Manual

samyuktaramnath

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1 Introduction

This manual details how to control the setup of the Roomba interfaced with a Raspberry Pi, which rotates in the direction of a sound and moves towards it, using stereo microphones attached to the Raspberry Pi.

The manual is organized as follows :

1. Required Components
2. Setup of Raspberry Pi
3. Interfacing RPi with Roomba
4. Controlling and Moving the Roomba
5. Audio Source Localization with Stereo Microphone Set
6. Running the whole system

2 Required Components

The components required for the whole experiment are:

2.1 Electronic Components

1. 1 TSR1-2450 Traco Power — Bestell-Nr.: 156673 - 62
2. 7-pin Mini-DIN connector — Bestell-Nr.: 731781 - 62
3. 1 circuit board Bestell-Nr.: 531109 - 62
4. 1 socket row: Bestell-Nr.: 1303422 - 62
5. cable: Bestell-Nr.: 1398078 - 62
6. 10x 1kOhm resistor — Bestell-Nr.: 1089147 - 62
7. 10x 2kOhm resistor — Bestell-Nr.: 405299 - 62

8. 2x Green LEDs — Bestell-Nr.: 180182 - 62
9. 1 Red LED — Bestell-Nr.: 173533 - 62
10. 1 Stereo Microphone set

2.2 Major Components

1. Raspberry Pi 2 Set —Bestell-Nr.: 1317772 - 62 (With Edimax Wifi Adapter, Memory card with Raspbian Jesse Installed)
2. iRobot Roomba 500

3 Setup of Raspberry Pi

The Raspberry Pi, once unpacked, needs to be setup for wireless access. The steps to do the same are detailed below : The Raspberry Pi Model 2 comes with an Edimax Wifi Adapter, 5V wall power adapter, and an 8GB NOOBS memory card with Raspbian Jessie as the operating system installed on it. Upon opening the Pi, one will notice that there is neither a display, nor a keyboard. Hence, there is no way to communicate with the Raspberry Pi the first time it starts up.

3.1 Enable SSH

Required items : USB keyboard (say from a PC), Pi, Wall charger with appropriate adapter Steps to start up the Pi from scratch :

1. Connect the 5V adapter to a plug with a suitable adapter to a wall socket. Confirm that the power LED (green) switches on, and that the activity LED (yellow) does not blink. Disconnect power.
2. Insert the NOOBS memory card with Jessie OS installed on it.
3. Connect a portable keyboard (perhaps from a nearby PC) before connecting the Pi to power. If you have a display, connect the display as well, but it is not needed if you press the down arrow keys correctly as described.
4. Connect the Pi to a wall socket with the 5V adapter. Wait for one minute.
5. Type 'pi', ENTER, and then 'raspberry'
6. Type *sudo raspi-config*
7. Press ⇓ (down arrow key) 8 times and then press ENTER (To reach Advanced Settings)
8. Press ⇓ (down arrow key) 3 times and then press ENTER (To reach SSH settings)

9. Press ENTER thrice and then press ESC
10. Write *sudo shutdown -h now* and wait till the yellow light stops blinking
11. If all is well, SSH should have been enabled, and you can now access the Pi with an ethernet cable.

3.2 Connecting to the Pi via SSH, using Ethernet cable

You can use an ethernet cable to share internet with the Raspberry Pi and assign an IP to the Pi in order to communicate with the Pi.

1. Connect the laptop to a WiFi connection and in settings (for Ubuntu, double click on the network connections icon → Edit Connections → IPv4 Settings → Choose the method as Shared to other Computers).
2. Connect the Ethernet cable to the laptop and to the Raspberry Pi, and connect the Raspberry Pi to the power supply.
3. type *ifconfig* into a terminal on the laptop to find out the Ethernet IP of the laptop. (Mine was 141.24.14.xx).
4. Install the Nmap module on the laptop, by typing *sudo apt-get install nmap*.
5. In the terminal on the laptop, type *sudo -sS nmap 141.24.14.00/24*.
6. The output should show the IP address of the Raspberry Pi. Type *ssh pi@IPaddress* . If all went well, it should ask you for a password, which is 'raspberry'. Enter the password and you should be connected!
7. Now that you are accessing the Pi's terminal, you can try downloading a song using the *wget* (since Internet is being shared from your laptop) and playing it with the Pi's inbuilt audio output. If this works, you're ready to set up WiFi on the Pi!

3.3 Setting up WiFi on the Pi

Now that the Pi is accessible via the Ethernet cable, WiFi can be set up on it. The difficulty was in getting the setup to connect to the Eduroam network. [2]

1. Connect the Edimax Wifi adapter to a USB port on the Pi while it is switched off.
2. Type *sudo service networking stop* to stop networking.
3. On the Pi, edit the */etc/network/interfaces* file with the following content :

```
# interfaces(5) file used by ifup(8) and ifdown(8)

# Please note that this file is written to be used with
    dhcpcd
# For static IP, consult /etc/dhcpcd.conf and 'man dhcpcd.
    conf'

# Include files from /etc/network/interfaces.d:
source-directory /etc/network/interfaces.d

auto lo
iface lo inet loopback

iface eth0 inet manual

allow-hotplug wlan0
iface wlan0 inet manual
    wpa-conf /etc/wpa_supplicant/wpa_supplicant.conf

allow-hotplug wlan1
iface wlan1 inet manual
```

4. On the Pi, edit the */etc/wpa_supplicant/wpa_supplicant.conf* file (keeping in mind to avoid any unnecessary spaces, for example between ssid and = and "eduroam"):

```
ctrl_interface =DIR=/var/run/wpa_supplicant GROUP=
    netdev
update_config=1

network={
        ssid="eduroam"
        key_mgmt=WPA-EAP
        auth_alg=OPEN
        eap=TTLS
        identity="yourID@tu-ilmenau.de" # not the email
            address but the ID
        password="yourPassword"
        phase2="auth=MSCHAPV2"
        pairwise=CCMP
        proto=WPA RSN
}
```

5. Run wpa supplicant by typing :
sudo wpa_supplicant -i wlan0 -c /path/to/wpa_supplicant.conf -B

6. reboot the Raspberry Pi by typing *sudo reboot*.

7. When the Raspberry Pi reboots, the Edimax WiFi adapter should now start blinking. To test whether it has successfully connected to the WiFi network, one can type *ifconfig* in the Raspberry Pi's terminal and check whether the wlan0 section has an IP address.

8. If *ifconfig wlan0* gives an IP address, note it down and disconnect the Ethernet cable, and then type *ssh pi@WiFiIPaddress*. Enter the password 'raspberry' when prompted, and SSH into the RPi wirelessly!

3.4 Sending a Mail with the wlan0 IP address from the RPi at start-up

Now all that's left is to find out the wireless IP address of the Raspberry Pi at start-up and we can do this by sending a Mail from the Pi with the necessary information at start-up.

1. create an email ID for the purpose of receiving IP addresses. (in my case rpiams13@gmail.com . The following instructions work for gmail accounts.)

2. install ssmtp on the RPi by typing *sudo apt-get install ssmtp* in the Pi's terminal.

3. install heirloom-mailx on the RPi: (this took up less space than another similar program, mailutils) by typing *sudo apt-get heirloom-mailx* in the Pi's terminal.

4. edit the /etc/ssmtp/ssmtp.conf file, by adding the lines below:

```
AuthUser=rpiams13@gmail.com # mail ID created for
    this purpose
AuthPass=raspberryams13  # password for the gmail
    account created
FromLineOverride=YES
mailhub=smtp.gmail.com:587
UseSTARTTLS=YES
```

5. Write a shell script to send the mail with the ouput of the ifconfig command to the mail ID : rpiams13@gmail.com (rpiams13@gmail.com sends the mail to itself), save it on the RPi and make it executable.

```
sleep 15
echo "\$(/sbin/ifconfig wlan0)" | mail -s "mail from
    pi(subject of mail)" rpiams13@gmail.com
```

6. Add a cron job to execute at startup:
   type *sudo crontab -e* # edits the crontab file.
   Add the following line at the end of the file:
   @reboot /home/pi/send_mail.sh

7. sudo reboot and check whether the mail has been received at the email ID.

3.5 Syncing the Raspberry Pi with a home PC

It would be advisable to have a repository of programs on a PC and automatically update the programs on the Pi after editing them on the PC. One can do this with the help of the linux command rsync, which allows for remote transfer of files. This command can be saved as a shell script and executed on the Raspberry Pi.

```
rsync −avuz −−delete−after
    NameOfHostComputer@AddressOfHostComputer:
    pathToFolderWithCodesHostComputer/∗
    pathToTargetFolderOnPi
```

4 Interfacing Raspberry Pi with Roomba

Now that the RPi has been set up for wireless access, it must be interfaced with the Roomba. The Roomba has a 12V power output, while the RPi requires a 5V power input. The voltage converter from Traco Power performs this voltage conversion. The Rx and Tx pins of the Roomba supply 5V, whereas the RPi operates on 3.3V for its Tx and Rx pins.

The circuit to be soldered onto the Raspberry Pi is detailed with the help of the blog entry at the DKØTU blog by G.Schuller, Simple 5V Serial Interface for Raspberry Pi 2 and 3 [1]

The circuit for the same is given in figure 1, obtained from [1] and modified:
The pin diagram of the Raspberry Pi 2 is given in figure **??** : [1]

4.1 7 Pin Mini-DIN connector

The 7-pin Mini-DIN connector must be connected by wires to the appropriate pins on the Roomba. This manual has a pinout for the 7 pins on page 3. The relevant pins are : pin1/pin2, pin3,pin4,pin5/pin6. Note that the pinout diagram shows the pinout of the top view of the Roomba where pins 5,6,7 and towards the bottom of the Roomba, so one must be careful to note this while soldering the relevant wires onto the 7 pin Mini-DIN connector.

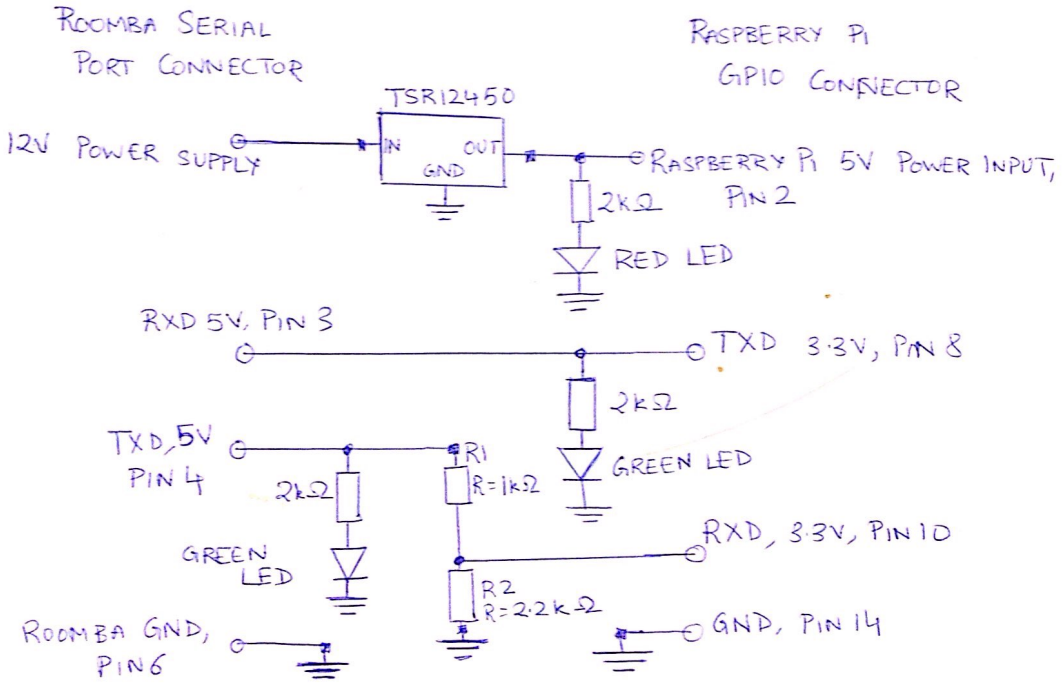

Figure 1: Circuit for Raspberry Pi - Roomba interface

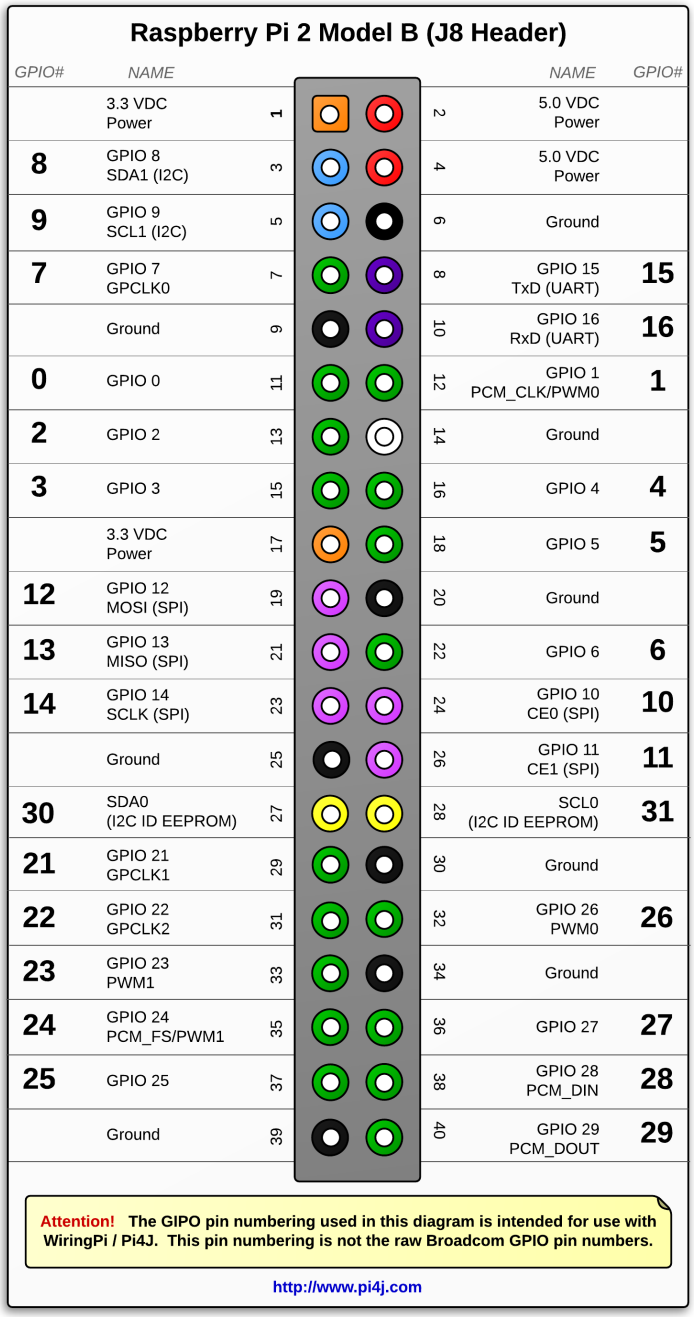

Figure 2: Raspberry Pi 2 pinout

5 Controlling and Moving the Roomba

Directions to control the Roomba are given in [3] : serial interface with Roomba The Roomba is operated by sending byte opcodes for startup. The startup could be in a number of modes : Passive (which doesn't accept any new commands), Safe (which accepts commands but keeps the safety features such as bump sensors working), and Full (which allows full control of the Roomba).

The Roomba has been set up in the safe mode so that lifting the Roomba stops it from moving at any time.

The control sequence for operating the Roomba is :

1. open the serial port for the Raspberry Pi to communicate with the Roomba
2. Start command : opcode [128]
3. Set Mode: Safe (opcode: [130/131], Full (opcode : [132])
4. To Move the Roomba: Serial sequence: [137] [Velocity high byte] [Velocity low byte] [Radius high byte] [Radius low byte]
   (a) To move the Roomba in a straight line : Radius : 32768 (0x8000)
   (b) To rotate the Roomba counterclockwise : Radius : 1 (0x0001)
   (c) To rotate the Roomba clockwise : Radius : -1 (0xffff)
5. To stop the Roomba sequence : [137] [0] [0] [0] [0]

The Roomba can be moved by a particular angle or moved forward by a particular distance by using the velocity and python's inbuilt timing capabilities. The library of functions to startup, rotate the Roomba by a particular angle or move ahead by a particular distance, and to stop, is included in the appendix and the folder.

6 Audio Source Localization

A stereo microphone set (left and right microphones)is connected to the Raspberry Pi via a USB sound card. The signal from the microphone is read using PyAudio, which returns a single array of values, of length of the specified block. The left and right channel signals are interleaved in the read array, which means that each alternate value belongs to one channel. Separation is done by separating the odd and even values in the array. The flow of the program is shown in fig 4 :

The top view of the Roomba shown in fig 3.

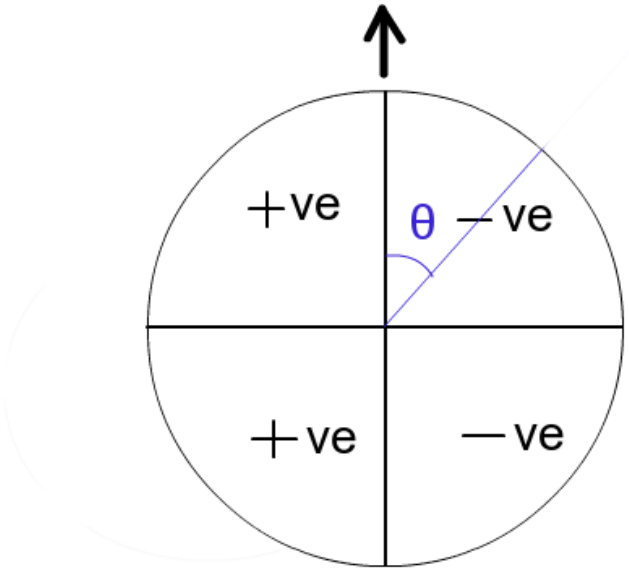

Figure 3: Top view of Roomba

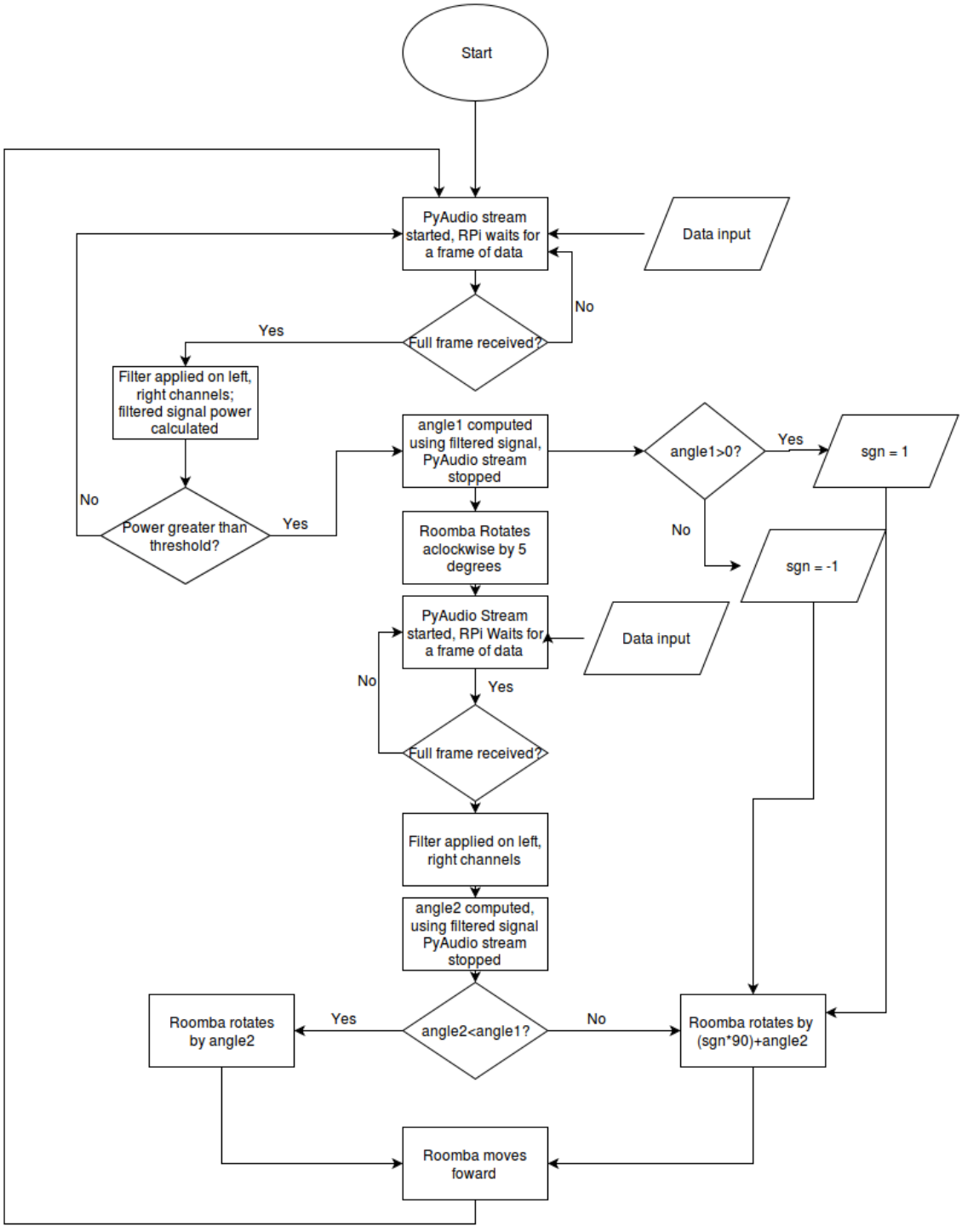

Figure 4: Software Flowchart

7 Running the Whole System

The steps for setting up and running the whole system are:

1. Make sure the Roomba is sufficiently charged.
2. Set the microphones on a ruler at about 15cm apart, place them opposite each other on a diameter so they look like 'ears' for the Roomba.
3. Connect the microphone set to the Raspberry Pi, via a USB sound card.
4. Connect the Edimax Wifi adapter to the Raspberry Pi.
5. Set the Raspberry Pi at an appropriate place on the Roomba, and connect the RPi to the Roomba via the 7 pin Mini-DIN connector.
6. Wait a few seconds for the Raspberry Pi to turn on, wait for the Edimax Wifi Adapter to start blinking. Check the email address to which the RPi sends its WLAN IP address.
7. Open a Linux terminal on the host PC (Ctrl-Alt-T). SSH into the Raspberry Pi wirelessly, by typing:
   ssh -X pi@WLANIPAddress.
8. Enter the password when prompted to (raspberry). (It would be advisable to change this from the default).
9. Once you have logged into the Pi, move to the relevant folder. In the case of this specific Pi, type
   cd Documents/pythonCodes
10. Switch on the Roomba by pressing the main button, a sound will alert you that it is on and ready to receive commands.
11. In the terminal, type *python correlationCheckrpi2.py*
12. Wait for a few seconds, and say something. The Roomba should move towards you. It is important to keep the sound source in the same position, it works better when the source is closer to the ground, and it may not come towards the voice immediately, but may take multiple steps to do so.
13. If any changes are made in the code, the final step is to type the following commands:
    cd Documents/pythonCodes
    ./getFromRemote.sh This will update any changes to any of the codes made in the folder. (Make sure that the Folder name on the computer is appropriately named, in my case it is Documents/PythonCodes/RaspberryPiCodes on the host PC. This needs to be updated in getFromRemote.sh).

References

References

[1] G. Schuller. "Raspberry Pi Serial Interface." *Raspberry Pi Serial Interface.* N.p., n.d. Web. 01 Dec. 2016. *https://www.dk0tu.de/blog/2016/06/25_Raspberry_Pi_serial_Interface/*

[2] Price, Will. "Eduroam on the Raspberry Pi." *Eduroam on the Raspberry Pi.* N.p., n.d. Web. 01 Dec. 2016. *http://www.willprice.org/2014/03/17/eduroam-on-the-raspberry-pi.html*

[3] "Irobot ® Roomba 500 Open Interface (OI) Specification". N.p., 2016. Web. 15 Dec. 2016.