STM32-Based Motion Detection System Using a PIR Sensor and LED Indicators

Module: Digital Electronics 2B (EEDE226)

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Abstract

This project implements a motion detection system using an STM32 Nucleo-F411RE microcontroller and a PIR (Passive Infrared) sensor. The system measures motion intensity and indicates three warning levels using different LEDs: blue for low motion, green for medium motion, and orange for high motion. The project demonstrates how microcontrollers can process real-time sensor input and provide proportional visual alerts. The final system accurately differentiates between varying levels of motion and provides stable LED feedback without delay, highlighting efficient embedded programming techniques.

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1. Introduction

Motion detection systems are widely used in security, automation, and monitoring applications. These systems detect human or object movement and trigger corresponding actions or alerts. The STM32 microcontroller family provides an ideal platform for such systems because of its fast processing speed, low power consumption, and peripheral flexibility. This report presents the design and implementation of a motion detection system using an STM32 Nucleo-F411RE and an HC-SR501 PIR sensor. The project detects different levels of motion activity and provides visual warnings using blue, green, and orange LEDs. The system's performance was verified through practical testing.

2. Objectives

- To design and implement a motion detection system using the STM32 microcontroller and PIR sensor.
- To detect varying levels of motion and indicate each level using distinct LED colors.

- To write efficient C code that ensures immediate LED response without blocking delays.
- To test and verify the functionality of the system using real-time motion events.

3. Literature Review / Background

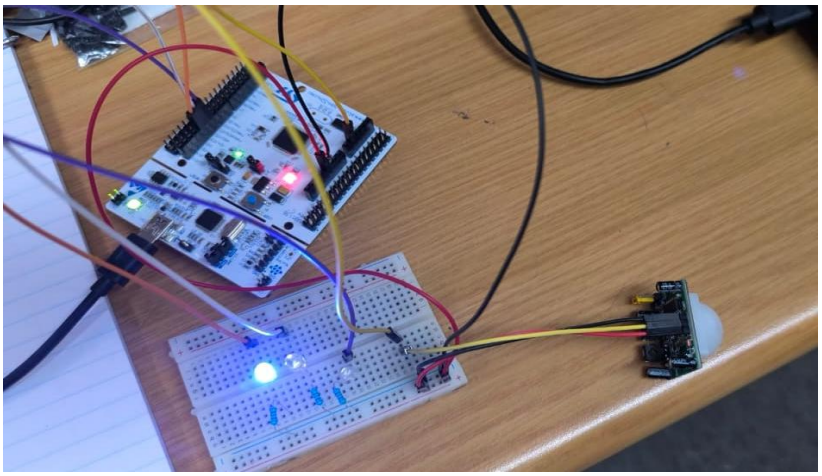
A PIR (Passive Infrared) sensor detects motion based on changes in infrared radiation caused by moving objects emitting heat. When motion is detected, the sensor's output pin goes HIGH, which can be read by a microcontroller. The STM32 Nucleo-F411RE, based on the ARM Cortex-M4 processor, provides multiple GPIO pins, timers, and interrupt capabilities—making it suitable for signal-based applications like motion detection. The system uses non-blocking LED flashing, allowing continuous sensor monitoring while indicating motion levels through LEDs. By counting the number of motion triggers within a fixed time window, the system differentiates between low, medium, and high activity levels.

4. Methodology

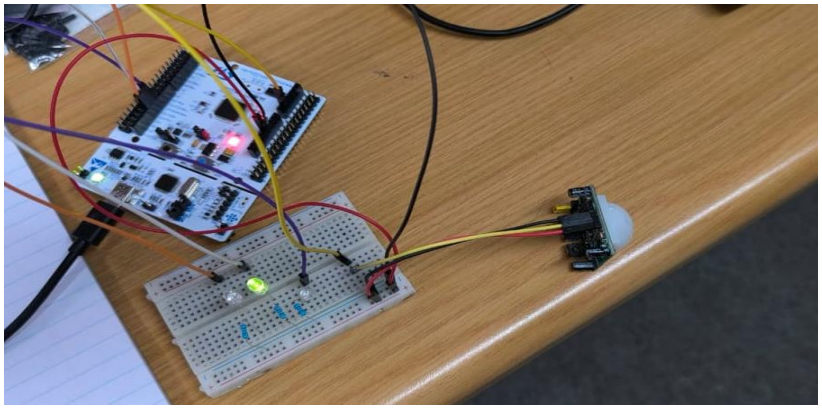
Hardware Components:
- STM32 Nucleo-F411RE board
- HC-SR501 PIR motion sensor
- Three LEDs (Blue – Low motion, Green – Medium motion, Orange – High motion)
- Resistors (220Ω – 330Ω)
- Breadboard and jumper wires

Circuit Design:
The PIR sensor's output pin is connected to GPIOA Pin 1 on the STM32. The three LEDs are connected to GPIOA pins 5 (blue), 6 (green), and 7 (orange), respectively. Each LED is connected in series with a resistor to limit current.

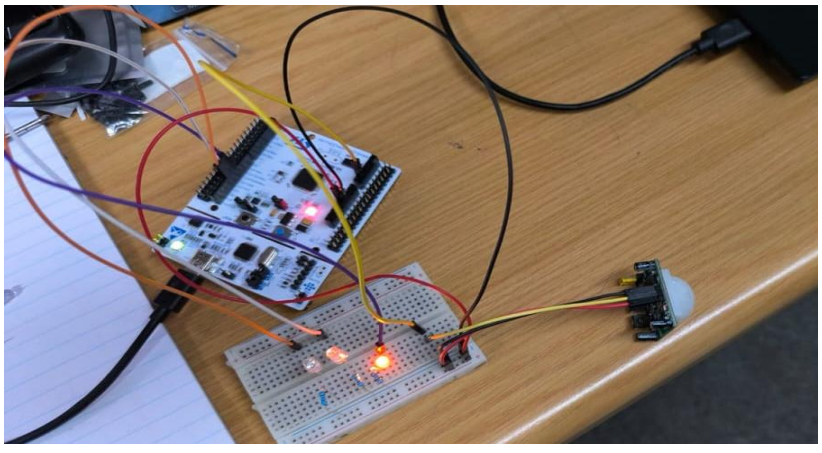
Low: Blue LED is lit.



Medium: Green LED is lit.



High: Orange LED is lit.



Software Implementation:
- Developed using STM32CubeIDE.
- Configured GPIOs as digital input (PIR) and digital outputs (LEDs).
- Implemented a motion counting algorithm within an 800 ms time window.
- Defined thresholds: Low (5–12), Medium (13–17), High (18+).
- LEDs flash at different rates for each level.
- Debouncing is implemented to prevent false triggers.
- Code is non-blocking for immediate LED updates.

5. Data / Results

Motion Count (within window)	Motion Level	LED Color	LED Flash Rate (Hz)
0 – 4	None	Off	0
5 – 12	Low	Blue	1 Hz
13 – 17	Medium	Green	2 Hz
≥ 18	High	Orange	5 Hz

Observation: During testing, the PIR sensor accurately detected movement within its 5–7 m range. LED response was immediate and stable. Low motion caused the blue LED to blink slowly, medium motion triggered faster blinking of the green LED, and high motion caused rapid orange LED flashing.

6. Analysis / Discussion

The project successfully implemented a reliable motion detection system using minimal hardware.
- Accuracy: The PIR sensor provided consistent results.
- Response Time: Non-blocking LED control ensured near-instantaneous response.
- Power Efficiency: STM32 operates efficiently at 3.3V.
- Software Reliability: Interrupt-safe logic ensured continuous detection.

The system could be improved by adding UART or display output for monitoring.

7. Conclusion

The STM32-based motion detection system achieved all its objectives. The system effectively distinguished between low, medium, and high motion activities and provided corresponding LED indications using blue, green, and orange LEDs. The project demonstrates efficient integration of sensors and microcontrollers in embedded systems.

8. Recommendations

- Add UART or Bluetooth communication for remote data display.
- Integrate a buzzer or LCD display for additional feedback.
- Implement data logging for motion monitoring.
- Optimize sensitivity thresholds for different environments.

9. References

1. STMicroelectronics. STM32 Nucleo-F411RE Datasheet.
2. HC-SR501 PIR Sensor Datasheet.
3. STM32CubeIDE User Manual.
4. Online STM32 HAL documentation – https://www.st.com

10. Appendices

Appendix A – Source Code (main.c)
Appendix B – Circuit Diagram (STM32 to PIR and LEDs)