Rock N' Rover: Remote Control Car

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***Abstract* – This conference paper presents the design decisions, the parts selection, and the technology selection that went into this project. The Rock N' Rover remote control car contains DC motors, an infrared receiver, an ultrasonic sensor, and a camera. There is also a custom remote controller to control the car, as well as a mobile app to control the car. The infrared receiver is used to receive commands to drive the car, the ultrasonic sensor is used to detect objects in front of the car, and the camera is used to display a POV of the car.**

***Index Terms* – Camera, infrared, motors, remote control car, ultrasonic sensor, application.**

I. INTRODUCTION

The Rock N' Rover project is a sophisticated remote control car, which merges advanced technologies to offer an engaging and practical application of engineering principles. The primary aim is to create a versatile and user-friendly remote control vehicle that integrates active communication, ultrasonic sensing, and live video streaming.

The motivation for the Rock N' Rover project arises from an interest in applying multidimensional engineering concepts to a real-world scenario. The project's objectives include designing and constructing a reliable remote control car equipped with DC motors, an infrared receiver, an ultrasonic sensor, and a camera. Another critical component is the development of a custom-built hardware remote controller to manage the car's movements using infrared transmission. Additionally, a significant goal is to design a user-friendly mobile application that serves as an alternative control interface, enhancing the user experience. The integration of a camera module is fundamental, providing a point-of-view video feed that allows users to navigate the car remotely with visual feedback. Ensuring the car's safe operation through the use of an ultrasonic sensor to detect and avoid obstacles is also a primary concern.

The significance of the Rock N' Rover project lies in its efficient application of conceptual knowledge. It offers hands-on experience in hardware design, software development, and system integration, highlighting the importance of diversified collaboration. Combining skills in electrical engineering, computer engineering, and software development, this project demonstrates the potential of integrating various technologies to create innovative solutions. The use of infrared communication for control, as well as the inclusion of ultrasonic sensors and a camera module, demonstrates the versatility and adaptability of modern engineering techniques.

The development of the Rock N' Rover also emphasizes sustainability and utility in engineering design. By applying efficient power management strategies and selecting components known for their reliability and longevity, the project aspires to create a sturdy vehicle capable of enduring various environmental conditions. Moreover, considerations for cost-effectiveness and accessibility ensure that the technology remains operational and expandable for broader applications beyond the academic setting. This approach not only enhances the project's educational value but also highlights its potential impact on advancing remote control systems in real-world circumstances.

The Rock N' Rover project is the product of academic knowledge, technical skills, and collaborative effort, aimed at creating an innovative and functional remote control car. This project not only showcases the capabilities of its creators but also serves as an inspiration for future exploration and development in the field of robotics and remote control systems.

II. TECHNOLOGIES

In this section, we will be discussing the technologies that will be used in the creation of the project.

Connecting The Hardware Controller To The Car

In order to connect our custom remote controller PCB to the car, three options were considered: Wifi, Bluetooth, and infrared transmission. Ultimately, it was decided to use the infrared transmission to communicate from the hardware-based remote controller to the car because we would not be sending/receiving a lot of data so we do not need the higher speeds that Wifi and Bluetooth offer. The remote controller also does not need as much range as Wifi and Bluetooth offer and since only one-way communication is needed, it was decided that infrared transmission was the best option to wirelessly control the car. The infrared protocol that will be used in the project is the NEC protocol, which has a carrier frequency of 38 kHz. This is the most common infrared protocol used. The wavelength of the infrared light being emitted will be 940 nm.

III. Part Selection

In this section, we will be discussing the various parts that will be used in this project.

A. Microcontroller

The microcontroller that will be used on both of the PCBs is the ESP32-U4WDH. It is a microcontroller created by Espressif Systems and offers internal Bluetooth and Wifi, and has internal flash storage. The internal flash storage offers a capacity of 4 MB and the microcontroller also has an SRAM capacity of 520 kB. The ESP32 is more powerful than other similar microcontrollers and there are many libraries that support the ESP32 microcontroller, which is why this microcontroller was chosen over other microcontrollers.

B. Infrared Emitter

An infrared emitter will be used to send commands from the hardware-based remote controller to the remote control car, in order to drive the car. The infrared emitter that was chosen for the project was the IN-S126ESGHIR. It is created by Inolux. It is a powerful infrared LED and has a maximum forward current of 100 mA, has a radiant intensity of 92 mW/sr, and has a narrow beam angle of 30 degrees. This emitter was chosen over other infrared emitters because it can be supplied with a high current, it has a high radiant intensity, so the infrared LED is very bright, and it has a narrow beam angle.

C. Infrared Receiver

An infrared receiver will be used to receive the commands from the hardware-based remote controller. The infrared receiver that will be used in this project is the TSOP38238 receiver, created by Vishay Electronics. It is a low-power infrared receiver with a typical current usage of 0.45 mA and it has a large receiving distance of 30 meters. The package also contains an internal demodulating circuit and an internal band-pass filter to filter out signals outside of the 38 kHz range. The large receiving distance and the internal demodulator and the internal band-pass filter are the three reasons this receiver was chosen over other infrared receivers.

D. Motor Driver IC

A motor driver IC is needed to control the motors. The motor driver must be a dual motor driver because two sides of the car must be controlled separately for one another, in order to turn the car left and right. The motor driver that will be used in this project is the DRV8835DSSR, created by Texas Instruments. It is a dual motor driver with a simple control interface, which is why this motor driver was chosen over other motor drivers. However, the downside to this is that there is no speed control, whereas other motor drivers offer speed control. The motor driver uses two pins to control the motors. One pin is used to toggle the motors on and off. The other pin is used to set the direction that the motor will spin.

E. 3.3V Step-Down Converter

A 3.3 V step-down converter is needed to convert the voltage on the car PCB from a 7.4 V lithium-ion battery pack to 3.3 V. The 3.3 V step-down converter will power the microcontroller, the motor driver logic, and the infrared receiver. The 3.3 V step-down converter that was chosen was the TSR 1-2433SM, created by Traco Power. It is a switching regulator with a high efficiency of 91%. It can supply up to 1 A of current and unlike other switching regulators, does not require any external capacitors or inductors because it has internal filter capacitors to filter out switching noise and noise from other sources. This was the main reason why this step-down converter was chosen over other converters.

F. 5V Step-Down Converter

A 5 V step-down converter is also needed to convert the voltage on the car PCB from a 7.4 V lithium-ion battery pack to 5 V. The 5 V step-down converter will power the motors and the ultrasonic sensor. A similar model to the TSR 1-2433SM was chosen for the 5 V step-down converter. The 5 V model is called the TSR 1-2450SM. Like the TSR 1-2433SM, it can supply up to 1 A of current and does not require any external capacitors or inductors.

G. 3.3V Step-Up Converter

On the remote controller PCB, a 3.3V step-up converter is needed because the remote controller PCB uses two AA batteries to deliver a voltage of 3 V. The microcontroller requires a minimum voltage of 3 V and as the battery charge drains, the voltage from the AA batteries could drop below 3 V. Therefore, a step-up converter is used to maintain a voltage above 3 V, regardless of the charge left in the battery. The MP3120-DJ-LF-Z is used in this project. It is a 3.3 V step-up converter created by Monolithic Power. It has a maximum efficiency of 96% and can provide up to 1.2 A of current.

H. ELEGOO UNO R3 Smart Robot Car Kit V4

The ELEGOO UNO R3 Smart Robot Car Kit V4 offers a comprehensive and user-friendly platform for those interested in robotics and programming, priced at $79.99. This kit features a car shape, aligning with specific project goals for a more compact and lightweight design. The dimensions are 8 x 7 x 6 inches, and it weighs just 2.3 pounds. The frame consists of two plastic plates held together by copper braces, allowing for either a protective enclosure of the components or an open top for easy access and adjustments.

The kit uses the TB6612 motor driver chip and CH340 USB to serial chip instead of the DRV8835 and HT42B534 chips. These components come pre-soldered for ease of assembly, making the setup process straightforward. The kit includes a pre-programmed Elegoo Uno, an Arduino replica, which integrates with the custom "SmartCar-Shield-V1.1" to manage various components. This shield controls features such as the infrared LED for remote control, ultrasonic sensor, and DC motors. The infrared remote controller and the companion app, which connects via Wi-Fi, offer versatile control options, including a joystick interface for steering and a camera module feed.

The kit comes with several valuable modules. The GY-521 module, featuring the MPU-6050 sensor, provides motion sensing and control with a three-axis gyroscope and accelerometer. This module can monitor the car's movement and adjust power to the wheels for optimal traction. The kit also includes a photoresistor line tracking module, although this feature might be redundant for some projects. The modular design allows for flexibility, enabling users to include or exclude components based on their specific needs.

The kit's extensive components list includes four wheels, four DC motors, an ultrasonic sensor module, a servo for the camera, and various brackets and extension shields. Additionally, it features a micro USB cable, a type B USB cable, a battery pack with lithium batteries, and a remote control. The camera module uses the ESP32S3WROOM1 chip, providing Wi-Fi connectivity and recording capabilities. This integration allows users to record and upload data directly to the Arduino.

Despite its many advantages, the kit has some limitations. It does not include certain components needed for a handheld PCB controller, such as joysticks, a potentiometer, an infrared LED transmitter, and a UART header pin. Additionally, there are no headlights included, which we need.

I. Headlights

The INJORA RC Headlights were chosen for their compatibility and ease of integration with the ESP microcontroller, as it operates at a voltage of 5V-7.4V, these LED headlights connect to two pins: 5V and GND. By connecting them to a digital GPIO pin on the ESP module, the headlights can be easily controlled. Their practical design, featuring a plastic hole on the bottom, allows for straightforward installation by drilling small holes through the car's frame and securing them with screws. Priced at just $9.98, these headlights are a cost-effective addition, providing adequate illumination and enhancing the overall functionality of the robot car kit.

J. Joystick Module

The COM-09032 joystick was chosen for its balance of functionality, cost, and user comfort. It operates at a voltage range of 3.3V-5V and features two potentiometers that control movement along the X and Y axes, providing precise control. The joystick includes a rubber nub, enhancing the user experience by making it comfortable to use. This joystick offers similar functionality of higher-end models, but at a significantly lower price, making it a cost-effective choice for controlling the Rockin' Rover.

K. Camera Module

The **ESP32 CAM** is a powerful microcontroller board designed for camera applications, featuring an integrated OV2640 camera module. It operates at a voltage of **3.3V** and requires an external **5V power supply** for stable operation. Unlike many microcontroller boards, the ESP32 CAM lacks a built-in USB port, necessitating the use of an external USB-to-TTL (UART) converter to upload code. A boot loader is required to enable the programming of the board via the UART interface. The absence of a direct USB connection makes initial setup slightly more complex, but this is offset by the board's robust feature set and wireless capabilities.

One of the standout features of the ESP32 CAM is its built-in Wi-Fi, which allows it to host a web server. This capability enables the streaming of video feeds over the network. In our project, we utilize this feature to connect the ESP32 CAM to a web server and obtain the IP address assigned to the device. This IP address is then embedded into the code of our companion app, enabling the app to display the live camera feed. This integration allows for real-time video streaming from the robot car to a mobile device, enhancing the remote control and monitoring capabilities of the system.

L. Application Technologies

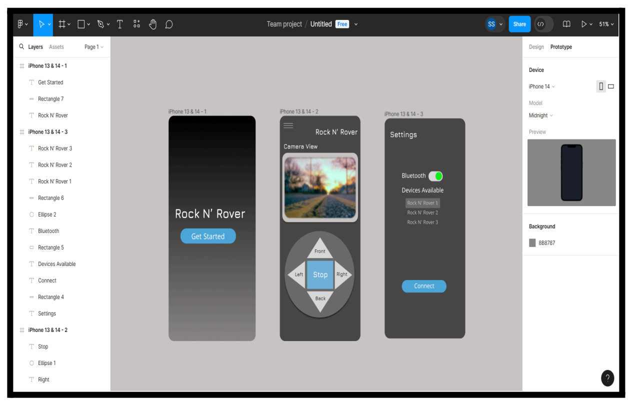
Several technologies are considered for developing the Rock N' Rover app: Arduino IDE provides a streamlined interface for writing and uploading code to Arduino boards, supporting a variant of the C++ programming language; Bluetooth Low Energy (BLE) is a wireless communication protocol suitable for short-range communication with low power consumption, enabling reliable mobile app control; MIT App Inventor is a web-based platform with a visual drag-and-drop interface, simplifying mobile app development for Arduino-based projects; and Blynk is a platform for building IoT projects with tools for developing mobile apps and connecting them to hardware devices, supporting various communication protocols. These technologies are evaluated based on ease of use, popularity, and complexity to determine their suitability for creating apps to control Arduino-powered RC Cars. Arduino IDE is user-friendly with extensive documentation, BLE offers reliable communication with some complexity, MIT App Inventor is beginner-friendly with limited advanced features, and Blynk provides a versatile platform for building IoT applications with some technical expertise required for advanced features.

We chose MIT App Inventor for developing the Rock N' Rover app due to its user-friendly interface and accessibility, making it an ideal choice for individuals with varying levels of programming experience. The platform's visual drag-and-drop interface simplifies the app development process, allowing us to design and deploy applications that interact seamlessly with Arduino-based hardware without delving deeply into complex coding syntax. MIT App Inventor democratizes app development by empowering users to bring their ideas to life quickly and efficiently, making it especially suitable for our project, which requires intuitive controls and real-time interaction with the RC car. Additionally, its robust feature set, including easy integration of Bluetooth connectivity and real-time telemetry data, enhances the user experience, allowing us to create a versatile and functional app for controlling the Rock N' Rover.

The Rock N' Rover App

A. Application Prototyping

The app controller for the Rock N' Rover was prototyped in Figma, a collaborative and cloud-based design tool. Figma's interactive prototyping functionalities allow designers to simulate user interactions and test the app's usability comprehensively. This ensures that the Rock N' Rover's app controller is refined for functionality and user satisfaction.



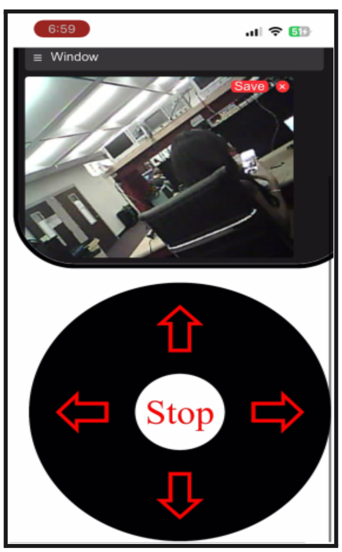
B. App Implementation

Creating an MIT App Inventor app involves several steps, each geared towards developing a functional and user-friendly application. The process begins with conceptualization and planning, defining the app's purpose, target audience, and key features. Following this, the design phase uses MIT App Inventor's drag-and-drop interface to assemble the app's user interface (UI), focusing on simplicity, consistency, and accessibility.

The coding phase involves using MIT App Inventor's visual programming language to define the app's behavior and functionality. Testing and debugging are critical stages where the app is tested across different devices and operating systems to identify and fix any issues. Finally, the app is packaged and distributed, with continuous improvement based on user feedback.

The user interface (UI) design prioritizes user experience and ease of navigation, with intuitive control layouts mimicking traditional RC controllers. Camera view integration provides real-time visual feedback for precise navigation and obstacle avoidance. The navigation system offers intuitive access to various sections, and the backend integration ensures reliable communication with the Arduino microcontroller through Bluetooth or Wi-Fi, enabling real-time responsiveness and error handling.

C. Application Design



The Rock N' Rover app's design blueprint strategically positions the landing page as the initial encounter for users, where the app's title takes center stage to establish brand identity. A prominent "Get Started" button prompts user interaction and redirects users to the home page, ensuring an intuitive start. The home page presents a comprehensive interface designed for rover navigation, featuring a central camera view for real-time visual feedback of the rover's surroundings. Adjacent to the camera view are the primary navigation controls—Front, Back, Left, Right, and Stop buttons—allowing users to maneuver the Rock N' Rover with precision and ease. This integration of visual feedback and intuitive controls prioritizes user experience and functionality.

The Settings page serves as a pivotal hub for customization and control, including the ability to manage Bluetooth device access for wireless connections with the Rock N' Rover. Additional features, such as music streaming capabilities, LED light control for low-light visibility, and volume control for music playback, may be integrated based on project timelines and feature completion. These enhancements emphasize the app's commitment to versatility and user-centric design, providing an engaging and effortless exploration of the Rock N' Rover universe

IV. ENGINEERING SPECIFICATIONS

Our engineering specifications for the Rock N' Rover included several key requirements: the car's body must be at least 3 inches in width and 5 inches in length, the battery must be able to power the car for at least 1 hour, the car must be capable of moving forwards and backwards and turning left and right, and the total cost of the car must not exceed $800, with a budget of $200 per team member. Additionally, the headlights must be visible from at least 3 feet away, and the car must be able to drive a distance of at least 10 feet. However, our primary focus was on three demonstrable features: ensuring the car could travel a distance of 10 feet, move in all four directions, and achieve a directional accuracy of 90%.

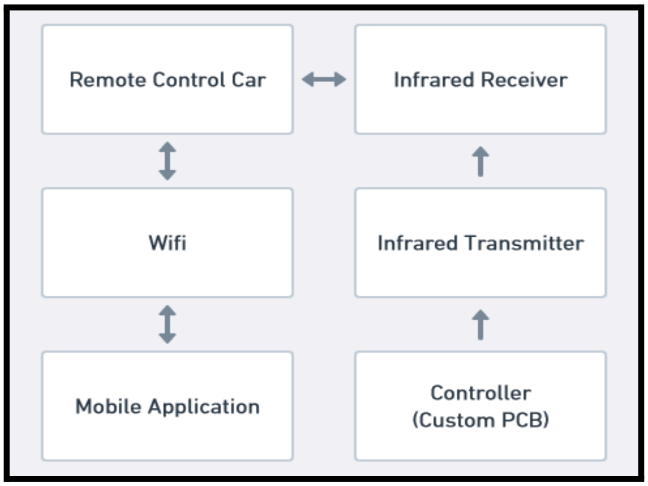
Key Specifications
Body of the car must be at least 3 inches in width and 5 inches in length
Battery must be able to power car for at least 1 hour
Car must be able to move forwards and backwards and turn left and right
Cost of the car must be at a maximum of $800 ($200 per team member)
Headlights must be visible from at least 3 feet away
Must be able to drive a distance of at least 10 feet

V. PROJECT DESIGN

In this section, we will discuss the block diagrams used to create our design, as well as other materials related to the design.

A. Main Block Diagram

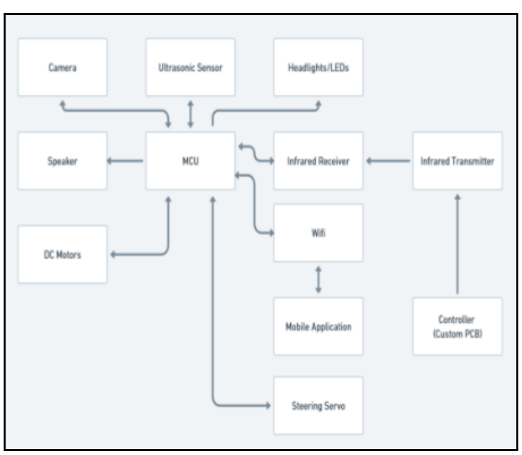
The block diagram below illustrates the main parts of the project.



The mobile application will communicate with the remote control car via Wifi. The hardware controller will send custom commands to the remote control car via infrared transmission. The infrared transmitter will be on the remote controller PCB and the infrared receiver will be on the remote control car PCB.

B. Remote Control Car Block Diagram

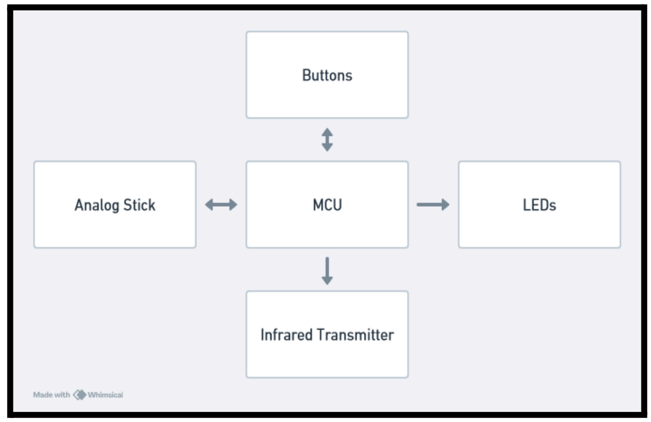
The block diagram below illustrates the remote control car connections.



The microcontroller will connect to several peripherals and will receive commands via infrared transmission from the hardware controller. The mobile application will communicate with the microcontroller via Wifi.

C. Controller Block Diagram

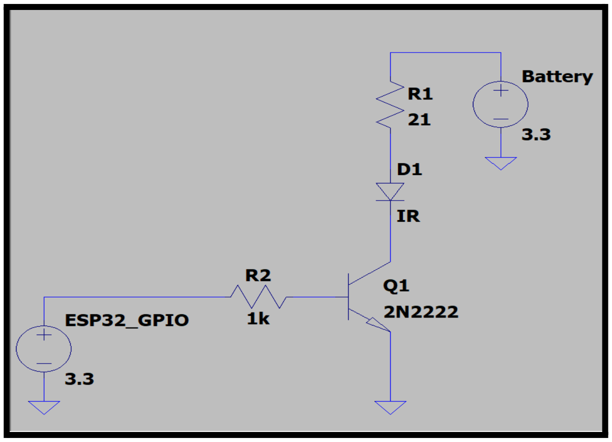
The block diagram below illustrates the hardware controller.



The hardware controller will include buttons, an infrared transmitter, and analog sticks. There are two analog sticks: one to control forwards/backwards motion and one to control left/right motion.

D. IR Transmitter Design

While selecting components, one design problem was noticed. The infrared transmitter could draw up to 100 mA. However, the ESP32's GPIO pins only support up to 40 mA of current.Therefore, if a component connected to a GPIO pins draws more than 40 mA, it could damage the microcontroller. In order to solve this problem, one must limit the current that the GPIO pin supplies to less than 40 mA. However, this means that the infrared light emitted will be less bright, resulting in reduced range. So, in order to prevent the infrared transmitter from drawing a lot of current from the GPIO pin, while also maintaining a strong infrared signal, the circuit below was used.



Basically, the ESP32's GPIO pin is connected to the base of a BJT transistor to switch the infrared LED on and off. The infrared LED draws power from the 3.3 V step-up converter rather than the ESP32. A current limiting resistor of 21 ohms is used to keep the current at a safe 80 mA, which is about 80% of the maximum forward current of the infrared LED.

VI. GROUP 15: TEAM MEMBERS & CONTRIBUTIONS

Ryan Kohel is set to graduate in Summer 2024 with a Bachelor's in Electrical Engineering. His academic interests span computer architecture, signal processing, and embedded systems. Ryan contributed significantly to the project with his expertise in hardware, including microcontroller selection, IR technology, converters, and PCB schematics.

Sanya Wadhwa is nearing completion of her studies in Computer Engineering, with a strong passion for software development, particularly in Frontend/UI Design. She has dedicated her academic career to understanding technology's interaction with user experience. Sanya's contributions to the project centered around creating the Senior Design Website, establishing standards and constraints, and developing software diagrams and prototypes.

Laila El Banna, also pursuing a degree in Computer Engineering, shares a deep interest in software development and UI design. Throughout her academic journey, she has focused on optimizing technology for user experience. Laila played a crucial role in the project by managing the budget, conducting research, defining design standards, and overseeing project milestones and schedules.

Michael Patalano is currently pursuing his electrical engineering degree with prior experience in Arduino IDE, robotics, and 3D modeling/printing. His academic journey has been shaped by a keen interest in applying technology to biomedical engineering, particularly in prosthetics design. Michael's contributions to the project included detailing automotive history, dissecting car functionalities, and analyzing various electronic components crucial for the project's success.

These team members bring a diverse range of skills and expertise to your senior design project, ensuring a well-rounded approach to both hardware and software development.

VII. FUTURE CONSIDERATIONS

If we had more time, our project would focus on several key enhancements. Firstly, integrating a speaker will enable two-way communication, enhancing interaction capabilities with the car. Additionally, expanding the camera module with advanced photo tracking algorithms will allow for target identification and autonomous following, akin to a pet dog. Moreover, we aim to advance autonomous navigation capabilities through robust algorithms, ensuring safe and efficient movement in varied environments. Integrating environmental sensors will provide crucial data for adaptability, while optimizing power management will extend operational longevity. These developments aim to elevate the car's functionality, user engagement, and adaptability, aligning with our goal of creating a versatile and efficient autonomous vehicle system.

VIII. CONCLUSION

Overall, the Rock N' Rover project represents a significant achievement in engineering innovation, blending theoretical knowledge with practical application to create a sophisticated remote control car. Throughout the development process, from initial concept to final implementation, the project has demonstrated the versatility and adaptability of modern engineering techniques. By integrating advanced technologies such as infrared communication, ultrasonic sensing, and live video streaming, the team has not only met but exceeded the project's objectives of functionality, usability, and educational value.

The success of the Rock N' Rover project can be attributed to its comprehensive approach to system design and integration. Each component, from the selection of microcontrollers and motor drivers to the implementation of sensor technologies, was carefully chosen to optimize performance and reliability. The custom-built hardware remote controller, utilizing infrared transmission for smooth vehicle control, highlights the team's attention to detail in meeting specific project requirements. Also, the development of a user-friendly mobile application with intuitive controls and real-time video feedback demonstrates the project's commitment to enhancing user experience and interaction.

Beyond its technical achievements, the Rock N' Rover project has encouraged critical learning experiences for its team members. Engaging in cross-functional collaboration, the project has strengthened skills in project management, technical problem-solving, and teamwork. The iterative design process, which involved prototyping, testing, and refining, not only enhanced the functionality of the remote control car but also provided realistic insights into overcoming engineering challenges. These experiences are significant in preparing students for future careers in engineering, where innovation and adaptability are crucial.

Furthermore, the significance of the Rock N' Rover project extends beyond its immediate educational context. By addressing real-world engineering challenges such as real-time navigation, obstacle detection, and remote communication, the project contributes to the broader advancement of robotics and remote control systems. The insights gained from this project can inform future research and development in remote controlled vehicles, emphasizing the role of experimentation and innovation in advancing technological capabilities. As technology continues to evolve, projects like Rock N' Rover inspire continued exploration and innovation in engineering fields, paving the way for future advancements in remote controlled systems and robotics. The project's success highlights the transformative impact of hands-on learning experiences and collaborative teamwork, shaping the next generation of engineers and innovators optimistic to tackle engineering challenges with creativity and proficiency.

IX. ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Professor Wei for his invaluable guidance, expertise, and unwavering support throughout this project. His insightful feedback and encouragement were instrumental in shaping our understanding and approach.

Additionally, we extend our thanks to Professor Das, Professor Wu, and Professor Sahawneh for their continuous guidance and helpful suggestions. Their expertise in Electrical and Computer Engineering enriched our project immensely.

We are also thankful to our friends and family for their unwavering support and encouragement through this project. Their belief in our abilities and their constant motivation played a crucial role in helping us achieve our goals.

Finally, we acknowledge the institutional support provided by the University of Central Florida, particularly the access to the senior design lab, whose facilities and equipment were instrumental in the success of our project.