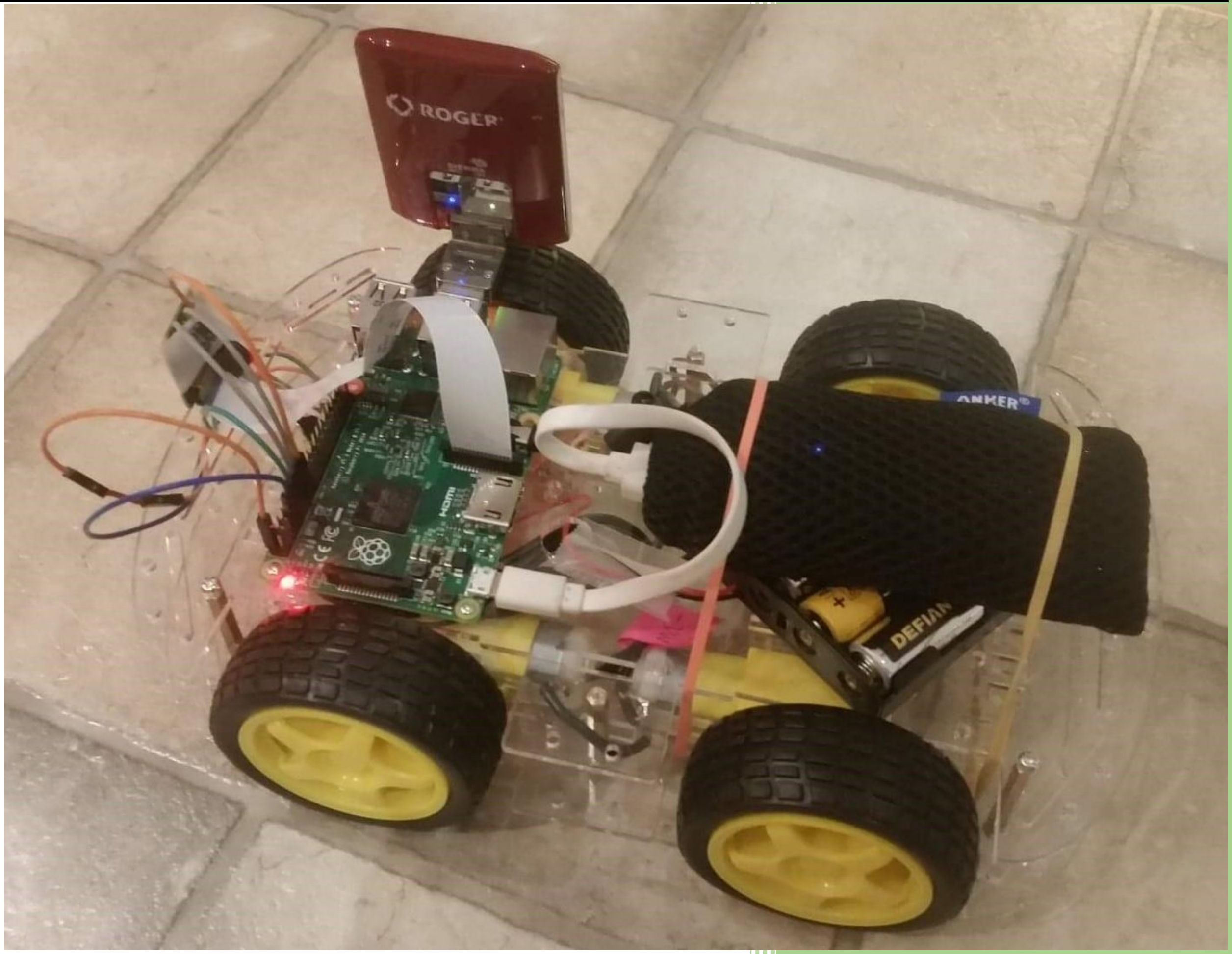
2018

Remote-controlled Camera Robot



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SUMMARY

This report is the outcome of our capstone project named “Remote-Controlled Camera Robot”. This project was completed by students from BCIT’s Telecommunications option in the ECET department. As a completed project, we successfully built a robot car which can be controlled from a web interface through WiFi or a data cellular system. Using a webpage, the user can access commands that allow the robot to move forward, back, and turn. The video feed from the robot is also visible here, and the user can send simple commands to the camera. For example, we can record video, turn on/ off the camera, get picture capture, etc. This project is not only successful according to the technical point, but has also been completed within the limited budget and timeline.

We broke down the project into two parts, which are hardware and software. The hardware part includes a 4-wheel chassis, Raspberry Pi, camera module, WiFi dongle, etc. In the software part, we have used Apache 2, HTML, Java, PHP, PiTunnel, etc. After building the hardware and software part separately, we can now control the robot car with Raspberry Pi, and communicate with it through a webpage.

We have created a very basic robot car which can controlled by a webpage but there are lots of other possibilities to make it more efficient. Such as stronger motors / wheels, a better camera, improvement of the power supply or batteries. These future improvements will be explained at the end of the document in the FUTURE RECOMENDATIONS section.

INTRODUCTION

Humans are not indestructible and sometimes it is better to send a robot in its place. For example, this can happen due to natural disasters or military zones where land mines are present. We want to be able to safely scout out these areas for information or even survivors.

To address these problems, we created a small robot, able to fit in small places and withstand the elements that humans normally cannot. It will be complete with wheels and a camera, all of which can be controlled remotely via Wi-Fi. We also created a webpage that allows a user to control the multi-directional movements and receive video feed from the robot.

BCIT's ECET department always encourages students to do a capstone project in their last term according to the students' interests, or instead, a project from a sponsor. As students of the telecommunication and network option, our group took this project because of our own interest in wireless communication, robotics and data processing. The departmental head of the telecommunication and network option, Ed Casas, and the project supervisor, Robert Trost, closely monitored and guided us to make the project working throughout the term. Our communication instructor, Susan Woo, supervised us to make the documentation for this project.

This documentation will provide enough information to rebuild this project or make any improvement in future. For the hardware part of this project, we have used equipment such as a Raspberry Pi 2B, camera module and 4-wheel chassis. We found lots of open source software such as HTML, Java Script, Apache 2, PHP, and PiTunnel.

We have displayed our budget from BCIT for this project, in Table 1, and our time management, in Table 2. In our block diagram of the project, shown in Figure 2: Block DiagramFigure 2, we can see how the wheels, camera and Raspberry Pi get connected with the webpage.

PROJECT OVERVIEW

The project is mainly focused on programming the Raspberry pi and making the webpage. We also needed to install the car with wheels, motors and some other hardware parts. After we organize the project, we divided the total work into two sections, hardware, and software.

Equipment

Most of this project is made up of programming, but some hardware equipment is also very important to make the full project working. The parts list is listed below, along with Figure 1 showing some sample pictures.

- Monitor, mouse, keyboard
- HDMI cable
- Raspberry pi 2B
- Camera (for raspberry pi)
- Chassis with four DC motors and wheels
- Two Battery Packs: one for powering up the Raspberry Pi and one for driving the motors which is a pack of six AA batteries
- L293D Motor Control Board (H-bridge)
- Wires
- Soldering iron
- Ethernet cable, Wi-Fi dongle, and data connection dongle

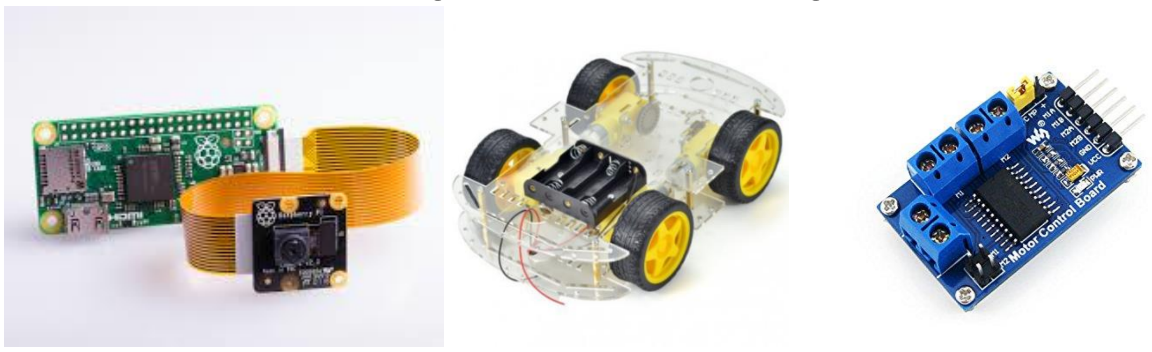


Figure 1: Parts (citations from left to right: [1], [2], [3])

Procedure

1) Get parts
2) Download the required programs onto the raspberry pi and install Python
3) Program commands for wheels to move forwards, backwards, and turn (test with LEDs)
4) Create a web page
5) Program controls on the web page to make the wheels move forwards, backwards, turn
6) Connect the camera to the Raspberry Pi
7) Make controls for the camera on the web page
8) Record video from the pi and send it to the web page

COSTS

After searching various web sites provided by our instructor, we can up with a budget plan. See Table 1 for details on the costs. This changed however, because we found almost all of our supplies from other instructors. We ended up using a Raspberry Pi model 2B instead of the 3B, but we didn't have to spend any money on it. Our only purchase was the 4-wheel chassis combo from Lee's Electronics. [2]

Table 1: Original Costs

Description	Price per unit	Units	Total Cost
Raspberry Pi 3b	$55.00	1	$55.00
Camera with cable	$30.00	1	$30.00
Wheels & Motors	$25.00	1	$20.00
			$105.00

Our budget limitation for this project was $200, which we stayed well under at only $25 for the 4-wheel chassis.

SCHEDULE

This project's final due date was November 27. Therefore, we created a schedule to fit that time frame (see Table 2). All three of us put work into each area as a group in our project labs. The only adjustment we made to our original schedule was delaying the interfacing of the wheels by seven days.

Table 2: Time Schedule

Due Date	Description
Sep 29	Get parts
Oct 3	Software setup
Oct 15	Program wheels
Oct 26	Create web page
Oct 30	Interface wheels with web page
Oct 30	Add turning
Nov 9	Connect and program camera
Nov 23	Include video streaming function to the web page
Nov 26	Final testing

Block Diagram

We are talking about a robot which has motion in 4 directions and are controllable from a distance. For these features, we are using a Raspberry Pi as our central controller to be able to get the user commends through the web interface and send the proper commands to the motors which are controlling the wheels. The overview of the project, shown in Figure 2: Block Diagram, illustrate how hardware and software get connected with each other.

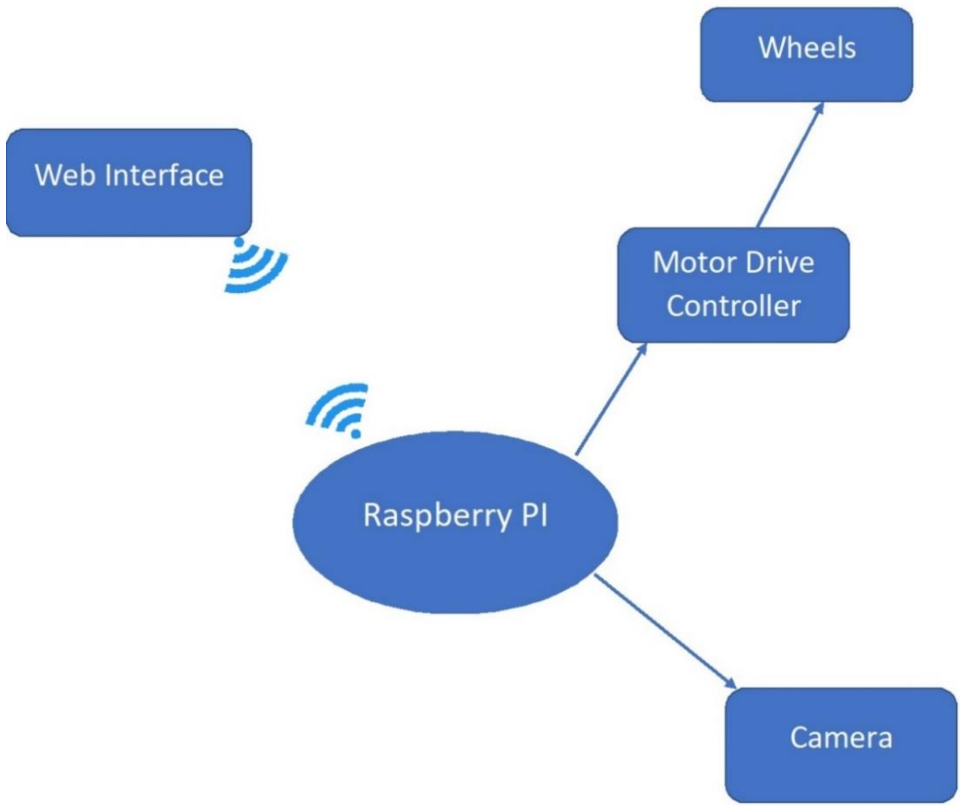


Figure 2: Block Diagram

HARDWARE DETAILS AND INSTALLATION

This section will provide details on the hardware specifications that was used, and also the installation process.

Raspberry Pi

The first step of installing our hardware and starting the project is setting up the Raspberry Pi. We chose Raspberry Pi as our controller because it is a mini computer that is specifically created to make tech learning easier. It is cheap and easy to upgrade and add features to the project later.

It has a lot of components for computer-based projects, like USB ports, an Ethernet port, an SD card slot, Wi-Fi antenna ports, and more. Below, in Table 3: Hardware Components and Specifications for Raspberry Pi 2B are some details of the model that we are using, Raspberry Pi 2B.

Table 3: Hardware Components and Specifications for Raspberry Pi 2B

CPU and Processor	Quad-core ARM Cortex-A7 CPU 0.9 GHz
Memory	1GB SDRAM
Ports	Audio: 3.5 mm jack, Storage: microSD card slot, Network: 10/100 Mb/s
Power	Micro USB DC 5 V 800 mA for the Pi board

There are a few components you will need before you can get started for setting up and coding the Raspberry Pi:

- Power supply for Raspberry Pi you can easily use the Android cellphone charger or lab's power supply. But test the current to be in range to prevent the damage the raspberry
- USB keyboard
- USB mouse
- An HDMI cables
- An ethernet cable (or Wi-Fi dongle)

A connection to the Internet is not required for setup, but many Raspberry Pi projects use them.

- A monitor
- microSD card

The microSD card must have at least 8 GB of storage. You can purchase one that comes pre-loaded with Raspberry Pi's New Out of Box Software (NOOBS), but you can also download the software for free from the website, so there is no need to purchase a special NOOBS microSD card. [4] See APPENDIX A: RASPBERRY PI INSTALLATION for more information on how to set up the Raspberry from scratch.

RPi Camera

The Camera module that we used, shown in Figure 3: RPi Camera Module, is Raspberry Pi Camera Module V2-8 Megapixel,1080p. This section will explain how to install the Raspberry Pi camera module:

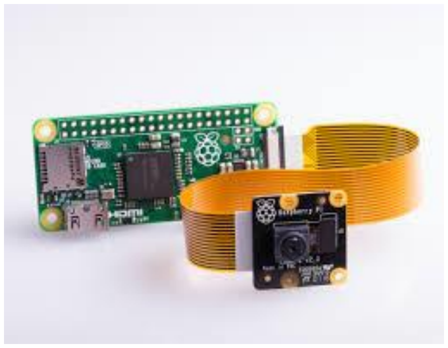


Figure 3: RPi Camera Module

1. This module is sensitive to static electricity. So, you need to discharge yourself before removing the camera from its cover.
2. Insert the Camera module's cable into the Raspberry Pi. The cable slots into the connector situated between the Ethernet and HDMI ports, with the silver connectors facing the HDMI port.
3. Reboot the Raspberry Pi.
4. Run "*sudo raspi-config*" in command window. If the "*camera*" option is not listed, you will need to update your Raspberry Pi: Run "*sudo apt-get update*" and "*sudo apt-get upgrade*" to update it.
5. To check if camera module is identified by Raspberry, Run "*sudo raspi-config*" again. The "*camera*" option should be there now.
6. It is necessary to go to the configuration menu and enable the camera.
7. Reboot the Raspberry Pi

Now it is ready to program.

Wheels and Motors

In this project we are using 4PCs DC Electric Motor 3-6V with 4Pcs Plastic Toy Car Tire Wheel, Mini Smart RC Car Robot Tires.

We connected two motors on one side together, and the same on the other side. In this case all we need is two commands for the robot's motions, meaning that the robot uses 2 pairs of powered wheels. Each pair turns in the same direction. For going forward, we send the forward command to both sides. And the backward command to both sides for going backward. But what about turning? We are using Point Turn Concepts. For turning, the car's one side must go forward while the other side goes backwards.

But we can't connect the motors directly to the Raspberry Pi pins. We need a motor controller board.

What is a motor controller "H-Bridge" and why do we need it?

When we connect the + wire of battery pack on one lead of DC motor and - wire on the other lead, the motor turns. Now if we switch the polarity connections, the motor turns the other direction. For switching the electric polarity, we need H-Bridge board.

In this Project we are using a Waveshare Onboard L293D Dual H-Bridge, shown in Figure 4: Waveshare onboard L293D Dual H-Bridge Motor Control Driver Module. [3] This means we have the ability to control two motors in either direction. Table 4: I/O Diagram for H-Bridge shows the input and output characteristics of the H-bridge.

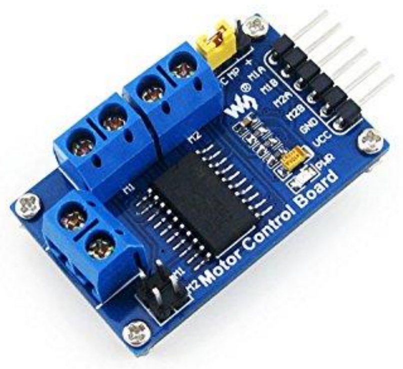


Figure 4: Waveshare onboard L293D Dual H-Bridge Motor Control Driver Module

Features

- Onboard dual H-bridge driver L293D
  Drives 2 DC motors or 1 stepping motor at one time
  600mA output current (peak 1.2A) per single bridge
  ESD protection
- 5V operating voltage, motor drive voltage 4.5V-36V
  Output via screw terminals, easy connection
- Dimension: 43mm*27mm
- Mounting hole size: 2mm
- Storage temperature: -25℃ ~ +130℃

How to use

- M1A/M1B: connects to motors in right side rotation controlling
- M2A/M2: connects to motors in left side rotation controlling
- GND: ground
- VCC: 5V power supply

Table 4: I/O Diagram for H-Bridge

M1A/M2A	M1B/M2B	M1/M2
1	0	Counterclockwise/Clockwise
0	1	Clockwise/Counterclockwise
1	1	Stop
0	0	Stop

Motors and wheels Installation

After gathering the parts, we now needed to solder wires to the motors, and connect them to the H-bridge, and Raspberry Pi.

Step 1: Installing the extra DC Power Supply for Motors

In this Project we are using two power supplies, one for the Raspberry Pi and other one for motors. Each motor needs a DC power supply in the Voltage range of 3-6V. We used the six AA battery Pack to drive our motors.

We learned to NEVER USE RASPBERRY PI's 5V source to drive the motors. We tested them this way which resulted in a burnt Raspberry Pi board!!!!

Step 2: Connector Wires for Driving the Direction on the Motor:

Figure 5: H-Bridge Wiring Diagram shows a wiring diagram of the H-bridge connected to each motor.

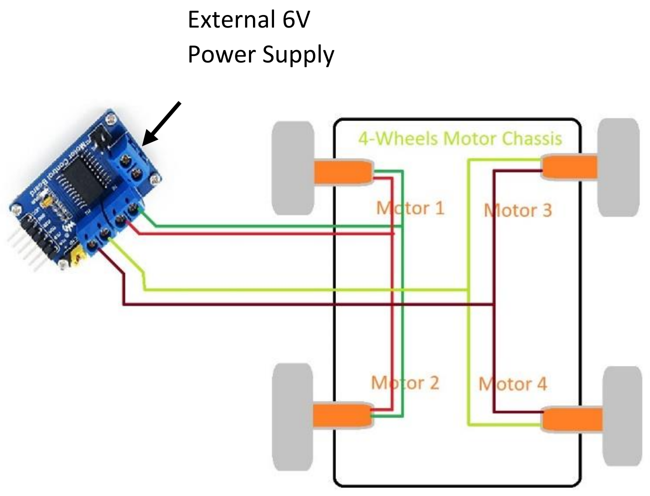


Figure 5: H-Bridge Wiring Diagram

The "GPIO" pins on the Raspberry Pi will be used to trigger the L293D direction.

We needed to attach a jumper wire from the + and MP pins on the H-bridge. This connected our external power supply to our motors. Since the WiringPi pin numbers of the Raspberry Pi are different versus the physical pin numbering we should be careful about wiring the wrong pins. These can be seen in APPENDIX B: RASPBERRY PI PIN It happened that our code was not controlling the motors on/off directions, we figure out that our physical wires connected to the wrong pins different from GPIO in our code.

Troubleshooting

We checked our physical pins, which we expected to be our motor controller inputs, with LEDs to make sure they our code was working properly. Our test setup is shown in Figure 6: Bread board for testing wire connections

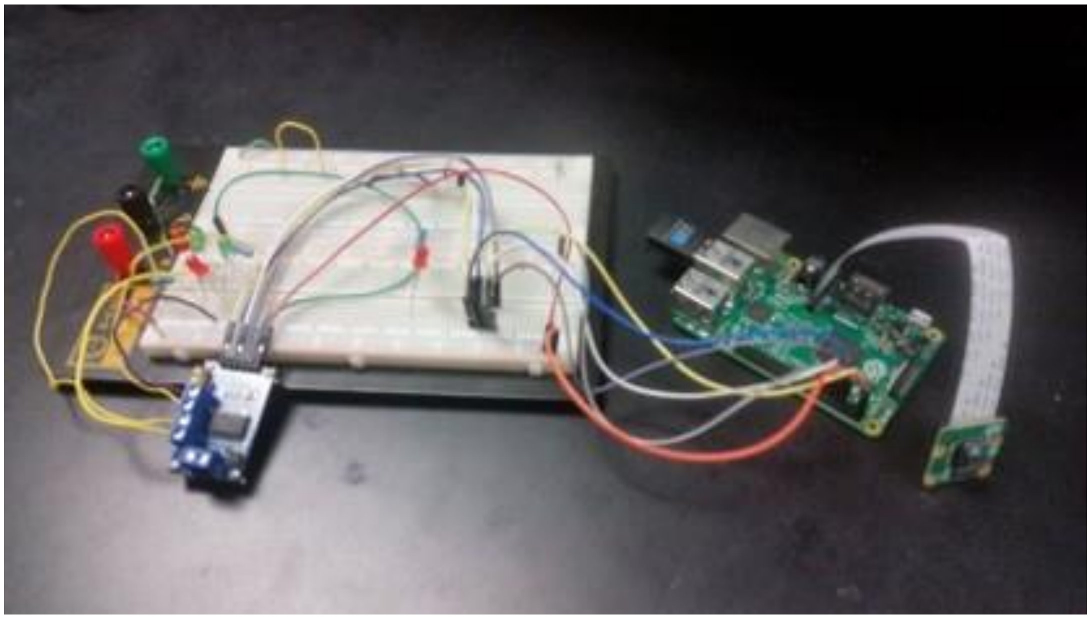


Figure 6: Bread board for testing wire connections

Hardware Problems That We Faced

We faced a number of problems, including burning our Raspberry Pi and connecting to WiFi.

Why Did Our Raspberry Pi Burn?????

Our Raspberry Pi burn as a result of drawing too much current from its GPIO pins. The mistake was connecting the motor pins directly to raspberry pins. Since motors draw more current in compare with LEDs, it is necessary to have separate power supply for motors.

Note that the maximum recommended current draw from the 3.3 V power output pins is 50 mA that is not enough for driving motors.

Cellular Data Dongle

We want our car to be able to go anywhere and still be able to control it from distance, so we needed internet connection. Since WiFi is not available everywhere, our next challenge was using cellular connectivity and data SIM. We used Rogers's network mobile SIM card. The broadband dongle plugs straight into the Raspberry Pi USB port, and allows it to access the internet on the go. We used the following link to help us install the cellular data package: https://blog.soracom.io/beginners-guide-to-iot-cellular-connectivity-on-raspberry-pi-and-linux-devices-55d4f7489adf [5]

Installation of the Data Dongle:

1. First we installed the network-manager package:

```
pi@raspberrypi:~ $ sudo apt-get update && sudo apt-get install network-
manager
```

2. After installing the network manager successfully, we made the 3G Dongle USB connections. We needed to add Rogers' network Access Point Name (APN):

```
pi@raspberrypi:~ $ sudo nmcli con add type gsm ifname "*" con-name rogers apn
ltemobile.apn
```

3. Reboot the Pi

```
pi@raspberrypi:~ $ sudo reboot
```

4. Once the Pi started rebooting, we hot plugged the USB Dongle to the Pi

The Pi is now connected to Rogers' cellular network. Each time a Dongle is plugged in, the Pi is restarted, or connection drops, it will automatically reconnect to the network.

SOFTWARE

After installing Raspbian, we could now add the rest of the software components. While testing the motion for the wheels, we attempted to use Python and Computer Graphics Interface (CGI). This worked initially, however we were unable to make a connection to our server this way. The following, outlines the software that we used in our final product.

The Server

Our original idea was to use a free web hosting server online. Upon experimenting with this, we realized the server required the IP address of the Raspberry Pi in order to communicate with it. This proved to be difficult as the Pi would potentially have a different IP address each time it connects to the internet.

The easy solution was to instead create the server on the Pi itself. We chose apache as our server because it works well with Raspbian and there is lots of helpful documentation online as well. Installation instructions for apache 2 can be found in APPENDIX C: SOFTWARE INSTALLATION

The server can be accessed by typing the local IP address of the Pi into a web browser. At first, we were only able to access the server if we were in the same local area network as the Pi. This issue will be discussed later in the PiTunnel section of this document. It should also be noted that we used JavaScript for our project, so it will need to be enabled on the browser that is being used.

RPi Cam Web Interface

There is an excellent, open-source interface for the Raspberry Pi camera module that can be downloaded from: https://github.com/silvanmelchior/RPi_Cam_Web_Interface [6]
Documentation for this software can be found at: https://elinux.org/RPi-Cam-Web-Interface [7]

After extracting the zip file, the folder needed to be moved into the Raspberry Pi directory: /var/www. Our apache server is set up to run code in this directory by default. Further installation instructions for this software can be found on the website [7] or in APPENDIX C: SOFTWARE INSTALLATION of this document. We will also need to install the WiringPi library, which contains commands for controlling the Pi's GPIO pins. Instructions for this can also be found in APPENDIX C: SOFTWARE INSTALLATION.

This package contains code for a variety of camera features such as low-latency video streaming, recording, motion detection, and even system controls for the Pi, such as rebooting the device. Figure 7: RPi Cam Display displays what will be shown on a web browser whenever the server is accessed from a computer or any other device with internet capabilities.

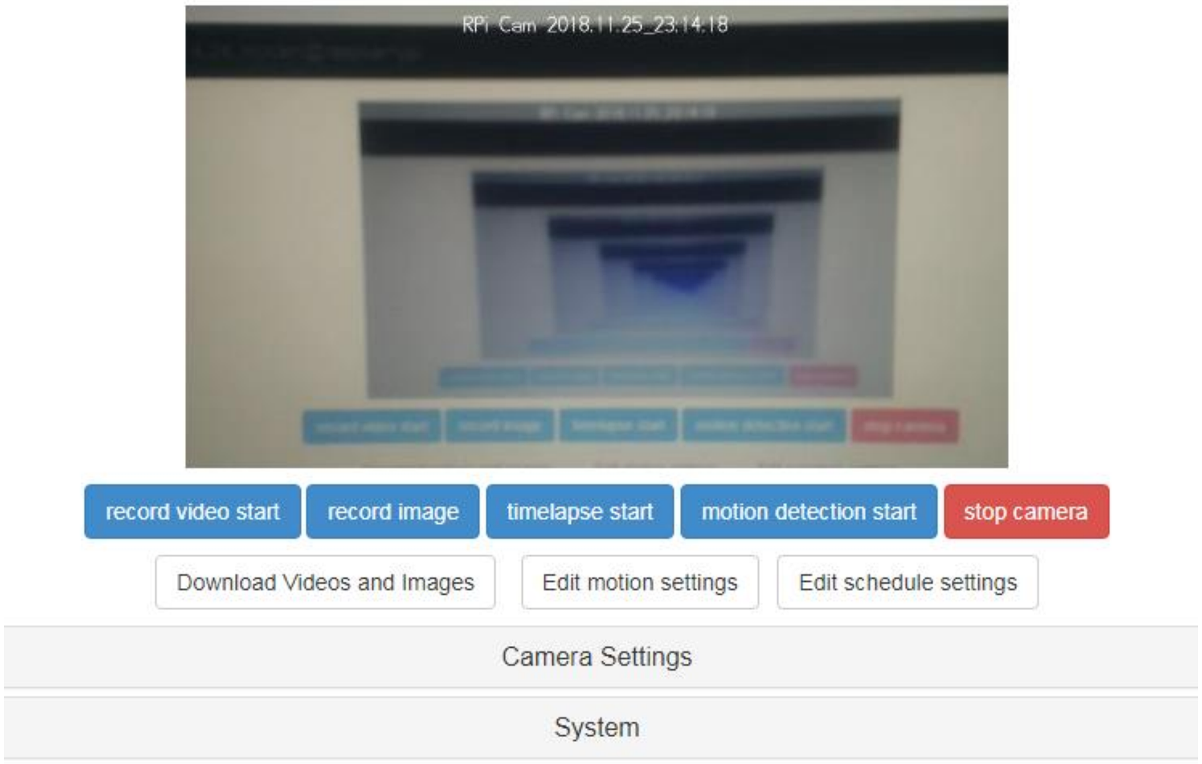


Figure 7: RPi Cam Display

This interface only works with apache, nginx, or lighttpd servers. Additionally, the program is only designed for a Raspberry Pi camera.

Raspberry Pi Permissions

Most files created on Raspberry Pi will only be readable by default. In order to write to and/or execute a file, use the following command:

- chmod -R 777 *filename*

Any additional permissions issues will most likely be solved by typing *sudo* right before the desired command.

Wheels Interface

The code for the RPi Cam Web Interface was written using HTML, JavaScript, and PHP. This influenced us to program our interface for the wheels using these languages as well. Instead of creating new files for our program, it was easier to add our code to the existing files in RPi Cam. Three files were edited in this way and the code added can be seen in APPENDIX D: CODE FOR THE WHEELS.

Index.php contains HTML code to create the visual layout that can be seen in Figure 7: RPi Cam Display We also added a line of text that says: 'Press w,a,s,d to move. To pivot left, press q, pivot right, press e.' This file also calls the functions keyUp() and getKeyPress(), which are defined in the script.js file.

Script.js is a JavaScript file that will contain functions related to user interactions on the web page such as clicking a button. The getKeyPress() function that we added will detect when a user presses a specific key. The keyUp() function detects when a user releases a key. Both functions will set a variable called ‘cmd’ to the corresponding command we want. For example, if the user presses ‘w’, cmd will be set to ‘forward’. We then use the AJAX GET method to send the cmd variable to cmd_func.php.

AJAX (Asynchronous JavaScript And XML) is a useful set of functions that were created to help with web development. It allows us to collect, update, and send data between our web page and server without having to refresh the page. The GET method is one example of a function we can use to send data from our web page to our web server. [8]

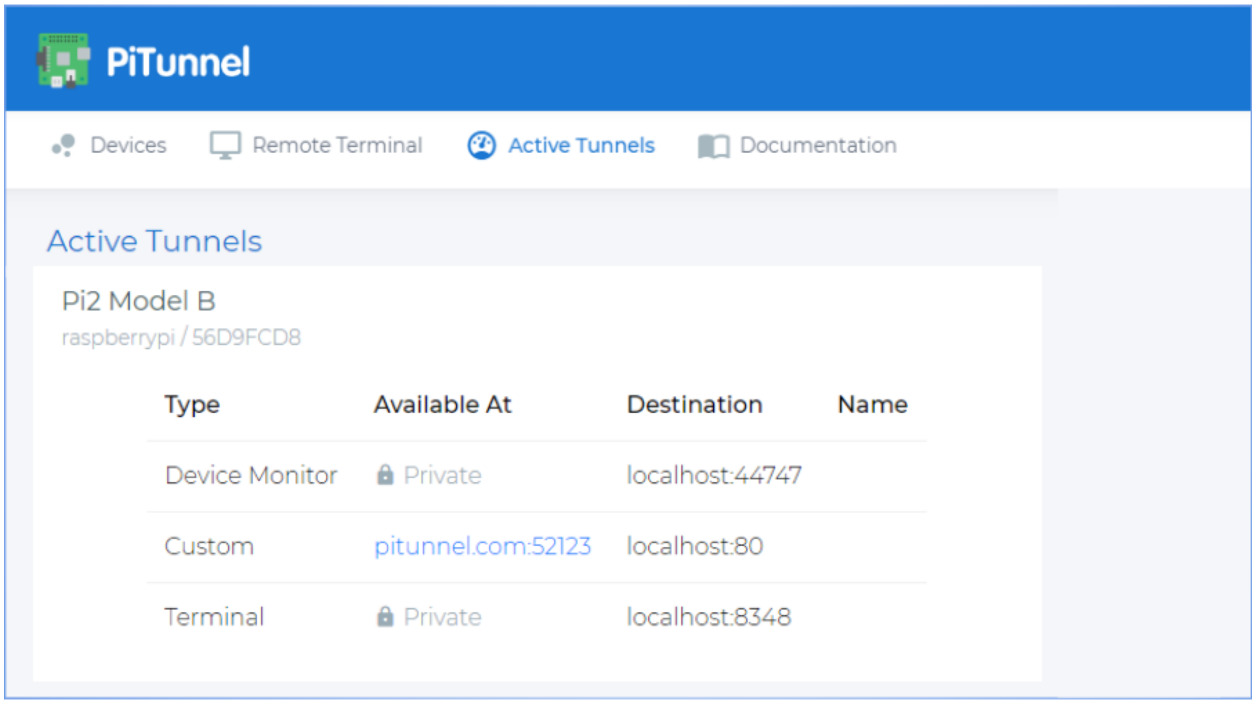
Cmd_func.php contains the code for the various commands we can run, such as moving the car forward. Php is a server-side language, so it allows us to control aspects of the Raspberry Pi (because our server is set up on the Pi itself). As an example, if cmd = ‘forward’, then cmd_func.php will turn on the corresponding Raspberry Pi GPIO pins to make the car move forward. It should be noted that the pins we use for our code are the WiringPi library’s pins. These are different from the Pi’s physical pins. A pinout diagram can be seen in APPENDIX B: RASPBERRY PI PINOUT

PiTunnel

As mentioned earlier, our web server was only accessible from devices that were on the same local area network. The most common solution to this would be to configure port forwarding on the router being used. As we did not have access to the router, we needed an alternative. We found a very useful website to assist us with this issue at: https://pitunnel.com. [9]

PiTunnel uses tunneling, which is a protocol that allows data of private networks to be sent over a public network. This method also gives our data packets encryption, making our data very secure. A free account on PiTunnel provides 100Mb/day of data transfer, which is perfect for a short demonstration. For long-term use, we would need to pay for a monthly subscription.

Figure 8: PiTunnel.com shows an example of what the website looks like.



Active Tunnels

Pi2 Model B

raspberrypi / 56D9FCD8

Type	Available At	Destination	Name
Device Monitor	Private	localhost:44747	
Custom	pitunnel.com:52123	localhost:80	
Terminal	Private	localhost:8348	

Figure 8: PiTunnel.com

To initiate communication to PiTunnel, we followed the installation instructions on the website. These commands can also be found in APPENDIX C: SOFTWARE INSTALLATION of this document. Now, whenever the Pi starts up with internet connection, PiTunnel will create a URL link in the ‘Active Tunnels’ section of PiTunnel.com. For example, in Figure 8: PiTunnel.com, the user may click on pitunnel.com:52123 to bring them to our webpage. The number, 52123, is the port number on PiTunnel that connects to port 80 of the Pi. Each time the Pi connects to the internet, a new port number will be generated.

Another useful feature of PiTunnel is the remote terminal. This provides access to the Pi’s command terminal, without the need of having to connect a mouse, keyboard, and monitor to the Pi.

CONCLUSION

Our goal for this project was create a robot car which can be controlled by a webpage wirelessly and when receiving any command like moving the car or recording video, it will function properly. Although we had some problems like not getting connection from WiFi, burning the Raspberry pi, and accessing the server on a public network, we were able fix all of those problems and make a working project.

FUTURE RECOMENDATIONS

This project has various options for future improvements, that we have listed below:

- Stronger motors/ wheels
- Powerful Battery / Solar Panel attached
- Improve camera quality
- Bluetooth instead of using cellular data/ WiFi
- Mobile App

As we had a budget limitation of $200, the wheels and motors we have used can only run on a smooth surface. Using stronger motors and wheels, the car could run on rough surfaces or climb hills. The battery pack and power bank we have used can only give power to the car for a few hours, but a more powerful battery or solar PV could make the robot run for a longer period of time.

The Raspberry Pi camera module we used could only view directly in front of the robot, but we can improve the robot's vision by adding a pivoting structure and a command to turn the camera independently from the robot. When WiFi or Cellular data isn't available Bluetooth is another option for get connected with the webpage.

We can control the car with any device like a laptop or mobile device but making a mobile app and for this project would be one of the most important features to add in the future.

REFERENCES

[1] Wikimedia Commons, "Raspberry Pi Zero with Raspberry Pi NoIR Camera," 22 March 2018. [Online]. Available: https://commons.wikimedia.org/wiki/File:Raspberry_Pi_Zero_with_Raspberry_Pi_NoIR_Camera_v2.jpg. [Accessed 9 September 2018].

[2] L. Electronics, "ROBOT 4 WHEEL CHASSIS," 17 November 2000. [Online]. Available: https://leeselectronic.com/en/product/100270.html. [Accessed 1 December 2018].

[3] Waveshare, "Motor Control Board," 22 February 2007. [Online]. Available: https://www.waveshare.com/motor-control-board.htm. [Accessed 1 December 2018].

[4] R. Pi, "NOOBS," 15 September 2008. [Online]. Available: https://www.raspberrypi.org/downloads/noobs/. [Accessed 28 September 2018].

[5] A. Susset, "Beginner's guide to IoT Cellular connectivity on Raspberry Pi and Linux devices," 12 May 2017. [Online]. Available: https://blog.soracom.io/beginners-guide-to-iot-cellular-connectivity-on-raspberry-pi-and-linux-devices-55d4f7489adf. [Accessed 1 November 2018].

[6] G. u. silvanmelchior, "silvanmelchior/RPi_Cam_Web_Interface," [Online]. Available: https://github.com/silvanmelchior/RPi_Cam_Web_Interface. [Accessed 1 November 2018].

[7] e. u. Jarrah31, "RPi-Cam-Web-Interface," 10 March 2014. [Online]. Available: https://elinux.org/RPi-Cam-Web-Interface. [Accessed 1 November 2018].

[8] w3schools, "AJAX Introduction," w3schools, 21 March 2000. [Online]. Available: https://www.w3schools.com/js/js_ajax_intro.asp. [Accessed 1 November 2018].

[9] D. Raftopoulos, "PiTunnel," 4 June 2017. [Online]. Available: https://pitunnel.com/. [Accessed 23 November 2018].

[10] PiPinout, "Raspberry Pi Pinout," 8 November 2015. [Online]. Available: https://pinout.xyz/pinout/wiringpi. [Accessed 1 November 2018].

APPENDIX A: RASPBERRY PI INSTALLATION

Most likely the new Raspberry Pi comes with the preinstalled Raspbian operating system on an SD card. If not, the first thing to do is installing it. For this action we need another computer with an SD card reader to install the image.

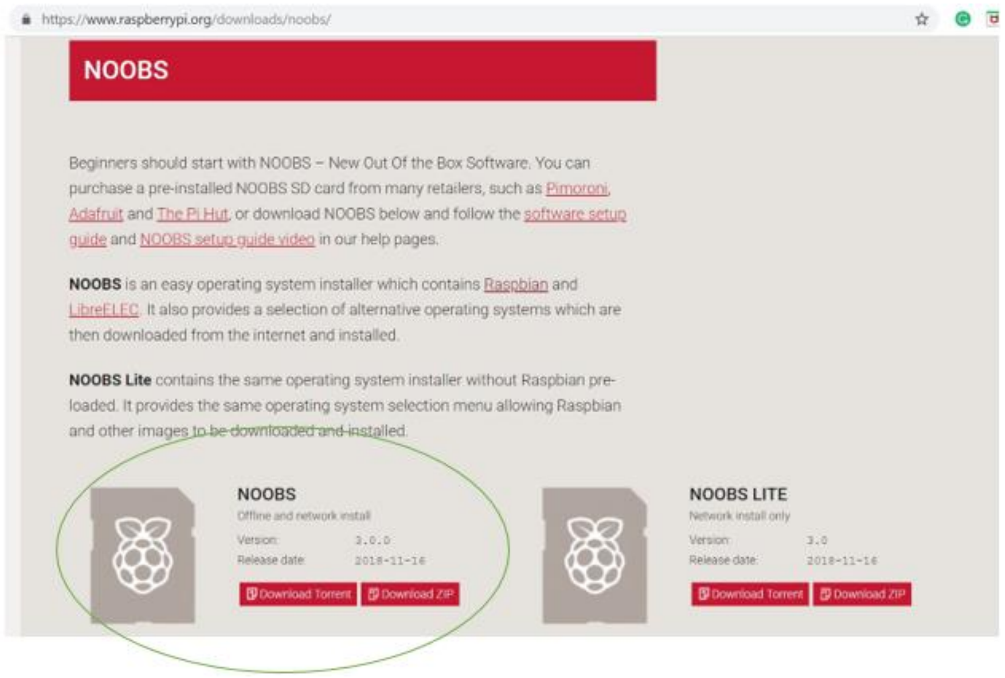
Step 1: Reformat your microSD card

Since we got the Raspberry from a previous project, it had some extraneous files on them. Reformatting it will remove all files and completely clear the card. So, our first step to getting started with our Raspberry Pi was to reformat the microSD card before downloading the operating system on it. So, we need an SD card adapter to be able to use our laptop card reader (if the laptop doesn't have card reader it is easy to simply use the USB card reader as well). Now download an SD formatter and format the SD card.

Step 2: Download NOOBS onto the microSD card

Now it is time to get NOOBS onto the microSD card. We downloaded NOOBS from the Raspberry Pi website: https://www.raspberrypi.org/downloads/noobs/. [4] Below, in Figure 9: Downloading NOOBS shows how the NOOBS website looks like.

Once it's loaded, we could plug it into the Raspberry Pi and configure the operating system. Since we want to use the Raspbian we downloaded the ZIP file of NOOBS Version 3.0.0 and not NOOBS Lite. It is a large file and took a while to complete.



https://www.raspberrypi.org/downloads/noobs/

NOOBS

Beginners should start with NOOBS – New Out Of the Box Software. You can purchase a pre-installed NOOBS SD card from many retailers, such as Pimoroni, Adafruit and The Pi Hut, or download NOOBS below and follow the software setup guide and NOOBS setup guide video in our help pages.

NOOBS is an easy operating system installer which contains Raspbian and LibreELEC. It also provides a selection of alternative operating systems which are then downloaded from the internet and installed.

NOOBS Lite contains the same operating system installer without Raspbian pre-loaded. It provides the same operating system selection menu allowing Raspbian and other images to be downloaded and installed.

NOOBS
Offline and network install
Version: 3.0.0
Release date: 2018-11-16

NOOBS LITE
Network install only
Version: 3.0
Release date: 2018-11-16

Figure 9: Downloading NOOBS

When the download completes:

1. Open the zipped NOOBs folder
2. Select all files and folders
3. Drag and drop all selected NOOBS files into the **SD card**.

Now it's time to plug in the SD card to Raspberry Pi:

1. Right-click on the **SD card icon**.
2. Select **Eject SD Card** to remove the card reader from you PC safely.
3. Remove the card reader from your computer.
4. Remove the microSD card from the card reader.

Step 3: Set up your Raspberry Pi

1. Plug in the microSD card into the Raspberry Pi card slot.
2. Plug the USB mouse into one of the USB ports
3. Plug the USB keyboard into one of the USB ports
4. Connect the Raspberry Pi to the monitor using the HDMI cable
5. Connect an ethernet cable to be able to use the Internet
6. Power up the Raspberry Pi

Step 4: Download the Raspbian operating system on the Raspberry Pi

After Powering on the Raspberry, a start-up screen showed up. We are using the Raspbian operating system:

1. Select Raspbian.
2. Click Install.

The Raspbian installation took a while. Once the installation process is finished, Raspbian automatically began to boot.

Step 5: Configure your Raspberry Pi

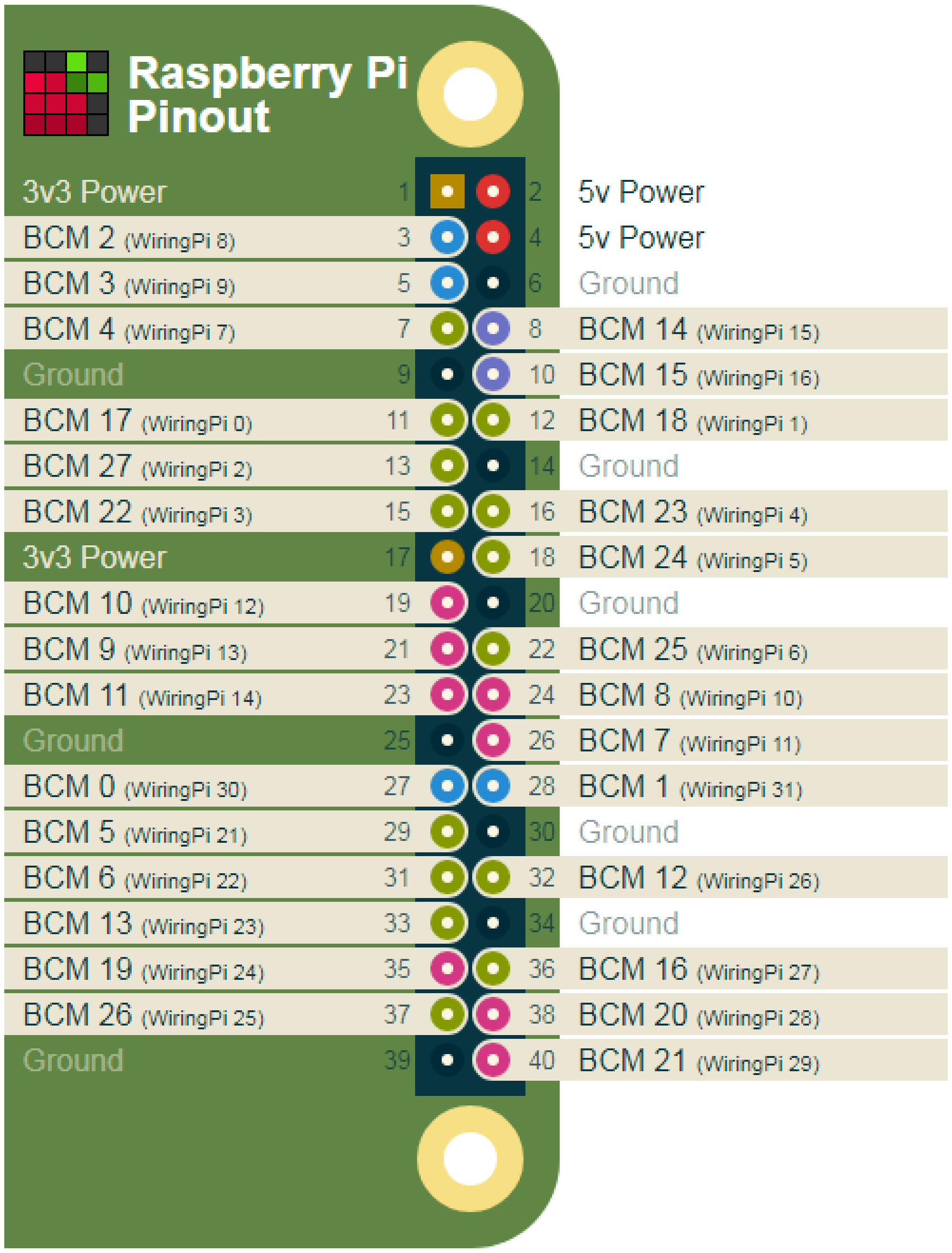
After installing the Raspbian we need to configure the Raspberry Pi system in order to add the location, date, and time. These windows were pup up to setup, but they are accessible through Menu as well:

1. Click Menu in the upper left corner of the screen.
2. Select Preferences in the dropdown menu.
3. Select Raspberry Pi Configuration under Preferences
4. Set the Location, Time zone, and Keyboard language

Now, the Raspberry Pi is ready to use and Program.

APPENDIX B: RASPBERRY PI PINOUT

The Raspberry Pi's pinout configuration can be seen in Figure 10: Raspberry Pi Pinout It is also cross-referenced with the WiringPi library's pinouts. These pin numbers differ because WiringPi was a library originally created for the Arduino microcontroller.



Raspberry Pi Pinout

3v3 Power	1	2	5v Power
BCM 2 (WiringPi 8)	3	4	5v Power
BCM 3 (WiringPi 9)	5	6	Ground
BCM 4 (WiringPi 7)	7	8	BCM 14 (WiringPi 15)
Ground	9	10	BCM 15 (WiringPi 16)
BCM 17 (WiringPi 0)	11	12	BCM 18 (WiringPi 1)
BCM 27 (WiringPi 2)	13	14	Ground
BCM 22 (WiringPi 3)	15	16	BCM 23 (WiringPi 4)
3v3 Power	17	18	BCM 24 (WiringPi 5)
BCM 10 (WiringPi 12)	19	20	Ground
BCM 9 (WiringPi 13)	21	22	BCM 25 (WiringPi 6)
BCM 11 (WiringPi 14)	23	24	BCM 8 (WiringPi 10)
Ground	25	26	BCM 7 (WiringPi 11)
BCM 0 (WiringPi 30)	27	28	BCM 1 (WiringPi 31)
BCM 5 (WiringPi 21)	29	30	Ground
BCM 6 (WiringPi 22)	31	32	BCM 12 (WiringPi 26)
BCM 13 (WiringPi 23)	33	34	Ground
BCM 19 (WiringPi 24)	35	36	BCM 16 (WiringPi 27)
BCM 26 (WiringPi 25)	37	38	BCM 20 (WiringPi 28)
Ground	39	40	BCM 21 (WiringPi 29)

Figure 10: Raspberry Pi Pinout

APPENDIX C: SOFTWARE INSTALLATION

This appendix contains the additional lines of code that are required for installation of the following software. These lines are meant to be directly entered into the Raspberry Pi's terminal.

Apache 2

```
sudo apt-get update
sudo apt-get upgrade
sudo apt-get install apache2 -y
```

PHP

```
sudo apt-get install php libapache2-mod-php -y
```

RPi Cam Web Interface

(After downloading the RPi Cam package from GitHub and moving the extracted folder to /var/www)

```
cd /var/www/RPi_Cam_Web_Interface
./install.sh
sudo /etc/init.d/apache2 restart
```

WiringPi

```
sudo apt-get install git git-core
git clone git://git.drogon.net/wiringPi
cd wiringPi
./build
```

PiTunnel

```
curl https://pitunnel.com/install/JUI0pZcRw | sudo python
```

This next command can be entered in the command line, but if added to the /etc/rc.local file on the Raspberry Pi, it will execute whenever the Pi starts up.

```
pitunnel --port=80 --http --quiet &
```

APPENDIX D: CODE FOR THE WHEELS

Code for the wheels interface was added to existing files of the RPi Cam Web Interface. Shown below is the code we added and which files they were added to.

index.php

This section of code was added after the secondary-buttons section in index.php

```
<div class="container-fluid text-center"></div>
<div class="container-fluid text-center">
<font size="+2"><strong>
<?php echo('Press w,a,s,d to move. To pivot left, press q, pivot
right, press e.');?>
</strong></font>
</div>
<div class="container-fluid text-center"></div>

<script type="text/javascript">
     keyUp();
     getKeyPress();
</script>
```

script.js

script.js can be found in the js folder. These are just functions so they can be added anywhere in the file.

```
function getKeyPress() {
ajax_status.open("GET", "cmd_func.php?cmd=reset", true);
ajax_status.send();

document.onkeypress = function (e) {
     e = e || window.event;
     k = e.keyCode

     if(k == 119){ //w key is pressed
     ajax_status.open("GET", "cmd_func.php?cmd=forward", true);
          }
     else if(k == 97){ //a
     ajax_status.open("GET", "cmd_func.php?cmd=left", true);
          }
     else if(k == 115){ //s
     ajax_status.open("GET", "cmd_func.php?cmd=reverse", true);
          }
     else if(k == 100){ //d
     ajax_status.open("GET", "cmd_func.php?cmd=right", true);
```

```
          }
     else if(k == 113){ //q
     ajax_status.open("GET", "cmd_func.php?cmd=pivot_left",
     true);
          }
     else if(k == 101){ //e
     ajax_status.open("GET", "cmd_func.php?cmd=pivot_right",
     true);
          }
     else {
     ajax_status.open("GET", "cmd_func.php?cmd=reset", true);
          }

     ajax_status.send();
     };
}

function keyUp() {
//when user releases the key, turn off motors
document.onkeyup = function (e) {
     ajax_status.open("GET", "cmd_func.php?cmd=reset", true);
     ajax_status.send();
     };
}
```

cmd_func.php

Script.js will give this file (cmd_func.php) a command to execute. We must first declare the Raspberry Pi pins as outputs at the beginning of the code.

```
<?php
     define('BASE_DIR', dirname(__FILE__));
     require_once(BASE_DIR.'/config.php');

     //important to note, WiringPi library's pin numbers are
     different from Raspberry Pi's physical pin numbers
     system ('gpio mode 4 out');//pin 16 on Raspberry Pi
     system ('gpio mode 0 out');//pin 11
     system ('gpio mode 2 out');//pin 13
     system ('gpio mode 3 out');//pin 15
.
.
.
```

We must also add the forward, reverse, ect. commands inside the function sys_cmd($cmd). This code can be anywhere underneath it using else if statements.

```
//direction commands
else if(strncmp($cmd, "reset", strlen("reset")) == 0) {
     system ('gpio write 4 0');
     system ('gpio write 0 0');
     system ('gpio write 2 0');
     system ('gpio write 3 0');
     }
else if(strncmp($cmd, "forward", strlen("forward")) == 0) {
     system ('gpio write 4 0');
     system ('gpio write 0 1');
     system ('gpio write 2 1');
     system ('gpio write 3 0');
     }
else if(strncmp($cmd, "left", strlen("left")) == 0) {
     system ('gpio write 4 1');
     system ('gpio write 0 1');
     system ('gpio write 2 1');
     system ('gpio write 3 0');
     }
else if(strncmp($cmd, "reverse", strlen("reverse")) == 0) {
     system ('gpio write 4 1');
     system ('gpio write 0 0');
     system ('gpio write 2 0');
     system ('gpio write 3 1');
     }
else if(strncmp($cmd, "right", strlen("right")) == 0) {
     system ('gpio write 4 0');
     system ('gpio write 0 1');
     system ('gpio write 2 0');
     system ('gpio write 3 0');
     }
else if(strncmp($cmd,"pivot_left", strlen("pivot_left")) == 0) {
     system ('gpio write 4 1');
     system ('gpio write 0 0');
     system ('gpio write 2 1');
     system ('gpio write 3 0');
     }
else if(strncmp($cmd,"pivot_right",strlen("pivot_right"))== 0) {
     system ('gpio write 4 0');
     system ('gpio write 0 1');
     system ('gpio write 2 0');
     system ('gpio write 3 1');
     }
```