

Video Acquisition README

By: Zachary Carey

Introduction

This document will act as a complete user and set-up manual for the Pritzker Marine Laboratory's Multiple Raspberry Pi Camera Recording System. This is a system of ten raspberry pi cameras mounted above the flume tank at the Pritzker Marine Lab. These ten cameras are mounted inside a sealed 3-D printed box, which is then mounted to a rafter above the tank. The raspberry pi's are powered via a micro-USB cable, and data will be transmitted via a CAT 5+ ethernet cable all wired together via the rafters to access points away from the tank. Data is transmitted between the host computer and the raspberry pi's using a network switch and Secure Shell Protocol (SSH). Each of the steps discussed have detailed set-up instructions below, right up to saving and playing the videos and timestamps on the host computer.

Materials List

- 10 Raspberry Pi (3 model B+)
- 10 Picamera (Raspberry Pi NoIR Camera V2)
- 10 Micro-SD Cards (32GB)
- 10 Raspberry Pi and Picamera 3-D printed case
 - 3-D Printer
 - Filament
 - Screws (M2X5 and M2X3)
 - Rubber Grommet (1-1/8" Outside & 5/8" Inside Diameter)
- 1 Network Switch (24-Port Gigabit Desktop/Rackmount Switch, TL-SG1024D)
- 10 Ethernet Cables
 - 75ft (5) and 50 ft (5)
- 10 Micro-USB Cables
 - 10 Micro-USB Extensions (Male to Female, 10 ft)
- PVC Board (1" x 3" x 8')
- Threaded Rods (3/8")
- Wing nuts (3/8")
- Cable Ties
- Concrete Anchors (1-3/4")
- Silicone (Advanced White silicone)

Setting Up a New Raspberry Pi and Pi Camera

This project used a Raspberry Pi 3 (model B+) and associated Pi Camera (Raspberry Pi NoIR Camera V2) along with a 32GB micro-SD card. For setting up the raspberry pi first the operating system must be installed on the micro-SD card. To do this place the micro-SD card of interest into a micro-SD to SD converter if your control computer has an SD port just insert the setup converter. If your computer does not have an SD port you may have to convert micro-SD to USB or another port based on the computer. The simplest way to install the Raspberry Pi OS is to download the Raspberry Pi Imager to the host computer, download found as Link 1 in the “Links” section. Follow the steps in Link 1 and once the Raspberry Pi Imager is installed on the computer, open the app, something like Figure 1 should pop up. Click the box on the left stating “CHOOSE OS”, a drop down menu will appear, select “Raspberry Pi OS (32-bit)”. Click the box on the right stating “CHOOSE STORAGE”, another drop down menu will appear, select the name of the micro-SD card. The program will warn you but anything selected as the storage device will be wiped (all files deleted) before installing the OS, which is why it is crucial to make sure the micro-SD card is selected. Once all the details are confirmed press the button labeled “WRITE” and once a pop up confirms that the OS is installed you can eject the micro-SD card and it is ready for the raspberry pi.



Figure 1: Displays what the Raspberry PiOS installation software for the Micro-SD looks like. This image is taken from Link 1

Now that the Raspberry Pi OS has been installed on the micro-SD card the raspberry pi can go through its initial setup. This will require the micro-SD card, the micro-USB power cable, an HDMI cable, a TV/monitor, a USB mouse and keyboard. Just to orient ourselves with the raspberry pi unit Figure 2 displays a labeled raspberry pi unit. Once comfortable with the layout, follow these setup instructions closely, plugging in devices out of order could damage the equipment. First insert the micro-SD card in the slot. Secondly, plug in the USB mouse and keyboard. Next make sure the TV/Monitor is on and the correct input is selected, then plug in the HDMI cord. Note: all of this setup is done before because the raspberry pi lacks a power button, once connected to the power supply it's running, make sure that the raspberry pi is unplugged when not in use or when adding or removing cables. The natural final step is connecting the micro-USB power supply cable.

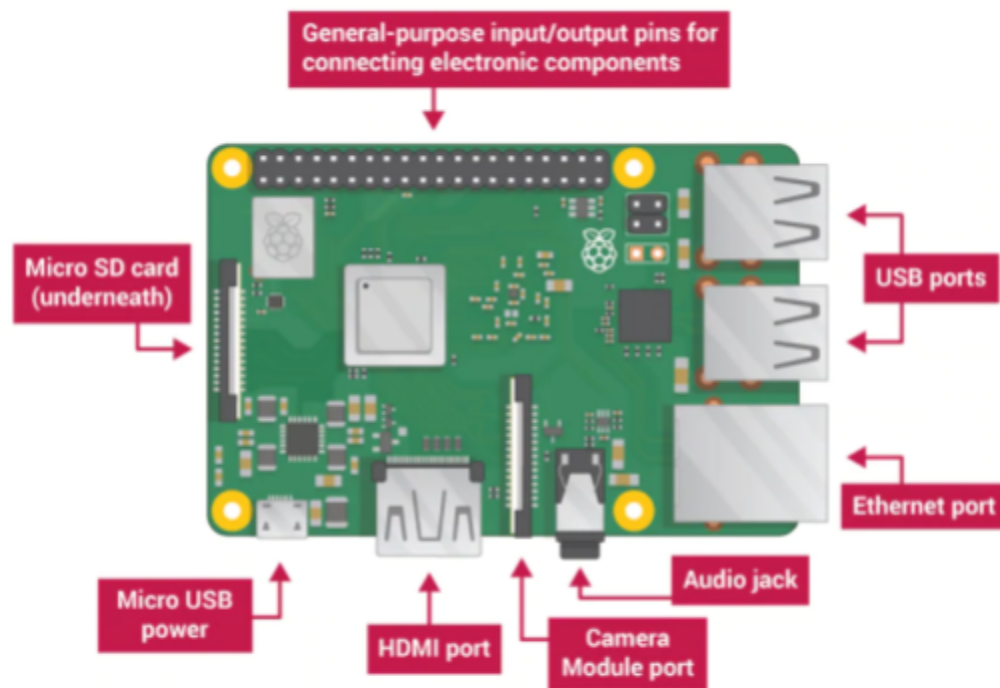


Figure 2: Displays a labeled diagram of a Raspberry Pi subunit. This image comes from Link 14.

Once this cable is connected lights should appear on the board and raspberries may appear on the TV/Monitor (screen). The first time setting up the raspberry pi a popup on the screen titled “Welcome to Raspberry Pi” will appear, select the “Next” button. In the new popup set your Country, Language, and Timezone, then click on the “Next” button again. The new popup will ask you to set a new password, and explain that the current username is “pi” and

password is “raspberry”, once a new password has been selected click on the “Next” button again. Now connect to your wireless network by selecting its name, entering the password, and clicking on the “Next” button again. In this penultimate popup just click the “Next” button and allow it to search for updates, once completed the final popup will appear asking you to restart if an update was found. Click on the “Restart” button and once restarted the raspberry pi is fully operational. For a more detailed walkthrough of setting up a new raspberry pi use Link 2 in the “Link” section.

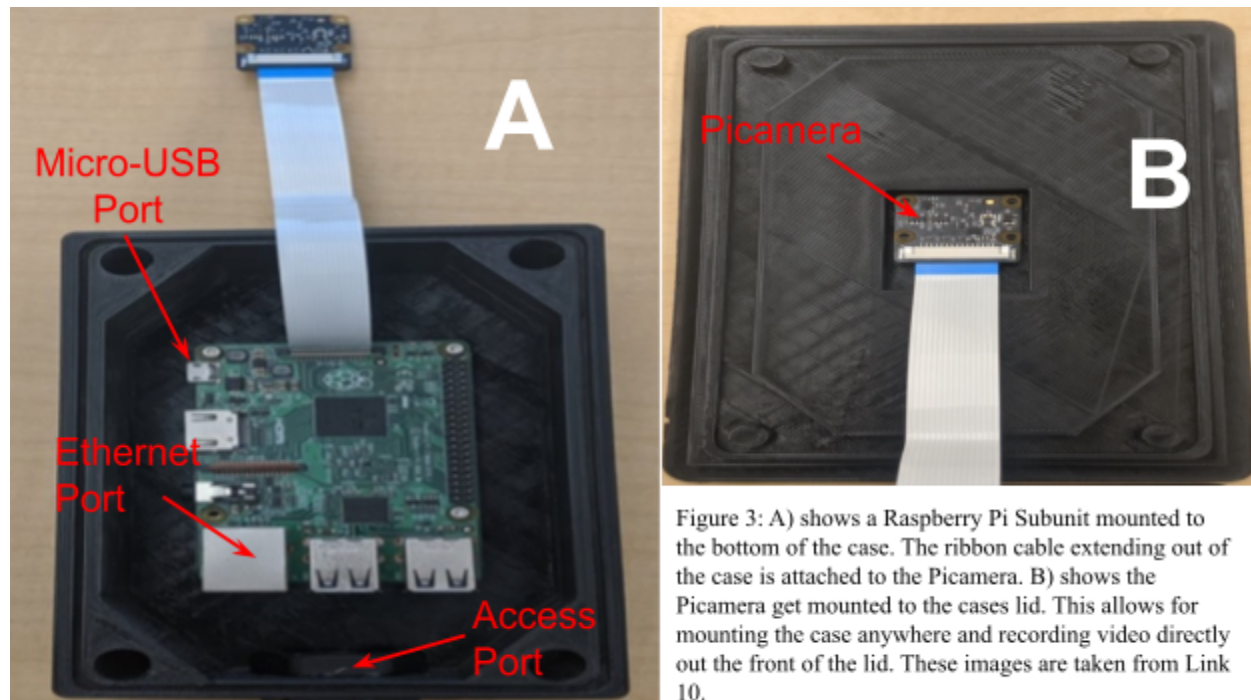
Now that the raspberry pi is operational the camera can be installed. Primarily locate the “Camera Module port” labeled in Figure 2. Notice the port has a black plastic clip, gently pull this clip up. You should see that one side of the port has contacts and one side of the pi camera ribbon cable has connectors. Make sure these contacts and connectors are facing each other when you push the end of the ribbon cable into the port. Push the black clip back down and the raspberry pi camera is officially installed. For a really good step by step gif of this use Link 3 in the “Link” section.

3-D Printing Sealable Case for Raspberry Pi and Pi Camera

For this application, over water, a system to protect the raspberry pi and camera had to be developed. This box had to not only be able to completely seal, but still have a clear port for the pi camera to view out of and a large port for the necessary cable to exit.

A model Raspberry Pi case was found at Link 10 and printed by Dr. Caitrin Eaton of New College’s Computer Science Department. Once printed the longer (M2X3) screws were used to attach the Raspberry Pi to the base of the case and the shorter (M2X5) screws were used to attach the Picamera to the lid. Figure 3 below shows what the Raspberry Pi (Figure 3A) and Picamera (Figure 3B) look like when mounted in the case. Once mounted a rubber grommet was inserted into the side access port to allow complete waterproof protection and wire access.

At this point all that's left to do is plug in the male portion of the Micro-USB extension and the ethernet cable into their respective ports of the Raspberry Pi subunit via the side access port. Once all wires are connected, the rim of the base is coated with a small amount of silicone and the lid is snapped on. The outer edge of the lid-base joint is also coated with enough silicone all the way around to seal the joint completely. These cameras are now sealed and prepared for mounting and wiring above the tank.



Mounting the Cameras in Cases Above the Tank

This was more challenging than expected due to the ceiling above the flume tank being concrete and quite close to the open top of the tank. The 3-D printed camera boxes have no way of being screwed into the concrete ceiling, so a more innovative solution to mounting was found. The idea was to create a long narrow rafter in the middle of the tank that the cameras could be zip tied to, as well as the cables. The rafter would be made of multiple long PVC boards (1" x 3" x 8"), and supported to the ceiling using concrete anchors (1-3/4"), threaded rod (3/8") and wingnuts (3/8"). Small primer holes were drilled into the ceiling (both in the middle of the tank and equidistant apart) and the concrete anchors are screwed into said holes. Once the anchors are in place each anchor gets a section of ~4 inch threaded rod screwed into the anchor. The PVC boards are then aligned with the threaded rods and their location marked on the PVC board so holes can be drilled through the board. Once done align the holes in the PVC boards with the threaded rods and push the PVC board all the way up to the ceiling (flush with the anchor). Attach the PVC board to this location by using wingnuts and washers to tighten down on the board via the threaded rod. Once the entire rafter is tightened to the ceiling cameras can be attached to it. Cameras are attached via two zip ties to the rafter and all associated wiring is run

around rafters to two access points. A mounted camera looks like Figure 4, while the entire mounted camera setup can be seen in Figure 5.



Figure 5: Displays what all 10 cameras look like mounted in the ceiling above the flume tank. For reference the flume tank is directly below in all these photos just cropped out for ease of viewing the rafter system.

Installing Necessary Programs on the Control Computer

There are a few required programs for the control computer to have installed in order to be able to use this system. This section will be broken down into underlined subsections providing instructions on how to install and set up the subsections program. General use of these programs will be explained in the sections to come.

PuTTY

PuTTY is the program that will be used to control actions in specific raspberry pi's terminal using SSH. To install PuTTY follow Link 4 in the "Links" section, or search "download

PuTTY”. Once on the website follow the instructions to download basic PuTTY based on your operating system. Once downloaded, double click the file and follow the onscreen instructions to install PuTTY. Once installed, open PuTTY to make sure it opens. It should look something like Figures 6 and 7.

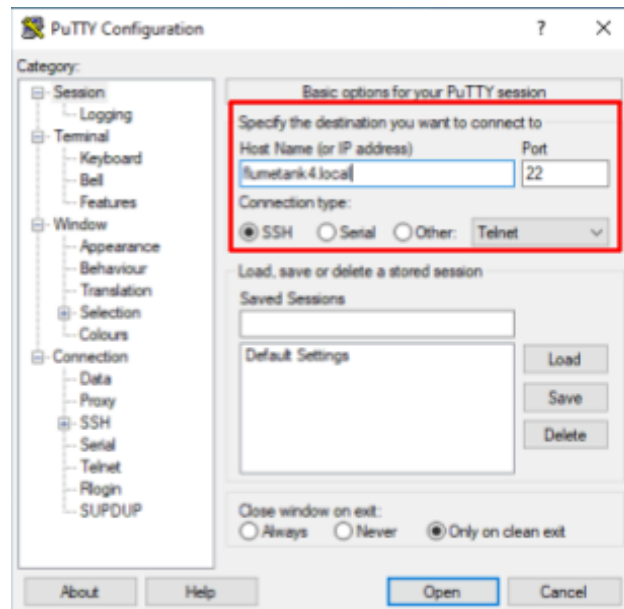


Figure 6: This is what PuTTY looks like upon launch. To sign into a Picamera via SSH enter the “Hostname.local” in the Host Name bar. The port information should autofill, after selecting SSH. The red box shows where all this information is to be entered.

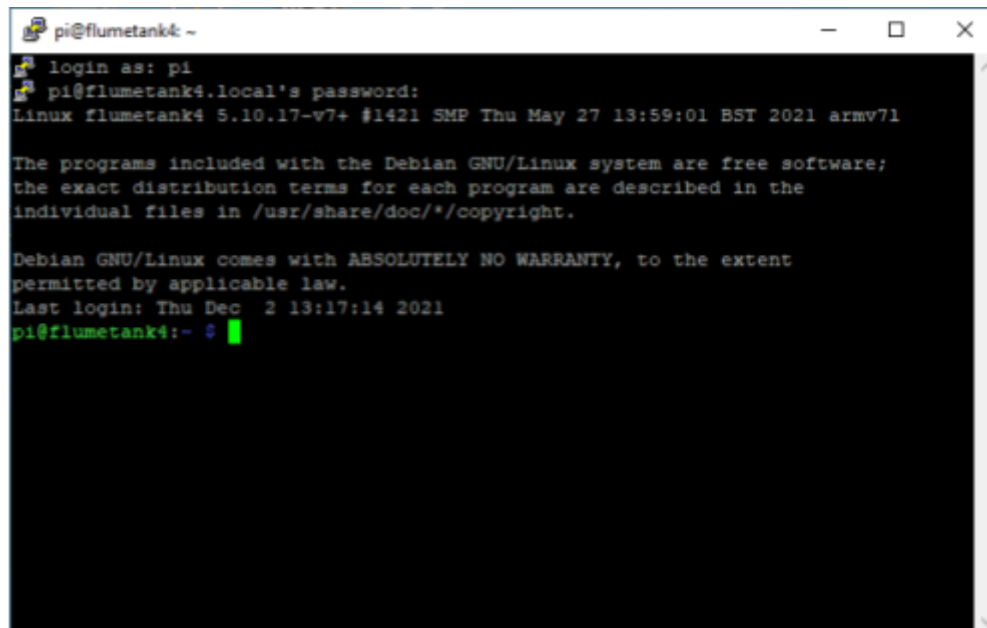


Figure 7: This is what PuTTY will bring up if connection to the Raspberry Pi was successful via SSH. For the Picamera set up at the Pritzker Marine lab enter Pi as the username and hit “Enter”, then enter the password from the Cheat Sheet and hit “Enter”. Once complete something similar to the green line of code should appear.

MTPuTTY

MTPuTTY does the same thing as PuTTY except it has the ability to control multiple raspberry pis at once by essentially opening each one in a new tab. To install MTPuTTY follow Link 5 in the “Links” section, or search “download MTPuTTY”. Once at the website follow the download instructions and choose “MTPuTTY INSTALLATION PACKAGE” to download. After this has downloaded, double click the file and allow MTPuTTY to install. After installation is complete, open MTPuTTY to make sure it opens. It should look like Figure 8.

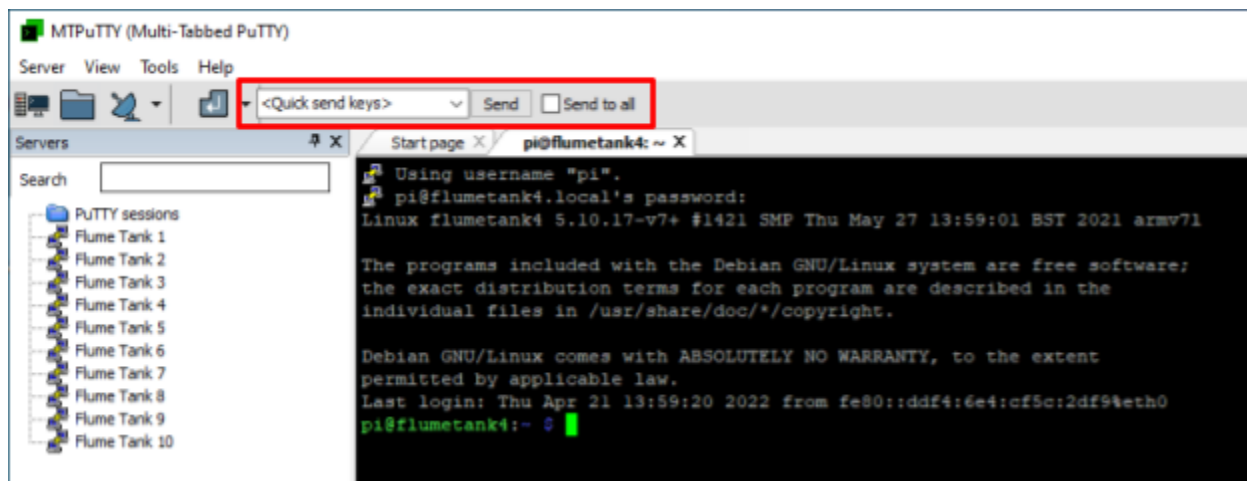


Figure 8: The only difference between MTPuTTY and PuTTY is the ability to open multiple instances of PuTTY as tabs in a window. This program will allow for the simultaneous recording of video on all 10 cameras. Inside the red box is a space where commands can be entered to send to all open tabs in the window at once. To do this select the “send to all” checkbox and enter the line of code like normal in the box titled “<Quick send keys>” and hit “Enter” all the code will run on all opened Picameras simultaneously.

WinSCP

Both WinSCP and PuTTY use SSH but WinSCP is used to move files between the control computer and the raspberry pis. To install WinSCP follow Link 6 in the “Links” section, or search “download WinSCP”. Once at the website follow the download instructions. After this has downloaded, double click the file and allow WinSCP to install. After installation is complete, open WinSCP to make sure it opens. For a more detailed installation guide follow Link 11 in the “Links” section.

Use SSH with PuTTY to Install Python 3.3.0 on Raspberry Pi

This section will serve both as a guide to the basics of using PuTTY and instructions to install Python 3.3.0 on the raspberry pi using PuTTY or MTPuTTY.

PuTTY Basics

One of the primary rules for being able to use PuTTY or any other SSH based program is that the desired raspberry pi/s must both be plugged into the power supply and into the network switch via ethernet cable. Note: the control laptop must also be connected to the network switch via an ethernet cable.

Logging into a Raspberry Pi

Once everything is connected and turned on, open the PuTTY program on the control computer. If you've been following this guide and have not yet changed the host name of the raspberry pi enter "raspberrypi.local" in the "Host Name (or IP address)" bar, otherwise enter the created hostname for the raspberry pi here. Next select the button to the left of "SSH" and finally click "Open". This may have a pop up about it being the first time connecting to this device just select the "Yes" button and a terminal like window will pop up. The first line should state something like "Login as:", next to it type the username (unless changed the username is "pi") and hit the "Enter" key. If the correct username was entered, a new line will pop up stating (If using standard host and usernames) "pi@raspberrypi's password:", input the password (unless changed the password is "raspberrypi"). If the correct password was entered you are officially logged into the raspberry pi.

Raspi-config and Changing Hostname

One of the important things to remember when working with multiple identical raspberry pis is that they need to have different hostnames to be accessed simultaneously via the same network switch. To do this follow the login instructions above, and once logged in enter "sudo raspi-config" in the terminal and hit the "Enter" key. A popup window like Figure 9 should appear. This is the raspi-config window, in which you can change everything and anything about the raspberry pi including connecting to WiFi and changing the password or hostname. Using the

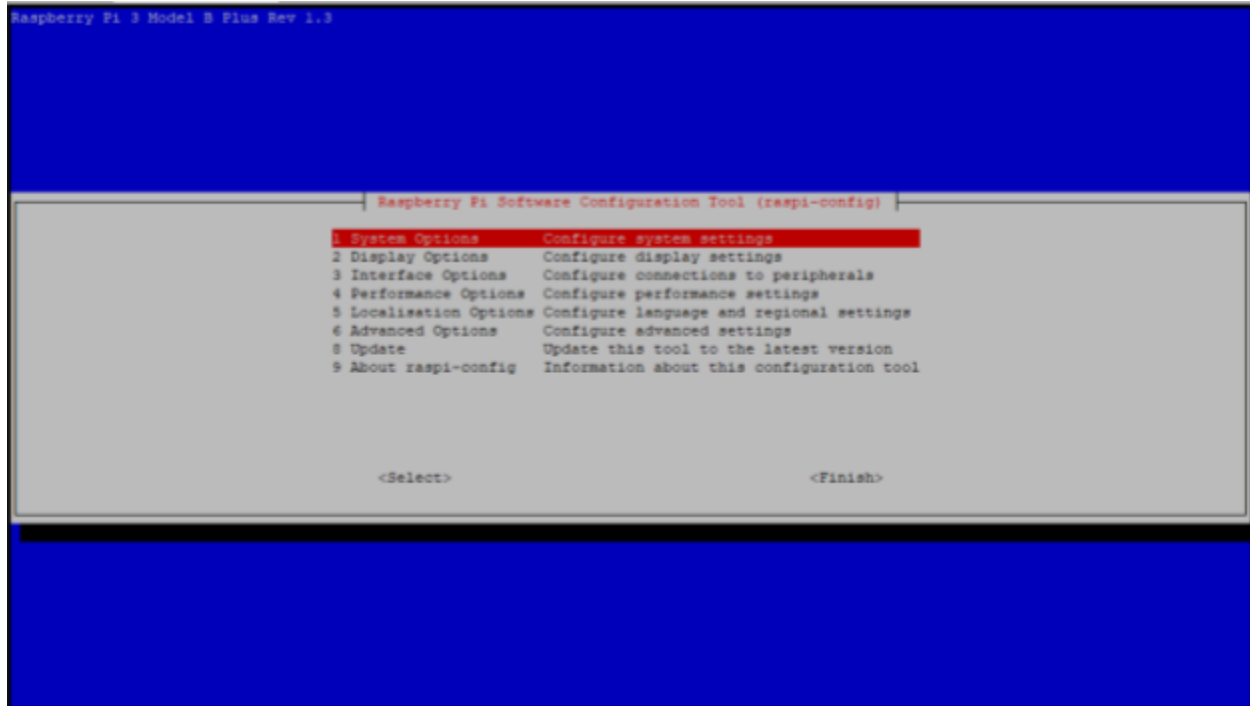


Figure 9: This is what the raspi-config interface looks like. Use the arrows and enter key to navigate the menu and select portions of the menu (respectively).

arrows select “Network Options” and hit the “Enter” key. Now select “Hostname” and hit the “Enter” key, this should popup a window with a textbox containing the hostname, replace or edit to the hostname in this textbox to change the hostname of the raspberry pi. Once satisfied with the selected hostname select “Ok” and hit the “Enter” key, and then select “Finish” and hit the “Enter” key. This should prompt you to reboot (restart) the raspberry pi, select “Yes” and hit the “Enter” key. After the raspberry pi restarts the hostname for PuTTY should be whatever you entered in that box earlier “.local” (e.g. “raspberrypi.local”). More detailed documentation is available at [Link 7](#) in the “Links” section.

Install Python 3.3.0 on the Raspberry Pi

To install Python 3.3.0 start by going to [Link 8](#) in the “Links” section. On this page right click on “Gzipped source tarball” and choose “Copy link address” from the browser popup menu. Now open PuTTY and login to the desired raspberry pi, and in the first line type “wget” followed by the copied link and hit the “Enter” key. When the terminal will allow you to type

again type the following on the line “tar -zxvf Python-3.3.0.tgz”, and hit the “Enter” key. Once that has finished type “cd Python-3.3.0” on the line and hit the “Enter” key to change directories to the newly downloaded python library. Type “./configure --enable-optimizations” in the new line and hit the “Enter” key to run the configuration command. Finally type “sudo make altinstall” in the new line and hit the “Enter” key. Once completed python 3.3.0 should be installed on the raspberry pi. Test this by restarting and re-logging into the raspberry pi and in the terminal type “python 3.3 --version” and hit the “Enter” key. A line printing the version should appear below the command line.

Use WinSCP to Move Files from Control Computer to Raspberry Pi

Another important part of this multi-pi camera system is the skill to move files from the control computer to each individual raspberry pi. This system requires the addition of a folder to each raspberry pi to generate the ability to produce the “timestamp file” and the “.h264 video file”. This folder is called “PicameraLibraryModified” and will be accessible in my GitHub in Link 9 in the “Links” section. This is a modified version of the “PicameraLibraryModified” folder created by Saxena et al. (2018).

To upload this folder to each raspberry pi download the folder from Link 9 to the control computer. Once downloaded, open WinSCP on the control computer, make sure the desired raspberry pi is powered on and connected to the control computer the same as for PuTTY. Now enter the hostname of the raspberry pi in the box titled “Host Name”. WinSCP also gives you the option to input the username and password, input these now for ease (if unchanged username = “pi”, password = “raspberrypi”) and click the “Login” button. A popup showing the login process should appear and once the login is complete it will disappear revealing the WinSCP window. In this window you will notice something that looks like two tabs, and each tab looks like a file explorer. The left tab is a file explorer for the control computer, and the right tab is the file explorer for the raspberry pi. To move the desired folder from the control computer to the raspberry pi, navigate to the folder containing “PicameraLibraryModified” on the control computer. Now on the right tab navigate into the single folder shown, this is where the “PicameraLibraryModified” folder will be copied. Right click on the “PicameraLibraryModified” folder in the control computer tab and select copy, then hover the mouse over empty space in the right tab and right click and select paste. The folder should now

be copied over into the raspberry pi. Examples of what the WinSCP program looks like during sign in check Figures 10 and 11.

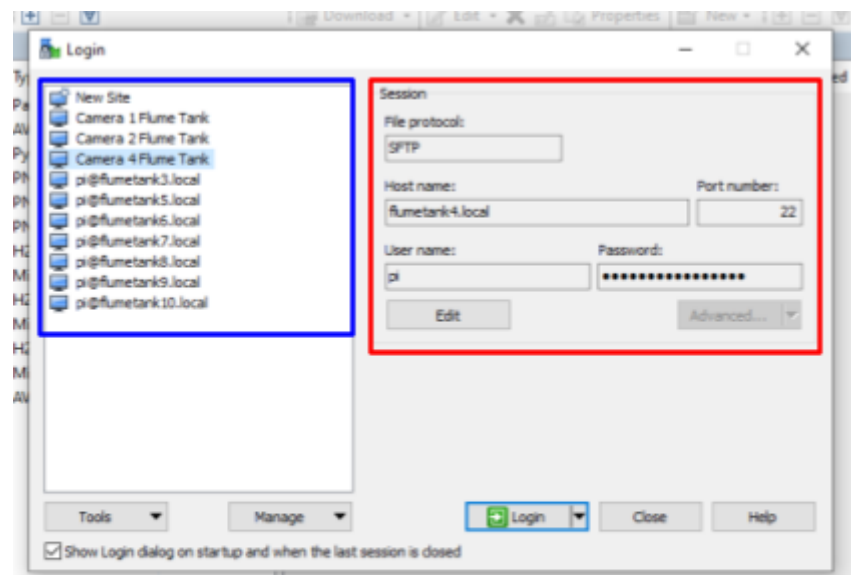


Figure 10: Shows what launching WinSCP should look like on the control computer. The red box shows where the same login information used to gain access via PuTTY should be entered for WinSCP. The blue box shows all the saved Picamera logins, which makes it easier to login to these Picameras later. Note: the majority of the window is cropped out to show the details in this small pop out.

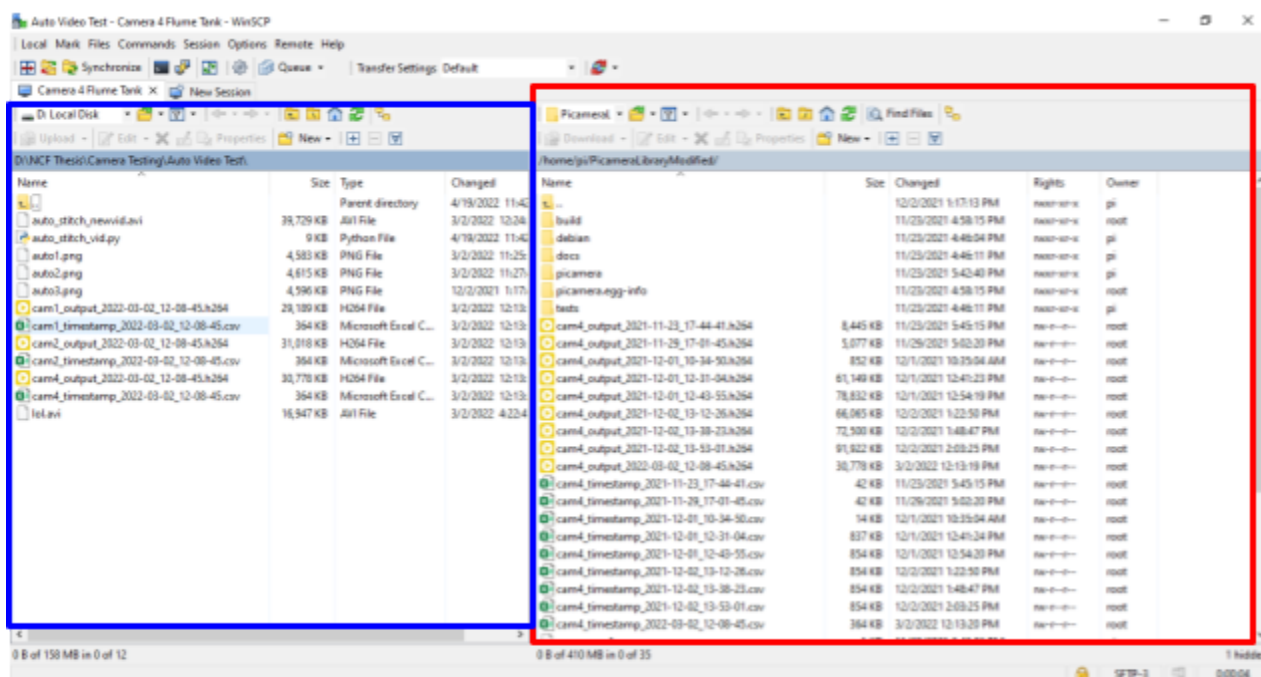


Figure 11: Displays what WinSCP looks like once logged in. The red box on the right is defined as the right tab in the discussion or the side for the Raspberry Pi “file explorer”. The blue box on the other hand is the “file explorer” for the control computer. Moving files between the red box and the blue box will transfer files in that direction (red to blue, or vice versa) to the destination Pi or computer.

Use MTPuTTY to Acquire Video on Ten Pi Cameras Simultaneously

Before continuing to attempt to record video footage, make sure that all the required steps above are followed for all raspberry pis. If anything is missing the program may crash or throw an error.

Start by connecting all raspberry pis to the network switch via their ethernet cables, and connect the control computer to the network switch as well. Now plug in the power sources for all the raspberry pis, and open MTPuTTY on the control computer. Hover the mouse over the symbol under the “Server” drop down menu (symbol looks like a desktop and monitor), something saying “Add server” should appear under the mouse, click this symbol. In the new popup window type the hostname in the slot titled “Server name”, also select the button corresponding to “SSH”. MTPuTTY also gives the option to login from this popup, input the username and password now for ease (if unchanged username = “pi”, password = “raspberrypi”) and click the “OK” button. This raspberry pi is successfully logged in, repeat these steps for all 10 raspberry pis.

Once all raspberry pis are signed on, you will notice that MTPuTTY places each raspberry pi’s “terminal” in a different tab. If you want to do something with only one raspberry pi, then treat that tab like a PuTTY window and enter commands like normal. If you want to do something with all the raspberry pis simultaneously MTPuTTY allows you to do this with the bar on the top of the screen to the left of “Send”. By writing the desired line of code in this bar followed by hitting the enter key that line of code will be run on all open tabs of MTPuTTY.

To record a video on all 10 cameras, we first need to switch all the directories to the one where “StartAcquisition_gpio.py” is located. If no changes have been made to the folder “PicameraLibraryModified” then the file should be here. To change all directories at once enter “*cd PicameraLibraryModified*” in the previously discussed bar and hit enter. All the open tabs should switch directories to this folder.

Once in the correct directory it's time to record video on the raspberry pis. In the same bar enter the following line of code:

```
“sudo python3.3 StartAcquisition_gpio.py -hr 0 -m 10 -s 20”
```

Where the amount of time the raspberry pi will record for is defined by the three numbers in the line of code. The values are defined as follows: hr is the number of hours, m is the number of minutes and s is the number of seconds. Hit the “Enter” key and the recording should start on all cameras simultaneously. After the amount of time entered has elapsed both a “.h264” video file and a “.csv” timestamp file are saved in the same location as the “StartAcquisition_gpio.py” file on each raspberry pi.

Save both the Timestamp and Video Files to Control Computer

To save the timestamp and video files use the WinSCP software to access the files on each individual raspberry pi. Change to the correct folder in the raspberry pi and copy the desired file to the control computer. Follow the instructions for using WinSCP to change folders and copy files. Repeat this for each raspberry pi.

How to Play a .h264 File on the Control Computer

First, Install Potplayer found in Link 12 of the Links section. Next open the Downloaded file and follow the setup instructions either onscreen or follow the instructions in Link 13 from 1:07 - 2:07 in the video. Once the install is completed, right click on the desired “.h264” file to play, select “Open With”, select “PotPlayer (64-Bit)”. The file should open in PotPlayer. Windows may ask to set this as the default app to open “.h264” files. If you set PotPlayer as the default you can just double click on “.h264” files to play them in the future. Installing PotPlayer will allow the control computer to play “.h264” files.

Links

1. <https://www.raspberrypi.com/software/>
2. <https://thepihut.com/blogs/raspberry-pi-tutorials/the-raspberry-pi-tutorial-beginners-guide>
3. <https://projects.raspberrypi.org/en/projects/getting-started-with-picamera/2>
4. <https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html>
5. <https://ttypius.com/downloads/>
6. <https://winscp.net/eng/download.php>
7. <https://www.raspberrypi.com/documentation/computers/configuration.html>

8. <https://www.python.org/downloads/release/python-330/>
- 9.
10. <https://www.thingiverse.com/thing:3950645>
11. <https://winscp.net/eng/download.php>
12. <https://potplayer.daum.net/>
13. <https://www.youtube.com/watch?v=eUthpHtT1bk> (1:07 - 2:07)
14. <https://thepihut.com/blogs/raspberry-pi-tutorials/the-raspberry-pi-tutorial-beginners-guide>
- 15.

Cheat Sheet

This Cheat Sheet serves as a quick manual to be used whenever trying to use the Picamera recording system at the Pritzker Marine Laboratory.

Primary Setup

1. There are three sealed bags of cables hanging outside the flume tank Figure CS 1 below.



Figure CS 1: Shows the three bags of cables, two of which on the table one suspended in another location on the same side. The two bags on the table mainly contain and waterproof the ethernet cable (the exception of three power cables in the rightmost bag). While the suspended bag is mainly filled with power cables.

2. Open all the sealed bags being very cautious with the sharp implement used to cut through the taped “neck” of the bag. (Figure CS 2)



Figure CS 2: Shows the use of a razor blade to cut through the taped neck of the bag. Be very cautious to not cut through the rubber of the ethernet cables, make small cuts in tape slowly to prevent this.

3. Connect power and unpack the control laptop
4. Retrieve the Network Switch from its indoor secured location (Currently in Pritzker 118)
(Figure CS 3)



Figure CS 3: Shows the network switch in its box and the control laptop plugged in and ready to go.

5. Unbox the contents of the Network Switch box shown in Figure CS 4

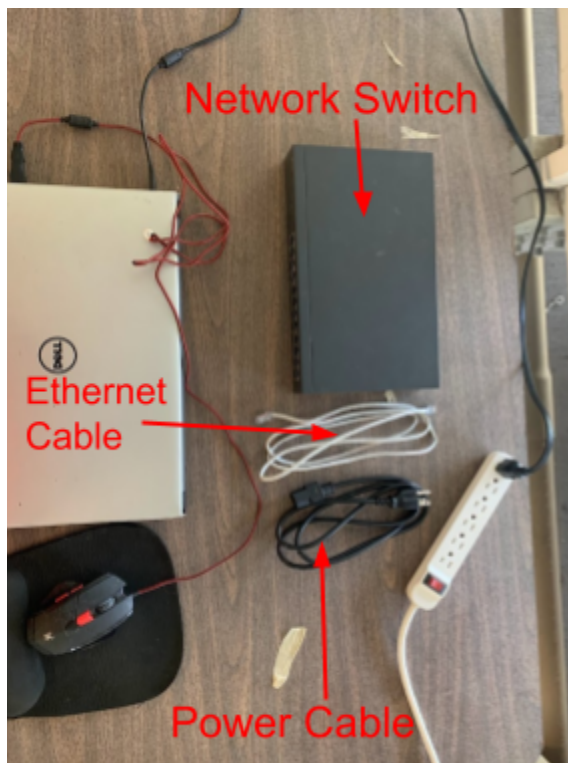


Figure CS 4: Shows all the contents of the network switch box.

6. Plug the Network Switch's power cable into the back (Figure CS 5)



Figure CS 5: Demonstrates connecting the network switch to power.

7. Plug in the white ethernet cable between the control computer and network switch (Figure CS 6)



Figure CS 6: A) shows the white ethernet cable being connected to the network switch. B) shows the other end of the white ethernet cable being plugged into the control computer

8. Next Connect all the Blue (Picamera) Ethernet cables into the network switch like the example 3 in Figure CS 7



Figure CS 7: Shows three ethernet cords being plugged in as an example of what all ten should look like. To note the alternating pattern of one above and one below is not required but makes it easier to interpret what's happening if a connection error occurs.

9. Once ready to begin recording and only then, plug in all ten cameras to power like the one in Figure CS 8.



Figure CS 8: Diagrams plugging in a single Picamera. This must be done for all cameras desired to be used in the recording (in general 10). Note for the Pritzker setup a large majority of the cords are suspended in a secondary location on the same side of the tank. These all must be plugged in as well

10. Now that all ten Picameras are plugged into and connected to the network switch, check to make sure that all the ports on the network switch that have cables plugged in are lighting up like in the control interface of the network switch

Record

11. Open the Control Computer and launch MTPuTTY (Figure CS 9)

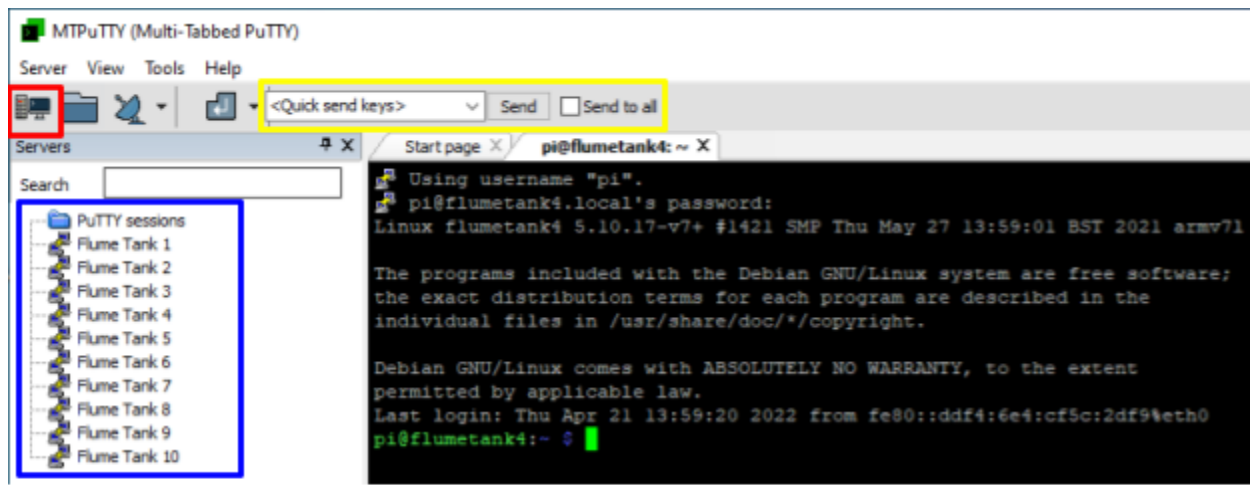


Figure CS 9: Shows an example of the MTPuTTY window. Use the logo highlighted in the red box to manual login to a Picamera. If the Picamera login is saved click it from the blue box to open it as a new tab. Open all 10 Picameras as tabs in this window. Use the yellow box to send the line of code replacing “<Quick send keys>” to all tabs. Make sure to tick the box next to “send to all”

12. Login into all 10 Picameras in MTPuTTY window, use Figure CS 9 as a guide

13. Once logged into all 10 Picameras enter the following line of code in place of “<Quick send keys>” in the yellow box of Figure CS 9.

- `“cd PicameraLibraryModified”`
- `“sudo python3.3 StartAcquisition_gpio.py -hr 0 -m 10 -s 20”`
- DO NOT** click the “Send” button to send either code a or b to all, click into the box with code and hit the “Enter” key to send to all
- Edit the number to the right of -hr (hours), -m (minutes), and -s (seconds) to the desired recording duration.
- Make sure to check the box next to “send to all”

14. The line of code in Step 13b, should show up in place of the green colored box in Figure CS 9. The code will run for the amount of time specified in the line

15. **DO NOT** unplug or mess with any of the cabling surrounding the tank while the code is running. This will ensure successful video production.

16. Once the code shows that it has completed and saved the files move onto saving the videos

Save Recording and Timestamps

17. Launch WinSCP and login into a single one of the 10 Picameras
18. Navigate to the folder on the Raspberry Pi containing the saved video files, it may be similar to that of Figure CS 10.

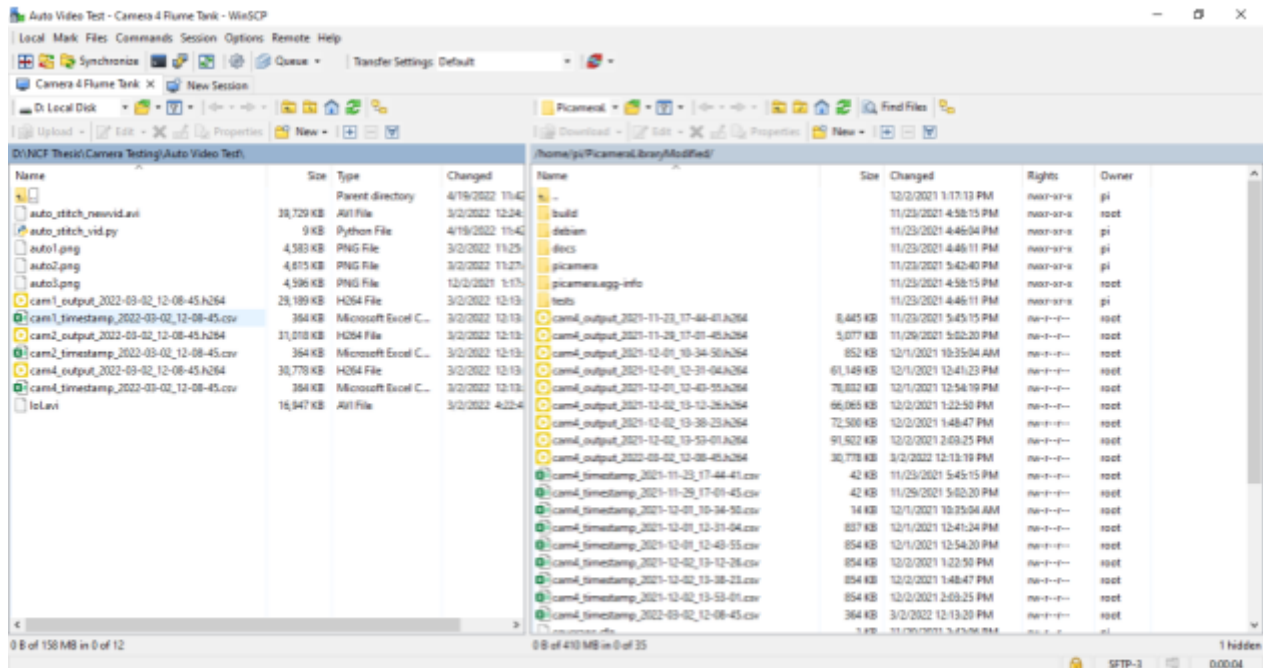


Figure CS 10: The right tab shows the Raspberry Pi file explorer. The folder containing saved videos may be the same as depicted here. The left tab shows the file explorer of the control computer, in this create a folder for all the videos from the 10 cameras to be saved together.

19. Copy the video and timestamp files for the correct trial on the right to the associated folder on the control computer on the left.
20. Repeat this process for all 10 Picameras to get all 10 videos necessary for video stitching.

Put Away Materials

21. Now that video recording and file retrieval is complete, certain materials must be secured to protect them from damage in the outdoor environment (water, dirt, etc.)
22. The network switch and associated cables should be repackaged into the network switch box as previously found
23. All cables must be placed in bags and off the ground
 - a. Bundle the cables into plastic garbage bags as initially grouped Figure CS 1
 - b. Tape the neck of the garbage bags as to seal out any possible moisture and dirt from the cables
24. Break down the control computer and return the Network switch to its correct location.

