Intelligent Intruder Detection System Using Arduino and Passive Infrared Sensors

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***Abstract*-This project implements an Arduino-based model, which has the potential to be an affordable and robust PIR Motion Sensor-based Home Security System, that was designed and constructed in Proteus 8. The mechanism incorporates a Passive Infrared (PIR) motion sensor, which is activated when it detects the unauthorized movement of a human. The motion of a person triggers and alert mechanism when the sensor gets the motion. In response to the signals from the sensors, a built-in alarm in the form of an LED or buzzer that is controlled by the Arduino microcontroller is activated. Additionally, the system can be upgraded to add features such as mobile notification for remote access control. Before a hardware application, the system is tested and debugged thanks to the emulator application Proteus 8 which allows precise testing of the construction. This project illustrates how contemporary technology, which is affordable and widely accessible, can be used in a simple and effective way to enhance home security.**

Keywords- PIR Sensor, Arduino Microcontroller, Proteus 8 Simulation, Sensor-based Security System

I. Introduction

Recently, security systems have become a crucial component of domestic and commercial structure due to the growing necessity of protecting properties and people. Though effective, traditional security systems can be quite cumbersome to install, costly, and laborious to maintain. On the other hand, modern alternative options that are low-cost and based on microcontroller platforms such as Arduino offer a more practical and modular approach towards individual and lesser security needs. In this paper, we describe a cost-effective yet efficient motion detection, alarm signalling, and information delivery security system based on PIR sensor, Arduino microcontroller, LCD, a buzzer, LED, and a control switch. The system is preferably constructed to accomplish a targeted goal while minimizing cost factors as much as possible. This is achieved regardless of the myriad of security contexts that would require emphasis. In the proposed system, the Arduino microcontroller is the main CPU, which receives traceback motion beams from the PIR sensor, and turns on other parts in charge of motion detection. A user is alerted of the motion via a sound, visual alert is provided by the LED light, and motion status is constantly updated on the LCD display.

The main goal of the study is to develop a user friendly and cost-effective security system that could be installed on residential apartments, offices, and other places that will require basic monitoring. The module architecture allows the extension in the attachment of more sensors or communication modules for ready-to-connect out-of-the-box connection.

The rest of this paper is structured as follows: The section II, represents to motion detection security systems. The section III describes the research strategy and its design with the implementation of the developed system. Section IV presents the results of performance appraisal of the system. Section V concludes the text by providing a discussion of perspectives for the development of the research.

II. Implementation

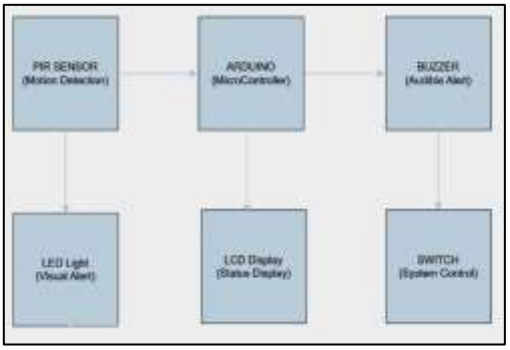

Fig.1 Block Diagram

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A) The PIR sensor is interfaced with Arduino that will give an output when there is a motion.
B) As per the sensor input, the Arduino controls the LED light by turning it on and controls the buzzer using the alarm.
C) The LCD in this device shows some messages like, "Motion Detected" or any current status of the system.
D) The switch should be used to lock or unlock the system and, thereby, enable the system operation by the user.

III. Objective

The project is aimed to develop an Arduino-based security system using a PIR sensor to detect movement and turn on alerting devices, which the system is efficient and inexpensive on security monitoring and control.

A. System Overview

The proposed system consists of motion detection-based security system whereby a PIR sensor is used for sensing movement. The Arduino processes the sensor and turns on a buzzer and LED. The motion sensor is powered using an LCD display that receives system status information and a switch that lets the user to turn the system ON or OFF.

B. Hardware

1) Hardware Functionality

a) PIR Sensor: This is used for detecting motion. It works on the principle of detecting infrared radiation emitted by moving objects. It ranges from 5 to12 meters that can be adjustable based on the sensor model.
A passive infrared (PIR) sensor is an electronic tool used to detect motion or detect infrared radiation emitted by things in its view. Active infrared sensors are widely known for their simplicity, small cost, and reliability reasons. The term "passive" makes us understand that this sensor does not emit some forms of energy but instead detects some infrared energy emitted by adjacent objects.

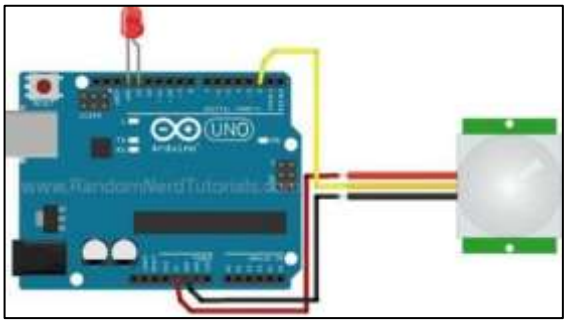

Fig. 2 PIR Sensor

Specification of PIR Sensor:

Detection range: up to 7 meters

Detection angle: 110 degrees

Operating voltage: DC 4.5V - 12V DC

Output signal: 3.3V digital output

Delay time: adjustable from 0.3 seconds to 5 minutes

Operating temperature: -15°C to +70°C

Sensitivity: Adjustable

b) Arduino Microcontroller: This is the main part that gets the sensors' inputs and gives the outputs. Advanced Microcontroller is Arduino Mega. Number of GPIO Pins: 54 digital pins, 16 analog pins. Memory: 256 KB Flash memory (compared to 32 KB in Arduino Uno).

c) Buzzer: This will make a noise when movement is sensed. High-Performance Buzzer contains Sound Output with 85–100 dB at 10 cm and the Frequency Ranges from 1 to 4 kHz.

d) LED Light: This is a light which comes on when motion has been detected.

e) LCD Display: It gives a message based on the status of the system. For example, "System Ready" and "Motion Detected."

f) Switch: It is for turning the system ON or OFF manually.

g) Resistors: These connect the LED's and the switch and are for current limiting.

h) Wires and Breadboard: These make electrical connections between different components to try and use.

2) Future Development

a) Linkage with IoT: This integrates Wi-Fi or Bluetooth modules for sending notifications instantly to mobile gadgets or online databases for surveillance.

b) Camera Integration: This function works with a camera module that is capable of capturing images and videos whenever there is an activity.

c) Advanced Sensors: More precision in motion detection can be achieved by eliminating the use of the PIR sensor and instead using ultrasonic or microwave sensors.

d) Solar Power Support: Using solar panels in such a way that the system becomes energy independent and self-sustaining.

C. Hardware Connections

1) PIR Sensor to Arduino:
   a) VCC Pin: 5V pin of the Arduino
   b) GND Pin: GND pin of the Arduino
   c) OUT Pin: Connects to a digital input pin (for example D2) on the Arduino which is used to send motion detection signals.

2) Buzzer to Arduino:
   a) One terminal of the buzzer is linked to the digital output pin (for example D3) of the Arduino.
   b) The wire of the ground is connected to the Buzzer through its other terminal.

3) LED to Arduino:
   a) The positive terminal of the LED is connected to D4 pin through 220Ω current limiting resistor.
   b) The negative terminal of the LED is soldered to GND pin.

4) LCD Display to Arduino (using I2C):
   a) SDA Pin: Connect to the SDA pin of Arduino (A4 on Arduino Uno).
   b) SCL Pin: Connect to the SCL pin of Arduino (A5 on Arduino Uno).
   c) VCC Pin: Connect to the 5 V power pin on Arduino.
   d) GND Pin: Connect to GND pin in Arduino.

Now let's talk about the Arduino:
One terminal of the switch is connected to one of the Arduino's digital input pins, for example, pin D5.
The other terminal is connected to the communication ground pin, consistent with the figure. A pull-down resistor, for example, a 10kΩ resistor, may be used to help avoid false detections.

Let us consider the power supply now:
Connect a 5V regulated power supply to any power input pin of the Arduino. Also, make sure the power supply can deliver good amount of power (more than 1 amp) to all the components connected to it.

Connecting Wire and Breadboard:

Breadboard and jumper wires can be used for prototyping and connecting all the components with the Arduino.

D. Software

The components of the software are the Arduino IDE, which is where code intended for the Arduino microcontroller is written, compiled, and uploaded through the system. The use of the built-in libraries of the Arduino system includes use of "LiquidCrystal_I2C.h" for the control of the LCD display. The program logic accepts data coming from the PIR sensor, responds to the alerts by activating the buzzer and LED, modifies the status in the LCD, and controls the switches for the sake of system operation.

a) Arduino IDE: This is the core software tool developed, compiled, and uploaded in the Arduino microcontroller. It comes with C/C++ programming support and the basic libraries that aid the integration of the hardware.
b) Arduino Libraries: LiquidCrystal_I2C Library: This is the library required to connect to the LCD by I2C protocols, which is a standard that minimizes wire connections.
c) Servo Library (Optional): This library would be useful if you'll use additional components such as a servo motor.
d) Wire Library: It's mainly used for I2C communication between Arduino and the LCD.
e) System Code/Logic: The application code contained in the C/C++ is embedded with the logic for detecting movement, communicating the status of the system, and how the users operate the system.
f) IR Sensor Input: We are code that reads signals from the observer PIR sensor. It is expected that the Arduino inspects the digital output pin of the sensors with the voice signal of high or low level depending on the detections.
g) Control for the buzzer and LED, Arduino generates a signal for the turn on of substitute thermal sources in the area of any detected motion involving the two devices. A set for the signals together with what kind of alerts is configured through input from the PIR sensor.
h) Updates LCD Display, coding on LCD that will flash messages that may appear in real time like "system ready", "motion detected" end.
i) Switch Functionality: This switch input is always read. The operator has a chance of using the push button to turn the system ON or OFF.

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E. System Functionality

All the components are initialized by the Arduino. The LCD shows the phrase “system ready” and the Arduino is always ready for an input from the PIR sensor and a switch.

Idle State:

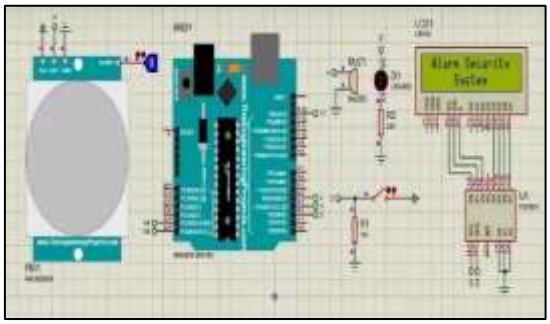

Fig. 3 Ideal State Diagram

In the idle state, if no movement is perceived and the system is idle, then the LED and Buzzer remain OFF. The LCD indicates that “system ready” mode been activated depending on the position of the switch is shown in figure 3.

By maintaining this idle state, the system ensures energy efficiency, stability, and readiness for immediate response while keeping users informed about its operational status.

Motion Detected:

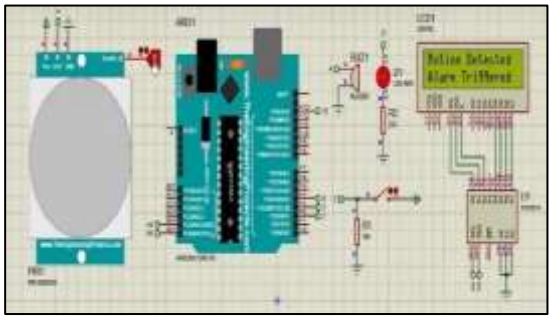

Fig. 4 Motion Detection State Diagram

Upon the detection of movement by the PIR sensor, there will be a sound alert from the buzzer. LED is switched on. and then LCD is changed to read “motion detected” is shown in figure 4.

The Arduino continuously monitors the above input:

If the signal is LOW, it means no motion is detected, and the system remains in the idle state.

If the signal turns HIGH, the Arduino recognizes motion and initiates the alert state.

Switch Control:

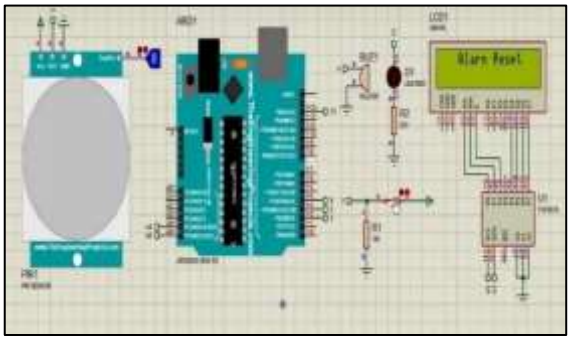

Fig. 5 Switch control State Diagram

When the switch is used to turn off the system, every response (alert, LED, updating messages on the LCD) is suspended and the system goes into a passive stage is shown in figure 5.

F. Result

The PIR sensor and Arduino-based security system functioned effectively, both in identifying motion as well as alerting to it on time. Upon receiving the input from the PIR motion sensor, the Arduino was able to turn on the buzzer, LCD display, as well as the LED light whenever motion was detected. The delay in alarm activation was the shortest possible was not exceeded between the triggering of the sensor and the sounding of the alarm. Messages were shown on the LCD panel, and LED lights were provided for visual indication. The switch was used for ease of handling of the system and because of the low-power consumption design, long-term reliability was ensured. The system was consistent, effective, and workable in a variety of scenarios.

System Behavior:

Detection motion through the PIR sensor rang. Within moments, alerts like buzzers and LEDs start coming out when detected. Status on system can be seen through an LCD display screen provided to the user. Sense and provide feedback by its action on the happening. Arm or disarm can be performed using a switch given on the circuit.

Applications:

House protection security systems.

Surveillance of an office place.

Lights or alarms that work off motion.

Motion activated security camera networks

Industry Machinery Monitoring

In the field of astronomy, meteorological satellites and in medicine.

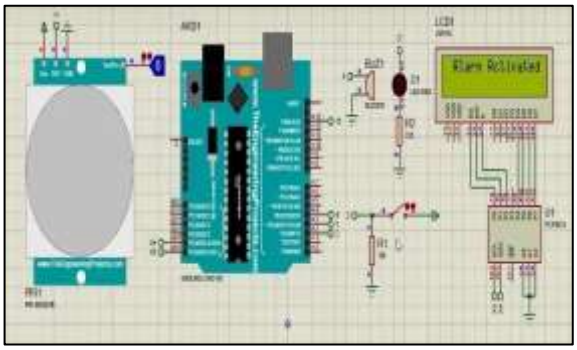

Fig. 5 Output State Diagram

G. *Key Features*

1) Budget and Easy Installation: The cost-effective materials (PIR sensor, Arduino, buzzer, LED, etc.) enables the system to be implemented in a wide range of environments without much strive.
2) Energy Efficient: This system is energy efficient, and it can be implemented in the home and office for an extended period.
3) Modular and Scalable Architecture: WIFI connection, remote control or other security devices can be added easily and incorporated into the design thanks to the modular design.
4) Trustworthy Detection: The system accurately senses motion and produces the appropriate alerts based on the real-world situations, thereby allowing timely intervention during security threats.

IV. Performance

The alarm was even effective in case of a breach warning the wearer making use of the LED light and LCD. It was evident that the system was effective in always performing better than the preset standard as it consistently ran various constant tests over duration and was awarded low power usage rates. Normal practice however also showed that the system performance was not bad as it was able to respond to movements at an average speed but was able to detect them consistently. So, all the factors listed above suggest that this system can be employed for security applications.

The proposed system demonstrates excellent performance in terms of accuracy, reliability, and energy efficiency. Its low cost and scalability make it a practical solution for security applications in residential, commercial, and industrial environments.

V. Conclusion

The goal of this project was to build a motion sensor-based security system using PIR sensor and Arduino, in combination with other many peripherals such as Buzzer, LCD, LED, and switch. The system is designed to provide automatic email alerting when motion has been detected. It is an efficient method of improving security, while also being quite cheap.

Key advantages of the system encompass its ease of installation, reduced cost and low energy requirements. It can be easily placed into diverse settings and provides instant notification with the help of sound and light. The system further offers great flexibility in that it can be controlled with a switch to enable or disable the whole system easily.

The result of the undertaken project is a system that is capable of detecting motion quite reliably and alerts the user of system status and triggers lights by a buzzer, LED light and LCD display towards that end. The system works successfully with the targets achieved of offering an efficient system for low scale needs of security such as home. Future enhancement may include improving sensor distance enhancing wireless functionalists as well as other aids for security.

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