: 40 grams.

3.3.2 Relay Module

The relay is a controllable switch that isolates the control part from the power part. It's a widely-used component when you want to make the link between electronics and electricity. It opens or closes a contactor on a power circuit according to a signal between 0 and 5V (Figure 11).

Figure 11. Relay module

Arduino relay 220V/230V features

- Power supply: 5 V.
- Current consumption: 15 mA - 20 mA.
- Relay type: electromechanical.
- Rated load current: 10 A.
- Switching voltage: up to 250V (AC) and 30V (DC)

3.3.3 Numeric Keypad 4x4

A 4×4 matrix keyboard is a type of keyboard that uses a grid of 4 columns and 4 rows of keys to enter data. Each key is associated with a unique combination of rows and columns', making it possible to detect which key is pressed by measuring the resistance between rows and columns (Figure 12).

Figure 12. Numeric keypad 4x4

4×4 matrix keyboards are widely used in applications where space is limited, such as remote controls, portable electronics and industrial control devices. They are also popular in hobby and DIY projects, such as robotics and home automation.

3.3.4 Water Pump

A water pump is a device that uses an electric or gasoline motor to move liquids through a pipe. It is widely used for irrigation, water distribution, cooling and liquid transfer. Water pumps come in a variety of types, characterized by size, power, flow rate and operatingmode (Figure 13) (Suresh Kumar and al., 2023).

Figure 13. Water pump

Technical specifications of the 5V pump:

- Voltage: 2.5-6 V
- Maximum lift: 40-110cm
- Flow rate: 80-120L / H
- Water outlet outside diameter: 7.5 mm
- Inner diameter of water outlet: 5 mm
- Diameter: approx. 24 mm
- Length: approx. 45 mm
- Height: approx. 30 mm

3.3.5 Buzzer

Buzzers are found in various devices such as alarms, computers, timers and user input confirmation systems. They emit a continuous tone and have a minimum sound output of 70 dB at a distance of 1 meter. These buzzers have an electrical power rating of 3 V and a current consumption of 150mA (Figure 14).

Figure 14. Buzzer

Buzzer characteristics:

- Diameter 12 mm, height 9 mm
- Continuous ringing
- Black color
- Supply voltage :2V -4V
- One positive and one negative pin

3.3.6 Servomotor

A 5V servomotor is a type of electric motor that is generally supplied with a voltage of 5 volts, it can be used in many applications, including:

In Robotics to control the movements of arms, legs, heads and other moving parts of robots, in modelling whether for airplanes, cars, boats or model trains, to control rudders, steering wheels, propellers, and in home automation to control the opening and closing of roller shutters, doors and windows (Figure 15).

Figure 15. Servomotor

Servomotor technical data:

- Figure 11 5V servomotor
- Weight: 9 gr.
- Supply voltage: 4.8v to 6v.
- Speed: 0.12 s / 60° at 4.8v.

- Torque: 1.2 Kg / cm at 4.8v.

3.3.7 Other Electrical Components

The LED, or light-emitting diode, is a widely used optoelectronic component. It has a number of advantages, including ease of assembly on a printed circuit, low power consumption, mechanical strength, compact size and long life. Because of these characteristics, the LED has become an essential component in many applications.

The fan in our system acts as a cooling mechanism, in the case of very high temperature and medium soil humidity detection.

In electrical and electronic circuits, it is sometimes necessary to limit the current to protect certain components. Technical resistors" are used for this purpose. These electrical/electronic components have a specific resistance and are cylindrical in shape. They are manufactured with a porcelain support and covered with a layer of protective varnish. Technical resistors are used to control the flow of current and prevent damage to other components in the circuit.

3.4 Software

3.4.1 Arduino IDE

The Arduino Software (IDE) is an open-source development environment specially designed for programming and uploading code to Arduino boards. It runs on Windows, Linux and Mac OS X. The IDE is mainly written in the Java programming language (Arduino, 2024).

3.4.2 Fritzing

Fritzing is an open-source software package for electronic circuit design and schematic creation. It offers an interface that allows users to create, document and share their electronic projects (Fritzing, 2024).

3.4.3 PyCharm

PyCharm is an integrated development environment (IDE) created by JetBrains, a company specializing in software development tools. It is primarily designed to facilitate programming using the Python language (Pycharm, 2024).

4. System Design and Production

4.1 The Structure of the House

First of all, here's the architecture we've chosen. We've opted for a simple plan consisting of three bedrooms, a kitchen, a garage and a garden (Figure 16).

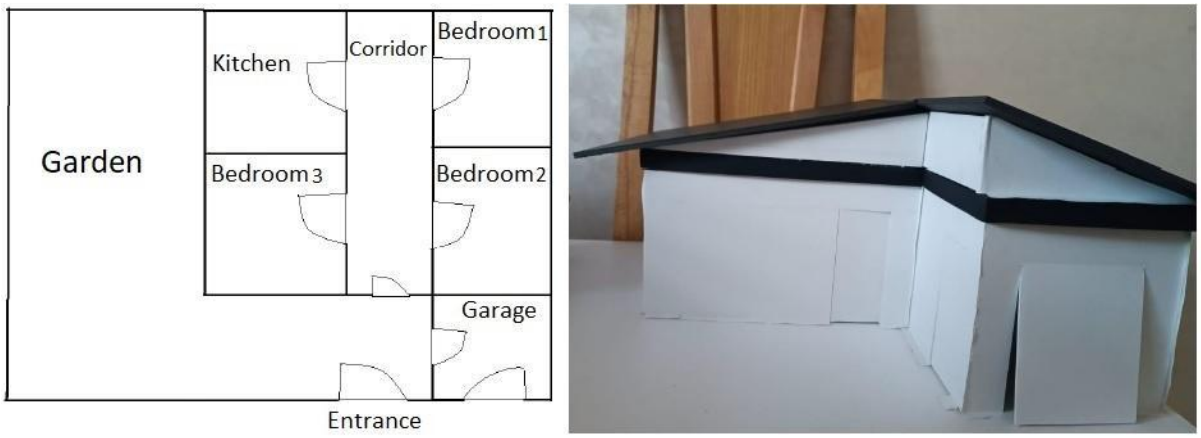

Figure 16. The house structure

4.2 Flame Detection System

A fire detection system is designed to detect the presence of a fire and alert people in the danger zone. The flame detection system works as follows: if the flame detector detects the presence of a fire, the buzzer sounds an alarm to alert residents to call for help and to leave the house to avoid the risk of intoxication caused by the smoke and gases that precede and accompany the arrival of flames (Mestouri and al., 2023). The KY-026 flame sensor was used for this system. The Arduino program for flame detection with a buzzer consists in reading the value of a flame sensor using the analogue pin. If the value exceeds a predefined threshold, indicating the presence of a flame, a buzzer connected to an Arduino pin is activated to emit an audible signal (Figure 17).

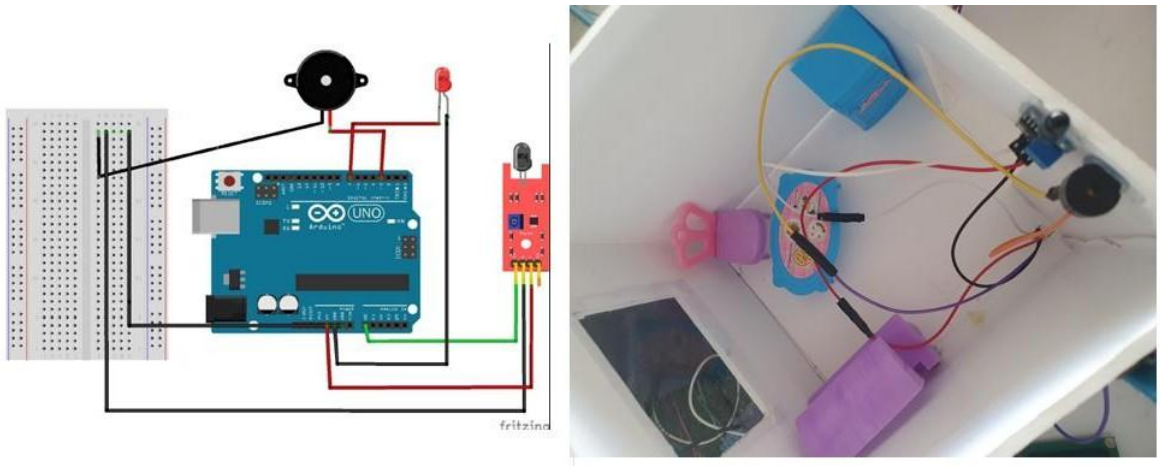

Figure 17. Simulation of the circuit using fritzing software and actual implementation of the flame detection system

4.3 Automatic Corridor Lighting System

An automatic corridor lighting system turns on the corridor light when the presence of a person in the corridor is detected, and turns it off when the presence of a person in the corridor is not detected.

An automatic lighting system is based on controlling the switching on and off of lights in the hallway of the house automatically, depending on the presence of people. The automatic lighting system is designed to save energy and improve safety by avoiding unnecessary lighting when the premises are empty. The system can be used in many areas of the home, such as staircases, bathrooms, garages, etc.

This system uses an HC-SR04 ultrasonic sensor, based on ultrasonic technology, toaccurately measure the distance to an object. The Arduino program for automatic lighting of the corridor consists in detecting the presence of a person in the corridor, and calculating his distance, then comparing it with a threshold distance which is the length of the corridor. If a person is detected, the lamp is switched on and remains switched on until a delay elapses (Figure 18).

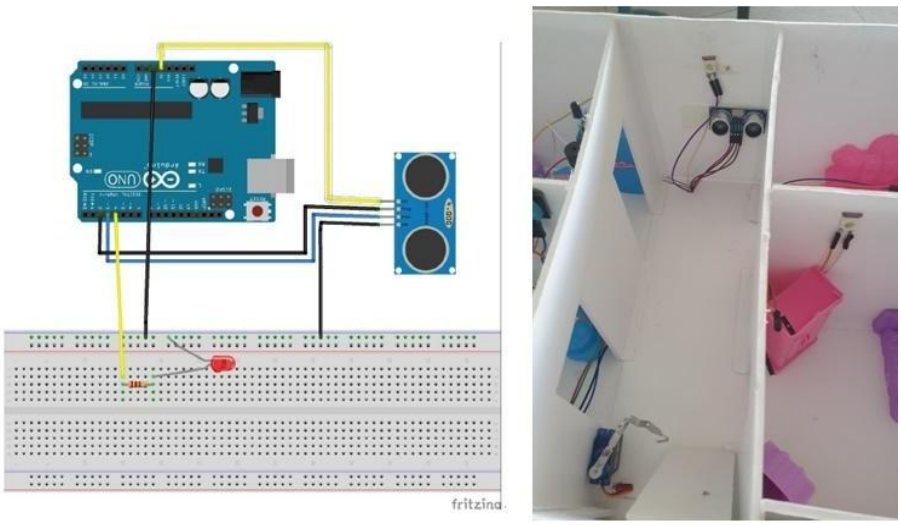

Figure 18. Simulation of the circuit using fritzing softwareand actual automatic corridor lighting system

4.4 Cooling System

In the following circuit, a cooling system has been created using a fan and a DHT11 temperature and humidity sensor:

We used a DHT11 temperature and humidity sensor that measures relative humidity and temperature, and displays it on an I2C LCD display. When the temperature exceeds the 21°C threshold, the fan automatically triggers to cool the house (Figure 19).

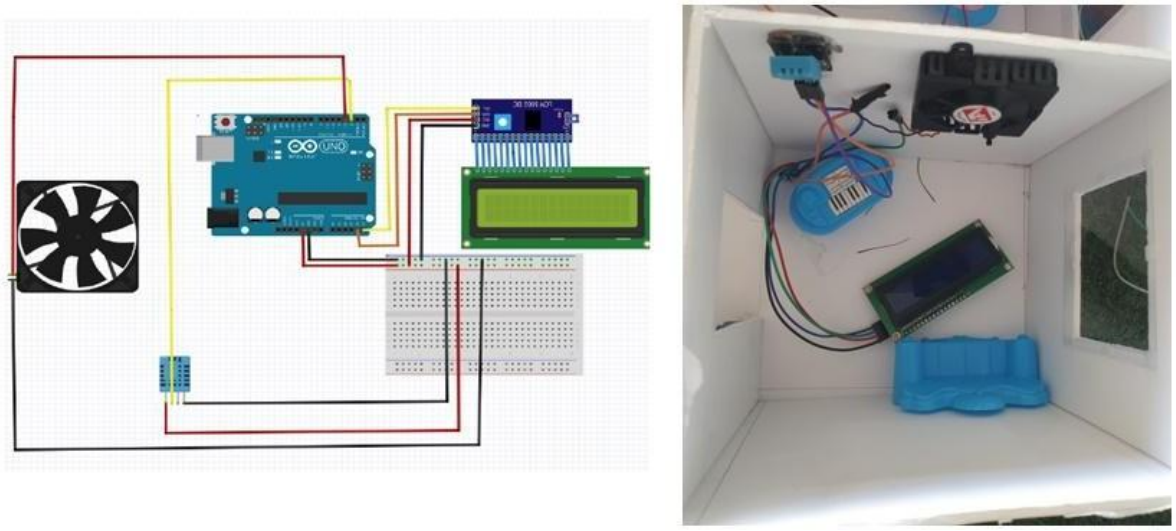

Figure 19. Simulation of the circuit using fritzing softwareand actual cooling system

4.5 Automatic Lighting with Remote Control

An interesting idea is to use an Arduino remote control to manage the lighting. This will enable us to control lights wirelessly using infrared signals.

To create this circuit, we used a KY022 remote control and infrared sensor, and 3 LEDs for 3 rooms. The Arduino remote control emits an infrared signal which is detected by the KY-022 infrared sensor. This sensor contains an integrated circuit that amplifies and decodes the signals to make them usable. Pressing button 1 on the remote-control switches on the lamp in room 1. Pressing button 1 a second time switches the lamp off. This on/off cycle is repeated each time button 1 is pressed. Similarly, pressing button 2 on the remote control activates the lamp in chamber 2. Pressing button 2 a second time will switch the lamp off, and this cycle can be repeated. Finally, press button 3 on the remote control to switch on the lamp in room 3. Pressing button 3 a second time turns the lamp off, and this pattern can be repeated (Figure 20).

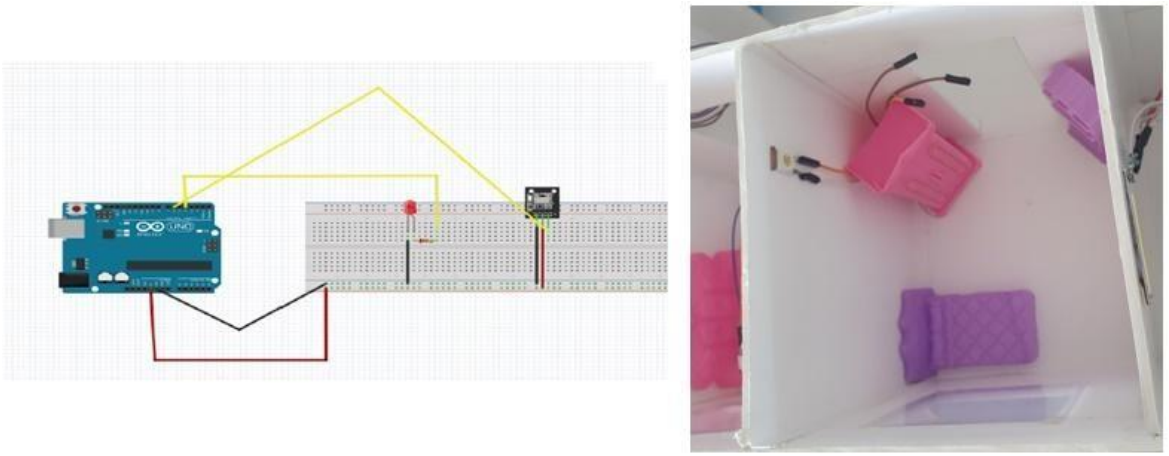

Figure 20. Simulation of the circuit using fritzing softwareand actual automatic lighting system

4.6 Door Safety System

A door security system is a device designed to protect the home from unwanted intruders. We've built a password-based door locking system by interfacing the Arduino board with a 4x4 keyboard to enter the password. This security system requires us to enter a password to open or close the door (Figure 21).

We've inserted an LCD into the circuit, which will initially display "Enter Password". The user will enter the code using a 4x4 matrix keyboard. This entered password will be sent to the Arduino board, which will display it on the LCD, then compare it with the valid code and display the result. Depending on the validity of the code, it will control the state of the door (open, close or no action).

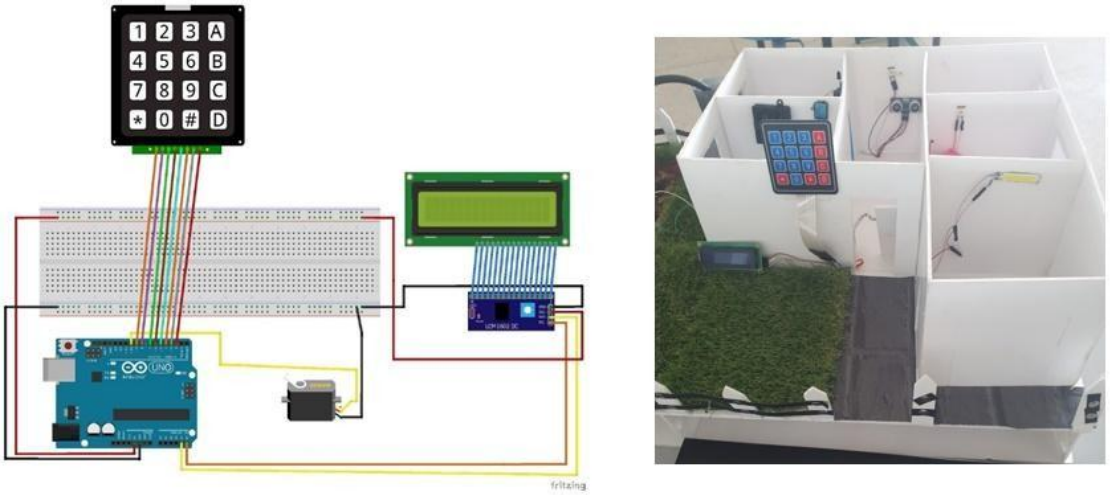

Figure 21. Simulation of the circuit using fritzing softwareand actual door security system

4.7 Automatic Watering System

The aim of an automatic watering system is to create an automatic watering system for plants, providing water only when needed. It can be used for a single plant or for a small plantation, and can be reproduced on different scales. This device allows you to take care of your plants when you're away, or to control the growth of species that are particularly sensitive to humidity thanks to precise settings (Figure 22).

This system is installed close to the plants to be monitored, and uses a soil moisture sensor to assess the level of soil moisture by measuring the resistance between two electrodes. This information is then used to control the activation of a 5V pump, which is driven by an Arduino board to supply water to the plants if required.

Figure 22. Simulation of the circuit using fritzing softwareand actual automatic watering system

4.8 Connected Parts in the Home

The aim is to set up a system that automatically sends an e-mail when a fire is detected. To do this, we'll use an Arduino connected to a fire sensor. Once the sensor is switched on, the Arduino will send its data via a wired connection to our python program, which will acquire it. If the data value indicates that the fire has started, an e-mail containing "fire detected in your house" will be sent to our mailbox, otherwise the phrase "there is no fire" will be displayed in the PyCharm console.

To establish communication between PyCharm and the Arduino, we used the PySerial library. This library manages serial communication between the computer and the Arduino.

To send data from PyCharm to our e-mail address, we used the following libraries: Smtplib. This library lets you send e-mails using SMTP (Simple Mail Transfer Protocol). Email Message: This class, present in the email.message library, allows us to create e-mail objects. We can customize the email content; define the sender, recipient, subject and other relevant parameters (Figure 23).

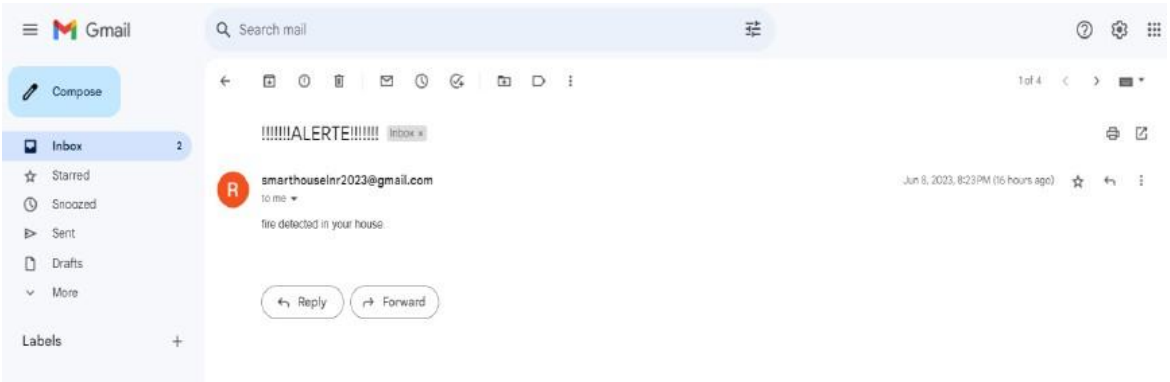

Figure 23. Flame alarm email

5. Conclusions

In conclusion, this document presents the creation of a smart home, which represents a significant advance in the field of home automation, since it brings together not only security, but also comfort (by adding automatic watering to smart homes) and energy savings. Our project was guided by the conviction that technology can play a major role in improving our daily lives. Thanks to home automation, we were able to create practical applications such as an intelligent fire control system, room cooling, remote control of lighting and front door, and an automatic garden watering system. These applications have been designed to simplify daily tasks and provide a more comfortable, safer experience for home occupants, while consuming little energy, making life easier for vulnerable people. The system is inexpensive and easy to implement. All system tasks are successfully completed. And we're currently developing a Smartphone application to manage and control our home remotely.

Acknowledgment

The authors declare no conflict of interest.

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