Cognitive Testing Platform User Guide

How to build, use, and maintain this system

Overview

This cognitive testing platform was originally designed for the CDC as a Georgia Tech Capstone Design project. The system displays a series of cognitive tests on a screen that primates are able to interact with using a joystick. Each “game mode” tests and measures different cognitive abilities such as image recognition, reaction time, and short-term memory retention. Upon completion of a cognitive task, the test subject will receive a banana-flavored food pellet to reinforce the behavior.

The pellet dispenser is 3D printable and is driven by a 3.2V stepper motor. A raspberry pi controls the dispenser, displays the tests, and records the animal’s responses. Each test is written in Python, and the source code is included with this document for customization. The 3D printable files are similarly customizable with 3D modeling software. The entire system is designed in a way that is easy for researchers to use, clean, and set up from outside an animals’ enclosure. The features of the system include:

- Multiple “game modes” to test different cognitive abilities
- Dispenses food pellets when test subject “wins”
- Can be set-up from outside an enclosure
- Can be easily cleaned by researchers

The design team consists of 5 graduating seniors in the Georgia Tech school of Electrical and Computer Engineering: Collin Moore, Jonathan Procter, Ashwin Ramanathan, Samuel Yeomans, and Nathan Zavanelli.

Ordering Parts

Materials

Description	Model #/specs	Price ($348.24 total*)
Raspberry Pi	Model 3B	$39.95
Raspberry Pi power supply	5.1V @ 2.5A DC	$7.95
SD card	32 GB recommended	$7.00
DC & Stepper Motor Pi Hat	Adafruit ID: 2348	$22.50
Stepper Motor	SM-42BYG011-25	$15.95
USB Gamepad	Logitech Gamepad F310	$18.85
HDMI cable	Anything works	$6.00
Monitor	HDMI, built-in speakers	$60.00
USB mouse and keyboard	Anything works	$18.99
Flexible PVC tubing	½” inner diameter	$9.89
Jumper wire kit	male-male, male-female	$5.79
Crimpable connectors	Need 4 per system	$10.98
Break away headers	0.1" spacing, 11.5mm length	$1.50
PLA filament	Depends on your printer	$23.99
Screws for tall posts	m3, 60mm, x2	$0.49
Screws for short posts	m3, 50mm, x2	$0.55
Screws for rotor	m5, 14mm, x1	$0.11
Screws for Pi hat	m2.5, 14mm, x4	$1.72
M3 nuts	m4, x4	$0.01
M2.5 nuts	m2.5, x4	$0.63
M2.5 standoffs	m2.5, 12mm, x4	$2.56
Heat shrink tubing	Optional	$7.95
AV cart	Anything works	$84.88

* rough estimate based on prices as of time of writing (Dec. 4, 2019), shipping not included

Tools

Description	Model #/specs	Price ($143.35 total*)
Soldering iron	Anything works	$27.99
Solder	Recommend lead-free	$10.99
Crimping pliers	18-26AWG compatible	$22.99
Wire stripper	Anything works	$6.99
Screw tap	m5	$9.40
Cordless drill	Anything works	$44.00
Heat gun	Anything works	$20.99

* rough estimate based on prices as of time of writing (Dec. 4, 2019), shipping not included

Notes on picking parts

This system was designed with future expansion in mind. The parts you ultimately choose may be different from what's listed above. If you do choose to make changes to our design or if you're interested in what specifications are important, read these notes to guide your thinking on what parts you need.

Raspberry Pi model 3B

- Theoretically, any Raspberry Pi that has the same pinout as the model 3B (such as the Raspberry Pi Zero) would work. However, the Pi hat is sized for a model 3B, which allows it to be screwed in place. Doing this minimizes mechanical wear on the GPIO pins, which extends the lifetime of the system.

DC & Stepper Motor Pi Hat

- This Pi Hat is a motor driver. Our wiring assumes your motor draws between 200 and 300mA at 3.2V, which is the max that the Pi's 5V GPIO pin can handle. If your motor draws more power, here's a setup guide.[1] You will additionally need a dedicated external power source. Do not solder the jumper wire in step 5 under the "Hardware Assembly" section; follow the setup guide from Adafruit instead.
- If your software implementation is significantly different from ours, you may want to read this software guide[2] for info on talking to the Pi hat.

Motor

- The CAD files included with this document have been adjusted from the original open source design [3] to fit our motor. If you want to use a different motor, we recommend using a 3.2V motor that draws between 200 and 300mA of current (see above note "DC & Stepper Motor Pi Hat"). The rotor will fit any 5mm drive shaft, and the base fits a 42mm width motor. These dimensions can be changed in 3D modeling software if your motor is different (see section on 3D Printing).

USB gamepad

- Anything that is USB compatible and has a joystick will work

Monitor

- The monitor we chose has built-in speakers, but you can plug a set of speakers into the Pi's audio jack if your monitor doesn't.

PLA filament

- PLA prints can be made food safe. See "3D Printing" section for details.
- Your printer will determine the exact filament you need.
- If you don't have a 3D printer, you can send the STL files to a third-party 3D printing service. See "3D Printing" section below.

Heat shrink tubing

- Not strictly necessary, but keeping the motor wires together helps them not get tangled. We only used one piece at the end, but if you use enough, you can cover the wires completely. Just remember to leave room at the end.

AV cart

- This is to make the system more portable, but mounting the system to a cage is another option. We don't have much mechanical engineering experience, so we couldn't find a general-purpose solution that fits most cages.

Soldering iron

- Only 2 leads need to be soldered (see "Hardware Assembly"). If you chose a motor that draws more than 5V @ 300mA, do not solder this connection. See above notes "DC & Stepper Motor Pi Hat" and "Motor".
- Soldering Guide [4]

Crimping tool

- Used to crimp header pins onto the motor wires
- Crimping Tool Guide [5]
- Alternative solutions: solder the motor wires to breakaway headers or jumper wires

Drill and screw tap

- Used to tap m5 threading into the rotor
- Alternative solutions: use a D-key motor and modify the rotor's socket to accept it
- Threaded inserts [6] can be applied in lieu of threading the plastic itself. See Hardware Assembly section for details.

Heat gun

- Used for the optional heat shrink tubing. If you decide against the tubing, the heat gun is not necessary.
- Alternative solutions: use a hair dryer, barbecue lighter, or soldering iron (note: these solutions are commonly cited in the DIY community, but aren't necessarily professional)

3D Printing

Food safe printing

PLA prints can be made food safe. However, we aren't experts with food safe 3D printing. We suggest you do your own research to be on the safe side. Here are some tips we found in our research:

- PLA is porous. Use a coating of food-grade resin or sealant to prevent bacteria from growing inside the material.
- Annealing PLA prints in an oven can reduce layer lines, microscopic cracks, and porousness. It also increases the strength and stiffness of the print.
- Brass print heads may contain lead. Food safe extruders are available.
- Some PLA has non-food safe additives. Look for a "food safe" label.
- Cleaning the print head helps remove non-food-grade plastic.
- Printing a small object in food safe material helps remove non-food-grade plastic.
- Wash the print with soap and water after it's been printed and after use.

Editing STL files

The original feeder we based our design on was kindly provided on thingiverse.com as an open-source design. Here, we have provided a link to the original dispenser [3] and we've included our edited STL files with this document. We chose to add a threadable socket to the rotor so that it can fit any shape of motor shaft, and we've adjusted the overall dimensions to suit the motor we chose. Some changes you may want to consider if you need to make adjustments: the size of rotor holes and socket, the size of the seat in the bottom of the base, the volume of the bowl, the length of the spout, add threading to the rotor socket (or hole for a threaded insert), raise the base to fit the electronics underneath the dispenser.

We used a student version of Fusion 360 as our 3D modeling software. This tutorial series [7] was enough to teach the basics of using Fusion 360. The same presenter also made a tutorial specific to modifying STL files [8].

Print settings we used

- Printer: Stratasys F170
- Orientation: rotor was printed upside down to reduce support material
- Infill: 50%, sparse

Don't have a 3D printer?

Several 3D printing services exist. Many of them have an online form where you can submit STL files to be printed and shipped to you.

Software Setup

Clone an Existing System (Recommended)

The simplest setup for a new system would be to maintain a clone image of a working system, that way all of the required packages and code is there already. A useful guide for cloning the SD card of a Pi can be found here [9]. Once a clone exists, you can simply copy it to multiple SD cards and plug those into a newly built system and boot it.

Setup a System from a Blank SD Card

1. Use a PC to install NOOBS [10] on the SD Card

2. Put SD Card in, boot the Pi, and select Raspbian to install in the NOOBS interface

3. After following the prompts and reaching the desktop screen, open a Terminal and install the following python packages:
   pysimplegui
   pygame
   adafruit-circuitpython-motorkit
   adafruit-circuitpython-motor
   These can be installed via the command:
   `pip install pysimplegui adafruit-circuitpython-motorkit adafruit-circuitpython-motor pygame --user`

4. Now put the testing platform codebase on the Pi, either via USB flash drive or through cloning the GitHub repo through the following steps.
   a. Open a Terminal and cd into the desired directory
   b. **`git clone https://github.com/jprocter/CognitiveTestingPlatform`**

5. Setup is complete. Follow the README [11] in the codebase (or from GitHub) to get started.

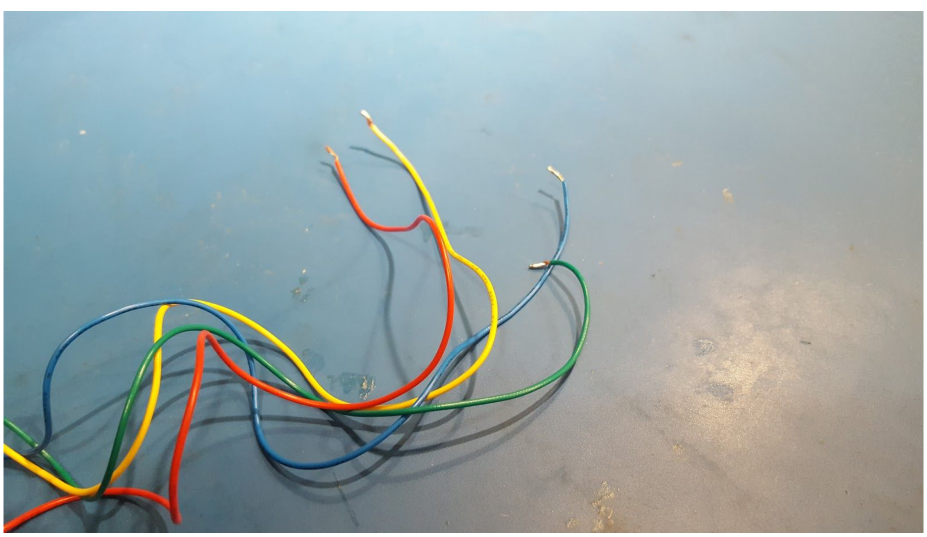
Hardware Assembly

You will need:

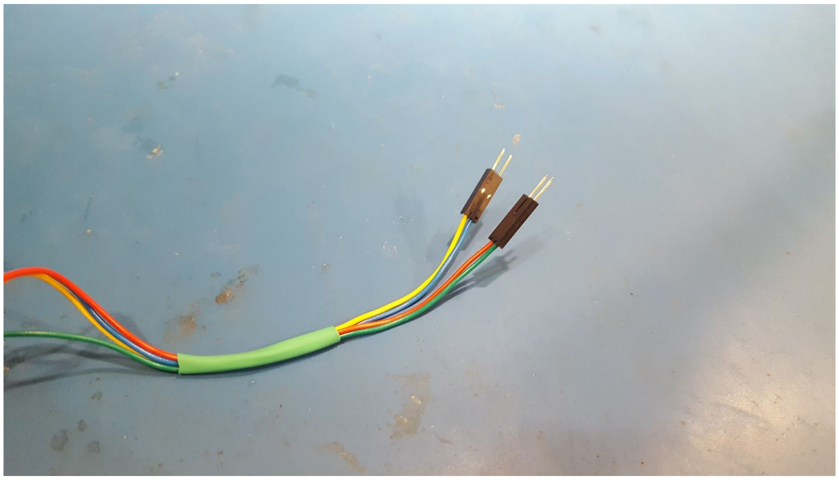
A. Assembled Raspberry Pi and Pi hat
B. 3D Printed feeder parts
C. 1/2” ID 5/8” OD flexible tubing
D. Cordless Drill
E. M5 drill bit
F. 14mm M5 screw x 1
G. 50mm M3 screws x 2
H. 60mm M3 screws x 2
I. M3 nuts x 4
J. Silicone Adhesive
K. Stepper motor
L. Wire crimper 18-26 gauge
M. Wire stripper
N. Soldering Iron
O. Leadless Solder

The following steps will assume the Pi Hat is properly assembled.

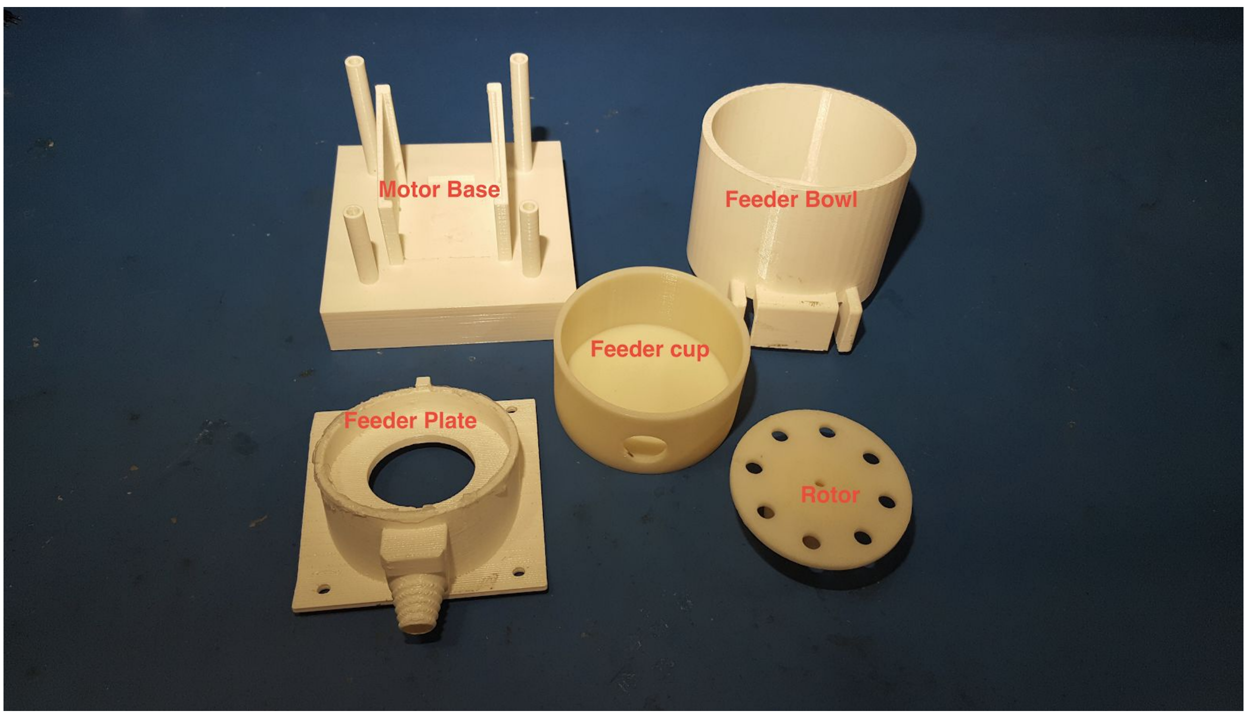
Preliminarily, either crimp male headers onto the wires [12] of the stepper motor or use a soldering iron to wick them for easier assembly.



Wicked wires



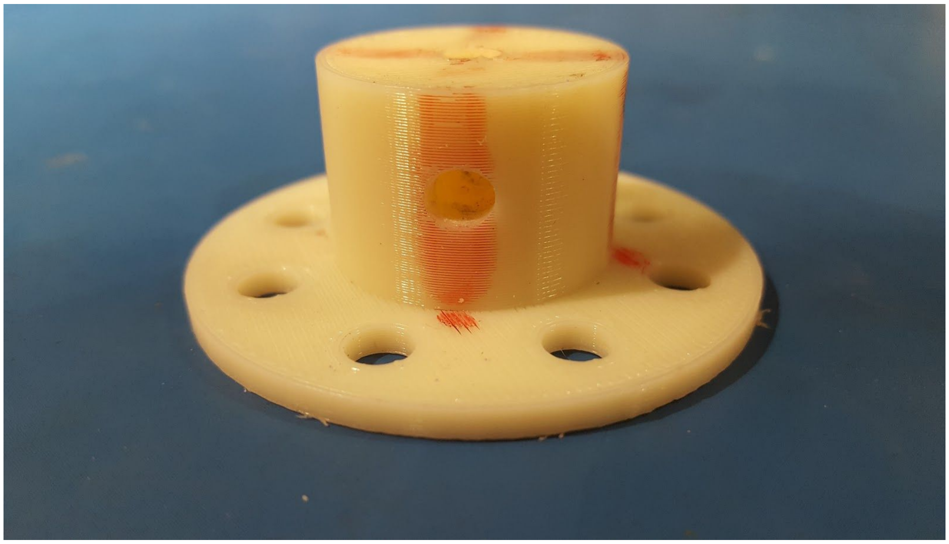
Crimped wires with added heat shrink



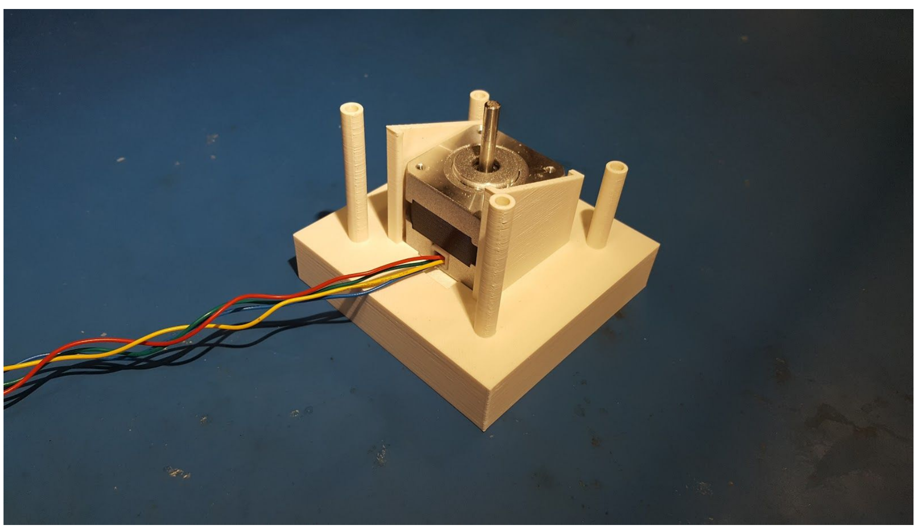
Labels of feeder parts

1. Tap an M5 thread onto the rotor shaft as shown. The center of the tap to the bottom of the shaft should be no more than 7mm.

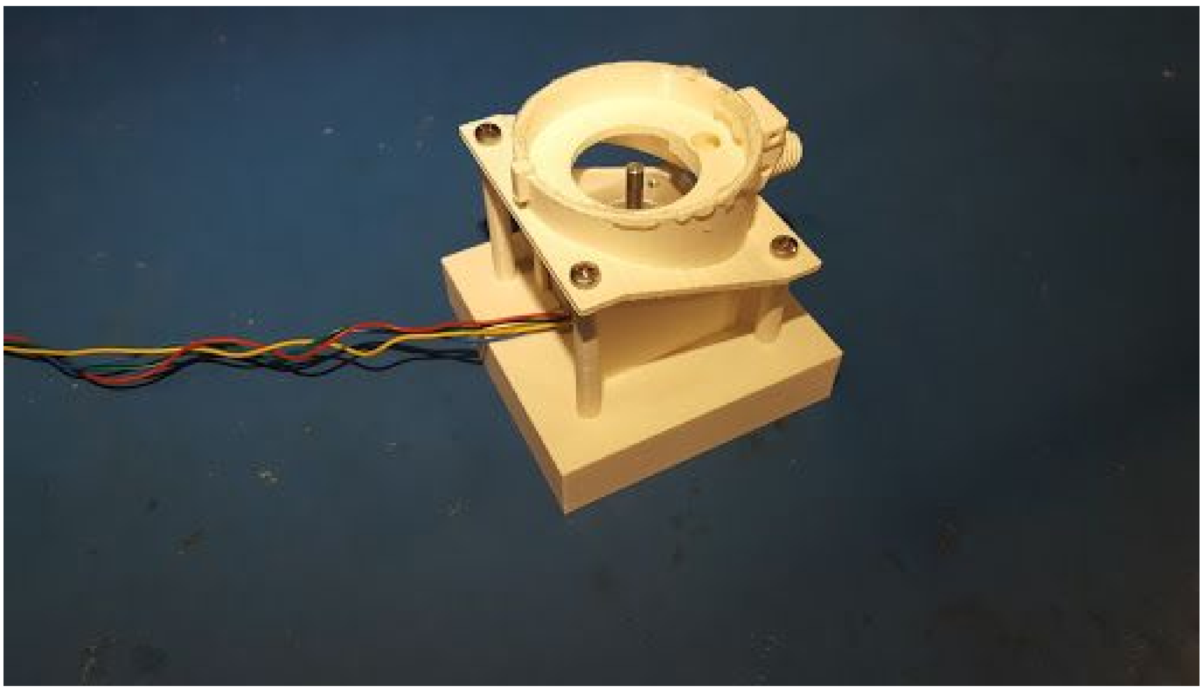
   Alternatively, you can drill a hole (or add a hole to the CAD model) and use a threaded insert [13].

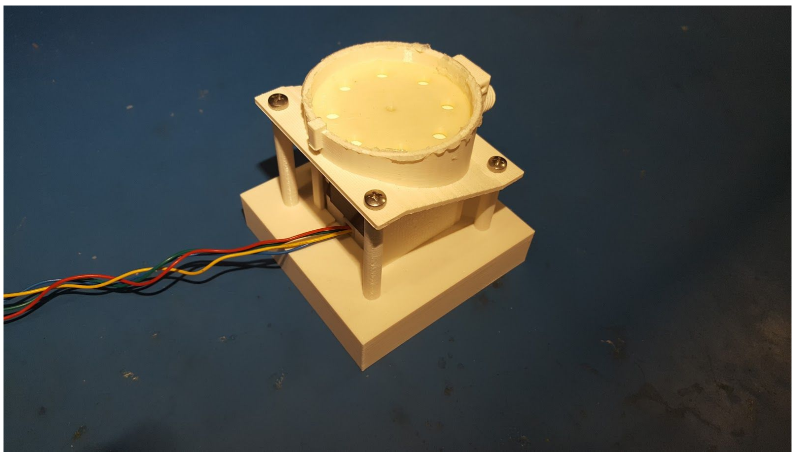
2. Apply silicone adhesive to the motor base plate before inserting the motor into the base.

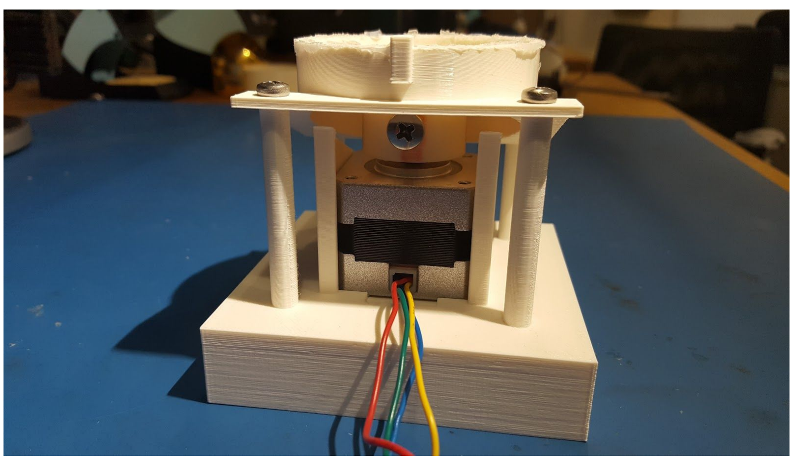
   

3. Place the feeder plate onto the posts as shown.
    a. Using the 50mm M3 screws on the shorter posts
    b. Using the 60mm M3 screws on the longer posts
    c. Screw the m3 nuts onto the bottom of the base where the M4\3's are peeking through. *The adhesive has not dried. Do not flip upside down.*



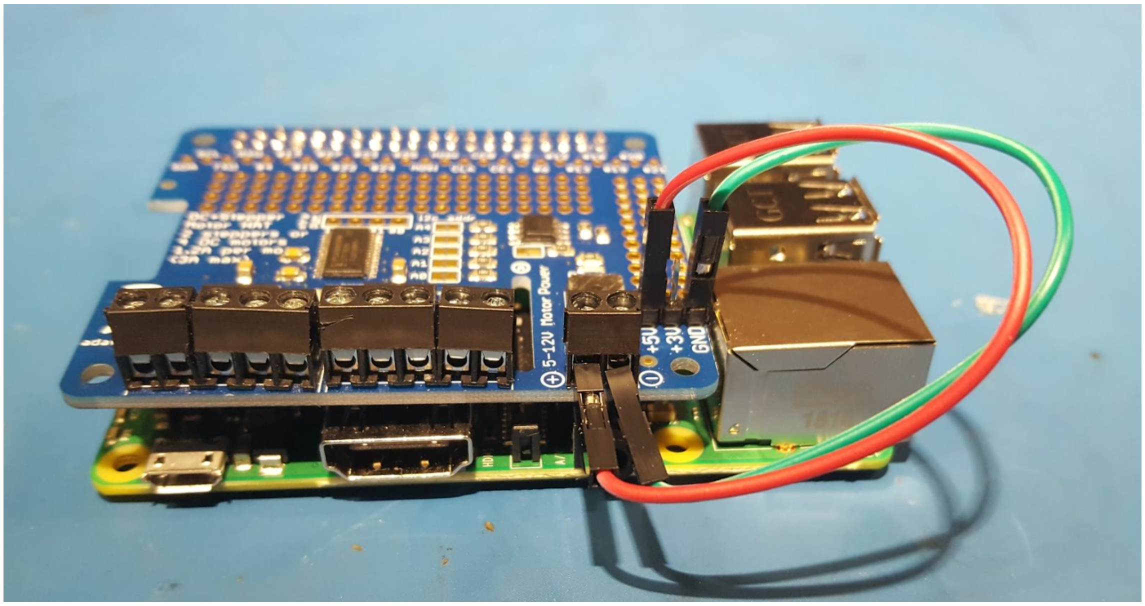
4. Place the rotor shaft onto the stepper motor shaft and screw in the M5 screw into the tapped hole on the rotor shaft tightly as shown below.





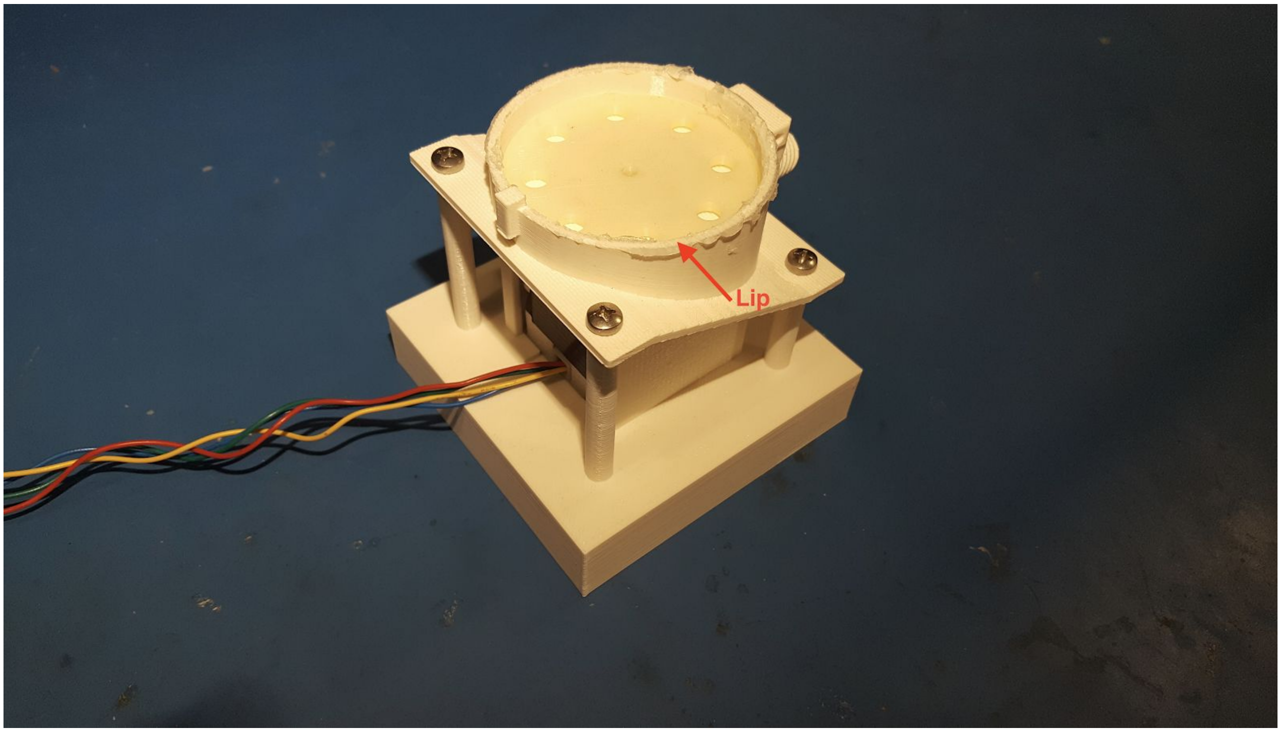
5. If the Pihat is attached to the Pi, Detach the Pi hat from the Raspi and then [Solder](#) [4] male jumper leads to the pi hat's +5 and GND rails

6. Reattach the pihat and plug soldered leads into pi hat screw terminals as shown.
   +5 rail --> ⊕
   GND --> ⊖

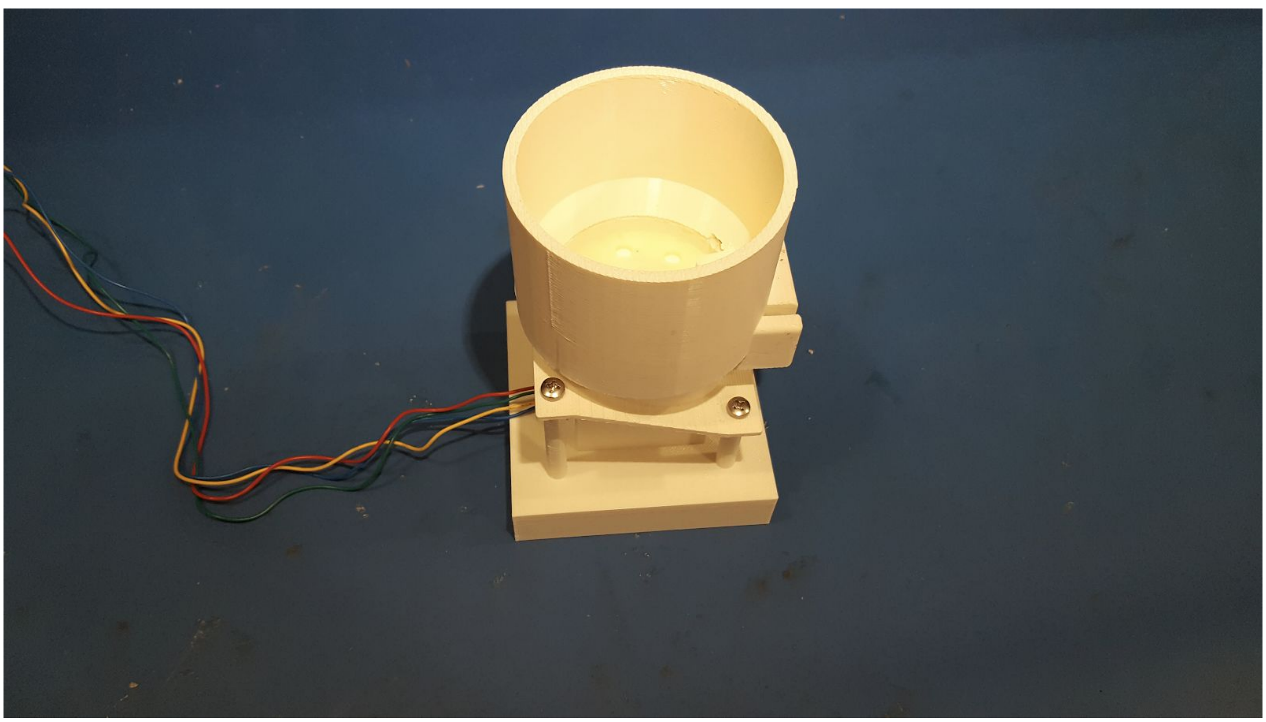


7. Place the M2.5 standoffs between the holes on the corners of the Pihat and the Raspi.
   a. These holes should line up just fine.
   b. Using the M2.5 screws, screw the standoffs into place from the top of the Pihat.

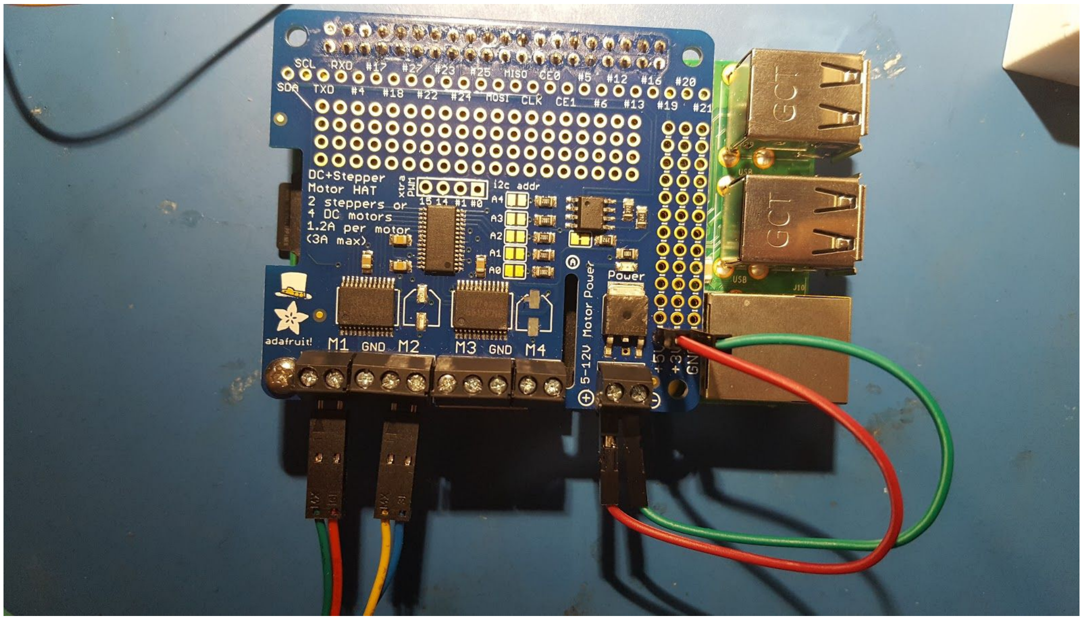
8. Place silicone adhesive on the lip of the feeder as marked below.



9. Immediately affix the feeder bowl to the feeder as shown.



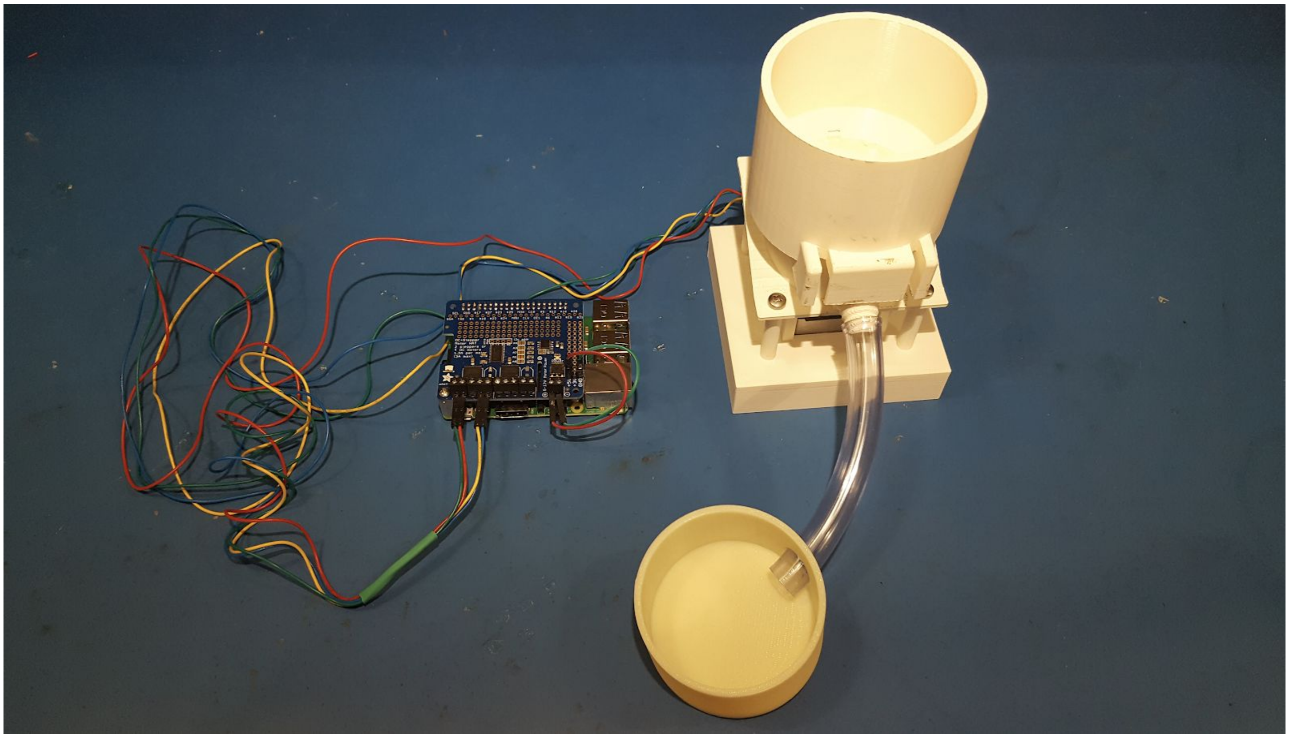
10. Plug motor wires into the pi
    Green --> M1 (left)
    Red   --> M1 (right)
    Yellow --> M2 (left)
    Blue   --> M2 (right)



11. Apply a ring of silicone adhesive to the spout of the feeder and the hole on the feeder cup.

12. Affix the flexible tubing to the feeder spout and cup as shown below of the fully assembled system.

13. Let the adhesive dry for at least 24 hours before use.



Completed system

Using the System

Starting the System

1. Make sure the joystick is plugged in (this will cause 'game.py' to crash)
2. Run 'menu.py'
    a. Open Terminal and use cd to navigate to main/ directory
    b. Run command 'python menu.py' (might need to replace 'python' with 'python3')
3. In the new window, find 'Use Parameters from File,' click 'Browse' and use 'defaults.txt' or another desired parameters file. Then click 'Load'.
4. Change any desired parameters using the menu.
5. (Optional) save current parameters to a named file by typing the name in the 'Save Current Parameters to File' text box. Then click 'Save'.
6. Click 'Go'. This will run 'game.py'
7. In the new window, select which Animal ID to use for results. Then click 'Run'
8. The tasks marked as active in the parameters will now run in a fullscreen window. Results can be found in main/results/{ID}Data.txt. A joystick is required to play the 2D games.
9. You can also run 'game.py' by itself, however this requires a 'parameters.txt' to be in the main directory already.

Changing Parameters

Editing Parameter Values and Adding New Parameters is outlined in the GitHub README [11].

Note: Titration parameter currently does NOTHING and is not used at all

'parameters.txt' should always hold the current desired parameters to be used in 'game.py', there are two ways to change the values there.

1. 'menu.py' provides an interactive way to load a default/previous parameter file and then modify their values by replacing the text there.
2. Create and write to 'parameters.txt' manually (Warning: there is a certain syntax to all of the parameters that is expected in 'game.py')

For best results with this method, use 'defaults.txt' as a basis for 'parameters.txt' to ensure the syntax will not cause issues.

How to Retrieve Data

Results can be found in ‘main/results/{ID}Data.txt’. Multiple sessions with the same {ID} will all be in one file. Use a USB flash drive or SSH connection to copy the result files from the Raspberry Pi.

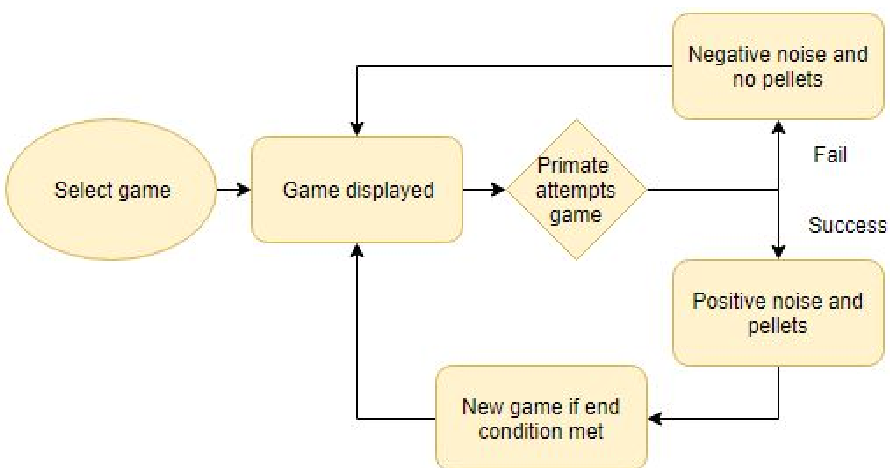
How to Clean the Dispenser

The pellet dispenser can be easily disassembled and cleaned with soap and water. Be sure to disconnect the Raspberry Pi and motor beforehand. 3D printed parts are generally not dishwasher safe as they will warp over time. However, annealing [15] can make some types of PLA dishwasher safe [16].

If the motor gets wet, dry it off and make sure no corrosion forms. The motor is far less susceptible to water damage than the other electronics. If any other electronics get wet, disconnect and dry them thoroughly before testing.

After washing the dispenser, you may wish to reapply food-grade silicone adhesive to the base of the motor and between the bowl and plate during reassembly.

Typical Use Case Flowchart



Credits and Info

About this project

This system was originally designed in partnership between the CDC and Georgia Tech as a Capstone Design project. The design team consists of 5 graduating seniors in the school of Electrical and Computer Engineering: Collin Moore, Jonathan Procter, Ashwin Ramanathan, Samuel Yeomans, and Nathan Zavanelli. The final deliverables for this project can be found on the design team's project website [14].

About the original feeder design

The original, open-source food pellet dispenser [3] was kindly made available on thingiverse.com. This food pellet dispenser was developed by Dr. Andrew Maurer's Lab in the McKnight Brain Institute at the University of Florida.

References

[1] https://learn.adafruit.com/adafruit-dc-and-stepper-motor-hat-for-raspberry-pi

[2] https://learn.adafruit.com/adafruit-dc-and-stepper-motor-hat-for-raspberry-pi/installing-software

[3] http://www.thingiverse.com/thing:1771176

[4] https://www.makerspaces.com/how-to-solder/

[5] https://www.instructables.com/id/Dupont-Crimp-Tool-Tutorial/

[6] https://www.amazon.com/initeq-M5-0-8-Threaded-Inserts-Printing/dp/B077CG1W3L

[7] https://www.youtube.com/watch?v=A5bc9c3S12g

[8] https://www.youtube.com/watch?v=yxC-kwuksug

[9] https://beebom.com/how-clone-raspberry-pi-sd-card-windows-linux-macos/

[10] https://www.raspberrypi.org/documentation/installation/noobs.md

[11] https://github.com/jprocter/CognitiveTestingPlatform/blob/master/README.md

[12] https://learn.sparkfun.com/tutorials/working-with-wire/all#how-to-crimp-an-electrical-connector

[13] https://youtu.be/G-UF4tv3Hvc

[14] http://ece4012y201908.ece.gatech.edu/2019fall/sd19f07/

[15] https://www.fargo3dprinting.com/annealing-makes-3d-prints-better/

[16]https://3dprintingindustry.com/news/filaments-ca-releases-fully-food-safe-pla-for-3d-printers-140861/