Department of Computer and Information Systems Engineering

MBSD OEL REPORT

Autonomous Rover

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Abstract

This report presents the design and implementation of an autonomous obstacle-avoiding rover based on the Arduino Uno microcontroller platform. The rover utilizes DC motors for mobility, an ultrasonic sensor mounted on a servo motor for obstacle detection, and a motor driver for power management. The system demonstrates fundamental principles of embedded systems design, sensor integration, and autonomous navigation. The rover successfully detects obstacles in its path and makes navigation decisions autonomously, showcasing practical applications of microprocessor-based system design concepts.

1. Introduction

1.1 Project Overview

The autonomous obstacle-avoiding rover project combines hardware and software components to create a self-navigating vehicle capable of detecting and avoiding obstacles in its environment. This project demonstrates the practical application of microprocessor-based system design principles and serves as an educational platform for understanding autonomous navigation systems.

1.2 Objectives

- Design and construct a four-wheeled mobile rover using Arduino Uno as the central control unit
- Implement obstacle detection using an ultrasonic sensor mounted on a servo motor
- Create a stable and reliable power distribution system for motors and electronics
- Demonstrate reliable autonomous operation in varied environments
- Learn the principles of microprocessor based designs to solve real world problems through a simple project.

1.3 Applications

Autonomous rovers have numerous practical applications including:

- Search and rescue operations in hazardous environments
- Automated warehouse management and inventory systems
- Agricultural monitoring and inspection
- Educational platforms for teaching robotics and programming
- Prototyping for advanced autonomous vehicle research

2. System Hardware Design

2.1 Component Selection and Specifications

2.1.1 Microcontroller

- Arduino Uno R3
  - ATmega328P microcontroller
  - Operating voltage: 5V
  - Input voltage: 7-12V (recommended)
  - 14 digital I/O pins (6 with PWM)

- 6 analog input pins
- 32 KB flash memory
- 16 MHz clock speed

2.1.2 Locomotion System

- DC Motors (4 units)
  - Operating voltage: 3-12V DC
- Wheels (4 units)
  - Diameter: 2.5''
  - Material: Plastic and rubber

2.1.3 Motor Control

- Motor Driver
  - L298N Dual H-Bridge Motor Controller
  - Logic voltage: 5V
  - Motor supply voltage: 5-35V DC
  - PWM speed control capability

2.1.4 Sensing System

- Ultrasonic Sensor
  - Ultrasonic distance sensor
  - Operating voltage: 5V
  - Range: 2cm - 400cm
  - Measuring angle: 15 degrees
- Servo Motor
  - Operating voltage: 4.8-6V
  - Torque: 2.5kg/cm at 4.8V
  - Speed: 0.1s/60° at 4.8V
  - Rotation range: 180 degrees

2.1.5 Power Supply

- 4 Rechargeable lithium batteries each of 3.7V
- Power distribution system

2.2 System Architecture

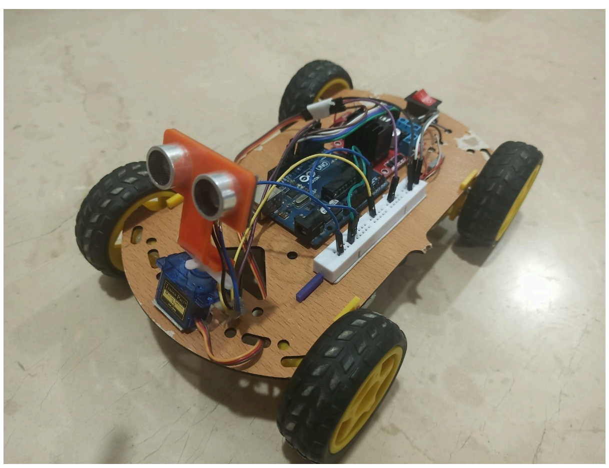
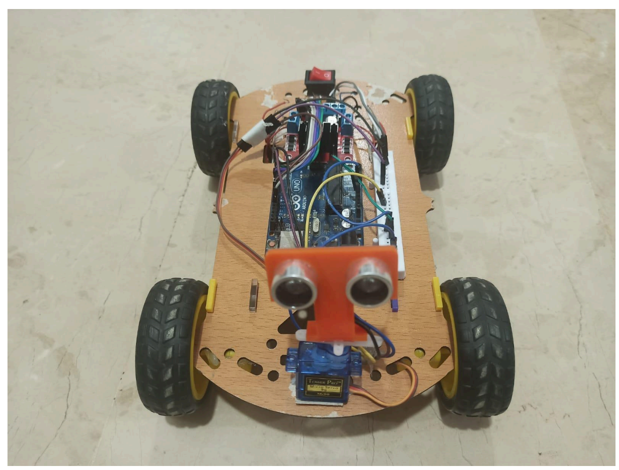
The hardware architecture centers around the Arduino Uno as the main processing unit. The system is organized into the following subsystems:

1. **Control Unit**: Arduino Uno microcontroller board
2. **Locomotion System**: Four DC motors with wheels
3. **Motor Control**: Motor driver controlled by Arduino
4. **Sensing System**: Ultrasonic sensor mounted on an SG90 servo motor
5. **Power Management**: Battery and voltage regulation circuitry

2.3 Circuit Design and Integration

The circuit integration follows these key connections:

- Arduino digital pins 4, 7, 8, and 12 connect to the L298N motor driver inputs for controlling Motor A (left motor) and Motor B (right motor).
- Arduino digital pins 2 and 3 connect to the ultrasonic sensor's trigger and echo pins, respectively.
- Arduino digital pin 11 provides PWM control for the servo motor.
- 5V power is supplied to the sensors and servo via Arduino's regulated output.
- External battery power is connected to the motor driver to meet higher current requirements.
- A common ground connects all components to ensure proper circuit operation.

3. Software Design

3.1 Development Environment

- Arduino IDE for programming
- Language: C/C++ with Arduino libraries

3.3 Algorithm Design

3.3.1 Main Control Loop

The main control algorithm follows this sequence:

1. Initialize all components and set initial positions
2. Scan surroundings with the ultrasonic sensor
3. Determine the path
4. Navigate according to decision logic
5. Continuously monitor for new obstacles
6. Repeat from step 2

3.3.2 Obstacle Detection

The obstacle detection is done by the ultra-sonic sensor. When it detects an obstacle, an immediate decision is made to relocate the rover.

3.3.3 Navigation Decision Making

When an obstacle is detected, the rover follows this decision-making process:

1. If the forward path is clear (distance > threshold), continue forward
2. If an obstacle is detected (distance < threshold): a. Stop b. Scan left and right for open paths c. Select the direction with the greater measured distance d. If both directions are blocked, reverse and turn e. Resume forward movement

4. Implementation

4.1 Physical Construction

The rover chassis was constructed using hard wood, with considerations for:

- Weight distribution and center of gravity
- Motor and wheel mounting
- Component placement accessibility
- Battery compartment location
- Sensor positioning for optimal detection

4.2 Hardware Integration

The integration process followed these steps:

1. Assembly of the chassis and mounting the motors

2. Installation of wheels and testing mechanical alignment
3. Mounting the Arduino and motor driver board
4. Mounting the ultrasonic sensor on the servo
5. Power system integration
6. Wiring and connections according to the design

4.3 Software Implementation

The software implementation was developed in phases:

1. Basic motor control testing
2. Servo movement calibration
3. Ultrasonic sensor distance measurement validation
4. Integration of servo and sensor for scanning
5. Implementation of the obstacle detection logic
6. Development of the navigation decision-making logic
7. Final integration and testing of the complete system

4.4 Calibration and Testing

The following calibration procedures were performed:

- Servo angle calibration for accurate scanning positions
- Ultrasonic sensor distance measurement verification
- Motor speed adjustment for straight-line movement
- Turn angle calibration for consistent navigation
- Distance threshold tuning for obstacle detection

5. Performance Evaluation

5.1 Test Methodology

The rover was evaluated using the following methods:

- Straight line navigation testing
- Obstacle detection accuracy measurement
- Navigation decision consistency evaluation
- Battery life assessment under continuous operation
- Performance in different lighting and surface conditions

5.2 Performance Metrics

Key performance indicators included:

- Obstacle detection range and accuracy
- Navigation success rate in varied environments
- Battery life under typical operation
- Maneuverability in confined spaces

5.4 Limitations and Challenges

Several challenges were encountered during development:

- Motor power consistency across different battery charge levels
- Mechanical stability on uneven surfaces
- Servo movement speed affecting real-time navigation decisions

6. Future Improvements

6.1 Hardware Enhancements

Potential hardware improvements include:

- Additional sensors (IR, light, temperature) for enhanced environmental awareness
- Improved motor encoders for accurate positioning
- Wireless communication module for remote monitoring
- Higher capacity battery system
- More powerful microcontroller for advanced algorithms

6.2 Software Enhancements

Future software developments could include:

- Mapping and localization capabilities
- Path planning algorithms
- Machine learning for improved decision making
- User interface for parameter adjustment
- Data logging and analysis features

7. Conclusion

The autonomous obstacle-avoiding rover project successfully demonstrates the application of microprocessor-based system design principles. By integrating sensors, actuators, and control algorithms, the rover achieves autonomous navigation in dynamic environments. The project showcases practical implementation of theoretical concepts and provides a foundation for more advanced robotic applications. The modular design approach allows for future enhancements and adaptations for specific use cases.