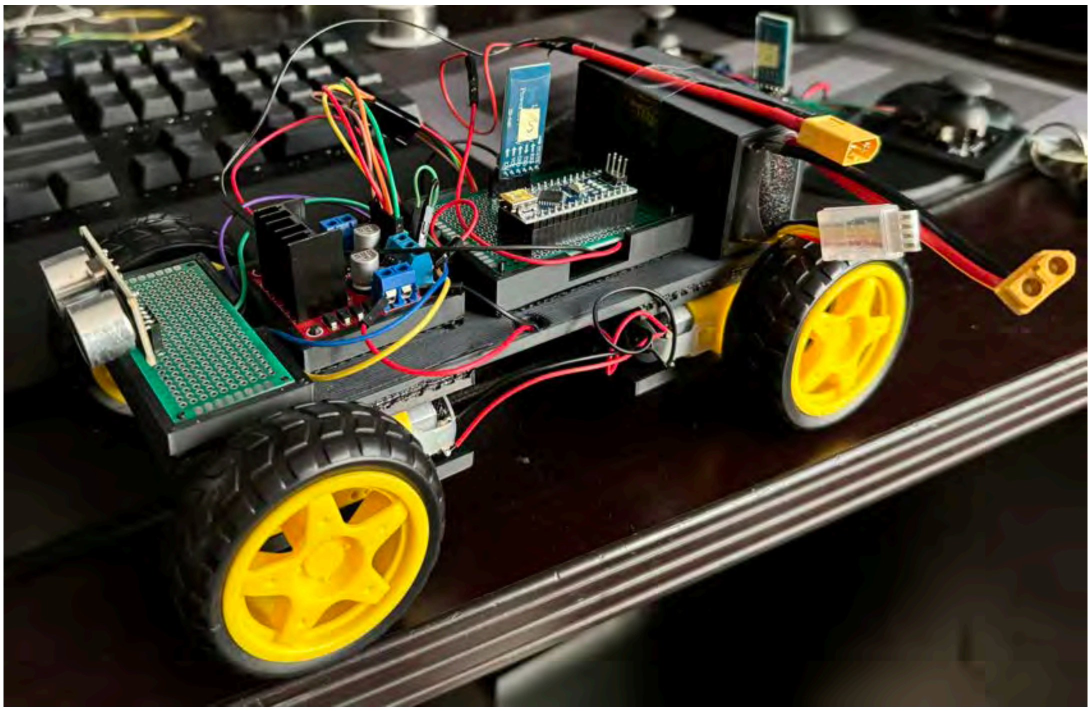
Arduino-Based RC Car with Crash Detection Capability



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Abstract

This report presents the comprehensive development and implementation of an advanced Arduino-based remote-controlled (RC) car equipped with a sophisticated crash detection system. Conceived to showcase critical concepts in computer engineering, the project spanned a rigorous three-month timeframe and covered key areas such as embedded systems design, sensor integration, and wireless communication. Every component of the RC car, including the meticulously crafted chassis mounts for electrical components, was designed and 3D printed from scratch, demonstrating high proficiency in CAD software and 3D printing technology.

The RC car is wirelessly controlled using an RC transmitter and receiver, with an Arduino microcontroller managing motor control. The integration of an ultrasonic sensor enables real-time crash detection, allowing the car to effectively identify and navigate around obstacles. The Arduino code was meticulously developed to handle motor operations, process sensor data, and execute collision response protocols with precision. This required an in-depth understanding of real-time data processing and the ability to design efficient algorithms for motor control and sensor data integration.

Comprehensive testing and calibration were undertaken to ensure reliable performance across diverse environments. This included rigorous stress testing of the 3D-printed chassis to ensure structural integrity, as well as extensive testing of the motor control algorithms and crash detection system in various scenarios. The project culminated in thorough documentation of the design process, including detailed circuit diagrams and well-annotated code, accompanied by an in-depth analysis of testing results.

This report encapsulates the project's ambitious objectives, robust methodology, and successful outcomes, highlighting advanced technical skills and exceptional problem-solving capabilities. The modular nature of the design allows for easy upgrades and scalability, reflecting a forward-thinking approach to engineering. The successful completion of this project underscores the innovative potential of integrating 3D printing and Arduino technology in cutting-edge engineering solutions, providing valuable insights into the practical application of theoretical knowledge and demonstrating the feasibility of developing sophisticated systems within a constrained timeframe.

Introduction

The development of remotely controlled vehicles represents a significant area of interest in Embedded Systems and Robotics. This project focuses on creating an Arduino-based remote-controlled (RC) car with integrated crash detection using an ultrasonic sensor. The main goal of this personal project is to demonstrate some of the essential concepts I have learned so far in computer engineering. I chose this project because I wanted to demonstrate a complex project that could still be accomplished within three months. This timeframe would allow the experience of this project to be both a practical and educational endeavor, which would showcase skills that are helpful to know in practice for future career prospects.

To initiate the project, I conducted extensive research to gain a thorough understanding of its goals and to identify the most effective methods for achieving them. I began by reviewing numerous RC car designs to determine a suitable starting point. With a clearer vision in mind, I sketched rough drafts of the desired design, outlining the necessary components and their layout on the RC car's physical body. Following these preliminary sketches, I started learning 3D modeling using Fusion 360, a CAD software that I deemed ideal for this project. I compiled a list of components essential to the build and, once acquired, conducted multiple test prints to evaluate the fit and function of the 3D models I had created. This process not only enhanced my skills in creating custom 3D components but also provided valuable experience in 3D printing and problem-solving within an engineering design context.

At the heart of the project's functionality, I chose the Arduino Nano. The original plan for the project was to use two full-sized Arduino Uno boards. Still, after some design reconfigurations, I changed to a smaller/compact version for both the controller and the car itself. The Arduino Nano attached to the body of the RC car manages motor operations, wireless communication, and sensor data processing. I chose an ultrasonic sensor for the crash detection system because of its accuracy and reliability in detecting obstacles. This sensor's integration will allow the RC car to identify if a potential collision is about to occur and ultimately stop the rotation of the motors, controlling the car's wheels, enhancing its operational safety, and demonstrating real-time data processing.

This project's objectives included the successful design and assembly of the RC car, the integration of wireless control systems, using the HC-05 Bluetooth module, and the implementation of an effective crash detection mechanism. Through extensive testing and iterative development, the project aims to achieve seamless integration of these components, ensuring reliable performance and showcasing advanced technical skills.

This report provides a detailed account of my personal project's development, from initial design and component selection to assembly, coding, and testing. The report also documents the challenges encountered and solutions implemented, offering insights into the practical application of theoretical knowledge in computer engineering. By the project's conclusion, the RC car successfully met all the desired objectives, demonstrating the feasibility and effectiveness of combining 3D printing and Arduino technology in innovative engineering projects.

Weekly Project Outline:

Phase 1: Planning and Research (Week 1)

- Identify key features: RC control, crash detection, motion sensor integration, etc.
- Set performance criteria and success metrics for the project.

Start Designing and Gathering Resources (Week 2-3)

- Created straightforward 3D models in Fusion 360 to 3D and printed a chassis for the RC car.
- Collect all needed components used throughout the project (Listed in the Components List).

Test Modeled Components and Establish Bluetooth Connection (Week 3-4)

- Printed numerous modules that would hold the hardware components on the car and the controller.
- Based on the research, a basic program in C++ would be created to pair the two HC-05 Bluetooth modules once specific commands were put in and AT mode was activated.

Continue Sizing and Testing Orientation of Components (Week 5-6)

- Research the dimensions of the components being used and make sure that there is enough space for the future wiring of the circuit to be protected from being compromised by other ports/wires being utilized.

Phase 2: Begin Soldering Hardware Components (Week 6-7)

- Research which ports the components are supposed to be connected to.
- Create an example schematic of the circuit layout based on the information determined from researching which ports would be prioritized for this project's objective.
- Solder female pin header socket connector strips to PCB Perfboard so that the Arduino Nano and HC-05 have a proper circuit connection.
- Finish building the connection between the HC-05, Arduino Nano, and Power Supply.

Add Wiring for RC Components (Week 7-9)

- Solder connection for the Ultrasonic sensor and DC motor driver.
- Test the connection between these components and the Arduino Nano.
- Analyze the program that would allow the motors to rotate correctly.
- Tests power needed by components to determine the least amount of power necessary for the motors and sensor to communicate effectively.

Phase 3: Begin Construction and Testing on Controller (Week 9-10)

- Finish testing the controller housing module by 3D printing components separately and analyze if they are working as intended.
- Wire the needed joystick modules to the Arduino Nano and HC-05 housing.

Finishing Arduino Based RC car with crash detection (Week 10-11)

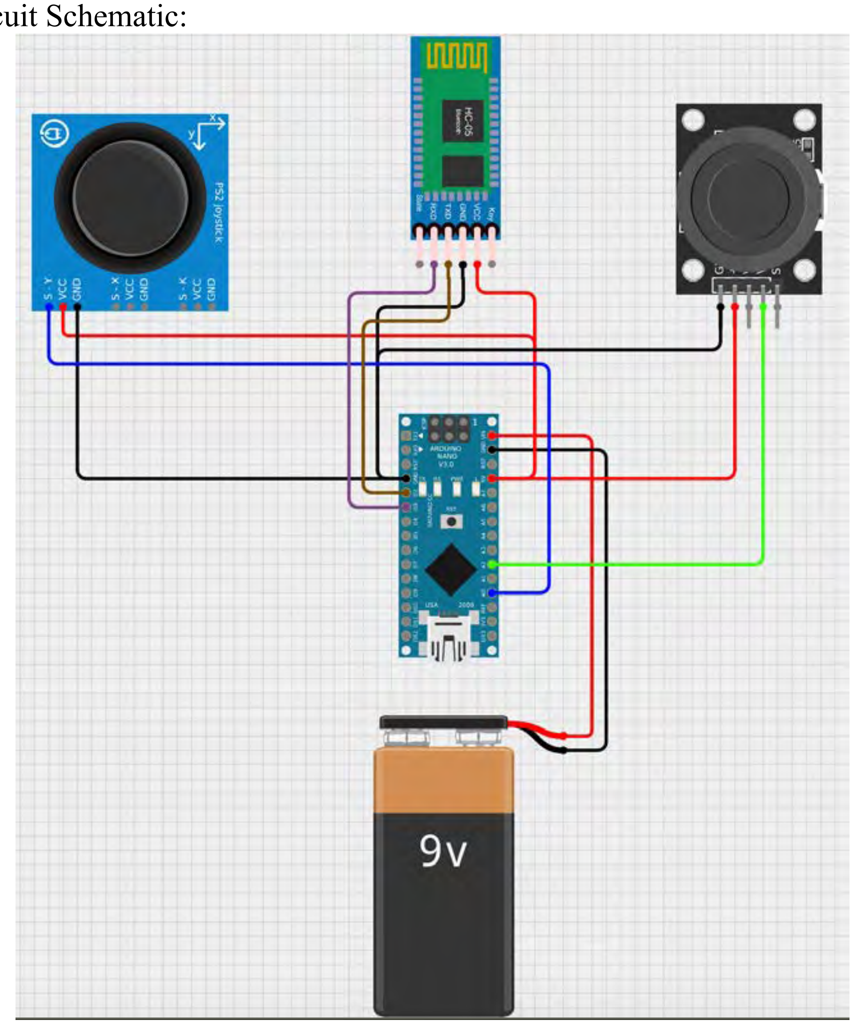
- Finish constructing and testing the transmitting controller.
- Establish a testing environment to determine what data is being sent via the Bluetooth signal from the transmitter to the receiver.
- Ensure that the data metrics match the desired specifications that were originally envisioned at the beginning of the project.
- Finish securing the various components onto the RC car and complete the essential wiring/cable management.
- Complete the final test run of the RC car's crash detection and solidify the entire design.

Components List

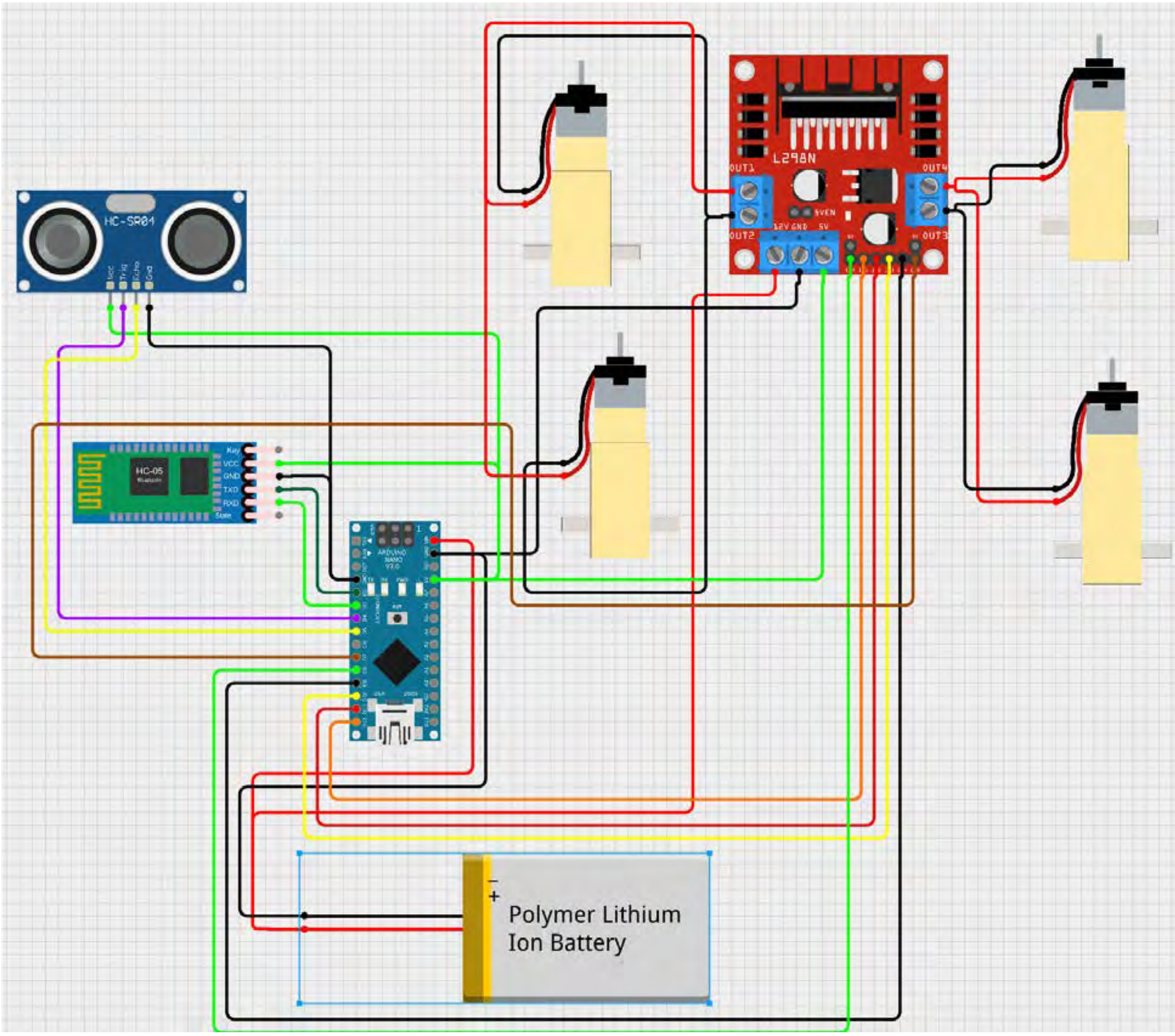
- Arduino Nano Microcontroller (2)
- HC-05 Bluetooth Module (2)
- PCB Perfboard 5 x 7 (2)
- PCB Perfboard 3 x7 (1)
- L298N Motor Driver (1)
- DC Motor (4)
- DC Motor Tire (4)
- Ultrasonic Sensor (1)
- PS2 Joystick Module (1)
- KY-023 Dual Axis Joystick Module (1)
- 9 Volt Battery (1)
- Lipo Battery 2200 mAh 11.1 Volt (1)
- Female Pin Headers
    - 1 x 16 (4)
    - 1 x 5 (2)

Circuit Layout

Controller Circuit Schematic:



Car Circuit Schematic:



Bluetooth connection process:

To establish the method of communication between the Arduino on the controller and the Arduino on the car, I chose to use two HC-05 Bluetooth modules configured in a master-slave relationship. In this setup, the master module, designated as the transmitter or controller, communicates with the slave module, which serves as the car's receiver.

I learned the steps to pair the HC-05 modules in the desired master-slave configuration through extensive research and referencing several online sources. The process involved holding the button on each HC-05 module and then uploading the code to the Arduino. At the same time, the module was connected correctly (Connection shown in the circuit diagrams above). Then, numerous AT commands are entered into the serial monitor to set the modules to their respective roles. In the resources page, I have provided links to the GitHub repositories containing the code to configure these relationships, detailed instructions, and the specific AT commands employed to achieve the master-slave setup.

Ultrasonic sensor and motor driver connection

To create an RC car with crash detection capabilities, I conducted extensive research on the integration of a DC motor driver and an ultrasonic sensor. While most available resources focused on autonomous obstacle-avoiding rovers, which aligned partially with my project's goals, they did not fully meet my specific requirements. Drawing from these sources, I adapted and refined the circuit configuration to better suit the unique needs of my RC car. This process involved carefully selecting and modifying various connection methods observed in existing designs to achieve a highly efficient and functional setup tailored for crash detection in an RC car.

The L298N motor driver was selected for its reliability and ability to control two DC motors simultaneously, essential for the RC car's mobility. Critical connections include powering the driver with a 12V supply and ensuring a common ground with the Arduino. Control inputs (IN1, IN2, IN3, IN4) are connected to Arduino digital pins for motor direction, while ENA and ENB are connected to PWM pins for speed control. Motor outputs (OUT1, OUT2, OUT3, OUT4) connect directly to the motor terminals. This setup allows precise control over the RC car's speed and direction, ensuring efficient and responsive motor operation.

Process of Designing Chassis

The design process for the 3D-printed RC car chassis began with defining the design specifications. The chassis was designed to fit within a 200mm x 100mm x 50mm envelope and included mounting points for the motors, wheels, battery, Arduino board, and sensors. The target weight was set below 150 grams to ensure optimal performance, and reinforcement ribs and structures were incorporated to enhance structural integrity.

The CAD modeling was done using Fusion 360. The design process involved creating 2D sketches of the chassis layout, which were then extruded into 3D models. Features such as mounting points, holes, and reinforcement ribs were added to the model. Stress analysis was performed to identify and strengthen weak points, ensuring the final design met all performance and durability requirements.

The assembly process involved attaching the motor mounts to the chassis using fitted sockets to secure the battery holder and mount the Arduino board and sensors. I then can secure the motors using gorilla glue connected to mount holders for the motors. The final assembly included wiring the electronic components to ensure proper connectivity.

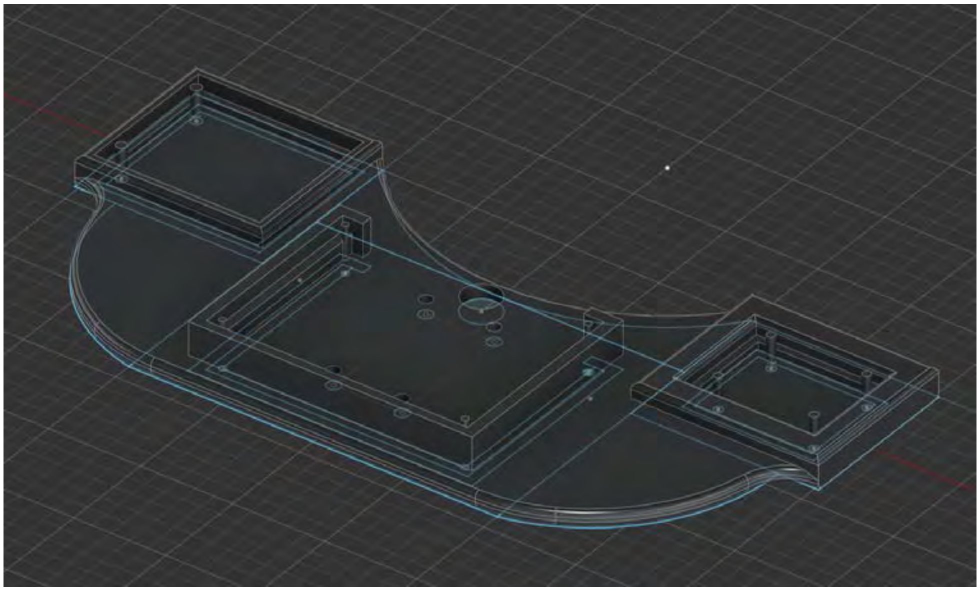
The printing process was carried out in several stages to ensure accuracy and minimize errors. Before starting the print job, the print bed was cleaned, and the printer was calibrated. The CAD model was sliced using Creality Paint, generating the G-code for the printer. The printing process was monitored to detect any issues, and post-processing steps included removing supports, sanding rough edges, and assembling the printed parts.

Process of wiring

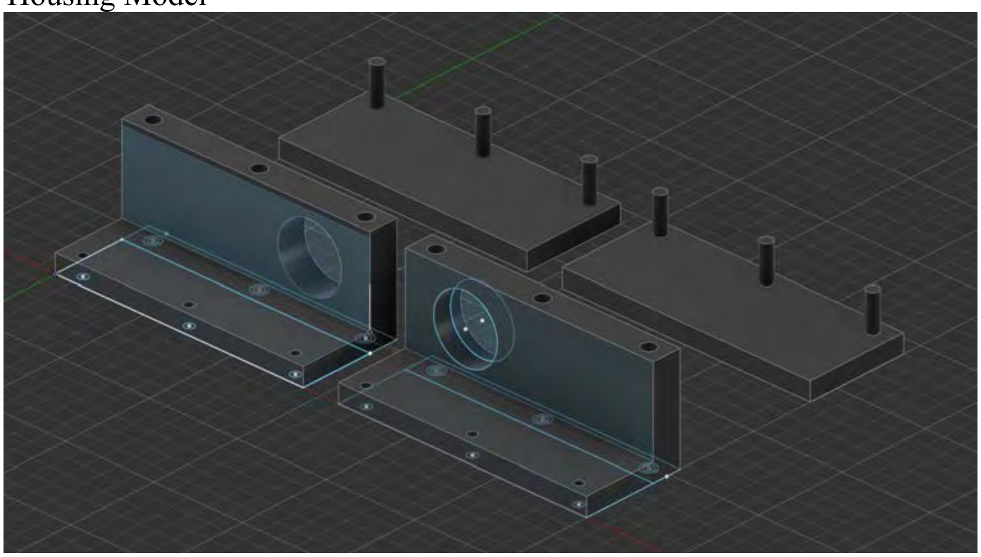
This wiring process ensures that the RC car is properly powered, and all components are connected for optimal functionality. The Arduino Nano acts as the central control unit, receiving inputs from the Bluetooth module and ultrasonic sensor, and controlling the motors via the L298N motor driver. This setup enables the RC car to move and detect obstacles, enhancing its crash detection capabilities.

3D Printed Models

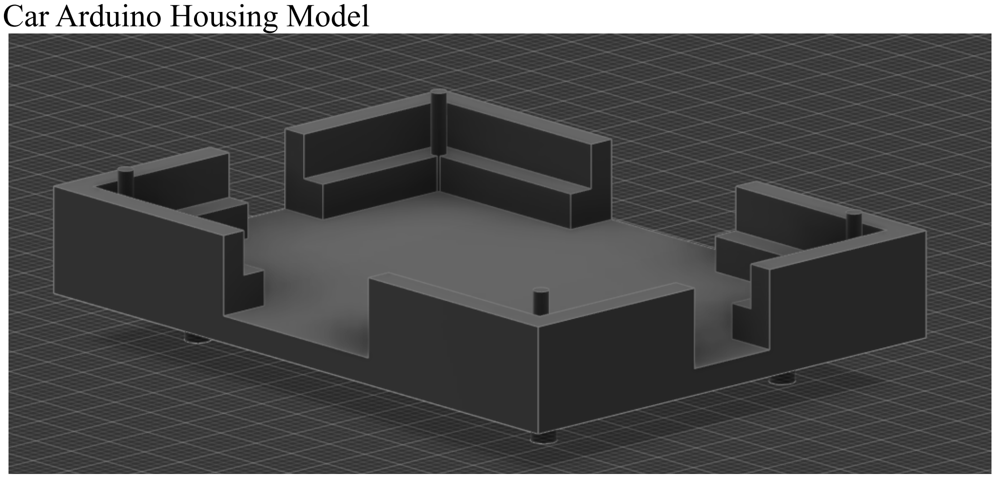
Finished Controller Model



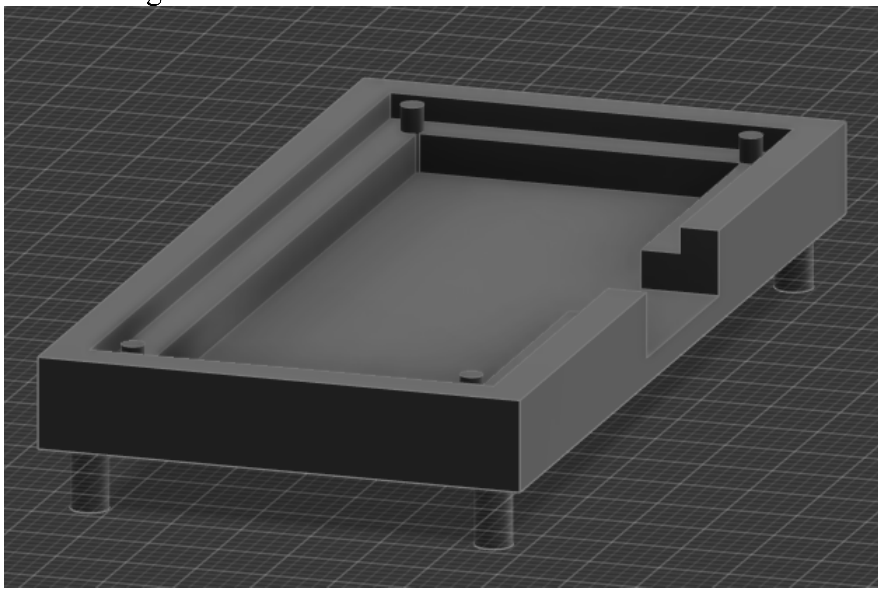
DC Motor Housing Model



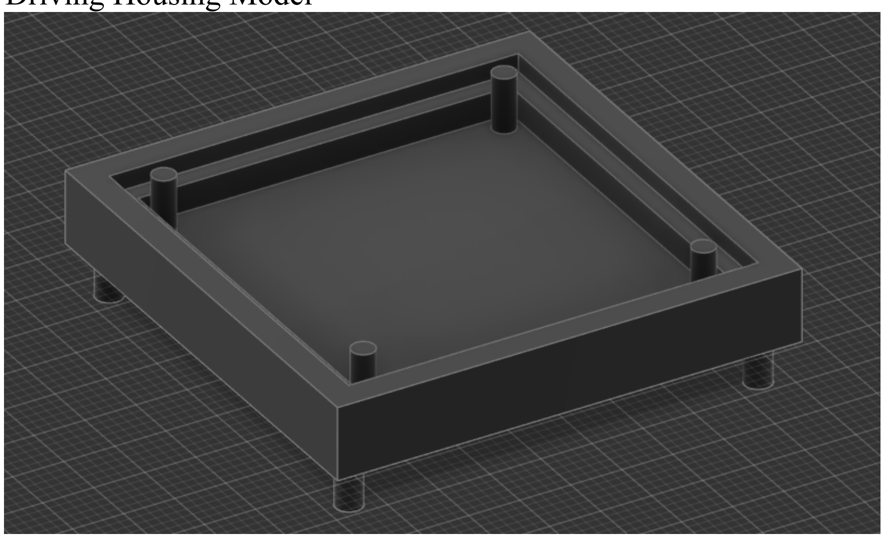
Main RC Car Arduino Housing Model



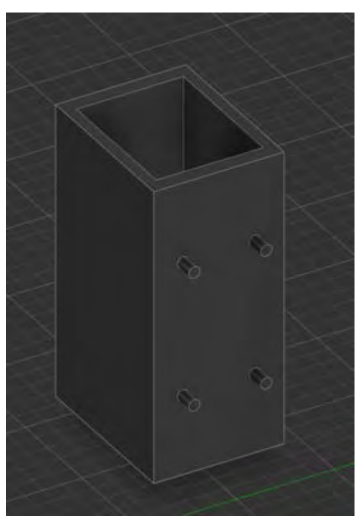
Ultrasonic Sensor Housing Model



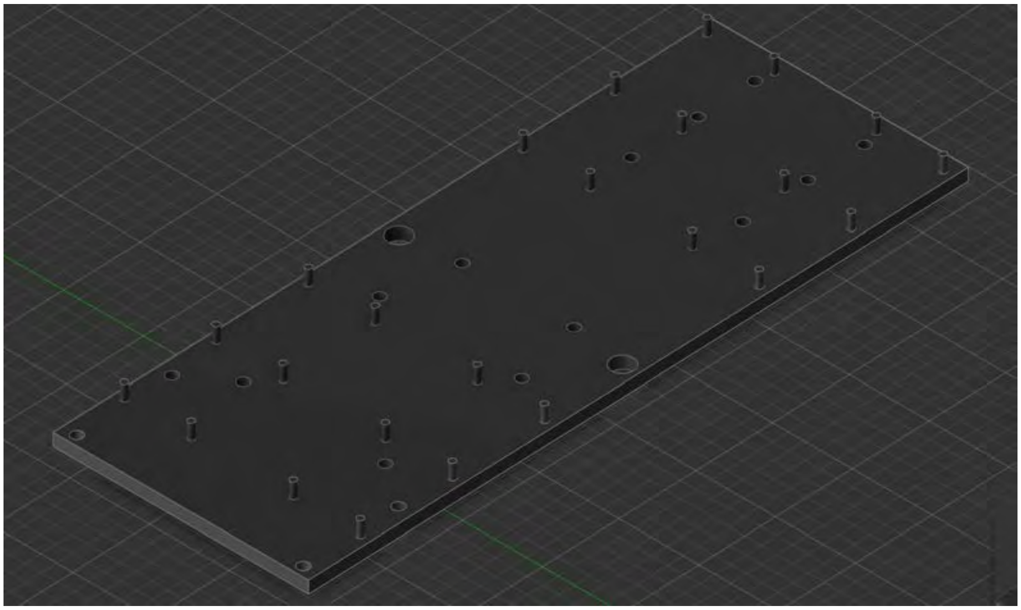
L298N Motor Driving Housing Model



Li-po Battery Housing Model

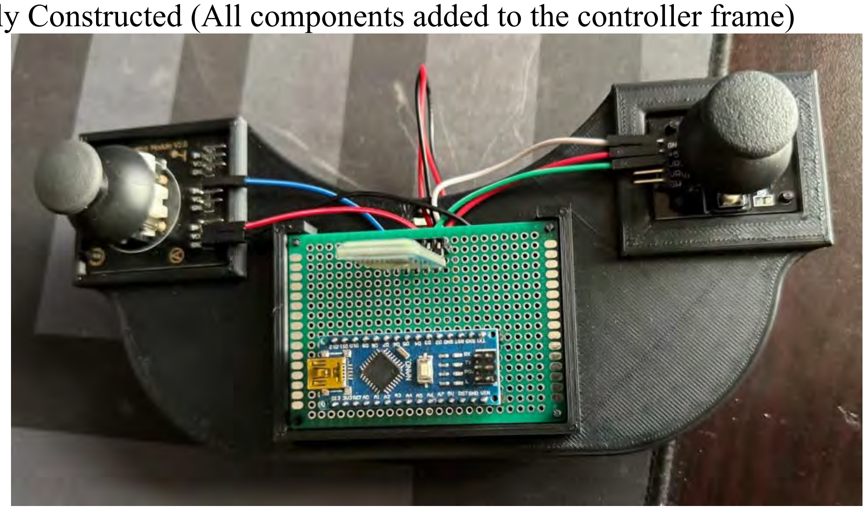


Main RC Car Platform



Fully Assembled Chassis Frame (Prior to adding components and resoldering motor mounts)

Controller Fully Constructed (All components added to the controller frame)



Post Completion Remarks

The successful completion of this Arduino-based RC car project showcases the effective integration of multiple engineering disciplines, including embedded systems design, wireless communication, sensor integration, and 3D printing. The chassis' meticulous design and 3D printing, combined with the integration of advanced components such as the Arduino Nano, HC-05 Bluetooth module, and ultrasonic sensors, culminated in a highly functional and adaptable RC car with sophisticated crash detection capabilities.

The project journey began with extensive research and planning, a phase that laid a robust foundation for subsequent stages. Each phase of the project, from initial design sketches and CAD modeling to assembly and rigorous testing, was carefully executed to ensure that all components functioned seamlessly together. The iterative development process, which included numerous test prints and component adjustments, was crucial in refining the design and ensuring the reliability and performance of the final product.

The integration of the ultrasonic sensor for real-time crash detection was a significant highlight, allowing the RC car to autonomously identify and avoid obstacles. This feature, coupled with precise motor control and responsive handling enabled by the Bluetooth-controlled Arduino system, demonstrated advanced technical proficiency and innovative problem-solving skills.

Throughout the project, a modular approach was adopted, facilitating efficient troubleshooting and modifications and providing a pathway for future enhancements and scalability. This forward-thinking design ethos not only reflects an adaptability to evolving technological landscapes but also underscores the potential for continuous improvement and future innovation.

The extensive testing and calibration ensured that the RC car operated reliably in various environments, effectively responding to wireless commands and executing collision avoidance maneuvers. This thorough validation process underscored the project's commitment to reliability and performance.

In conclusion, this RC car project is a testament to the capabilities of combining Arduino technology and 3D printing to develop sophisticated engineering solutions. It highlights the importance of interdisciplinary knowledge and the power of innovative thinking in advancing technology and solving real-world problems. The project served as a practical application of theoretical knowledge and provided valuable insights into the complexities and rewards of hands-on engineering. The experience gained and the skills demonstrated through this project will undoubtedly contribute to future endeavors in engineering and technology.

I have shared my code repositories and provided a video demonstration of the RC car working. I believe that this project not only showcases my technical skills and ability to execute complex engineering tasks but also serves as a strong foundation for future innovation and practical applications in the field of robotics and embedded systems.

Resources Page

GitHub Repository Link: https://github.com/MakanHaghighi19/RC_Rover.git

Video Demo: https://youtu.be/jXFSHGo6UZk

https://www.instructables.com/How-to-Configure-HC-05-Bluetooth-Module-As-Master-/

https://lastminuteengineers.com/hc05-at-commands-tutorial/

https://lastminuteengineers.com/l298n-dc-stepper-driver-arduino-tutorial/

https://www.youtube.com/watch?v=IHiw94knXWg

https://www.youtube.com/watch?v=1n_KjpMfVT0&t=35s

https://www.youtube.com/watch?v=ENRFh83hHM8

https://www.autodesk.com/learn/ondemand/curated/fusion-360-quick-start-guide