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Smart Home Security using Arduino-based Internet of Things (IoT) Intrusion Detection System

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Abstract

Home intrusion detection systems (IDS) have become increasingly important in our modern community due to their high performance in adequately securing the home environment. Nowadays, there is an incessant increase in the number of theft cases hence a need for an intrusion detection system to detect any intruder around our homes. The aim of This paper is to develop a Smart Home Security using an Arduino-based Internet of Things (IoT) Intrusion Detection System. This security system is built using Arduino Uno, ultrasonic sensor and GSM module for efficient monitoring of intruders and sending of SMS alerts to the homeowners at a point of intrusion which is made possible through the Internet of Things network. The Internet of Things is simply a type of network used to connect anything with the Internet based on stipulated protocols through information sensing equipment to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and or administration. The proposed system uses an Arduino microcontroller programed to coordinate the activities of the various components connected together for efficient communication using C++ programming language through the Arduino Integrated Development Environment (IDE). The system is simple and highly efficient as it is capable of detecting any intruder within the monitoring environment and triggering an SMS alert once an intruder is found.

Keywords: Intrusion; Detection; Arduino; Internet of Things; Smart home; Sensor

1. Introduction

The need for home protection has always been there but in recent times, considering a dramatic rise in petty crimes like robbery and theft, the need has been more strongly felt to have foolproof protection of the belongings and the family members. With the growing number of IoT related devices, smart homes promise to make our lives easier and more comfortable (1) in terms of security and other related life styles. Home security has come a long way in the last few decades, it was in the hands of a guard who manually provided surveillance during nights in the earlier days, but it was not foolproof as it was only normal for him to have a momentary lapse of concentration and even sleep off completely. It was then that home alarm systems based upon electronic circuits were developed which proved to be highly reliable and were appreciated by the people as they were relieved from constant monitoring of their homes. Home security has changed a lot from the last century and will continue to change in the coming years. Security is an important aspect or feature in smart home applications. The new and emerging concept of smart homes offers occupants a comfortable, convenient, and safe environment. One of the major concerns of people is security and most importantly premise security either in the home or office. Protecting physical assets such as refrigerators, washing machines and other valuables that need surveillance even if one is not around to keep any eyes on them from theft and vandalism [2] is of top priority for many people. Some valuable physical assets such as machines and other accessories may need replacement in the event of theft or destruction thereby increasing the cost of running a home. Various homes are destroyed or attacked without the incense of the owners. Smart home intrusion detection system is important in the

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monitoring of our environment and helps one to be at alert if there is a close movement in our environment. A smart home security system keeps homeowners, and their property, safe from intruders by giving the indication in terms of short message in addition to other benefits that may be associated with it. As the population of the country increases, the need for a smart home intrusion detection system also increases beyond the use of conservative methods. Smart homes in simple terms can be described as homes that are fully automated in terms of carrying out a predetermined task, providing feed back to the home users and responding accordingly to situations. Smart home security systems such as controlled network, and communication systems, emergency response, anti-theft monitoring systems require automated and controlled systems both near and at a distance of control. The focus of this paper is to develop a smart home intrusion detection system that detects an intruder within the monitored area in the environment using an ultrasonic sensor and Arduino Uno with a GSM module in an Internet of Things (IoT) environment. The concept of Internet of Things (IoT) describes the network of things (physical objects) that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet using a controller such as Arduino. The Arduino is an incredibly flexible microcontroller and development environment that can be used to control devices and read data from all kinds of sensors. Its simplicity and extensibility, in addition to its great success and adoption by users, have led to the development of a variety of hardware extensions and software libraries that enable wired and wireless communication with the Internet. Arduino is the ideal open hardware platform for experimenting with the world of the Internet of Things (3).



Figure 1 Arduino based Internet of Things Network

For the purpose of efficient monitoring of the home environment, the intrusion detector has a transmitter coupled with a portable receiver to alert homeowners through SMS in situations of break-ins or entering into the home while the owners are out of their homes. The intrusion detection system usually sends this message through an emergency number which is provided to the system by the homeowners. A smart home security system is usually made up of a control center and sub-systems.

1.1. Control Centre

The Control Centre is the Arduino Uno Board which is the central processor for a smart home security system. Arduino Uno is a microcontroller-based open-source electronic prototyping board that can be programmed with an easy-to-use Arduino integrated development environment (IDE). This IDE provides cross platform application for windows, MacOS, and Linux for uploading the code into the Arduino board. The Arduino IDE supplies a software library that provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that is compiled and linked with a program stub main () into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. The Arduino Uno has easy to use hardware and software that are capable of reading inputs - light on a sensor, a finger on a button, or a Twitter message and turn it into an output - activating a motor, turning on an LED, publishing something online [4] among others. The Arduino Uno is usually controlled with a set of instructions sent to the microcontroller on the board through the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing. The control center is shown in figure 2 below

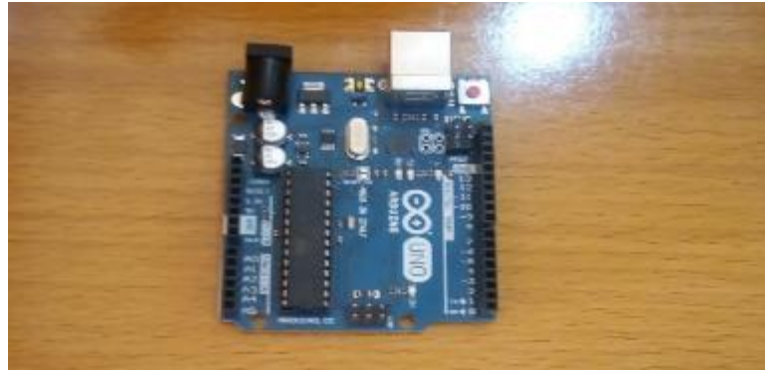


Figure 2 Smart Home Security Control Center

1.2. The Subsystems

The sub-systems include Ultrasonic Sensor, SIM800, GSM module, Jumper wires, among others.

Ultrasonic Sensor: The Ultrasonic Sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e., the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has traveled to and from the target) as shown in figure 3 below

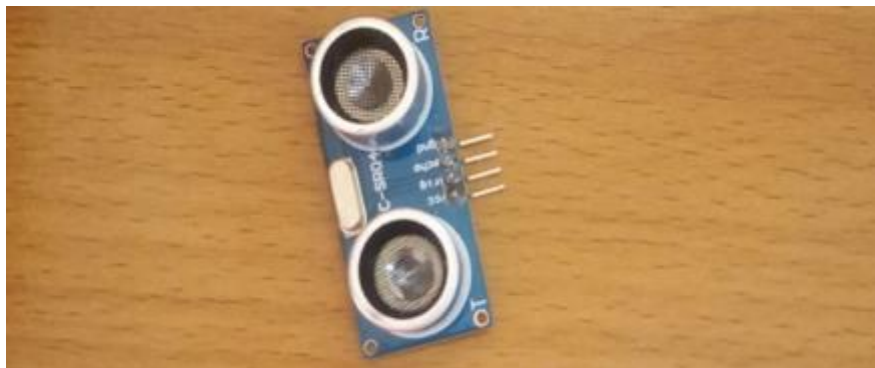


Figure 3 Ultrasonic Sensor

Ultrasonic sensors are used primarily as proximity sensors. They can be found in automobile self-parking technology, smart security system and anti-collision safety systems.

1.3. SIM800 GSM Shield

The SIM800 GSM shield is a GSM modem, which can be integrated into a great number of IOT projects. This shield is capable of performing almost all the functions of a normal cell phone such as SMS text messages, make or receive phone calls, connecting to the internet through TCP/IP among others and above all, it supports quad-band GSM network, meaning it works pretty much anywhere in the world.

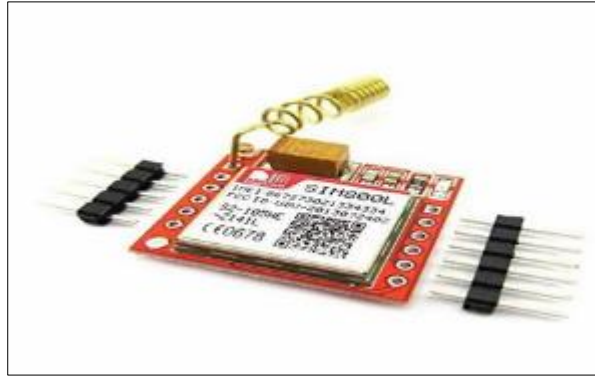


Figure 4 Top view of SIM800 GSM shield as a Sub-system

1.4. Jumper Wires

The Jumper wires are used to connect two points in a circuit. All Electronics stocks jumper wire in a variety of lengths and assortments. Frequently used with breadboards and other prototyping tools to make it easy to change a circuit as needed.

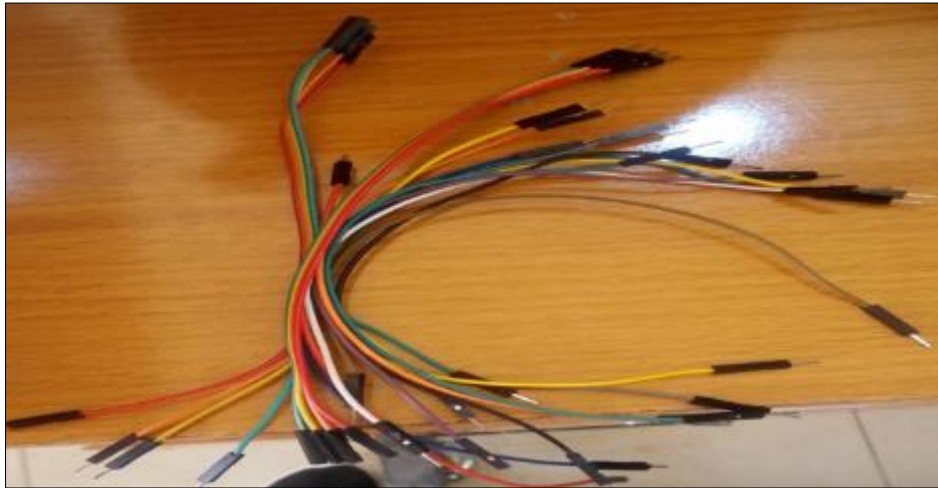


Figure 5 Jumper wires as a Sub-system

2. Review of Related Literature

The relevance of smart home security system has continued to gain ground to ensure the safety of the residents as a result many researchers has developed various smart home intrusion detection system to efficiently monitor their home environment. [5] developed a smart security box using Arduino and GSM module for smart home intrusion detection. The system was implemented using the GSM module, servo motor, buzzer, light-dependent resistor sensor and a light-emitting diode. The system was run using the appropriate Arduino codes in an Arduino microcontroller to efficiently drive the hardware and trigger light, sound and SMS to the homeowners. [6] developed a GSM based home security alert system using a passive infrared sensor that triggers an alarm and SMS once an intruder is detected within the monitored environment. [7] developed a GSM Based Smart Security System Using Arduino to remotely monitor an environment for intruders through SMS and mobile phone call whenever the homeowner is away from home and triggers alarm both in audio and video form when the owner is within the home environment. The system was implemented using Passive Infrared (PIR), MQ2, MQ7 and the DHT 11 sensors in monitoring intruders and other related household defects. [8] developed a GSM and Arduino based Smart Home Safety and Security System for monitoring of intruders and other household equipment defects using Arduino microcontroller. The system was able to lock and unlock doors, detect intruders using passive infrared sensor (PIR), monitors fire outbreak using smoke sensor and trigger fire alarm, monitors gas leakage using LPG sensor and send appropriate SMS to homeowners once a particular incidence is properly identified. [9] developed an Intelligent Arduino Home Based Security System Using Global System for Mobile Communication (GSM) and Passive Infrared (PIR) Sensor for monitoring intruders and alerting homeowners through

SMS. The system was implemented using C programming language loaded on an Arduino Uno microcontroller through the Arduino integrated development environment (IDE). [10] developed a Smart Home System Based on a GSM Network to monitor any undesired events, such as intrusion, gas leakage and fire outbreaks in the house and send a warning signal to the homeowner in real-time through Short Message Service (SMS). The developed system was able to control the security situation of the home through three basic ways: SMS using a GSM network, smartphone app using a Bluetooth module, and infrared (IR) control using an IR module.

3. Methodology

In this paper, a Smart Home Security using Arduino-based Internet of Things (IoTs) Intrusion Detection System (IDS) was developed. This system uses Arduino Uno microcontroller as its main processing unit. It uses GSM technology to connect and send coordinates of the scene of intrusion to the user through SMS in the form of message alert. The SMS is triggered once the ultrasonic sensor sensed a motion or detect an intruder within the monitored environment and generates a signal that communicate the coordinates of the scene to the Arduino Uno microcontroller. The Arduino extracts the required data received from the ultrasonic sensor signal and further send corresponding message signal to the GSM module for onward transmission to the homeowner in the form of SMS. The ultrasonic sensor detects an intruder and his distance using an echo received from emitted sound wave. This sensor outputs sound wave within a specified frequency and receive as input the echo that bounces from the intruder. To determine the intruder's distance, the system mathematically evaluates the time taking from the point of emission of the sound wave to the time of return of the echo and use it to obtain the actual distance of the intruder within the monitored environment. The signal generated is then transmitted to the Arduino microcontroller for onward processing. The Arduino Uno collects the signal from the ultrasonic sensor connected to its inputs and sends the instructions to the Global System for Mobile Communication (GSM) module. The GSM module was used to enable mobile communication through SMS. It basically consists of the Subscriber Identity Module (SIM) card and the operator over subscription through mobile network and very flexible to plug and pay devices. It uses AT (attention) command to efficiently communicate with the Arduino microcontroller system.

The Arduino Uno is directly connected to the system via a USB connector. The Ultrasonic Sensor which helps in detecting intrusion is connected to the Arduino Uno through jumper wires with SIM800 GSM shield for sending SMS that notifies the homeowner when an intruder enters the monitoring environment as shown in figure 6 below

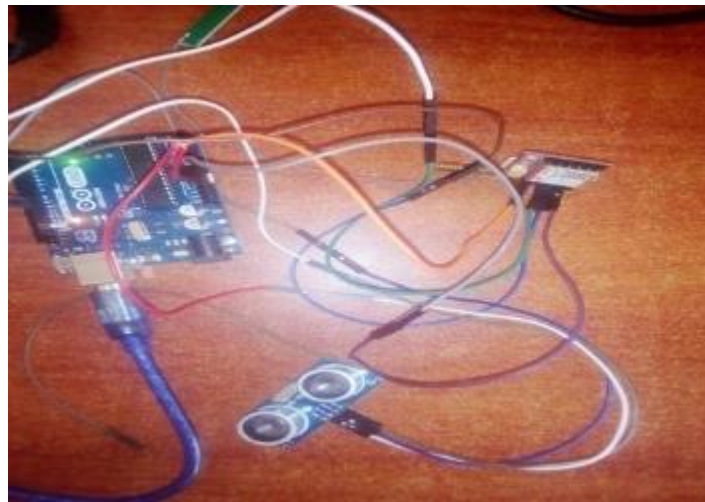


Figure 6 The Proposed System Component Connectivity

The monitoring system is built with low-cost embedded devices (Sensor, Arduino and GSM module) which help in tracking intruders and transmit the status by sending an SMS alert to the homeowner only when intruder enters into the monitoring environment else no message is sent.

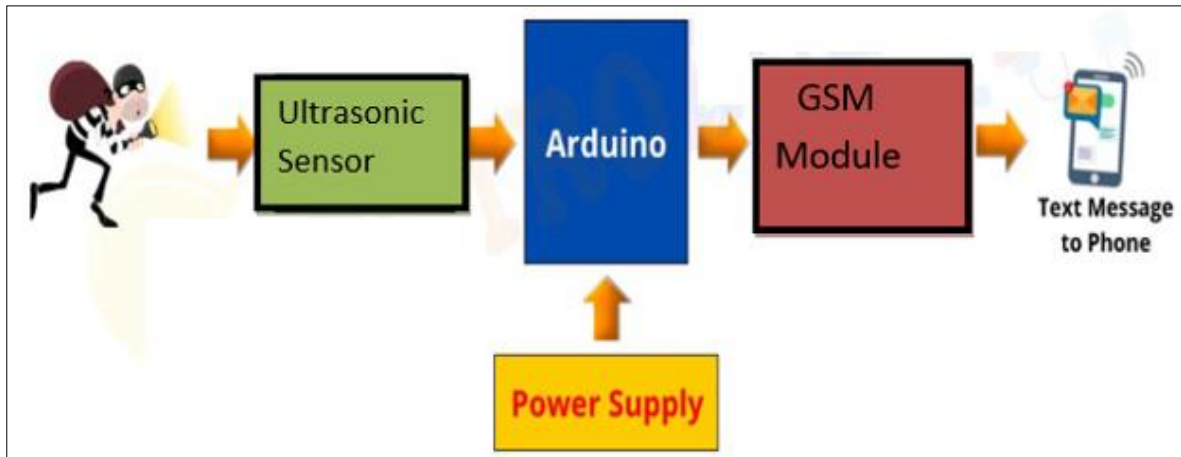


Figure 7 Proposed System Architectural Model

The Arduino was configured alongside all the other modules such as the Ultrasonic Sensor, SIM800 GSM shield, a SIM card, and all the requirements needed for its functionalities. The system flow diagram showing the logical sequence in the working process of the smart home intrusion detection system is displayed in Figure 8 below.

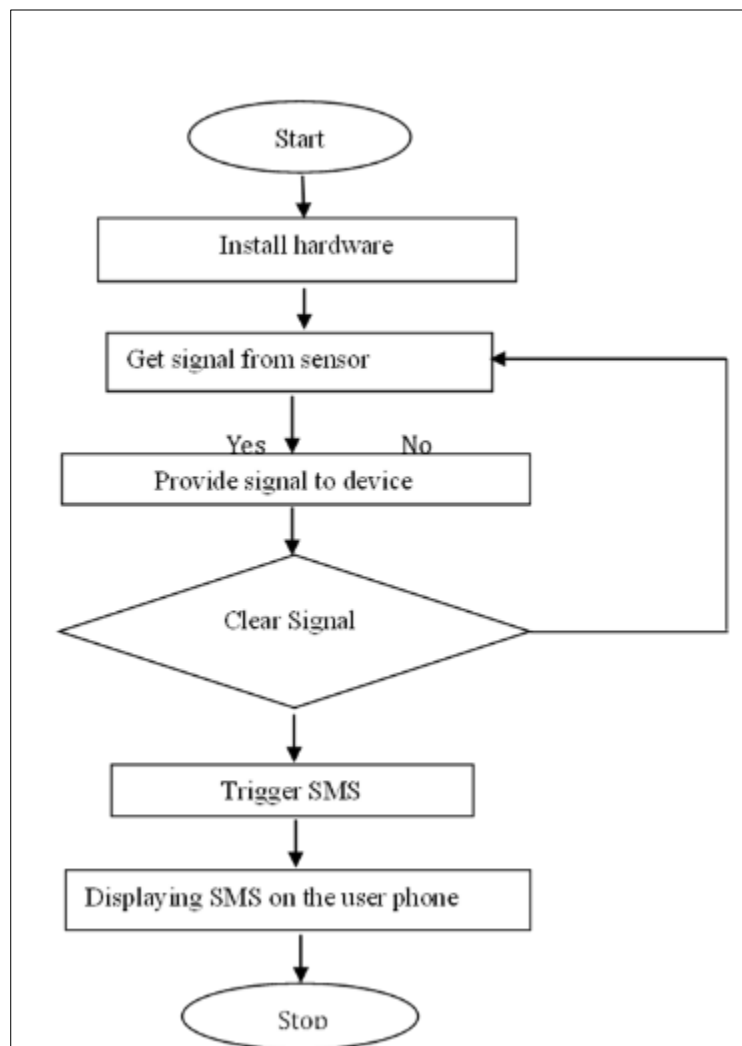


Figure 8 System flow diagram

4. Results and Discussion

The proposed system was tested to determine its correctness, completeness, and its overall efficiency in detecting intruders as well as to show that all logical conditions and decision statements are free from errors using a well-designed test data capable of testing all possible security conditions. The actual test result of this work was obtained from two (2) test cases as described in Table 1 below

Table 1 Evaluation results

Actual Test	Expected Action	Result obtained
Case 1: Intruder at home.	Trigger SMS alert	SMS "intruder at home"
Case 2: No Intruder at home.	Keep monitoring without any alert	No message was sent when no intruder is at home.

Upon sufficient testing, the system has meet its design and development objectives by performing its functions within an acceptable time in its target environments as all the features that are stipulated in the system are functioning perfectly. The proposed system has shown some performance improvement over the existing system and hence achieved the expected result.

5. Conclusion

The Smart Home Security using Arduino-based Internet of Things (IoT's) Intrusion Detection System is a modern technology based security guard that is targeted at alerting the homeowner in times of security bridge at home. The system is developed using the combination of hardware and software. The major hardware components of the system include Arduino Uno, Ultrasonic Sensor and GSM Modern while the software was coded in C++ programming language and loaded into the Arduino microcontroller through the Arduino IDE. The proposed system is capable of providing security and safety of homes and hence can be used for both personal and business purposes to improve safety and security, communication, and effective monitoring of homes or offices. Although this system is highly efficient in surveillance, it can be improved upon by using a technologically improved GSM module capable of facilitating faster and easier SMS alerts and by incorporating more hardware to improve its functionality and security sophistication.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have no conflict of interest.

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