First Person VR Interface with RC Car

Team 7 – Deniz Yıldırım, Erik Jacobson, Sang Baek Han
ECE 445 Project Proposal – Spring 2020
TA: Weihang Liang

1 Introduction

1.1 Objective

RC (Radio-controlled) cars are very fun but often lack immersion, and they are hard to control because the person controlling it can lose line of sight. We want to give players the perception that they are a small person inside a RC car, making the experience more immersive and fun. In order to make this happen, we will use a VR (Virtual Reality) headset and a fisheye camera that can display in 180 degrees. The players controlling the RC car would never lose sense of where the RC car is as they would feel like they are inside the car and would be able to see its surrounding by looking around. A steering wheel and hands could be rendered on top of the video feed to let players control the car by holding the virtual steering wheel with their VR controllers.

1.2 Background

While there are some RC cars with cameras in the market, they fail at being immersive because they keep using traditional remote controllers and often do not give users the ability to see the surrounding of RC car as the camera faces only forward [1]. The RC toy vehicles in general do not gain much progress in terms of user experience. In the VR community, there is little interest and research on using VR as an input and output device for robots compared to other areas where VR is used [2]. Thus, this project is a good opportunity to explore new and different ways VR technology can be used. While our project is about RC cars, the idea challenges the usual approach to virtual reality and hopes to widen its use cases. We hope to experiment with the idea that while VR can make us exist in immersive virtual environments, it can also make us exist in real but unreachable environments such as inside an RC car. The same concept can be applied to have a more immersive presence in parts of the world that humans cannot reach as easily as robots do.

1.3 High-Level Requirements

- Camera must be able to display the first-person point of view from RC car through VR headset with less than 1s delay.
- VR headset must be able to display the appropriate field of view based on the direction where the user faces, in 720p resolution and 30fps.
- Controller must be able to wirelessly control RC car with a camera with the max range of 9m.

2 Design

The successful working project consists of majorly five sections: a DC motor drive subsystem, a RC controller subsystem, a video transmission subsystem, a VR headset facing direction subsystem, and a power supply subsystem. The entire flow of the signals and the connections are shown in Figure 1 below.

A controller sends the direction and the speed signals to the Bluetooth, which the microcontroller receives them to control the PWM (Pulse-width modulation) signals. Appropriate PWM signals are sent to each H-bridge circuit, which controls the speed and the forward/reverse direction of DC (direct current) motor. The wheel rotates as the DC motor rotates.

A 180 degrees fisheye camera receives the curvilinear image in RGB, which is sent to the single-board computer. The curvilinear image is sent to the computer through Wi-Fi from the single-board computer. The computer converts the curvilinear image to the rectilinear image, then sent to the VR headset to display the appropriate portion of view to the user.

The 6V battery is the power source for the components that are on the RC car. The 5V voltage regulator is used to provide appropriate voltage to each component. The controller and VR headset have separate batteries attached on them.

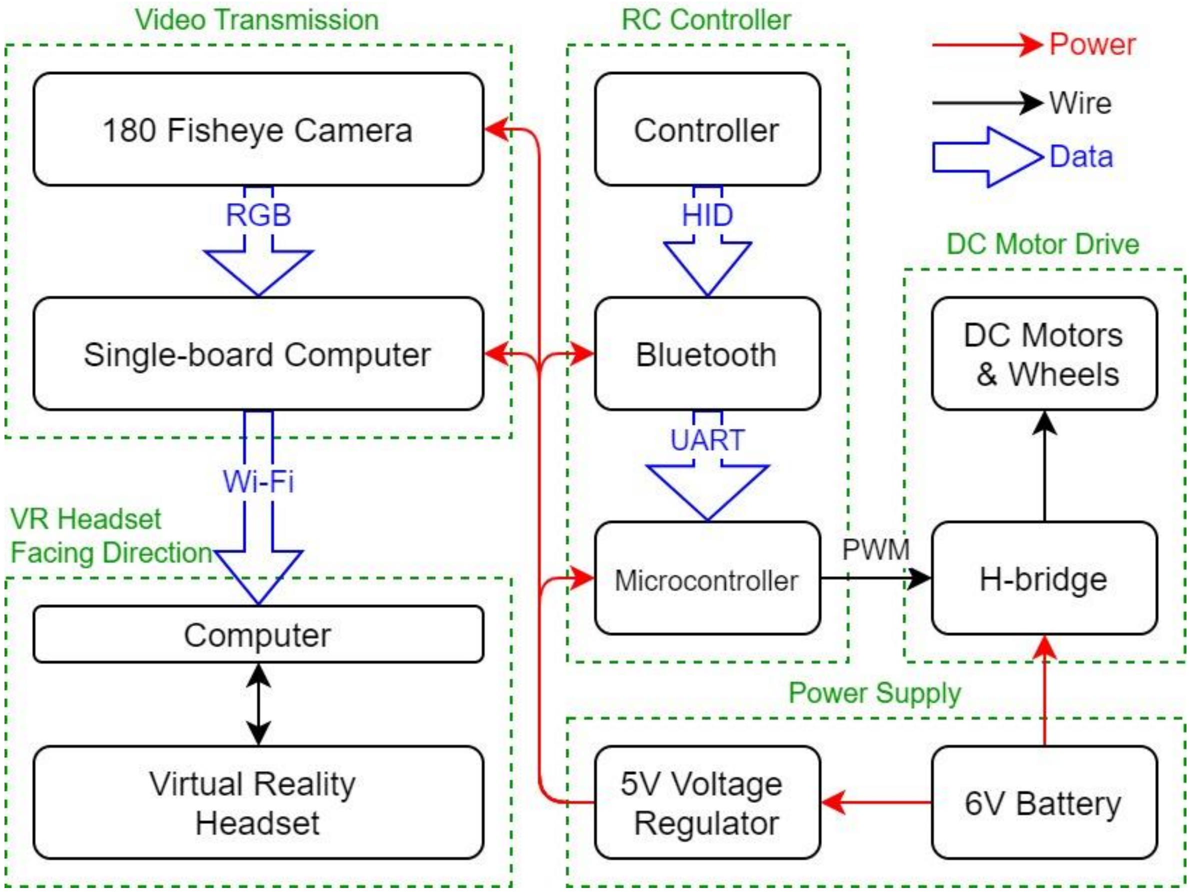

Figure 1. Block Diagram of Radio-controlled Car, Controller, and Virtual Reality Headset

The RC car has rest of the components attached besides from the controller and the VR headset. The physical diagram shown in Figure 2 shows the approximate locations of where it will be located on the RC car. Four wheels are directly attached each DC motor. Four DC motors are directly connected to each H-bridge on the PCB (printed circuit board). Four H-bridge circuits are connected to each output port of the microcontroller. Appropriate output ports on the microcontroller send out appropriate PWM signals to each H-bridge circuit. Bluetooth chip is attached on PCB, which is connected to the microcontroller, to receive the speed and the direction signal from the controller.

6V battery is connected to the PCB to provide appropriate voltages to each component. On the PCB, 6V battery is connected to two parts: H-bridge circuits and 5V voltage regulator. 5V voltage regulator is connected to the microcontroller, the Bluetooth chip, and the single-board computer to provide 5V voltage supply. The single-board computer is connected to the fisheye camera to provide 5V voltage supply to the fisheye camera and to receive the curvilinear image from it.

The controller, the computer, and the VR headset are not designed by ourselves, so these are not shown in the physical diagram.

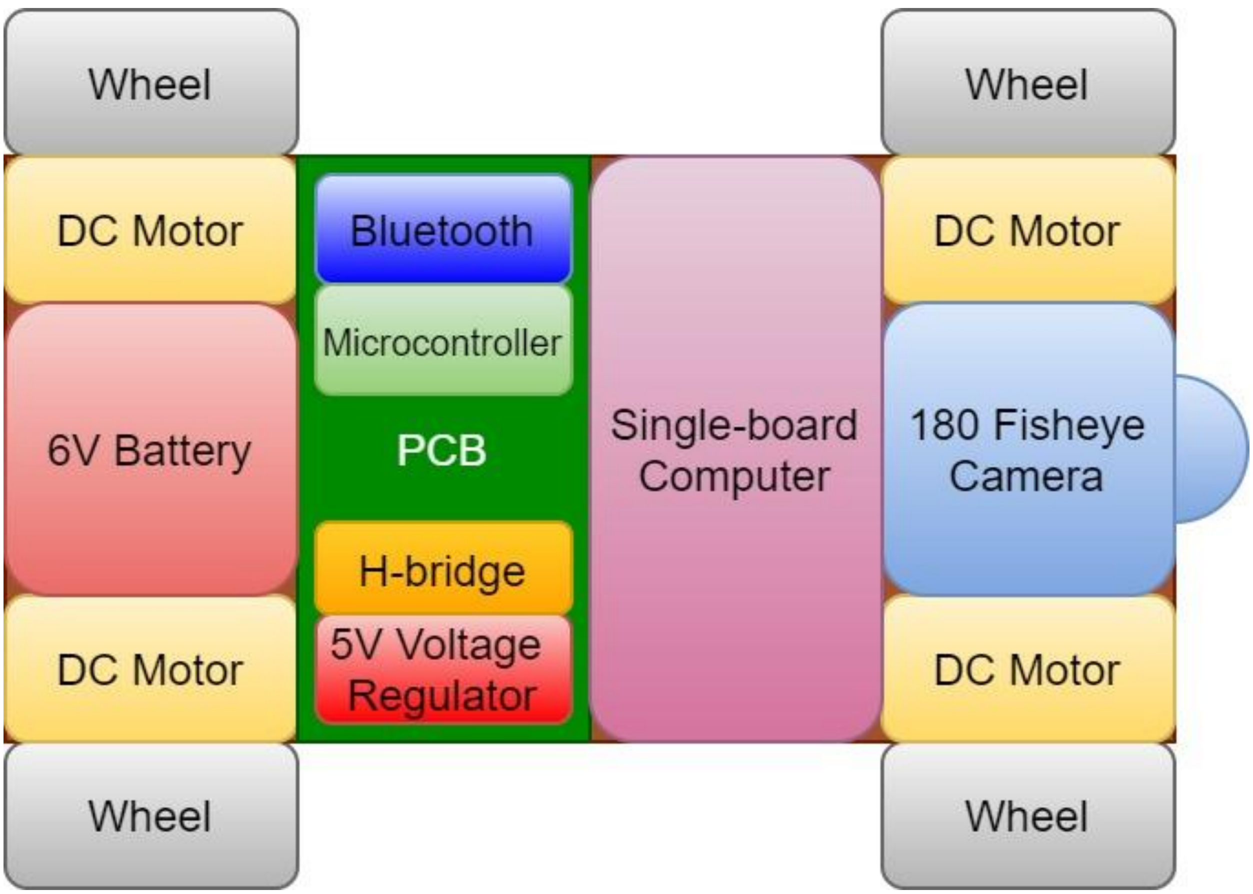

Figure 2. Physical Diagram of Radio-controlled Car

2.1 DC Motor Drive Subsystem

The DC motor drive subsystem is the body of RC car. Four wheels are attached on four DC motors, which are connected to H-bridge to control the clockwise or the counterclockwise rotation. PWM signals sent to each H-bridge circuit to control the speed of DC motors.

2.1.1 H-bridge

H-bridge controls the direction and the speed that the DC motor will rotate. PWM signal from the microcontroller is fed into the appropriate H-bridge circuits to control the speed of DC motors. Besides the control of forward and reverse rotation of DC motor, H-bridge also prevents short circuits.

Requirement 1: H-bridge must avoid getting short circuit.

Requirement 2: H-bridge must provide at least 160mA at 4.8-6V.

2.1.2 DC Motors and Wheels

The wheels of same size are attached to the direct current motors of same products. DC motors rotate in forward or reverse direction based on the H-bridge. The speed of DC motors is controlled by PWM signal.

Requirement 1: The wheels must be same size with same weight to maintain the balance.

Requirement 2: The DC motors must be same products to have a same speed output when moving forward or reverse.

2.2 Radio-controlled Controller Subsystem

The radio-controlled controller subsystem is the brain of the RC car. The controller allows the user to control the direction of the movement and how fast the RC car moves. The Bluetooth chip is connected to the microcontroller to receive these control signals from the controller. The microcontroller decides which H-bridge circuit will get the PWM signals to rotate the DC motors based from the control signals received from the Bluetooth chip.

2.2.1 Microcontroller

The microcontroller handles the PWM signal and which DC motors to rotate. It communicates with the Bluetooth chip, which receives the speed signal and the direction of RC car movement from the controller. The speed signal is converted to the PWM signal in appropriate ratio and the direction of RC car movement is controlled based on the decision of which DC motors to rotate forward and reverse.

Requirement: The microcontroller must be able to produce PWM signal from the speed signal given by the controller.

Requirement 2: The microcontroller must be able to understand which DC motors to rotate based from the direction signal given by the controller.

2.2.2 Bluetooth

The Bluetooth chip receives the signals that determine the speed and the direction of movement of the RC car from the controller. These signals are sent to the microcontroller to control the DC motors.

Requirement 1: The Bluetooth chip must be able to communicate over HID (Human Interface Device) with the controller.

Requirement 2: The Bluetooth chip must be able to communicate over UART (Universal Asynchronous Receiver/Transmitter) with the microcontroller.

2.2.3 Controller

The controller allows the user to decide which direction to move the RC car at how fast the user want. It communicates in HID with the Bluetooth chip. There will be two version of the controllers: the smartphone version for prototyping and the VR controller as a final product.

Requirement: The controller must be able to control the speed and the direction of RC car movement.

2.3 Video Transmission Subsystem

The 180 degrees fisheye camera is attached on the front of RC car, which provides the 180 degrees view to the user. The fisheye camera sends the curvilinear image to the microcontroller and the microcontroller transmits the curvilinear image to the VR headset through Wi-Fi.

2.3.1 180 Fisheye Camera

The 180 degrees fisheye camera inputs the image in curvilinear. This need to be converted to rectilinear image so that the view doesn't look distorted to the user, but this will be done on the computer to avoid any delay on the microcontroller.

Requirement 1: The 180 degrees fisheye camera must be able to send the curvilinear image to the microcontroller in RGB.

Requirement 2: The 180 degrees fisheye camera must be able to capture 720p image.

2.3.2 Single-board Computer

The SBC (single-board computer) receives the curvilinear image from the fisheye camera, then transmits to the VR headset through Wi-Fi. Since the curvilinear to the rectilinear conversion takes place in the VR headset, there is no image processing needed to be done on the microcontroller.

Requirement 1: The SBC must be able to communicate over RGB to receive and send the curvilinear image.

Requirement 2: The SBC must be able to communicate over Wi-Fi with IEEE 802.11 protocol.

2.4 VR Headset Facing Direction Subsystem

We need to be able to show the video feed to the user by converting the video from curvilinear to rectilinear and displaying it on a VR headset. The video should be reactive to the movements of the headset and the view should not be distorted.

2.4.1 Virtual Reality Headset

A VR headset that connects to a computer is required to show the video feed to the user. The VR headset should be compatible with the Unity software. Head movements should be tracked, and the appropriate portion of the view must be shown according to the direction the headset is facing. Because a VR headset is relatively expensive, we are planning to lease one from the library which limits our options to Oculus Rift, Oculus Go, Oculus Quest and HTC Vive. We believe Oculus Rift is the best option for this project since it works well with Unity, is wired to the computer and is easy to work with.

Requirement 1: The field of view on the VR headset should be at least 90 degrees.
Requirement 2: Both rotational and linear movements should be detected by the headset and that data should be acquirable in the Unity.
Requirement 3: The display must at least be capable of 720p resolution and 30fps.

2.4.2 Curvilinear to Rectilinear Conversion

Because of the fisheye camera we use, the video will be in curvilinear perspective. The barrel distortion caused by the lens requires rectilinear correction which should be applied in Unity before sending the video to the VR display. In this stage, any other distortions encountered is also fixed to make the video suitable for VR.

Requirement: The video feed displayed on the VR headset should not be noticeably distorted.

2.5 Power Supply Subsystem

A power supply is required to run the entire system while the power is turned on. The battery directly feed voltage to the H-bridge circuit and the voltage regulator. The voltage regulator regulates 5V to the rest of the chips. The controller and the VR headset have separate batteries attached to them.

2.5.1 Battery

The NiMH (nickel metal hydride) battery must be able to keep the circuit working when the power is switched on. Four AA-sized rechargeable NiMH batteries must be connected in series to provide voltage of 5V or higher.

Requirement: The battery must be able to store enough charge to provide at least 200mA at 4.8-6V for 10 hours once fully charged.

2.5.2 Voltage Regulator

The 5V voltage regulator must be able to provide 5V to the rest of chips besides from the H-bridge circuit, the controller, and the VR headset.

Requirement: The voltage regulator must provide 5V±5% from a 4.8-6V source.

2.6 Risk Analysis

The obstacles that will be encountered in this project will probably mostly be related to the VR display. The hardest part of the project will be eliminating distortions caused by the lens before displaying it on the VR headset. We will focus most of our time to perfect the curvilinear to rectilinear transform as well as other transforms needed to rid the video from distortions.

Another challenge is the issue of delay in video transmission. Some amount of lag is inevitable because the communication between the camera and the VR headset is wireless. We plan to eliminate lag as much as possible by limiting the video feed to 180 degrees instead of 360 degrees and doing all the heavy video processing on the PC. Some other steps we might take include sending frames as jpegs or making the video black and white. Additionally, even if the video feed is lagging, we will let the user look around in the latest frame that is received by the PC so the lag will not be nauseating.

3 Ethics and Safety

As with any RC drone or RC car, there arises a problem of users abusing the system to access or view locations which are otherwise off-limits to non-credentialled humans. This could lead to a leak in potentially harmful or confidential data, especially as our project deals with video feed.

Furthermore, our RC car can remain motionless and appear power off while still recording people without proper consent. Even while in motion, bystanders may be unaware of the functions of our product and therefore unaware of their presence on a camera. We can prevent this by flashing the LEDs on the single-board computer every few seconds.

Any time you work with remote systems and batteries, a battery explosion could not only endanger yourself, but also civilians. However, we mitigate this risk by not using Lithium-ion battery, but instead NiMH batteries. Modern NiMH battery contains a safety system that prevent it from over-charging, which can help to prevent from any type of heat explosion [3].

The possibility of losing control of the vehicle or being unaware of your surroundings is very real; while the vehicle will move very slow, the risk of falling off a ledge or a person tripping on it is not trivial. It might bump into a person, but we will minimize the damage to the person by limiting the maximum speed of RC car.

Any VR experience comes with a risk of nausea. VR sickness has symptoms similar to motion sickness and is theorized to be caused by sensory conflict. The duration and severity of the nausea differs from person to person. We will try to eliminate nausea by following VR Best Practices given by Oculus [4].

References

[1] "Virtual Reality Car," Amazon. [Online]. Available: https://www.amazon.com/dp/B076T48JNW/. [Accessed: 13-Feb-2020].

[2] "AR/VR (XR) Discussion," Unity Forum. [Online]. Available: https://forum.unity.com/forums/ar-vr-xr-discussion.80/. [Accessed: 13-Feb-2020].

[3] "BU-408: Charging Nickel-metal-hydride," Charging Nickel-Metal-Hydride Batteries – Battery University, 17-May-2016. [Online]. Available: https://batteryuniversity.com/learn/article/charging_nickel_metal_hydride. [Accessed: 14-Feb-2020].

[4] "Oculus Best Practices Guide," Oculus Developer Website. [Online]. Available: https://developer.oculus.com/design/book-bp/. [Accessed: 13-Feb-2020].