E-Maxx Mirage

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***Abstract*—A high-performance remote-controlled car has been retrofitted with a camera that streams video footage to a virtual reality headset. A Raspberry Pi interface is integrated into the system for video transmission and remote control. WiFi technology is utilized for high-quality video streaming and radio signals for precise vehicle control. The system creates a realistic driving simulation by integrating a steering wheel and pedals for remote-control.**

***Index Terms*—Wireless Communication, Radio Control, Virtual Reality, Stabilization, Raspberry Pi**

I. Introduction and Motivation

The Traxxas E-Maxx, a preexisting RC car, is the foundation for our radio-controlled virtual reality project. To explore distant environments and create a near in person driving experience, this remote controlled car has been modified. This is accomplished by having a raspberry pi 4 with a raspberry pi camera affixed to the chaise of the car. The raspberry pi 4 creates a local area network. An immersive and interactive experience has been created by enabling real-time video streaming to a virtual reality headset.

To help the experience feel realistic, a steering wheel and pedals are integrated for remote control. This not only enhances the user experience but also introduces a dynamic element to the remote control experience. This was accomplished by connecting the car's transmitter to digital potentiometers, which allowed the speed and turning of the car to be controlled through a Raspberry Pi. The Raspberry Pi then connects to the wheel and pedals through USB. Furthermore, the car includes a rotational platform for the camera to expand the degree of view and is complemented by motion stabilization technology. This approach was designed to mitigate motion sickness and provide users with an immersive experience. This project has established a system that finds applications in entertainment, education, and virtual training. With an inexpensive approach, this makes it affordable for anyone.

II. Related Work

A. Radio Control

A team at the RCC Institute of Information Technology constructed a remote-controlled car that is operated by motion gestures [2]. Some similarities to the E-Maxx Mirage include implementing a distinct control scheme for an RC-controlled car, employing the I2C protocol for various components, and utilizing a Raspberry Pi to interface input, which is subsequently transmitted to the receiver. One of the differences is the use of an encoder and decoder, whereas the E-Maxx Mirage uses the original RC transmitter and receiver, thus there was no need to construct an encoder and decoder. The control method is through an accelerometer, compared to the E-Maxx Mirage implementation which uses direct input devices such as a wheel and pedals. The implementation of the I2C protocol in this project is slightly different because RCC Institute of Information Technology uses I2C to control inputs going into the Raspberry Pi to then be encoded. E-Maxx Mirage differs by using the Raspberry Pi as the I2C master to control other devices.

B. Virtual Reality

A team of three engineers in Taiwan proposed using a virtual reality headset to view footage from an endoscope camera used in minimally invasive surgeries [3]. The camera would follow the movement of the surgeon's head allowing the surgeon to have more control over their surgical tools inside patients. Using a virtual reality headset, also called a head-mounted display (HMD), allows users to experience a full field of view which creates a better depth perception. To record the surgeon's head movements, two lighthouses tracked an HTC Vive headset allowing for high-precision manipulation of the camera inside the patient. A virtual reality headset that uses base stations or lighthouses will be used for E-Maxx Mirage because it is more accurate and easier to implement. An HTC Vive Pro with two SteamVR 2.0 base stations will monitor head movement.

C. Wireless Communication

Raspberry Pis work great with other devices wirelessly. A common way to connect a Raspberry Pi to another device is through a local area network (LAN). Several guides exist on how to set up as a LAN [1]. This local area network is used to transfer data between several different Raspberry Pis and other devices. This implementation uses a dedicated router and network switch as the main host and can be set up to access the outside internet or be completely offline. Raspberry Pis can also connect to other devices through direct radio control through a transceiver. A transceiver typically connects only two devices together, not groups of devices. Radio control modules work great for small amounts of data that need to be sent fast while wireless LANs work great for sharing large amounts of data with one or more devices.

III. E-MAXX MIRAGE PROPOSAL

A. The Car

The E-Maxx's reliability and durability makes it a stable platform for our project. With the potential to bear a load, this vehicle accommodates the attachment of devices, enabling a focus on refining radio control methods and enhancing the virtual reality experience, rather than starting from scratch to create a new car.

The Traxxas E-Maxx's stable chassis, depicted in Fig. 1, and design make it well-suited for camera integration, offering a seamless solution for capturing dynamic and high-quality visuals. Leveraging an established model like the E-Maxx not only provides dependability but also with a vibrant community of RC enthusiasts and developers.

Fig. 1. E-Maxx car.

B. Radio Control

To both simplify and retain the original control protocol, the original radio transmitter for the car was utilized. This will be done by using a Raspberry Pi and two digital potentiometers as well as the original transmitter as indicated in Fig. 2

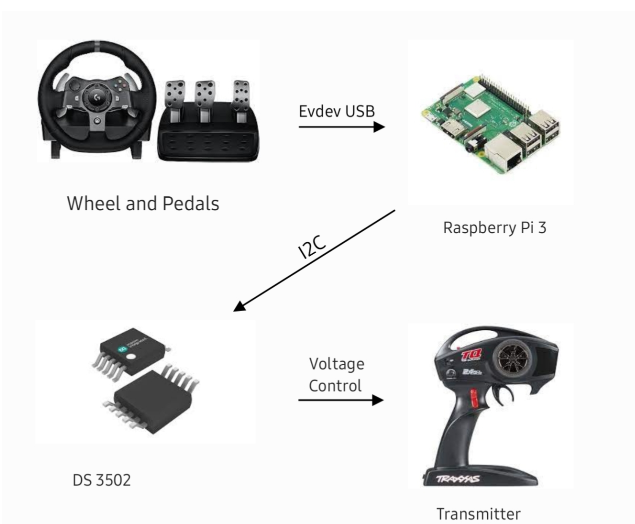

Fig. 2. Diagram for RC car control flow.

1) Radio Transmitter: The radio transmitter being used utilizes four potentiometers to control the RC car. Steering and acceleration each have two. One for raw input and another for trim to correct imperfections in values. The input potentiometers were replaced while keeping the trim potentiometers for fine-tuning. The rest of the circuitry from the transmitter will be reused and placed into a new 3d printed shell for better space utilization. The high voltage is 5v while the low voltage is connected to ground. This leaves the middle voltage to range from 3V to 2V with an initial value of 2.5V. These values are true for both of the control potentiometers.

2) Digital Potentiometers: To control the transmitter using digital signals, two DS3502 digital potentiometers are used. These potentiometers meet the voltage requirements needed for controlling the transmitter. These potentiometers require capacitors to smooth out the voltage as well as pull-up resistors on a custom PCB.

$$V_{RW} = V_{RL} + \frac{WR}{127}(V_{RH} - V_{RL}) \tag{1}$$

The datasheet provides Equation (1) to calculate the voltage output of the potentiometer. A total of 25 values will determine the output voltage. This means 25 different points of turning and acceleration using these digital potentiometers. Communication between the DS 3502 and Raspberry Pi will be done using I2C.

3) Controlling the Potentiometers: The device to control the two DS3502 devices will be a Raspberry Pi 3. This device will run a C program that will correctly set the desired values. This program will also interface with a USB steering wheel and pedals such as the Logitech G25. This set of wheels and pedals will provide a Direct Input protocol to the Raspberry Pi. Different modes are used to limit the speed of the RC car as it will be too fast for the user, thus the need for multiple speed modes will be necessary.

C. Wireless Transmission

The entire user experience is based around the camera that will be mounted to the car. To control the car effectively, the user needs to be able to make decisions based on the car's current soundings. The car will not be in the user's direct line of sight so a camera is used to transmit video from the car to the user. It is vital that the camera can send video footage fast enough for the user to control it in real-time. Using a VR headset also requires the camera to record in at least 90 frames per second (FPS) to prevent motion sickness in the user. Fig. 3 shows a picture of the current camera module that is being used.

1) Support: The Raspberry Pi official camera module is capable of recording video in 120 FPS at 1536 × 864, (admittedly, a rather odd resolution). Several libraries already exist for this camera module, written in several different programming languages. The primary package used is the picamera2 module written in Python.

2) Encoding: The picamera2 module is capable of encoding raw footage from the Raspberry Pi Camera Module 3. The H264 encoder, the JPEG encoder, and the MJPEG

Fig. 3. Raspberry Pi Camera Module 3

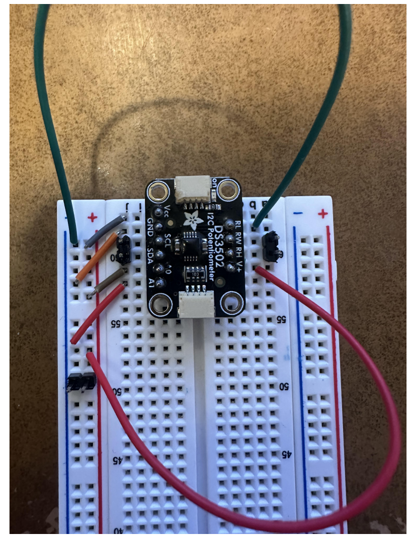

Fig. 4. Single Ds3502 test circuit.

encoder are some of the options. The H264 encoder will be used, as it supports the resolution and frame rate needed. The H264 encoder is implemented using the Raspberry Pi's built-in hardware, supporting up to 1080p at 30 FPS. A lower resolution will be used in order to get a higher frame rate. One of the parameters that can be changed using this encoder is the bitrate which is measured in kbps. In order to stream video with a resolution of 1536 × 864 at 120 frames per second, the bitrate needs to be in the range of 12,144 - 23,058 kbps. This also means that there needs to be a way to transmit that much data wirelessly.

3) Wireless Transceiver Modules: Streaming high-resolution video at 120 frames per second requires a strong reliable method of transmission. Several radio frequency modules exist that would do this. WiFi networks are also capable of transmitting this much data.

D. Testing

1) Radio: DS 3502 digital potentiometers have been obtained and a simple circuit has been created to test them as shown in Fig. 4. A basic C program that runs on a Raspberry Pi has been written to communicate to the DS3502 and can successfully change the voltage to be anywhere between 2 and 3 volts. A basic program has also been created that can utilize EVDEV for Linux to listen to digital input devices such as Xbox controllers and wheels. This program simply shows which input is pressed and is currently working correctly.

2) Wireless Communication: To test the wireless transmission from the camera to the VR headset, first a connection is established between the camera and a receiver device, such as a computer or Raspberry Pi. This initial step allows the assessing of the quality and reliability of the wireless link by transmitting camera footage to the receiver device. Then factors such as signal strength, throughput, latency, and potential interference can be analyzed. Once the wireless transmission to the receiver device is validated, the next step is to incorporate the received camera footage into the VR headset. This integration into the VR headset involves ensuring seamless communication between the receiver device and the VR headset, verifying compatibility, and assessing the performance of the wireless transmission within the VR environment.

3) Car: During the testing phase for the carriage design, an iterative design strategy will be employed, utilizing 3D printing to produce prototypes of the carriage, intended for the accommodation of a camera and signal-transmitting peripherals. The design will feature a stabilization device tailored for the camera's needs. Through this iterative process, the carriage design will be refined and optimized by successive prototyping, ensuring the functionality and efficiency of both the camera housing and stabilization components. This systematic testing approach is geared towards enhancing the overall performance and reliability of the carriage, providing for the placement and stabilization of the camera. Notably, this design is intended to be mounted atop the E-Maxx undercarriage shown in Fig. 1, with no planned alterations to the current undercarriage. The goal is to create a carriage that can be easily attached to any type of remote control car.

E. Risk Assessment

1) Red Level: With so many wireless communication links to our radio control, there are multiple points of failure. Potentially, there could be issues with wireless bandwidth meaning we may not find a wireless module capable of transmitting fast enough.

The biggest risk is the stability and strength of the WiFi signal, particularly its impact on camera transmission. Delays in data transfer due to weak WiFi signals could cause user discomfort and motion sickness. The fluctuating quality of WiFi in environments with physical obstructions or interference could further complicate maintaining a stable connection between the camera and the VR headset over extended distances or in complex settings.

To fix these issues, we are considering multiple strategies to enhance communication stability, including reducing transmission resolution from 1536 x 864 to 1280 x 720, or possibly lower if necessary. Additionally, we are experimenting with various communication setups. Using the Raspberry Pi as a WLAN access point is most likely our best bet. These measures will lower the risks associated with wireless communications and ensure the overall reliability of our system.

2) Yellow Level: The limited granularity the potentiometers provide may also be insufficient and result in a lack of control.

To help mitigate these risks, we will test each aspect individually and have different methods to achieve the result. An example of this could be using a different microcontroller or a simpler controller such as a Wii remote nunchuck which is already being used for testing.

3) Green Level: Stabilizing the camera poses a potential risk. It may induce motion sickness in users due to unintended motion that deviates from what is expected. Maintaining stability in the camera system is crucial to prevent discomfort and nausea among users, as any unexpected movements can adversely impact their experience and well-being.

If stabilization does not work correctly, slowing the car down will be the best option to achieve a more stable image.

F. Group Management and Communication Plan

Our team operates on a structured weekly meeting schedule to establish goals and keep our professor informed of our progress through weekly email updates. While each member is assigned specific tasks, we prioritize collaboration and mutual support throughout the project.

Due to our team's widespread living situations, with each member residing in different directions from the school, we've opted to utilize the labs provided by the university as a dedicated workspace for storing and working on the car. This arrangement allows us to efficiently collaborate and leverage our collective expertise. We plan to utilize a consistent weekly meeting day for collaborative work sessions, during which we will address challenges, refine our approach, and set new goals. Outside of these meetings, each team member will dedicate individual time to their assigned tasks to ensure continuous progress and maximize productivity.

G. Schedule and Milestones

From now until the end of April:

- Test control system for RC car. -Alex
- Create programs for controlling RC Car using Nunchuck. -Alex, Kyla
- Create custom PCB for driving transmitter. - Mike, Kyla
- Establish transmission of live footage from the camera: Enabling live video transmission is crucial for providing real-time feedback to the user. - Murphy

By the end of May:

- Enhance video footage clarity through optimization: Optimizing video clarity ensures that the transmitted footage is clear and detailed. -Murphy
- Start developing the augmented reality functionality for the headset: Initiating this development early ensures sufficient time for implementation and testing. - Mike
- Have completed board tested and working for controlling RC Car. -Alex, Kyla

By the end of June:

- Design and 3D print a new enclosure for the RC car control system Circuit. -Alex, Kyla
- Implement stabilization for the camera system: Stabilizing the camera improves the quality of the video footage, enhancing the overall user experience. - Alex, Kyla
- Finish developing the augmented reality for the headset: Completing the development of augmented reality features ensures a fully immersive user experience. - Mike
- Implement 360-degree vision capabilities for the camera: Adding 360-degree vision enhances the field of view and immersion, making it a significant milestone. - Mike, Murphy

By the end of July:

- Working Steering wheel controls for car. -Alex
- Finalize and apply finishing touches to the project: Completing any remaining tasks and applying final adjustments ensures the project meets all requirements and objectives. - Alex, Kyla, Mike, Murphy
- Conduct comprehensive testing and debugging: Thorough testing and debugging are essential to identify and address any issues or bugs before finalizing the project. - Alex, Kyla, Mike, Murphy
- Prepare project documentation and finalize presentation materials: Documenting the project and preparing presentation materials ensures a comprehensive understanding of the project's development and outcomes. - Alex, Kyla, Mike, Murphy

As we progress through our project timeline, we are committed to maintaining open communication and collaboration within our team. Regular meetings and updates will ensure that we stay aligned with our goals and make efficient use of our time. We understand the importance of flexibility and adaptability, and we are prepared to adjust our timeline as needed to address any challenges that may arise. Our goal is to deliver a high-quality, immersive remote control car system that meets or exceeds expectations. With a clear plan in place and a dedicated team effort, we are confident in our ability to achieve success and complete our project by the end of August.

IV. Conclusion

A remote control car add-on has been developed to capture live footage from an HD camera and transmit it back to the control station. The control station will include digital potentiometers that allow the connection of the RC car's original transmitter to a Raspberry Pi which is then controlled by an X-input controller. A wireless 2.4GHz radio capable of sending packets at 12,144 kbps is used for transmitting video footage live from the camera to the control station. At the control station, live camera footage is received and displayed in the VR headset, creating an immersive experience.

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