The German University in Cairo (GUC)
Faculty of Media Engineering and Technology
Computer Science and Engineering
Embedded System Architecture - CSEN 701

Project Title

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Chapter 1

Project Objectives

The objective of this project is to develop a functional embedded system capable of recording key metrics related to vehicle performance and environmental conditions using a Raspberry Pi Pico microcontroller. The system, functioning as a "black box," will monitor and store data such as speed, acceleration, rotation, temperature, and humidity. Additionally, it will detect collisions using an IR sensor and provide audio and visual alerts via a buzzer and LED indicators. This data collection aims to simulate a safety system for vehicles, demonstrating cost-effective monitoring and control for educational and prototyping purposes.

Specific objectives include:

— Recording and storing vehicle speed, acceleration, and angular velocity using the MPU 6050 sensor.

— Monitoring environmental parameters (temperature and humidity) using dedicated sensors.

— Detecting collisions and triggering alerts using an IR sensor, LED, and buzzer.

— Controlling the vehicle's motion via an H-bridge and DC motor.

— Powering the system with a lithium battery and ensuring modular and scalable design using breadboards and jumper wires.

Hardware Tools

The following hardware tools were used in the implementation of the project:

— Raspberry Pi Pico microcontroller

— MPU 6050 sensor (for acceleration and angular velocity)

— Temperature and humidity sensors

— IR sensor (for collision detection)

— H-bridge motor driver

— DC motor

— LED (visual alert)

— Buzzer (audio alert)

— Lithium battery

— Resistors

— Breadboard

— Jumper wires

Chapter 2

Introduction

2.1 Introduction

The importance of vehicle monitoring systems has grown significantly in recent years due to their role in improving safety, reliability, and accountability. Black box systems are integral to modern vehicles, providing critical data in accident analysis and performance optimization.

In this project, we develop a prototype of a simplified black box system using the Raspberry Pi Pico microcontroller, sensors, and actuators. The system emulates the functionality of data recording and alerting mechanisms, which are vital for vehicle safety. This project explores the integration of diverse hardware components to capture, store, and respond to real-time data effectively.

The use of low-cost components, such as the MPU 6050 sensor for motion tracking and environmental sensors for monitoring temperature and humidity, highlights the affordability of the system. Moreover, the inclusion of collision detection and alert mechanisms underscores its safety focus.

Chapter 3

Methodology

3.1 Methodology

The project methodology involves the following key steps:

3.1.1 Hardware Setup

— **Raspberry Pi Pico**: Acts as the central microcontroller, managing inputs and outputs.

— **MPU 6050**: Captures acceleration and angular velocity data.

— **Temperature and Humidity Sensors**: Measure environmental conditions.

— **IR Sensor**: Detects collisions by identifying sudden proximity changes.

— **DC Motor and H-Bridge**: Control the vehicle's movement, allowing forward and reverse motion.

— **LED and Buzzer**: Provide visual and auditory alerts upon collision detection.

— **Lithium Battery**: Supplies power to the system.

— **Breadboard and Jumper Wires**: Enable modular and flexible connections.

3.1.2 Software Implementation

— **Programming Environment**: Use MicroPython or C/C++ to program the Raspberry Pi Pico.

— **Data Collection and Storage**: Sensor data is periodically read and stored in memory.

— **Collision Detection Algorithm**: Detect abrupt changes in proximity using the IR sensor.

— **Alert Mechanism**: Trigger the buzzer and LED in response to a collision.

— **Motor Control**: Implement PWM signals to control the DC motor via the H-bridge.

3.1.3 Testing and Validation

— Individual components were tested for functionality.

— The integrated system was tested in controlled conditions to ensure accurate data collection, reliable collision detection, and proper response mechanisms.

Chapter 4

Results

4.1 Results

The project successfully implemented a prototype vehicle with a functioning black box system. The following outcomes were observed:

1. **Data Monitoring**: The MPU 6050 provided reliable acceleration and rotation data, while the temperature and humidity sensors recorded environmental conditions accurately.
2. **Collision Detection**: The IR sensor reliably detected collisions and triggered the LED and buzzer without false positives in normal operation.
3. **Motor Control**: The H-bridge allowed smooth control of the DC motor, enabling forward and reverse motion with PWM signals.
4. **Power Efficiency**: The lithium battery powered the system effectively, with stable performance over extended periods.
5. **Data Storage**: The Raspberry Pi Pico stored sensor data efficiently, making it retrievable for analysis.

Challenges encountered included fine-tuning the IR sensor to avoid environmental interference and ensuring stable connections on the breadboard during motion. These issues were resolved by adjusting sensor thresholds and securing wiring.

Chapter 5

Conclusion

5.1 Conclusion

This project demonstrated the feasibility of developing a cost-effective black box system using embedded systems technology. The integration of diverse sensors and actuators with the Raspberry Pi Pico provided a robust platform for real-time data collection, storage, and response mechanisms.

The success of the project highlights the potential of microcontroller-based systems in educational and prototyping applications. Future enhancements could include adding GPS for location tracking, wireless data transmission for remote monitoring, and improved enclosures for real-world deployment.

By implementing this system, we gained hands-on experience in embedded system design, sensor integration, and vehicle control, contributing to a deeper understanding of real-world applications in vehicle safety and monitoring.