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# **Autopilot Documentation**

***Release 0.3.0***

**Jonny Saunders**

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Autopilot is a Python framework to perform behavioral experiments with one or many [Raspberry Pis](#).

Its distributed structure allows arbitrary numbers and combinations of hardware components to be used in an experiment, allowing users to perform complex, hardware-intensive experiments at scale.

Autopilot integrates every part of your experiment, including hardware operation, task logic, stimulus delivery, data management, and visualization of task progress – making experiments in behavioral neuroscience replicable from a single file.

Instead of rigid programming requirements, Autopilot attempts to be a flexible framework with many different modalities of use in order to adapt to the way you do and think about your science rather than the other way around. Use only the parts of the framework that are useful to you, build on top of it with its plugin system as you would normally, while also maintaining the provenance and system integration that more rigid systems offer.

For developers of other tools, Autopilot provides a skeleton with minimal assumptions to integrate their work with its broader collection of tools, for example our integration of [DeepLabCut-live](#) as the *DLC* transform ([KLS+20]).

Our long-range vision is to build a tool that lowers barriers to tool use and contribution, from code to contextual technical knowledge, so our broad and scattered work can be cumulatively combined without needing a centralized consortium or adoption of a singular standard.

For a detailed overview of Autopilot’s motivation, design, and structure, see our [whitepaper](#).

---

### What’s New v0.4.0 - Become Multifarious (21-08-03)

- The [Autopilot Wiki](#) is live!!!! The wiki will be the means of gathering and sharing knowledge about using Autopilot, but it will also serve as an additional tool for building interfaces and decentralizing control over its development. Head to the [changelog](#) or the [Plugins & The Wiki](#) page to learn more
- Autopilot [plugins](#) are now live!!! Anything in your plugin directory is a plugin, extend most types of autopilot classes to implement your own custom hardware and tasks and anything else without modifying autopilot itself, then [submit it to the wiki](#) to make it immediately available to everyone who uses the system! Link it to all the rest of your work, the parts it uses, let’s make a knowledge graph!!!
- Tests and Continuous Integration are finally here!!! if there has been anything I have learned over the past few projects is that tests are god. Ours are hosted on [travis](#) and we are currently on the board with a stunning [27% coverage](#) at [coveralls.io](#)
- Lots of new hardware and transform classes! Take a look! [cameras.PiCamera](#), [timeseries.Kalman](#), [geometry.IMU\\_Orientation](#), [timeseries.Filter\\_IIR](#), [timeseries.Integrate](#), [geometry.Rotate](#), [geometry.Spheroid](#)
- Major improvements like stereo sound (Thanks [Chris Rodgers](#) !), multihop messages, direct messaging, programmatic setup... see more in the [changelog](#) <[changelog\\_v040](#)
- Continued work on deconvoluting and modularizing all the code structure!
- Removed limits on python version, now testing on 3.7, 3.8, and 3.9

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This documentation is very young and is very much a work in progress! Please [submit an issue](#) with any incompleteness, confusion, or errors!

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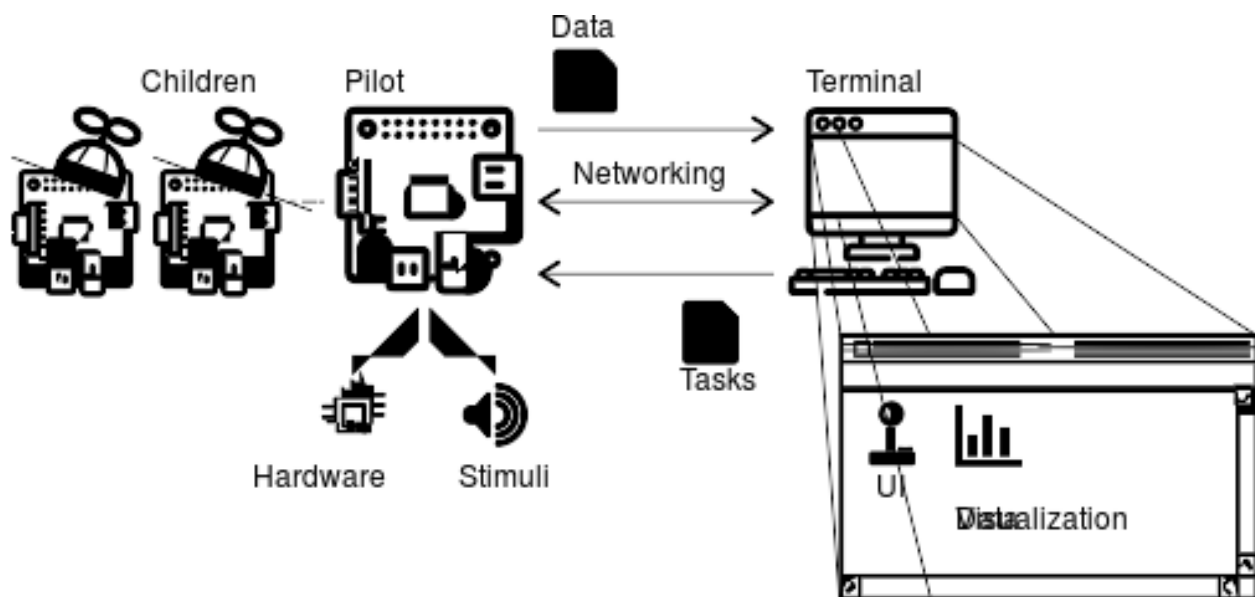
**Todo:** This page is still under construction! For a more detailed description, see the whitepaper, particularly “Program Structure”

<https://www.biorxiv.org/content/10.1101/807693v1>

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## PROGRAM STRUCTURE



Autopilot performs experiments by distributing them over a network of desktop computers and Raspberry Pis. Each Computer or Pi runs an Autopilot **agent**, like the user-facing *Terminal* or a Raspberry Pi *Pilot*.

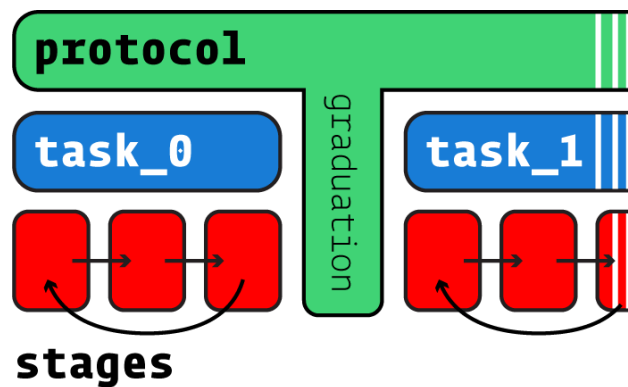
The *Terminal* agent provides a *gui* to operate the system, manage *Subject*s and experimental protocols, and *plots* for visualizing data from ongoing experiments.

Each *Terminal* manages a swarm of *Pilot*s that actually perform the experiments. Each *Pilot* coordinates *hardware* and *stimuli* in a *Task*. *Pilot*s can, in turn, coordinate their own swarm of networked *Children* that can manage additional hardware components – allowing *Task*s to use effectively arbitrary numbers and combinations of hardware.





## TASKS



Behavioral experiments in Autopilot consist of *Task*s. Tasks define the parameters, coordinate the hardware, and perform the logic of an experiment.

Tasks may consist of one or multiple **stages**, completion of which constitutes a **trial**. Stages are analogous to states in a finite-state machine, but don't share their limitations: Tasks can use arbitrary transitions between stages and have computation or hardware operation persist between stages.

Multiple Tasks can be combined to make **protocols**, in which subjects move between different tasks according to *graduation* criteria like accuracy or number of trials. Protocols can thus be used to automate shaping routines that introduce a subject to the experimental apparatus and task structure.

For more details on tasks, see `guide_task`



## MODULE TOUR

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**Todo:** A more comprehensive overview is forthcoming, but the documentation for the most important modules can be found in the API documentation. A short tour for now...

---

- *Terminal* - user facing agent class used to control and configure program operation. See `setup_terminal` and `setup.setup_terminal`
- *gui* - GUI classes built with PySide2/Qt5 used by the terminal
- *plots* - Classes to plot data from ongoing tasks
- *pilot* - Experimental agent that runs tasks on Raspberry Pis
- *networking* - Networking modules used for communication between agents, tasks, and hardware objects
- *subject* - Data and metadata storage
- *hardware* - Hardware objects that can be used in tasks
- *tasks* - Customizable and extendable Task templates
- *stim* - Stimulus generation & presentation, of which sound is currently the most heavily developed



## QUICKSTART

Autopilot is an integrated system for coordinating all parts of an experiment, but it is also designed to be permissive about how it is used and to make transitioning from existing lab tooling gentler – so its modules can be used independently.

To get a sample of autopilot, you can check out some of its modules without doing a fully configured *Installation*. As you get more comfortable using Autopilot, adopting more of its modules and usage patterns makes integrating each of the separate modules simpler and more powerful, but we'll get there in time.

### 4.1 Minimal Installation

Say you have a Raspberry Pi with *Raspbian installed*. Install autopilot and its basic system dependencies & configuration like this:

```
pip3 install auto-pi-lot
python3 -m autopilot.setup.run_script env_pilot pigpiod
```

### 4.2 Blink an LED

Say you connect an LED to one of the *gpio* pins - let's say (board numbered) pin 7. Love 7. Great pin.

Control the LED by using the *gpio.Digital\_Out* class:

```
from autopilot.hardware.gpio import Digital_Out
led = Digital_Out(pin=7)

# turn it on!
led.set(1)

# turn it off!
led.set(0)
```

Or, blink “hello” in morse code using *series()* !

```
letters = [
    ['dot', 'dot', 'dot', 'dot'], # h
    ['dot'], # e
    ['dot', 'dash', 'dot', 'dot'], # l
    ['dot', 'dash', 'dot', 'dot'], # l
```

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```
    ['dash', 'dash', 'dash']          # o
]
# make a series of 1's and 0's, which will last for the time_unit
times = {'dot': [1, 0], 'dash': [1, 1, 1, 0], 'space': [0]*3}
binary_letters = []
for letter in letters:
    binary_letters.extend([value for char in letter for value in times[char]])
    binary_letters.extend(times['space'])

time_unit = 100 #ms
led.series(id='hello', values=binary_letters, durations=time_unit)
```

## 4.3 Capture Video

Say you have a [Raspberry Pi Camera Module](#) , capture some video! First make sure the camera is enabled:

```
python3 -m autopilot.setup.run_script picamera
```

and then capture a video with `cameras.PiCamera` and write it to `test_video.mp4`:

```
from autopilot.hardware.cameras import PiCamera
cam = PiCamera()
cam.write('test_video.mp4')
cam.capture(timed=10)
```

---

**Note:** Since every hardware object in autopilot is by default nonblocking (eg. work happens in multiple threads, you can make other calls while the camera is capturing, etc.), this will work in an interactive python session but would require that you `sleep` or call `cam.stopping.join()` or some other means of keeping the process open.

---

While the camera is capturing, you can access its current frame in its `frame` attribute, or to make sure you get every frame, by calling `queue()` .

## 4.4 Communicate Between Computers

Synchronization and coordination of code across multiple computers is a very general problem, and an increasingly common one for neuroscientists as we try to combine many hardware components to do complex experiments.

Say our first raspi has an IP address `192.168.0.101` and we get another raspi whose IP is `192.168.0.102` . We can send messages between the two using two `networking.Net_Node` s. `networking.Net_Node` s send messages with a key and value , such that the key is used to determine which of its `listens` methods/functions it should call to handle value .

For this example, how about we make pilot 1 ping pilot 2 and have it respond with the current time?

On pilot 2, we make a node that listens for messages on port 5000. The `upstream` and `port` arguments here don't matter since this node doesn't initiate any connection, just received them (we'll use a global variable here and hardcode the return id since we're in scripting mode, but there are better ways to do this in autopilot proper):

```

from autopilot.networking import Net_Node
from datetime import datetime
global node_2

def thetime(value):
    global node_2
    node_2.send(
        to='pilot_1', key='THETIME',
        value=datetime.now().isoformat()
    )

node_2 = Net_Node(
    id='pilot_2', router_port=5000, upstream='', port=9999,
    listens={'WHATIS':thetime}
)

```

On pilot 1, we can then make a node that connects to pilot 2 and prints the time when it receives a response:

```

from autopilot.networking import Net_Node

node_1 = Net_Node(
    id='pilot_1', upstream='pilot_2',
    port=5000, upstream_ip = '192.168.0.102',
    listens = {'THETIME':print}
)

node_1.send(to='pilot_1', key='WHATIS')

```

## 4.5 Realtime DeepLabCut

Autopilot integrates [DeepLabCut-Live](#) [KLS+20] ! You can use your own pretrained models (stored in your autopilot user directory under `/dlc`) or models from the [Model Zoo](#).

Now let's say we have a desktop linux machine with DeepLabCut and dlc-live installed. DeepLabCut-Live is implemented in Autopilot with the `transform.image.DLC` object, part of the `transform` module.

First, assuming we have some image `img` (as a numpy array), we can process the image to get an array of x,y positions for each of the tracked points:

```

from autopilot import transform as t
import numpy as np

dlc = t.image.DLC(model_zoo='full_human')
points = dlc.process(img)

```

Autopilot's transform module lets us compose multiple data transformations together with `+` to make deploying chains of computation to other computers. How about we process an image and determine whether the left hand in the image is raised above the head?:

```

# select the two body parts, which will return a 2x2 array
dlc += t.selection.DLCSlice(select=('wrist1', 'forehead'))

```

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```
# slice out the 1st column (y) with a tuple of slice objects
dlc += t.selection.Slice(select=(
    slice(start=0,stop=2),
    slice(start=1,stop=2)
))

# compare the first (wrist) y position to the second (forehead)
dlc += t.logical.Compare(np.greater)

# use it!
dlc.process(img)
```

## 4.6 Put it Together - Close a Loop!

We’ve tried a few things, why not put them together?

Let’s use our two raspberry pis and our desktop GPU-bearing computer to record a video of someone and turn an LED on when their hand is over their head. We could do this two (or one) computer as well, but let’s be extravagant.

Let’s say **pilot 1**, **pilot 2**, and the **gpu computer** have ip addresses of 192.168.0.101, 192.168.0.102, and 192.168.0.103, respectively.

### 4.6.1 Pilot 1 - Image Capture

On **pilot 1**, we configure our *PiCamera* to stream to the gpu computer. While we’re at it, we might as well also save a local copy of the video to watch later. The camera won’t stop capturing, streaming, or writing until we call *capture()*:

```
from autopilot.hardware.cameras import PiCamera
cam = PiCamera()
cam.stream(to='gpu', ip='192.168.0.103', port=5000)
cam.write('cool_video.mp4')
```

### 4.6.2 GPU Computer

On the **gpu computer**, we need to receive frames, process them with the above defined transformation chain, and send the results on to **pilot 2**, which will control the LED. We could do this with the objects that we’ve already seen (make the transform object, make some callback function that sends a frame through it and give it to a *Net\_Node* as a *listen* method), but we’ll make use of the *Transformer* “child” object – which is a peculiar type of *Task* designed to perform some auxiliary function in an experiment.

Rather than giving it an already-instantiated transform object, we instead give it a schematic representation of the transform to be constructed – When used with the rest of autopilot, this is to both enable it to be dispatched flexibly to different computers, but also to preserve a clear chain of data provenance by keeping logs of every parameter used to perform an experiment.

The *Transformer* class uses *make\_transform()* to reconstitute it, receives messages containing data to process, and then forwards them on to some other node. We use its *trigger* mode, which only sends the value on to the final recipient with the key 'TRIGGER' when it changes.:



```

from autopilot.tasks.children import Transformer
import numpy as np

transform_description = [
    {
        "transform": "DLC",
        "kwargs": {'model_zoo': 'full_human'}
    },
    {
        "transform": "DLCslice",
        "kwargs": {"select": ("wrist1", "forehead")}
    }
    {
        "transform": "Slice",
        "kwargs": {"select":(
            slice(start=0,stop=2),
            slice(start=1,stop=2)
        )}
    },
    {
        "transform": "Compare",
        "args": [np.greater],
    },
]

transformer = Transformer(
    transform = transform_description
    operation = "trigger",
    node_id = "gpu",
    return_id = 'pilot_2',
    return_ip = '192.168.0.102',
    return_port = 5001,
    return_key = 'TRIGGER',
    router_port = 5000
)

```

### 4.6.3 Pilot 2 - LED

And finally on **pilot 2** we just write a listen callback to handle the incoming trigger:

```

from autopilot.hardware.gpio import Digital_Out
from autopilot.networking.Net_Node

global led
led = Digital_Out(pin=7)

def led_trigger(value:bool):
    global led
    led.set(value)

node = Net_Node(

```

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```
id='pilot_2', router_port=5001, upstream='', port=9999,
listens = {'TRIGGER':led_trigger}
)
```

There you have it! Just start capturing on **pilot 1**:

```
cam.capture()
```

## 4.7 What Next?

The rest of Autopilot expands on this basic use by providing tools to do the rest of your experiment, and to make replicable science easy.

- write standardized experimental protocols that consist of multiple Task s linked by flexible *graduation* criteria
- extend the library to use your custom hardware, and make your work available to anyone with our *plugins* system integrated with the *autopilot wiki*
- Use our GUI that makes managing many experimental rigs simple from a single computer.

and so on...

## INSTALLATION

Autopilot must be installed on the devices running the Terminal and the Pilot agents. The Pilot runs on a Raspberry Pi (remember: Pi for “Pilot”) and the Terminal runs on a regular desktop computer. So Autopilot must be installed on both. This document will show you how to do that.

### 5.1 Supported Systems

OS	<ul style="list-style-type: none"><li>• Pilot: raspiOS &gt;=Buster (lite recommended)</li><li>• Terminal: Ubuntu &gt;=16.04</li></ul>
Python Version	3.7
Raspberry Pi	>=3b

Autopilot is **linux/mac** only, and supports **Python 3.7**. Some parts might accidentally work in Windows but we make no guarantees.

We have tried to take care to make certain platform-specific dependencies not break the entire package, so if you have some difficulty installing autopilot on a non-raspberry-pi linux machine please submit an issue!

### 5.2 Pre-installation

#### 5.2.1 On the Pilot device

For Pilots, we recommend starting with a fresh [Raspbian Lite](#) image (see [the raspi installation documentation](#)). Note that the Lite image doesn’t include a desktop environment or GUI, just a command-line interface, but that’s all we need for the Pilot. It’s easiest to connect a monitor and keyboard directly to the Pi while configuring it. Once it’s configured, you won’t need to leave the monitor and keyboard attached, and/or you can choose to connect to it with ssh.

After the Pi has been started up for the first time, run `sudo raspi-config` to do things like connect to a wifi network, set the time zone, and so on. It’s very important to change the password for the *pi* user account to a new one of your choice so that you don’t get hacked, especially if you’re opening up ssh access.

It’s also best to update the Pi’s operating system at this time:

```
sudo apt update
sudo apt upgrade -y
```

Now install the system packages that are required by Autopilot. You can do this by running this command, or it's also available as a setup script in the guided installation of Autopilot. (`python -m autopilot.setup.run_script env_pilot`)

```
sudo apt install -y \  
    python3-dev \  
    python3-pip \  
    git \  
    libatlas-base-dev \  
    libsamplerate0-dev \  
    libsndfile1-dev \  
    libreadline-dev \  
    libasound-dev \  
    i2c-tools \  
    libportmidi-dev \  
    liblo-dev \  
    libhdf5-dev \  
    libzmq-dev \  
    libffi-dev
```

### 5.2.2 On the Terminal device

The following system packages are required by PySide2 (which no longer packages xcb):

```
sudo apt-get update && \  
sudo apt-get install -y \  
    libxcb-icccm4 \  
    libxcb-image0 \  
    libxcb-keysyms1 \  
    libxcb-randr0 \  
    libxcb-render-util0 \  
    libxcb-xinerama0 \  
    libxcb-xfixes0
```

### 5.2.3 Creating a Virtual Environment

We recommend using autopilot within a virtual environment – we primarily develop with *virtualenv* but *conda* also appears to work.

First, install *virtualenv* (see the [virtualenv docs](#)):

```
pip3 install virtualenv
```

Then, create a venv. By convention, these virtual environments are stored in the directory `~/.venv`, but they can be located anywhere.

**With `virtualenv`:**

```
mkdir ~/.venv  
python3 -m virtualenv ~/.venv/autopilot
```

**With `conda`:**

```
conda create --name autopilot python=3.7
```

The virtual environment must be “activated” now and any time you work with autopilot (`setup_autopilot` will detect which venv it is run from and source it in the launch script).

With `virtualenv`:

```
source ~/.venv/autopilot/bin/activate
```

With `conda`:

```
conda activate autopilot
```

Either way, you should see that the command prompt begins with the string “(autopilot)”. If you want to exit the virtual environment at any time, just type `deactivate`.

## 5.3 Installing Autopilot

Now we’re ready to install Autopilot on both the Pilot and Terminal devices. Follow the same instructions on both the Pi and the computer.

### 5.3.1 Method 1: Installation with pip

If you’re just taking a look at Autopilot, the easiest way to get started is to install with pip!

```
pip3 install auto-pi-lot
```

### 5.3.2 Method 2: Installation from source

If you want to start writing your own experiments and tinkering with Autopilot, we strongly recommend forking [the repository](#) and developing directly in the library so your gorgeous insights can be integrated later.

Clone the repository and install an “editable” version with `-e`, this makes it so python uses the source code in your cloned repository, rather than from the system/venv libraries.:

```
git clone https://github.com/wehr-lab/autopilot.git
cd autopilot
pip3 install -e .
```

---

**Note:** Depending on your permissions, eg. if you are not installing to a virtual environment, you may get a permissions error and need to install with the `--user` flag

---

---

**Note:** Development work is done on the dev branch, which may have additional features/bugfixes but is much less stable! To use it just `git checkout dev` from your repository directory.

---

## 5.4 Configuration

After installation, set Autopilot up! Autopilot comes with a “guided installation” process where you can select the actions you want and they will be run for you. The setup routine will:

- install needed system packages
- prepare your operating system and environment
- set system preferences
- create a user directory (default ~/autopilot) to store prefs, logs, data, etc.
- create a launch script

To start the guided process, run the following line.

```
python3 -m autopilot.setup
```

### 5.4.1 Select agent

Each runtime of Autopilot is called an “Agent”, each of which performs different roles within a system, and thus have different requirements. If you’re running the setup script on the Pi, select “Pilot”. If you’re running the setup script on a desktop computer, select “Terminal”. If you’re configuring multiple Pis, then select “Child” on the child Pis. Then hit “OK”.

You can navigate this interface with the arrow keys, tab key, and enter key.



### 5.4.2 Select scripts

Now you will see a menu of potential scripts that can be run. Select the scripts you want to run, and then hit “OK”. Note that even the simplest task (“free water”) requires pigpio, so you may want to include that one. You can see the commands that will be run in each of these scripts with `setup.run_script` in the `setup.scripts.SCRIPTS` dictionary.



**Note:** Autopilot uses a slightly modified version of pigpio (<https://github.com/sneakers-the-rat/pigpio>) that allows it to get absolute timestamps (rather than system ticks) from gpio callbacks, increases the max number of scripts, etc. so if you have a different version of pigpio installed you will need to remove it and replace it with this one (you can do so with `python -m autopilot.setup.run_script pigpiod`)

### 5.4.3 Configure Agent

Each agent has a set of systemwide preferences stored in `<AUTOPILOT_DIR>/prefs.json` and accessible from `autopilot.prefs`.

```

Setup Pilot Agent - 1/2
Base Prefs
Agent Name:      what_kind_of_agent-oh_yeah_a_secret_agent
Base Directory:  /home/you/autopilot
Push Port - Router port used by the Terminal or upstream agent:
5565
Message Port - Router port used by this agent to receive messages:
5560
Terminal IP:     192.168.1.129
Log Level:       (X)  DEBUG
                 ( )  INFO
                 ( )  WARNING
                 ( )  ERROR

System Configuration
Pilot Prefs
Binary mask controlling which pins pigpio controls according to their BCM numbering, see the -x parameter of pigpiod
11111100001111111111111111110000
Arguments to pass to pigpiod on startup
-t 0 -l
Pins to pull up on system startup? (list of form [1, 2]
Pins to pull down on system startup? (list of form [1, 2]

```

OK

### 5.4.4 Configure Hardware

If configuring a Pilot, you'll be asked to configure your hardware.

Press `ctrl+x` to add Hardware, and fill in the relevant parameters (most are optional and can be left blank). Consult the relevant page on the docs to see which arguments are relevant and how to use them.

```

Hardware Configuration
Use the ctrl+X menu to add new hardware

gpio.Digital_Out
name
pin
polarity      1
pull
trigger
pulse_width   100

```

OK

^X: Menu

After completing this step, the file *prefs.json* will be created if necessary and populated with the information you just provided. If it already exists, it will be modified with the new information while preserving the previous preferences.



You can also manually edit the `prefs.json` file if you prefer. [A template version for the Pilot is available](#) that defines the ports, LEDs, and solenoids that are necessary for the “free water” task, which may be a useful way to get started.

## 5.5 Networking

**Note:** Networking is a point of major future development, particularly how agents discover one another and how ports are assigned. Getting networking to work is still a bit cumbersome, but you can track progress or contribute to improving networking at [issue #48](#)

### 5.5.1 IP Addresses

Pilots connect to a terminal whose IP address is specified as `TERMINALIP` in `prefs.json`

The Pilot and Terminal devices must be on the same network and capable of reaching one another. You must first figure out the IP address of each device with this command:

```
ipconfig
```

Let’s say your Terminal is at 192.168.1.42 and your Pilot is at 192.168.1.200. Replace these values with whatever you actually find using *ipconfig*.

Then, you can test that each device can see the other with ping. On the Terminal, run:

```
ping 192.168.1.200
```

And on the Pilot, run:

```
ping 192.168.1.42
```

If that doesn’t work, there is something preventing the computers from communicating from one another, typically this is the case if the computers are on university/etc. internet that makes it difficult for devices to connect to one another. We recommend networking agents together using a local router or switch (though some have reported being able to [use their smartphone’s hotspot in a pinch](#) ).

### 5.5.2 Ports

Agents use two prefs to configure their ports

- `MSGPORT` is the port that the agent receives messages on
- `PUSHPORT` is the port of the ‘upstream’ agent that it connects to.

So, if connecting a Pilot to a Terminal, the `PUSHPORT` of the Pilot should match the `MSGPORT` of the Terminal.

Ports need to be “open,” but the central operation of a firewall is to “close” them. To open a port if, for example, you are using `ufw` on ubuntu (replacing with whatever port you’re trying to open to whatever ip address):

```
sudo ufw allow from 192.168.1.200 to any port 5560
```

## 5.6 Testing the Installation

A launch script should have been created by `setup_autopilot` at `<AUTOPILOT_DIR>/launch_autopilot.sh` – this is the primary entrypoint to autopilot, as it allows certain system-level commands to precede launch (eg. activating virtual environments, enlarging shared memory, killing conflicting processes, launching an x server, etc.).

To launch autopilot:

```
~/autopilot/launch_autopilot.sh
```

---

**Note:** Selecting the script alias in `setup_autopilot` allows you to call the launch script by just typing `autopilot`

---

The actual launch call to autopilot resembles:

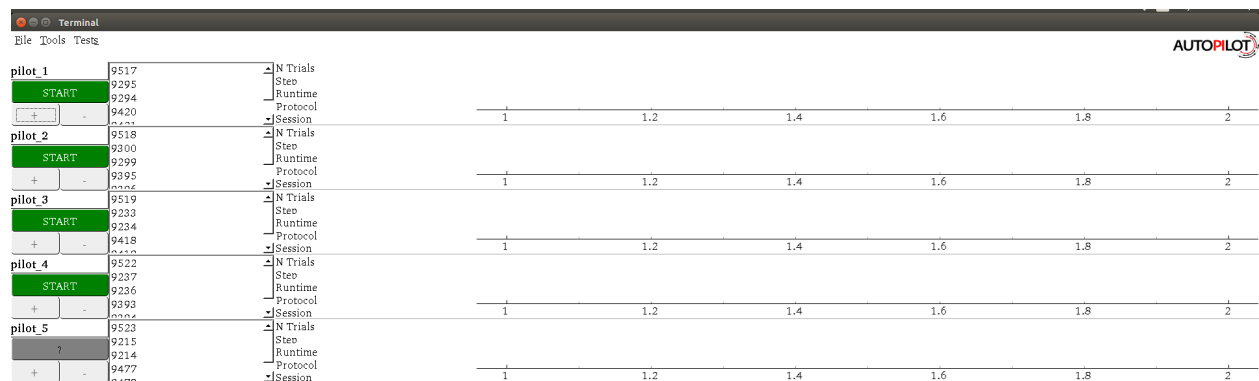
```
python3 -m autopilot.core.<AGENT_NAME> -f ~/autopilot/prefs.json
```

## TRAINING A SUBJECT

After you have set up a Terminal and a Pilot, launch the Terminal.

## 6.1 Connecting the Pilot

If the `TERMINAL_IP` and port information is correctly set in the `prefs.json` file of the Pilot, it should automatically attempt to connect to the Terminal when it starts. It will send a **handshake** message that lets the Terminal know of its existence, its IP address, and its state. Once the Terminal receives its initial message, it will refresh, adding an entry to its `pilot_db.json` file and displaying a control panel for the pilot.



If the Pilot is not automatically detected, a pilot can be manually added with its name and IP using the “New Pilot” command in the file menu.

## 6.2 Creating a Protocol

A Protocol is one or a collection of tasks which the subject can ‘graduate’ through based on configurable graduation criteria. Protocols are stored as `.json` files in the `protocols` directory within `prefs.BASEDIR`.

## 6.2.1 Using the Protocol Wizard

**Warning:** The Protocol Wizard does not currently support any Reward type except `time`, and the stimulus specification widget is limited to specifying ‘L’(left) and ‘R’(ight) sounds. This is related to the unification of the parameter structure in Autopilot 0.3 (see [To-Do](#)). Protocols can be edited after creation in the Protocol Wizard using the format examples in the manual protocol creation section below.

The Protocol Wizard allows you to build protocols using all the tasks in `autopilot.tasks` (specifically that are registered in the `TASK_LIST`). It extracts the `PARAMS` dictionary from each task class, adds a few general parameters, and allows the user to fill them.

For this example, we will create a protocol for a freely-moving two-alternative forced choice task<sup>1</sup>. This task has three ‘nosepokes,’ which consist of an IR break beam sensor, a solenoid, and an LED. The subject is supposed to poke in the center port to present a stimulus and begin a trial, and then report the identity of that stimulus category by poking in the nosepokes on either side. If the subject is correct, they are rewarded with water.

It is relatively challenging for an animal subject to learn this task without having a few beginning shaping steps that introduce it to the nature of the arena and the structure of the task. In this example we will program a three-step shaping regimen:

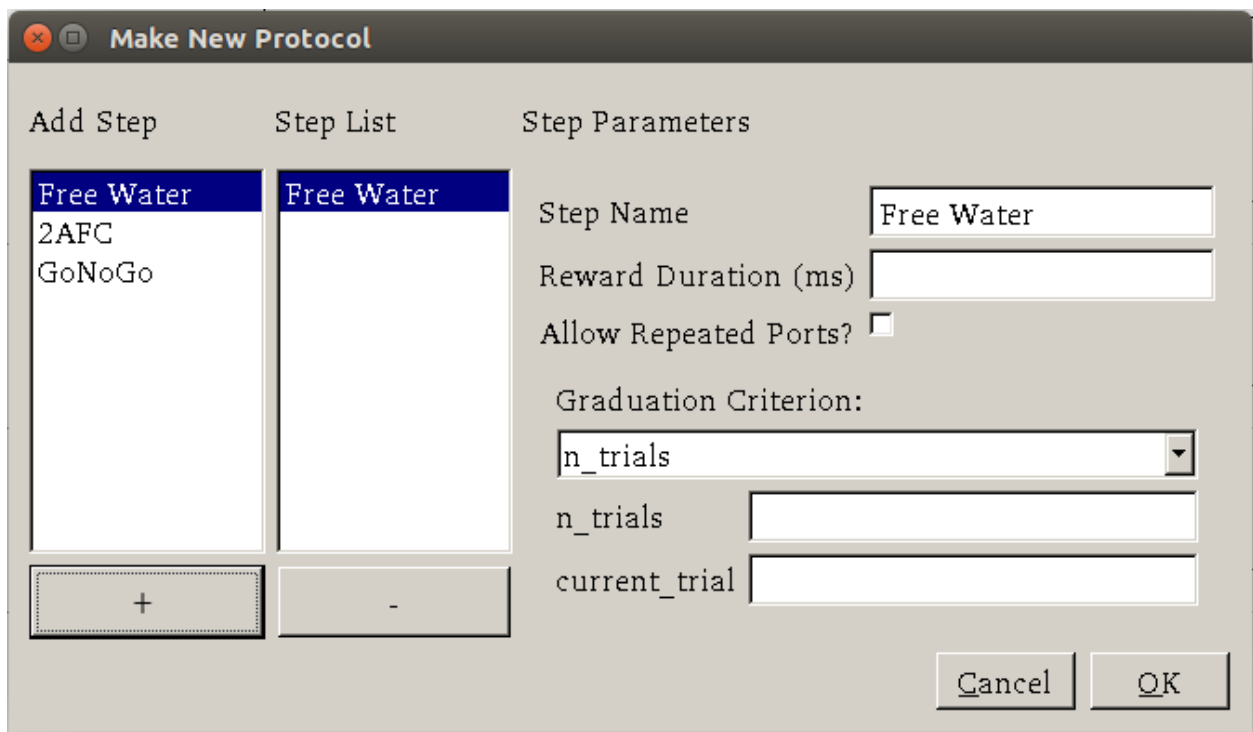
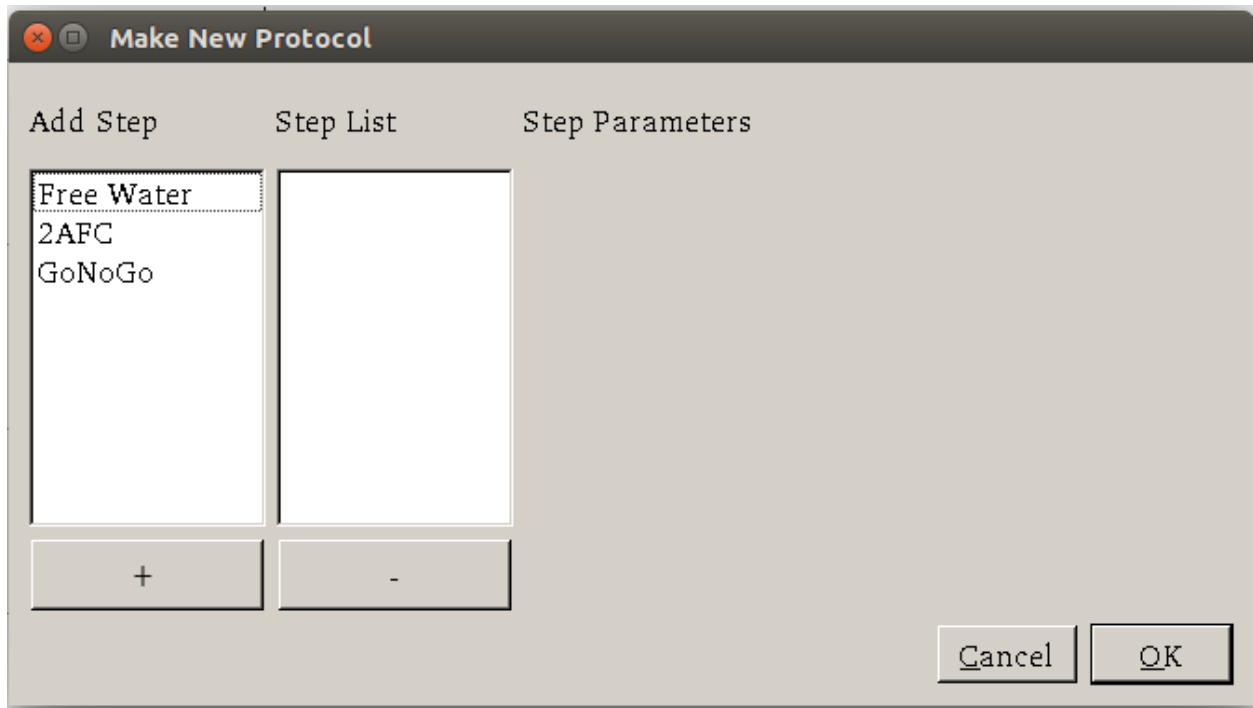
- **Step 1 - Free Water:** The subject will be rewarded for merely poking the IR sensor in order to let them know that in this universe water comes out of these particular holes in the wall
- **Step 2 - Request Rewards:** The task will operate as normal (stimuli are presented, etc.), but the subject will be rewarded for the initial center-poke as well as for a correct answer. This teaches them the temporal structure of the task – center first, then side ports.
- **Step 3 - Frequency Discrimination:** The final step of the protocol, the mouse is taught to respond left to a low-frequency tone and right to a high-frequency tone.

1. To start, select `New Protocol` from the ‘file’ menu.
2. Add a step from the list of tasks in the leftmost column by selecting it and pressing the ‘+’ button. Here we are adding the `Free Water` step.
3. Specify the parameters for the task in the rightmost window – we give 20ms of water every time the subject poke, etc.
4. Add the second “Request Rewards” step, the remaining options that are configured are: \* list \* of \* options
5. Press ok, save and name the protocol file.
6. That leaves us with a protocol file:

```
[
  {
    "allow_repeat": false,
    "graduation": {
      "type": "n_trials",
      "value": {
        "current_trial": "0",
        "n_trials": "100",
        "type": "n_trials"
      }
    }
  },
]
```

(continues on next page)

<sup>1</sup> Yes we are aware that the “two-alternative forced choice” task described here is actually maybe called a “yes-no task” because there is only one stimulus presented at a time. The literature appears stuck with this term, however.



**Make New Protocol**

**Add Step**      **Step List**      **Step Parameters**

Free Water  
2AFC  
GoNoGo

Free Water

Step Name: Free Water

Reward Duration (ms): 20

Allow Repeated Ports? ☐

Graduation Criterion:  
n\_trials

n\_trials: 100

current\_trial: 0

+      -

Cancel      OK

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```

    "reward": "20",
    "step_name": "Free Water",
    "task_type": "Free Water"
  },
  {
    "bias_mode": 0,
    "correction": true,
    "correction_pct": "10",
    "graduation": {
      "type": "n_trials",
      "value": {
        "current_trial": "0",
        "n_trials": "200",
        "type": "n_trials"
      }
    },
    "punish_stim": false,
    "req_reward": true,
    "reward": "20",
    "step_name": "request_rewards",
    "stim": {
      "sounds": {
        "L": [
          {
            "amplitude": "0.01",
            "duration": "100",
            "frequency": "4000",

```

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**Make New Protocol**

Add Step	Step List	Step Parameters	
Free Water	Free Water	Step Name	request_rewards
<b>2AFC</b>	<b>request_rewards</b>	Reward Duration (ms)	20
GoNoGo		Request Rewards	<input checked="" type="checkbox"/>
		White Noise Punishment	<input type="checkbox"/>
		Punishment Duration (ms)	
		Correction Trials	<input checked="" type="checkbox"/>
		% Correction Trials	10
		Bias Correction Mode	None Proportional
		Bias Correction Threshold (%)	
		Left Sounds	Right Sounds
		Tone	Tone
		<input type="button" value="+"/>	<input type="button" value="-"/>
		<input type="button" value="-"/>	<input type="button" value="+"/>
		Graduation Criterion:	
		n_trials	
		n_trials	200
		current_trial	0
<input type="button" value="+"/>	<input type="button" value="-"/>	<input type="button" value="Cancel"/> <input type="button" value="OK"/>	

(continued from previous page)

```

        "type": "Tone"
    }
    ],
    "R": [
        {
            "amplitude": "0.01",
            "duration": "100",
            "frequency": "10000",
            "type": "Tone"
        }
    ]
},
"tag": "Sounds",
"type": "sounds"
},
"task_type": "2AFC"
},
{
    "bias_mode": 0,
    "correction": true,
    "correction_pct": "10",
    "graduation": {
        "type": "accuracy",
        "value": {
            "threshold": "80",
            "type": "accuracy",
            "window": "1000"
        }
    },
    "punish_stim": false,
    "req_reward": false,
    "reward": "20",
    "step_name": "2AFC",
    "stim": {
        "sounds": {
            "L": [
                {
                    "amplitude": "0.01",
                    "duration": "25",
                    "frequency": "100",
                    "type": "Tone"
                }
            ],
            "R": [
                {
                    "amplitude": "0.01",
                    "duration": "100",
                    "frequency": "100",
                    "type": "Tone"
                }
            ]
        }
    }
},

```

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```

        "tag": "Sounds",
        "type": "sounds"
    },
    "task_type": "2AFC"
}
]

```

## 6.2.2 Manual Protocol Creation

Protocols can be created manually by...

1. Extracting the task specific parameters, eg:

```

params = autopilot.tasks.Nafc.PARAMS
# for example...
params['param_1'] = value_1

```

2. Adding general task parameters `stim`, `reward`, `graduation`, `step_name`, and `task_type`. These are just examples, the `stim` and `reward` fields can be any parameters consumed by a `Reward_Manager` or `Stimulus_Manager`. The `graduation` field can be any parameters consumed by a [Graduation](#) object. The `step_name` and `task_type` need to be strings, the `task_type` corresponding to a key in the `TASK_LIST`.

```

params.update({
    'stim': {
        'type': 'sounds',
        'sounds': {
            'L': [...],
            'R': [...],
        }
    },
    'reward': {
        'type': 'volume',
        'value': 2.5
    },
    'graduation': {
        'type': 'accuracy',
        'value': {
            'threshold': 0.8,
            'window': 1000
        }
    },
    'step_name': 'cool_new_step',
    'task_type': 'NAFC'
})

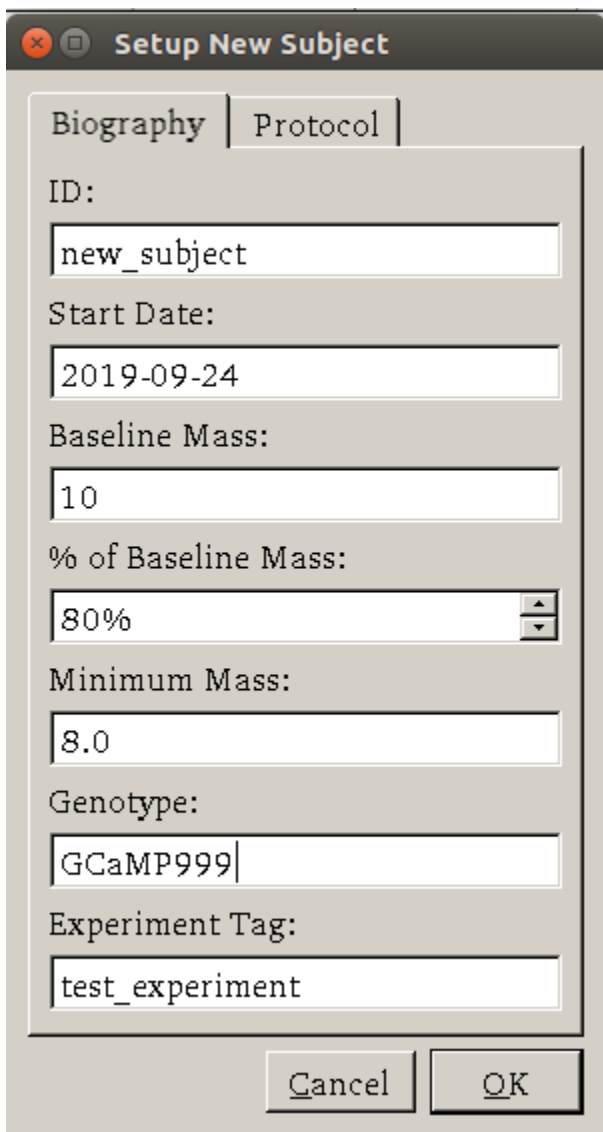
```

An example for our speech task can be found in `autopilot.tasks.protocol_scripts`.

## 6.3 Creating a Subject

A *Subject* stores the data, protocol, and history of a subject. Each subject is implicitly assigned to a Pilot by virtue of the structure of the `pilot_db.json` file, but they can be switched by editing that file.

1. Create a subject by clicking the + button in the control panel of a particular Pilot
2. Fill out the basic biographical information



The screenshot shows a 'Setup New Subject' dialog box. It has two tabs: 'Biography' and 'Protocol'. The 'Biography' tab is active. The fields and their values are: ID: new\_subject, Start Date: 2019-09-24, Baseline Mass: 10, % of Baseline Mass: 80% (selected from a dropdown), Minimum Mass: 8.0, Genotype: GCaMP999, and Experiment Tag: test\_experiment. At the bottom are 'Cancel' and 'OK' buttons.

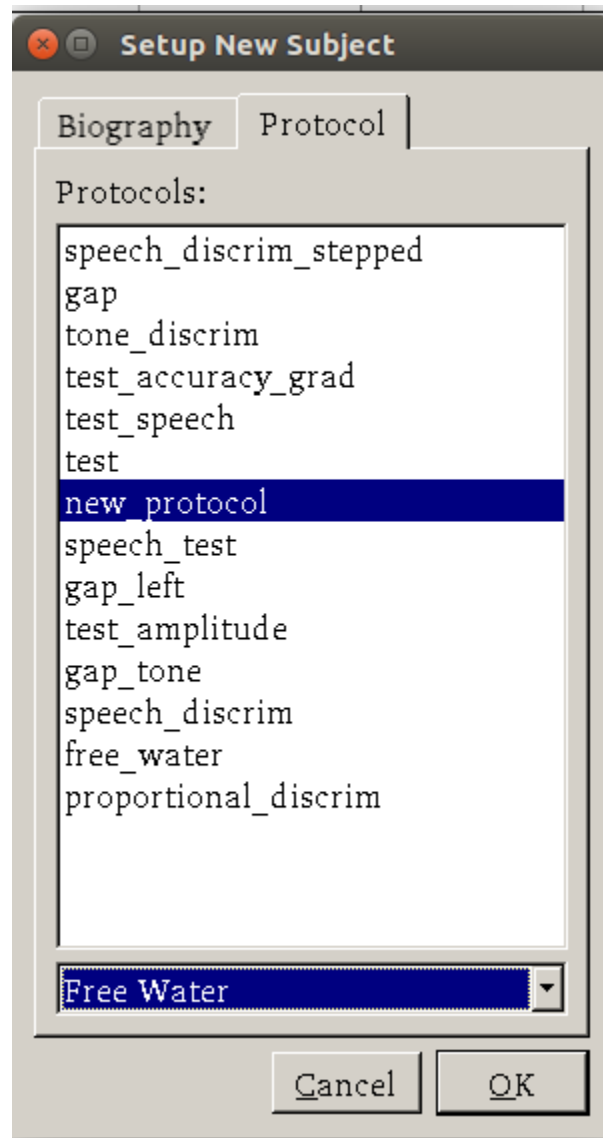
---

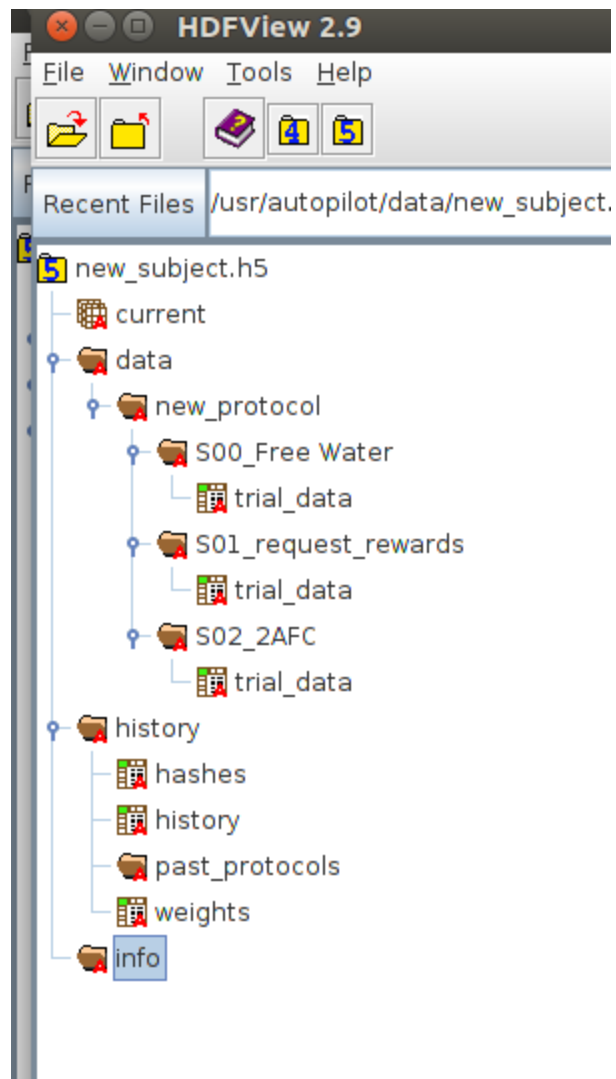
**Todo:** Currently the biographical fields are hardcoded in the Subject class. In the future we will allow users to create their own Subject schema where, for example, 'genotype' may not be as relevant.

---

3. Assign the subject to a protocol and step. Notice how the task we created earlier is here!

By creating one, we create an HDF5 file that stores a serialized version of the `.json` protocol file that was generated above, as well as the basic directory and table structure to enable the subject to store data from running the task.





## 6.4 Running the Task

1. Select the subject's name and press the start button! The Terminal will send a START message to the Pilot that includes the parameter dictionary for the current step, and if the Pilot is configured with the hardware required in the `HARDWARE` dictionary of the task, it should run.
2. The Terminal will initialize the Pilot's plot using the parameters in the task's `PLOT` dictionary and display data as it is received.

## 6.5 Debugging a Task

If a Pilot doesn't start the task appropriately, if you have installed the Pilot as a system daemon you can retrieve the logs and see the stack trace by accessing the pilot via SSH:

```
ssh pi@your.pi.ip.address
```

---

**Note:** Because Raspberry Pis are common prey on the internet, we strongly advise changing the default password, installing RSA keys to access the pi, and disabling password access via SSH.

---

and then printing the end of the logs with `journalctl`:

```
# print the -end of the logs for system -unit autopilot
journalctl -u autopilot -e
```

---

**Important:** This guide and `guide_hardware` are lightly out of date with v0.4.0 of autopilot, but still largely reflect the program design and its operation. For a simpler task, see [Blink](#) .

Many of these things can be done more elegantly, more simply, etc. now but we are a very small team and can only do so much work between releases! We'd be happy to get [documentation requests](#) or even a pull request or two to help us out until we can get to it :)

---



## WRITING A TASK

Some concepts of task design are also discussed in section 3.1 of the [whitepaper](#).

### 7.1 The Nafc Task

The Nafc class serves as an example for new task designs.

To demonstrate the general structure of Autopilot tasks, let's build it from scratch.

#### 7.1.1 The Task class

We start by subclassing the `Task` class and initializing it.

```
from autopilot.tasks import Task

class Nafc(Task):

    def __init__(self):
        super(Nafc, self).__init__()
```

This gives our new task some basic attributes and methods, including the `init_hardware()` method for initializing the `HARDWARE` dictionary and the `handle_trigger()` method for handling GPIO triggers.

#### 7.1.2 Four Task Attributes

We then add the four elements of a task description:

1. A **PARAMS** dictionary defines what parameters are needed to define the task
2. A **Data** (`tables.IsDescription`) descriptor describes what data will be returned from the task
3. A **PLOT** dictionary that maps the data output to graphical elements in the GUI.
4. A **HARDWARE** dictionary that describes what hardware will be needed to run the task.

## PARAMS

Each parameter needs a human readable tag that will be used for GUI elements, and a type, currently one of:

- `int`: integers
- `bool`: boolean (checkboxes in GUI)
- `list`: list of possible values in {'Name':int} pairs
- `sounds`: a `autopilot.core.gui.Sound_Widget` to define sounds.

To maintain order when opened by the GUI we use a `odict` rather than a normal dictionary.

```
from collections import odict

PARAMS = odict()
PARAMS['reward'] = {'tag': 'Reward Duration (ms)',
                    'type': 'int'}
PARAMS['req_reward'] = {'tag': 'Request Rewards',
                       'type': 'bool'}
PARAMS['punish_stim'] = {'tag': 'White Noise Punishment',
                        'type': 'bool'}
PARAMS['punish_dur'] = {'tag': 'Punishment Duration (ms)',
                       'type': 'int'}
PARAMS['correction'] = {'tag': 'Correction Trials',
                       'type': 'bool'}
PARAMS['correction_pct'] = {'tag': '% Correction Trials',
                           'type': 'int',
                           'depends': {'correction': True}}
PARAMS['bias_mode'] = {'tag': 'Bias Correction Mode',
                      'type': 'list',
                      'values': {'None': 0,
                                'Proportional': 1,
                                'Thresholded Proportional': 2}}
PARAMS['bias_threshold'] = {'tag': 'Bias Correction Threshold (%)',
                           'type': 'int',
                           'depends': {'bias_mode': 2}}
PARAMS['stim'] = {'tag': 'Sounds',
                  'type': 'sounds'}
```

---

**Note:** See the `Nafc` class for descriptions of the task parameters.

---

These will be taken as key-value pairs when the task is initialized. ie.:

```
PARAMS['correction'] = {'tag': 'Correction Trials',
                       'type': 'bool'}
```

will be used to initialize the task like:

```
Nafc(correction=True) # or False
```



## Data

There are two types of data,

- **TrialData** - where a single value for several variables is returned per ‘trial’, and
- **ContinuousData** - where values and timestamps are taken continuously, with either a fixed or variable interval

Both are defined by `pytables` `tables.IsDescription` objects. Specify each variable that will be returned and its type using a `tables.Col` object:

---

**Note:** See [the pytables documentation](#) for a list of `Col` types

---

```
import tables

class TrialData(tables.IsDescription):
    trial_num    = tables.Int32Col()
    target       = tables.StringCol(1)
    response     = tables.StringCol(1)
    correct      = tables.Int32Col()
    correction   = tables.Int32Col()
    RQ_timestamp = tables.StringCol(26)
    DC_timestamp = tables.StringCol(26)
    bailed       = tables.Int32Col()
```

The column types are names with their type and their bit depth except for the `StringCol` which takes a string length in characters.

The `TrialData` object is used by the `Subject` class when a task is assigned to create the data storage table.

## PLOT

The PLOT dictionary maps the data returned from the task to graphical elements in the `Terminal`’s `Plot`. Specifically, when the task is started, the `Plot` object creates the graphical element (eg. a `Point`) and then calls its `update` method with any data that is received through its `Node`.

Data-to-graphical mappings are defined in a `data` subdictionary, and additional parameters can be passed to the plot – in the below example, for example, a `chance_bar` is drawn as a horizontal line across the plot. By default it is drawn at 0.5, but its height can be set with an additional parameter `chance_level`. Available graphical primitives are registered in the `plots.PLOT_LIST`, and additional parameters are documented in the `Plot` class.

Data is plotted either by trial (default) or by timestamp (if `PLOT['continuous'] != True`). Numerical data is plotted (on the y-axis) as expected, but further mappings can be defined by extending the graphical element’s `update` method – eg. ‘L’(eft) maps to 0 and ‘R’(ight) maps to 1 by default.

```
PLOT = {
    'data': {
        'target'    : 'point',
        'response'   : 'segment',
        'correct'    : 'rollmean'
    },
    'chance_bar'    : True, # Draw a red bar at 50%
    'roll_window'   : 50    # n trials to take rolling mean over
}
```

The above PLOT dictionary produces this pretty little plot:

---

**Todo:** screenshot of default nafc plot

---

## HARDWARE

The **HARDWARE** dictionary maps a hardware type (eg. **POKES**) and identifier (eg. **'L'**) to a **Hardware** object. The task uses the hardware parameterization in the [prefs](#) file (also see `setup_pilot`) to instantiate each of the hardware objects, so their naming system must match (ie. there must be a `prefs.PINS['POKES']['L']` entry in `prefs` for a task that has a `task.HARDWARE['POKES']['L']` object).

```
from autopilot.core import hardware

HARDWARE = {
    'POKES':{
        'L': hardware.Beambreak,
        'C': hardware.Beambreak,
        'R': hardware.Beambreak
    },
    'LEDS':{
        'L': hardware.LED_RGB,
        'C': hardware.LED_RGB,
        'R': hardware.LED_RGB
    },
    'PORTS':{
        'L': hardware.Solenoid,
        'C': hardware.Solenoid,
        'R': hardware.Solenoid
    }
}
```

### 7.1.3 Initialization

First, the parameters that are given to the task when it is initialized are stored as attributes, either by unpacking `**kwargs`...

```
class Nafc(Task):

    def __init__(**kwargs):
        for key, value in kwargs.items():
            setattr(self, key, value)
```

Or explicitly, which is recommended as it is more transparent:

```
class Nafc(Task):

    def __init__(self, stage_block=None, stim=None, reward=50, req_reward=False,
                 punish_stim=False, punish_dur=100, correction=False, correction_pct=50.,
                 bias_mode=False, bias_threshold=20, current_trial=0, **kwargs):
```

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```

self.req_reward      = bool(req_reward)
self.punish_stim     = bool(punish_stim)
self.punish_dur      = float(punish_dur)
self.correction       = bool(correction)
self.correction_pct  = float(correction_pct)/100
self.bias_mode       = bias_mode
self.bias_threshold  = float(bias_threshold)/100

# etc...

```

Then the hardware is instantiated using a method inherited from the *Task* class:

```
self.init_hardware()
```

Stimulus managers need to be instantiated separately. Currently, stimulus management details like correction trial percentage or bias correction are given as separate parameters, but will be included in the `stim` parameter in the future:

```

# use the init_manager wrapper to choose the correct stimulus manager
self.stim_manager = init_manager(stim)

# give the sounds a function to call when they end
self.stim_manager.set_triggers(self.stim_end)

if self.correction:
    self.stim_manager.do_correction(self.correction_pct)

if self.bias_mode:
    self.stim_manager.do_bias(mode=self.bias_mode,
                              thresh=self.bias_threshold)

```

There are a few attributes that can be set at initialization that are unique:

- **stage\_block** - if the task is structured such that the *Pilot* calls each stage method and returns the resulting data, this `threading.Event` is used to wait between stages – an example will be shown below.
- **stages** - an iterator or generator that yields stage methods.

In this example we have structured the task such that its stages (described below) are called in an endless cycle:

```

# This allows us to cycle through the task by just repeatedly calling self.stages.next()
stage_list = [self.request, self.discrim, self.reinforcement]
self.stages = itertools.cycle(stage_list)

```

## 7.1.4 Stage Methods

The logic of a task is implemented in one or several **stages**. This example Nafc class uses three:

1. **request** - precomputes the target and distractor ports, caches the stimulus, and sets the stimulus to play when the center port is entered
2. **discrim** - sets the reward and punishment triggers for the target and distractor ports
3. **reinforcement** - computes the trial result and readies the task for the next trial.

This task does not call its own stage methods, as we will see in the Wheel task example, but allows the *Pilot* to control them, and advances through stages using a `stage_block` that allows passage whenever a GPIO trigger is activated. Data is returned from each of the stage methods and is then returned to the *Terminal* by the *Pilot*.

## Request

First, the `stage_block` is cleared so that the task will not advance until one of the triggers is called. The target and distractor ports are yielded by the `stim_manager` along with the stimulus object.

```
def request(self, *args, **kwargs):
    # Set the event block
    self.stage_block.clear()

    # get next stim
    self.target, self.distractor, self.stim = self.stim_manager.next_stim()
    # buffer it
    self.stim.buffer()
```

Then triggers are stored under the name of the trigger (eg. 'C' for a trigger that comes from the center poke). All triggers need to be callable, and can be set either individually or as a series, as in this example. A `lambda` function is used to set a trigger with arguments – the center LED is set from green to blue when the stimulus starts playing.

A single task class can support multiple operating modes depending on its parameters. If the task has been asked to give request rewards (see *Training a Subject*), it adds an additional trigger to open the center solenoid.

```
# set the center light to green before the stimulus is played.
self.set_leds({'C': [0, 255, 0]})

# Set sound trigger and LEDs
# We make two triggers to play the sound and change the light color
change_to_blue = lambda: self.pins['LEDS']['C'].set_color([0,0,255])

# set triggers
if self.req_reward is True:
    self.triggers['C'] = [self.stim.play,
                          self.stim_start,
                          change_to_blue,
                          self.pins['PORTS']['C'].open]
else:
    self.triggers['C'] = [self.stim.play,
                          self.stim_start,
                          change_to_blue]
```

Finally, the data for this stage of the trial is gathered and returned to the Pilot. Since stimuli have variable numbers and names of parameters, both the table set up by the *Subject* and the data returning routine here extract stimulus parameters programmatically.

```
self.current_trial = self.trial_counter.next()
data = {
    'target'      : self.target,
    'trial_num'   : self.current_trial,
    'correction'  : self.correction_trial
}
# get stim info and add to data dict
```

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```

sound_info = {k:getattr(self.stim, k) for k in self.stim.PARAMS}
data.update(sound_info)
data.update({'type':self.stim.type})

return data

```

At the end of this function, the center LED is green, and if the subject pokes the center port the stimulus will play and then the next stage method will be called.

The center LED also turns from green to blue when the stimulus begins to play and then turns off when it is finished. This relies on additional methods that will be explained below.

## Discrim

The discrim method simply sets the next round of triggers and returns the request timestamp from the current trial. If either the target or distractor ports are triggered, the appropriate solenoid is opened or the punish method is called.

The trial\_num is returned each stage for an additional layer of redundancy in data alignment.

```

def discrim(self,*args,**kwargs):
    # clear stage block to wait for triggers
    self.stage_block.clear()

    # set triggers
    self.triggers[self.target] = [lambda: self.respond(self.target),
                                   self.pins['PORTS'][self.target].open]
    self.triggers[self.distractor] = [lambda: self.respond(self.distractor),
                                       self.punish]

    # Only data is the timestamp
    data = {'RQ_timestamp' : datetime.datetime.now().isoformat(),
            'trial_num'    : self.current_trial}
    return data

```

**Todo:** pigpio can give us 5 microsecond measurement precision for triggers, currently we just use `datetime.datetime.now()` for timestamps, but highly accurate timestamps can be had by stashing the ticks argument given by pigpio to the `handle_trigger()` method. We will implement this if you don't first :)

## Reinforcement

This method computes the results of the tasks and returns them with another timestamp. This stage doesn't clear the stage\_block because we want the next trial to be started immediately after this stage completes.

The results of the current trial are given to the stimulus manager's `update()` method so that it can keep track of trial history and do things like bias correction, etc.

The TRIAL\_END flag in the data signals to the `Subject` class that the trial is finished and its row of data should be written to disk. This, along with providing the trial\_num on each stage, ensure that data is not misaligned between trials.

```
def reinforcement(self,*args,**kwargs):

    if self.response == self.target:
        self.correct = 1
    else:
        self.correct = 0

    # update stim manager
    self.stim_manager.update(self.response, self.correct)

    data = {
        'DC_timestamp' : datetime.datetime.now().isoformat(),
        'response'      : self.response,
        'correct'       : self.correct,
        'trial_num'     : self.current_trial,
        'TRIAL_END'     : True
    }
    return data
```

### 7.1.5 Additional Methods

Autopilot doesn't confine the logic of a task to its stage methods, instead users can use additional methods to give their task additional functionality.

These can range from trivial methods that just store values, such as the `respond` and `stim_start` methods:

```
def respond(self, pin):
    self.response = pin

def stim_start(self):
    self.discrim_playing = True
```

To more complex methods that operate effectively like stages, like the `punish` method, which flashes the LEDs and plays a punishment stimulus like white noise if it has been configured to do so:

```
def punish(self):
    # clear the punish block to the task doesn't advance while
    # punishment is delivered
    self.punish_block.clear()

    # if there is some punishment stimulus, play it
    if self.punish_stim:
        self.stim_manager.play_punishment()

    # flash LEDs and then clear the block once they are finished.
    self.flash_leds()
    threading.Timer(self.punish_dur / 1000.,
                    self.punish_block.set).start()
```

Additionally, since we gave the stimulus manager a trigger method that is called when the stimulus ends, we can turn the light blue when a stimulus is playing, and turn it off when it finishes

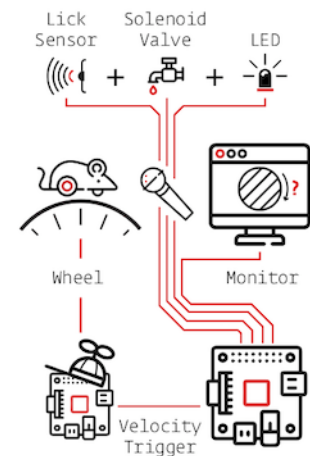
```
def stim_end(self):
    """
    called by stimulus callback

    set outside lights blue
    """
    # Called by the discrim sound's table trigger when playback is finished
    # Used in punishing leaving early
    self.discrim_playing = False
    #if not self.bailed and self.current_stage == 1:
    self.set_leds({'L':[0,255,0], 'R':[0,255,0]})
```

## 7.2 Distributed Go/No-Go - Using Child Agents

To demonstrate the use of Child agents, we'll build the distributed Go/No-Go task described in section 4.3 of the Autopilot whitepaper.

In short, a subject runs on a circular running wheel whose velocity is measured by a laser computer mouse. When the subject 'fixates' by slowing below a threshold velocity, an drifting Gabor grating is presented. If the grating changes angles, the subject is rewarded if they lick in an IR beambreak sensor. If the grating doesn't change angles, the subject is rewarded if they refrain from licking until the stimulus has ended.



### 7.2.1 Additional Prefs

To use a Child with this task, we will need to have a second Raspberry Pi setup with the same routine as a Pilot, except it needs the following values in its `prefs.json` file:

#### Child Prefs

```
{
  "NAME" : "wheel_child",
  "LINEAGE" : "CHILD",
  "PARENTID" : "parent_pilot",
  "PARENTIP" : "ip.of.parent.pilot",
  "PARENTPORT": "<MSGPORT of parent>",
}
```

And the parent pilot needs to have

#### Parent Prefs

```
{
  "NAME": "parent_pilot",
  "CHILDID": "wheel_child",
  "LINEAGE": "PARENT"
}
```

## 7.2.2 Go/No-Go Parameterization

The parameterization for this task is similar to that of the Nafc task above with a few extensions...

```
from autopilot.tasks import Task

class GoNoGo(Task):

    # Task parameterization
    PARAMS = odict()
    PARAMS['reward'] = {'tag': 'Reward Duration (ms)',
                        'type': 'int'}
    PARAMS['timeout'] = {'tag': 'Delay Timeout (ms)',
                        'type': 'int'}
    PARAMS['stim'] = {'tag': 'Visuals',
                      'type': 'visuals'}

    # Plot parameterization
    PLOT = {
        'data': {
            'x': 'shaded',
            'target': 'point',
            'response': 'segment'
        },
        # our plot will use time as its x-axis rather than the
        ↪ trial number
        'continuous': True
    }

    # TrialData descriptor
    class TrialData(tables.IsDescription):
        trial_num = tables.Int32Col()
        target = tables.BoolCol()
        response = tables.StringCol(1)
        correct = tables.Int32Col()
        RQ_timestamp = tables.StringCol(26)
        DC_timestamp = tables.StringCol(26)
        shift = tables.Float32Col()
        angle = tables.Float32Col()
        delay = tables.Float32Col()
```

We add one additional data descriptor that describes the continuous data that will be sent from the Wheel object:

```
class ContinuousData(tables.IsDescription):
    x = tables.Float64Col()
    y = tables.Float64Col()
    t = tables.Float64Col()
```

The hardware specification is also similar, with one additional Flag object which behaves identically to the Beambreak object with reversed logic (triggered by 0->1 rather than 1->0).



```
HARDWARE = {
    'POKES': {
        'C': hardware.Beambreak,
    },
    'LEDS': {
        'C': hardware.LED_RGB,
    },
    'PORTS': {
        'C': hardware.Solenoid,
    },
    'FLAGS': {
        'F': hardware.Flag
    }
}
```

Finally, we add an additional CHILDREN dictionary to specify the type of Child that we need to run the task, as well as any additional parameters needed to configure it.

The `task_type` must refer to some key in the `autopilot.tasks.CHILDREN_LIST`.

---

**Note:** The Child agent is a subconfiguration of the Pilot agent, they will be delineated more explicitly as the agent framework is solidified.

---

```
CHILDREN = {
    'WHEEL': {
        'task_type': "Wheel Child",
    }
}
```

### 7.2.3 Initialization

When initializing this task, we need to make our own `Net_Node` object as well as initialize our child. Assuming that the child is connected to the parent and appropriately configured (see the additional params above), then things should go smoothly.

**Warning:** Some of the parameters – most egregiously the Grating stimulus – are hardcoded in the initialization routine. **This is bad practice** but an unfortunately necessary evil because the visual stimulus infrastructure is not well developed yet.

```
from autopilot.stim.visual.visuals import Grating

def __init__(self, stim=None, reward = 50., timeout = 1000., stage_block = None,
              punish_dur = 500., **kwargs):
    super(GoNoGo, self).__init__()

    # we receive a stage_block from the pilot as usual, we won't use it
    # for task operation though.
    self.stage_block = stage_block
    self.trial_counter = itertools.count()
```

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```

# save parameters passed to us as arguments
self.punish_dur = punish_dur
self.reward = reward
self.timeout = timeout
self.subject = kwargs['subject']

# init hardware and set reward as before
self.init_hardware()
self.set_reward(self.reward)

# hardcoding stimulus while visual stim still immature
self.stim = Grating(angle=0, freq=(4,0), rate=1, size=(1,1), debug=True)

self.stages = itertools.cycle([self.request, self.discrim, self.reinforce])

```

### Initializing the Net Node.

The `Net_Node` gets the following arguments:

- `id`: The name that is used to identify the task's networking object so other networking objects can send it messages. We prefix the pilot's `prefs.NAME` with `T_` because it is a task, though this is not required.
- `upstream`: The name of the network node that is directly upstream from us, we will be sending our messages to the *Pilot* that is running us – and thus address it by its name
- `port`: The port of our upstream mode, most commonly the `prefs.MSGPORT`
- `listens`: A dictionary that maps messages with different `KEY`'s to specific handling methods. Since we don't need to receive any data for this task, this is blank,
- `instance`: Optional, denotes whether this node shouldn't be the only node that exists within the Agent – ie. it uses the same instance of the `tornado` `IOLoop` as other nodes.

```

self.node = Net_Node(id="T_{}".format(prefs.NAME),
                     upstream=prefs.NAME,
                     port=prefs.MSGPORT,
                     listens={},
                     instance=True)

```

And then to initialize our Child we construct a message to send along to it.

Note that we send the message to `prefs.NAME` – we don't want to have to know the IP address/etc. for our child because it connects to us – so the `Station` object handles sending it along with its `Pilot_Station.1_child()` listen.

```

# construct a message to send to the child
value = {
    'child': {'parent': prefs.NAME, 'subject': self.subject},
    'task_type': self.CHILDREN['WHEEL']['task_type'],
    'subject': self.subject
}

# send to the station object with a 'CHILD' key
self.node.send(to=prefs.NAME, key='CHILD', value=value)

```

## 7.2.4 The Child Task

The *Wheel\_Child* task is a very thin wrapper around a *Wheel* object, which does most of the work.

It creates a stages iterator with a function that returns nothing to fit in with the general task structure.

```
class Wheel_Child(object):
    STAGE_NAMES = ['collect']

    PARAMS = odict()
    PARAMS['fs'] = {'tag': 'Velocity Reporting Rate (Hz)',
                    'type': 'int'}
    PARAMS['thresh'] = {'tag': 'Distance Threshold',
                        'type': 'int'}

    HARDWARE = {
        "OUTPUT": Digital_Out,
        "WHEEL": Wheel
    }

    def __init__(self, stage_block=None, fs=10, thresh=100, **kwargs):
        self.fs = fs
        self.thresh = thresh

        self.hardware = {}
        self.hardware['OUTPUT'] = Digital_Out(prefs.PINS['OUTPUT'])
        self.hardware['WHEEL'] = Wheel(digi_out = self.hardware['OUTPUT'],
                                       fs = self.fs,
                                       thresh = self.thresh,
                                       mode = "steady")

        self.stages = cycle([self.noop])
        self.stage_block = stage_block

    def noop(self):
        # just fitting in with the task structure.
        self.stage_block.clear()
        return {}

    def end(self):
        self.hardware['WHEEL'].release()
        self.stage_block.set()
```

### 7.2.5 A Very Smart Wheel

Most of the Child's contribution to the task is performed by the `Wheel` object.

The `Wheel` accesses a USB mouse connected to the Pilot, continuously collects its movements, and reports them back to the Terminal with a specified frequency (fs) with an internal `Net_Node`

An abbreviated version...

```
from inputs import devices

class Wheel(Hardware):

    def __init__(self, mouse_idx=0, fs=10, thresh=100, thresh_type='dist', start=True,
                 digi_out = False, mode='vel_total', integrate_dur=5):

        self.mouse = devices.mice[mouse_idx]
        self.fs = fs
        self.thresh = thresh
        # time between updates
        self.update_dur = 1./float(self.fs)
```

The `Wheel` has three message types,

- 'MEASURE' - the main task is telling us to monitor for a threshold crossing, ie. previous trial is over and it's ready for another one.
- 'CLEAR' - stop measuring for a threshold crossing event!
- 'STOP' - the task is over, clear resources and shut down.

```
# initialize networking
self.listens = {'MEASURE': self.l_measure,
                'CLEAR'   : self.l_clear,
                'STOP'    : self.l_stop}

self.node = Net_Node('wheel_{}'.format(mouse_idx),
                     upstream=prefs.NAME,
                     port=prefs.MSGPORT,
                     listens=self.listens,
                     )

# if we are being used in a child object,
# we send our trigger via a GPIO pin
self.digi_out = digi_out

self.thread = None

if start:
    self.start()

def start(self):
    self.thread = threading.Thread(target=self._record)
    self.thread.daemon = True
    self.thread.start()
```

The wheel starts two threads, one that captures mouse movement events and puts them in a queue, and another that processes movements, transmits them to the Terminal, and handles the threshold triggers when the subject falls below a certain velocity.

```
def _mouse(self):
    # read mouse movements and put them in a queue
    while self.quit_evt:
        events = self.mouse.read()
        self.q.put(events)

def _record(self):

    threading.Thread(target=self._mouse).start()

    # a threading.Event is used to terminate the wheel's operation
    while not self.quit_evt.is_set():

        # ... mouse movements are collected into a 2d numpy array ...

        # if the main task has told us to measure for a velocity threshold
        # we check if our recent movements (move) trigger the threshold
        if self.measure_evt.is_set():
            do_trigger = self.check_thresh(move)
            if do_trigger:
                self.thresh_trig()
                self.measure_evt.clear()

        # and we report recent movements back to the Terminal
        # the recent velocities and timestamp have been calculated as
        # x_vel, y_vel, and nowtime
        self.node.send(key='CONTINUOUS',
                        value={
                            'x':x_vel,
                            'y':y_vel,
                            't':nowtime
                        })
```

If the threshold is triggered, a method (...`thresh\_trig`...) is called that sends a voltage pulse through the Digital\_Out given to it by the Child task.

```
def thresh_trig(self):
    if self.digi_out:
        self.digi_out.pulse()
```

## 7.2.6 Go/No-Go Stage Methods

After the child is initialized, the Parent pilot begins to call the three stage functions for the task in a cycle

Very similar to the Nafc task above...

- **request** - Tell the Child to begin measuring for a velocity threshold crossing, prepare the stimulus for delivery
- **discrim** - Present the stimulus
- **reinforce** - Reward the subject if they were correct

The code here has been abbreviated for the purpose of the example:

```
def request(self):
    # Set the event lock
    self.stage_block.clear()
    # wait on any ongoing punishment stimulus
    self.punish_block.wait()

    # set triggers
    self.triggers['F'] = [
        lambda: self.stim.play('shift', self.shift )
    ]

    # tell our wheel to start measuring
    self.node.send(to=[prefs.NAME, prefs.CHILDID, 'wheel_0'],
                   key="MEASURE",
                   value={'mode': 'steady',
                          'thresh': 100})

    # return data from current stage
    self.current_trial = self.trial_counter.next()
    data = {
        'target': self.target, # whether to 'go' or 'not go'
        'shift': self.shift,   # how much to shift the
                               # angle of the stimulus
        'trial_num': self.current_trial
    }

    return data

def discrim(self):
    # if the subject licks on a good trial, reward.
    # set a trigger to respond false if delay time elapses
    if self.target:
        self.triggers['C'] = [lambda: self.respond(True), self.pins['PORTS']['C'].open]
        self.triggers['T'] = [lambda: self.respond(False), self.punish]
    # otherwise punish
    else:
        self.triggers['C'] = [lambda: self.respond(True), self.punish]
        self.triggers['T'] = [lambda: self.respond(False), self.pins['PORTS']['C'].open]
```

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```

# the stimulus has just started playing, wait a bit and then shift it (if we're gonna
# choose a random delay
delay = 0.0
if self.shift != 0:
    delay = (random()*3000.0)+1000.0
    # a delay timer is set that shifts the stimulus after
    # <delay> milliseconds
    self.delayed_set(delay, 'shift', self.shift)

# trigger the timeout in 5 seconds
self.timer = threading.Timer(5.0, self.handle_trigger, args=('T', True, None)).
↪start()

# return data to the pilot
data = {
    'delay': delay,
    'RQ_timestamp': datetime.datetime.now().isoformat(),
    'trial_num': self.current_trial
}

return data

def reinforce(self):

    # stop timer if it's still going
    try:
        self.timer.cancel()
    except AttributeError:
        pass
    self.timer = None

    data = {
        'DC_timestamp': datetime.datetime.now().isoformat(),
        'response': self.response,
        'correct': self.correct,
        'trial_num': self.current_trial,
        'TRIAL_END': True
    }
    return data

```

Viola.

**Important:** This guide and `guide_task` are lightly out of date with v0.4.0 of autopilot, but still largely reflect the program design and its operation. This guide in particular became obsolete because most extensions to hardware objects are now done by subclassing generic hardware classes like `hardware.gpio.GPIO` and their descendents, which make it relatively clear what parts of the object need to be modified.

As such, this part of the docs was deprecated in v0.3.0 and has been mostly removed in v0.4.0 pending a fuller rewrite.

For now, see the API documentation section for `hardware` for more details on how to extend hardware classes :)

Sorry for the inconvenience, we are a very small team and can only do so much work between releases! We'd be happy

to get [documentation requests](#) or even a pull request or two to help us out until we can get to it :)

---



## WRITING A HARDWARE CLASS

There are precious few requirements for Hardware objects in Autopilot.

- Each class should have a `release()` method that stops any running threads and releases any system resources – especially those held by `pigpio`.
- **Each class should define a handful of class attributes when relevant**
  - `trigger` (bool) - whether the device is used to trigger an event. if `True`, `assign_cb()` must be defined and the device will be given a callback function by the instantiating `Task` class
  - `type` (str) - what this device should be known as in `prefs`. Not enforced currently, but will be.
  - `input` and `output` (bool) - whether the device is an input or output device, if either
- When making threaded methods, care should be taken not to spawn an excessive number of running threads, but this is a performance rather than a structural limit.

To use a hardware object in a task, its parameters (especially the pin number for `pigpio`-based hardware) should be stored in `prefs.json`.

A few basic Hardware classes are dissected in this section to illustrate basic principles of their design, but we expect Hardware objects to be extremely variable in their implementation and application.

### 8.1 GPIO with `pigpio`

Autopilot uses `pigpio` to interface with the Raspberry Pi's GPIO pins. All `pigpio` objects require that a `pigpiod` daemon is running as a background process. This used to be done by a launch script that started the pilots, but is now typically launched by `autopilot.external.start_pigpiod()`, which is called by `GPIO.init_pigpio()` so in general you shouldn't need to worry about it. If `pigpiod` is open in a separate process, or left open from a previous crashed run of Autopilot, you will likely need to kill that process before you can use more GPIO-based autopilot objects.

When instantiating a piece of hardware, it must connect to `pigpiod` by creating a `pigpio.pi` object, which allows communication with the GPIO. This is provided by the `GPIO.pi` property. The rest of the methods of GPIO-based objects are built around abstractions of commands to the `pi`. See `gpio.LED_RGB` for an example of a subclass that overrides some methods from the `gpio.GPIO` metaclass to be able to control three PWM objects with a similar syntax as other GPIO outputs.



## PLUGINS & THE WIKI

Autopilot is integrated with a [semantic wiki](https://wiki.auto-pi-lot.com), a powerful tool that merges human-readable text with computer-readable structured information, and blurs the lines between the two in the empowering interface of a wiki that allows anyone to edit it. The autopilot wiki is available at:

<https://wiki.auto-pi-lot.com>

In addition to a system for storing, discussing, and knitting together a library of technical knowledge, the wiki is used to manage Autopilot's plugin system. The integrated plugin/wiki system is designed to

- make it easier to **extend** and hack existing autopilot classes, particularly Hardware and Task classes, without needing to modify any of the core library code
- make it easier to **share code** across multiple rigs-in-use by allowing you to specify the name of the plugin on the autopilot wiki so you don't need to manually keep the code updated on all computers it's used on
- make a gentler **scaffold between using and contributing to the library** – by developing in a plugin folder, your code is likely very close, if it isn't already, ready to integrate back into the main autopilot library. In the meantime, anyone that is curious
- make it possible to **encode semantic metadata about the plugin** so that others can **discover, modify, and improve** on it. eg. your plugin might control an array of stepper motors, and from that someone can cherry-pick code to run a single one, even if it wasn't designed to do that.
- **decentralize the development of autopilot**, allowing anyone to extend it in arbitrary ways without needing to go through a fork/merge process that is ultimately subject to the whims of the maintainer(s) (me ), or even an approval process to submit or categorize plugins. Autopilot seeks to be as noncoercive as possible while embracing and giving tools to support the heterogeneity of its use.
- make it trivial for users to not only contribute *plugins* but design new *types of plugin-like public interfaces*. For example, if you wanted to design an interface where users can submit the parameters they use for different tasks, one would only need to build the relevant semantic mediawiki template and form, and then program the API calls to the wiki to index them.
- **todo** — fully realize the vision of decentralized development by allowing plugins to replace existing core autopilot modules...

## 9.1 Plugins

Plugins are now the recommended way to use Autopilot! They make very few assumptions about the structure of your code, so they can be used like familiar script-based experimental tools, but they also encourage the development of modular code that can easily be used by others and cumulatively contribute to a shared body of tools.

Using plugins is simple! Anything inside of the directory indicated by `prefs.get('PLUGINDIR')` is a plugin! Plugins provide objects that inherit from Autopilot classes supported by an entry in `registry.REGISTRIES`.

For example, we want to write a task that uses some special hardware that we need. We could start by making a directory within 'PLUGINDIR' like this:

```
plugins
├── my-autopilot-plugin
│   ├── README.md
│   ├── test_hardware.py
│   └── test_task.py
```

Where within `test_hardware.py` you define some custom hardware class that inherits from `gpio.Digital_Out`

```
from autopilot.hardware.gpio import Digital_Out

class Only_On_Pin(Digital_Out):
    """
    you can only turn this GPIO pin on
    """
    def __init__(self, pin, *args, **kwargs):
        super(Only_On_Pin, self).__init__(pin=pin, *args, **kwargs)
        self.set(1)

    def set(self, val):
        """override base class"""
        if val not in (1, True, 'on'):
            raise ValueError('This pin only turns on')
        else:
            super(Only_On_Pin, self).set(val)

    def release(self):
        print('I release nothing. the pin stays on.')
```

You can then use it in some task! Autopilot will use its registry `autopilot.get()` methods to find it after importing all your plugins. For example, we can refer to it as a string in our `HARDWARE` dictionary in our special task:

```
from datetime import datetime
import threading
import numpy as np
from autopilot.tasks import Task
from tables import IsDescription, StringCol

class My_Task(Task):
    """
    I will personally subject myself to the labor of science and through careful hours,
    ↪ spent meditating on an LED powered by an unsecured Raspberry Pi with the default,
    ↪ password i will become attuned to the dance of static pixels fluctuating on the,
    ↪ fundamental frequencies of ransomware and ssh bombardment to harness the power of both,
    ↪ god and anime
    """
```

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```

"""

PARAMS = {'infinite_light': {
    'tag': 'leave the light on indefinitely? are you sure you want to leave_
↳the rest of the world behind and never cease your pursuit of this angelic orb?',
    'type': 'bool'}}

HARDWARE = {'esoterica': {'the_light': 'Only_On_Pin'}}

class TrialData(IsDescription):
    ontime = StringCol(26)

    def __init__(self, infinite_light:bool=True, *args, **kwargs):
        super(My_Task, self).__init__(*args, **kwargs)
        self.init_hardware()
        self.hardware['esoterica']['the_light'].set(True)

        if not infinite_light:
            infinite_light = True
        self.infinite_light = infinite_light

        self.stages = [self.only_on]

    def only_on(self):
        self.stage_block.clear()

        if not self.infinite_light:
            threading.Timer(np.random.rand()*10e100, self.cease_your_quest).start()

        return {'ontime': datetime.now().isoformat()}

    def cease_your_quest(self):
        self.stage_block.set()
        self.hardware['esoterica']['the_light'].release()

```

Both your hardware object and task will be available to the rest of Autopilot, including in the GUI elements that let you easily parameterize and assign it to your experimental subjects.

**Todo:** We are still working on formalizing the rest of a plugin architecture, specifically dependency resolution among python packages, autopilot scripts, and dependencies on other plugins. All this in time! For now the wiki asks for a specific autopilot version that a plugin supports when they are submitted, so we will be able to track plugins that need to be updated for changes in the plugin API as it is developed.

## 9.2 Registries

Plugins are supported by the functions in the `utils.registry` module. Registries allow us to make definite but abstract references to classes of objects that can therefore be extended with plugins.

Since for now Autopilot objects are not guaranteed to have a well-defined inheritance structure, registries are available to the classes of objects listed in the `registry.REGISTRIES` enum. Currently they are:

```
class REGISTRIES(str, Enum):
    """
    Types of registries that are currently supported,
    ie. the possible values of the first argument of :func:`.registry.get`

    Values are the names of the autopilot classes that are searched for
    inheriting classes, eg. ``HARDWARE == "autopilot.hardware.Hardware"`` for
    ↪:class:`autopilot.Hardware`
    """
    HARDWARE = "autopilot.hardware.Hardware"
    TASK = "autopilot.tasks.Task"
    GRADUATION = "autopilot.tasks.graduation.Graduation"
    TRANSFORM = "autopilot.transform.transforms.Transform"
    CHILDREN = "autopilot.tasks.children.Child"
    SOUND = "autopilot.stim.sound.sounds.BASE_CLASS"
```

Each entry in the enum refers to the absolute package.module.class name of the topmost metaclass that is to be searched.

The `autopilot.get()` method first gets the base class with `find_class()`, ensures that plugins have been imported with `import_plugins()`, and searches for a subclass with a matching name with `recurse_subclasses()`. If none is found in the currently imported files, it parses the `ast` of any files below the base class in the path hierarchy. The distinction is because while we *do* assume that we can import anything we have made/put in our plugins directory, we currently *don't* make that assumption of the core library of autopilot – we want to be able to offer the code for tasks and hardware that have diverse dependencies while giving ourselves some protection against writing squirrely edge cases everywhere.

In practice, anywhere you go to make an explicit import of an autopilot class that is supported by a registry, it is good practice to use `autopilot.get` instead. It is called like:

```
# autopilot.get('registry_name', 'object_name')
# eg.
autopilot.get('hardware', 'Digital_Out')
```

Note how the registry name is not case sensitive but the object name is. There are a few convenience methods/calling patterns here too. Eg. to list all available objects in a registry:

```
autopilot.get('hardware')
```

or to list just a list of strings instead of the objects themselves:

```
autopilot.get_names('hardware')
```

or you can pass an object itself as the registry type in order to only find subclasses of that class:

```
GPIO = autopilot.get('hardware', 'GPIO')
autopilot.get(GPIO)
```

**Todo:** In the future, we will extend registries to all autopilot objects by implementing a unitary inheritance structure. This will also clean up a lot of the awkward parts of the library and pave the way to rebuilding eg. the networking modules to be much simpler to use.

That work will be the defining feature of v0.5.0, you can track progress and contribute by seeing the relevant issue: <https://github.com/wehr-lab/autopilot/issues/31>

as well as the issues in the v0.5.0 milestone: <https://github.com/wehr-lab/autopilot/milestone/2>

## 9.3 The Wiki API

The wiki’s semantic information can be accessed with the functions in the `utils.wiki` module.

Specifically, we make a function that wraps the [Semantic Mediawiki Ask API](#) that consists of a

- **query** or a set of **filters** that select relevant pages using their **categories** and **properties**, and then
- the **properties** to retrieve from those pages.

You can see a list of the [categories](#) and [properties](#) that can be used on the wiki.

For **Filters**:

- **Both** types of filters are specified with the `[[Double Brackets]]` of mediawiki
- **Categories** are specified with a single colon<sup>1</sup> like `[[Category:Hardware]]`
- **Properties** are specified with double colons, and take a property and a value like `[[Created By::Jonny Saunders]]`

The **queried properties** are specified with a list of strings like `['Has Datasheet', 'Has STL']`

So, for example, one could query the manufacturer, price, and url of the audio hardware documented in the wiki like:

```
from autopilot.utils import wiki

wiki.ask(
    filters=[
        "[[Category:Hardware]]",
        "[[Modality::Audio]]"
    ],
    properties=[
        "Manufactured By",
        "Has Product Page",
        "Has USD Price"
    ]
)
```

which would return a list of dictionaries like:

```
[{
    'Has Product Page': 'https://www.hifiberry.com/shop/boards/hifiberry-amp2/',
    'Has USD Price': 49.9,
    'Manufactured By': 'HiFiBerry',
```

(continues on next page)

<sup>1</sup> This is because categories are a part of mediawiki itself, but properties are implemented by semantic mediawiki. The two have slightly different meanings – categories denote the “type of something that a page is” and properties denote “the attributes that a page has”

(continued from previous page)

```

    'name': 'HiFiBerry Amp2',
    'url': 'https://wiki.auto-pi-lot.com/index.php/HiFiBerry_Amp2'
  },
  {
    'Has Datasheet': 'https://wiki.auto-pi-lot.com/index.php/File:HiVi-RT13WE-spec-sheet.
    ↪pdf',
    'Has Product Page': 'https://www.parts-express.com/HiVi-RT1.3WE-Isodynamic-Tweeter-
    ↪297-421',
    'Has USD Price': 37.98,
    'Is Part Type': 'Speakers',
    'Manufactured By': 'HiVi',
    'name': 'HiVi RT1.3WE',
    'url': 'https://wiki.auto-pi-lot.com/index.php/HiVi_RT1.3WE'
  }
}]

```

These functions can be used on their own to provide interactive, programmatic access to the wiki, but maybe more importantly it serves as a bridge between the wiki and Autopilot’s software. By building API calls into the various modules of autopilot that can query structured information from the wiki, the software can be made to take advantage of communally curated experimental and technical knowledge.

Additionally, since it is relatively simple to create new templates and forms (see the [Page Forms](#) and [Page Schemas](#) extensions that are used to create and manage them) to accept different kinds of submissions and link them to the rest of the wiki, and the plugin and registry system allow anyone to build the classes needed to take advantage of them, it becomes possible for anyone to create **new kinds of public knowledge interfaces to autopilot**. For example, if there was desire to share and describe parameterizations of a particular Task along with summaries of the data, then it would be possible to make a form and template on the wiki to accept them, and provide a GUI plugin to select *empirically optimal parameters for a given outcome measurement*, which would make all the *hard-won rules of thumb and superstition that guides a lot of the fine decisions in behavioral research obsolete in an afternoon*.

The use of the wiki to have communal control over plugins and interfaces makes it possible for us to move autopilot to a model of **decentralized governance** where the “official” repository becomes one version among many, but the plugins remain integrated with the system rather than live on as unrelated forks.

## 9.4 Plugins on the Wiki

Autopilot plugins can be found on the wiki here: [https://wiki.auto-pi-lot.com/index.php/Autopilot\\_Plugins](https://wiki.auto-pi-lot.com/index.php/Autopilot_Plugins)

*(at the moment the cupboard is relatively bare, but it always starts that way.)*

Within Autopilot, you can use the `utils.plugins.list_wiki_plugins()` function to list the available functions and return their basic metadata, which is a *very thin* wrapper around `utils.wiki.ask()`

To submit new plugin, one would use the relevant form: [https://wiki.auto-pi-lot.com/index.php/Form:Autopilot\\_Plugin](https://wiki.auto-pi-lot.com/index.php/Form:Autopilot_Plugin)

So we might submit our plugin “Fancy New Plugin” (by entering that on the form entry page), and filling in the fields in the form as requested:

Where we provide a description and other metadata – most important some git repository url – that describes the plugin. There are free text fields where appropriate, but also autocompleting token fields that let us keep some semblance of consistency in the semantic links we create. At the end you are then given a free-text field that accepts all common [wiki markup](#) as well as free declaration of any semantic links that aren’t asked for in the form.

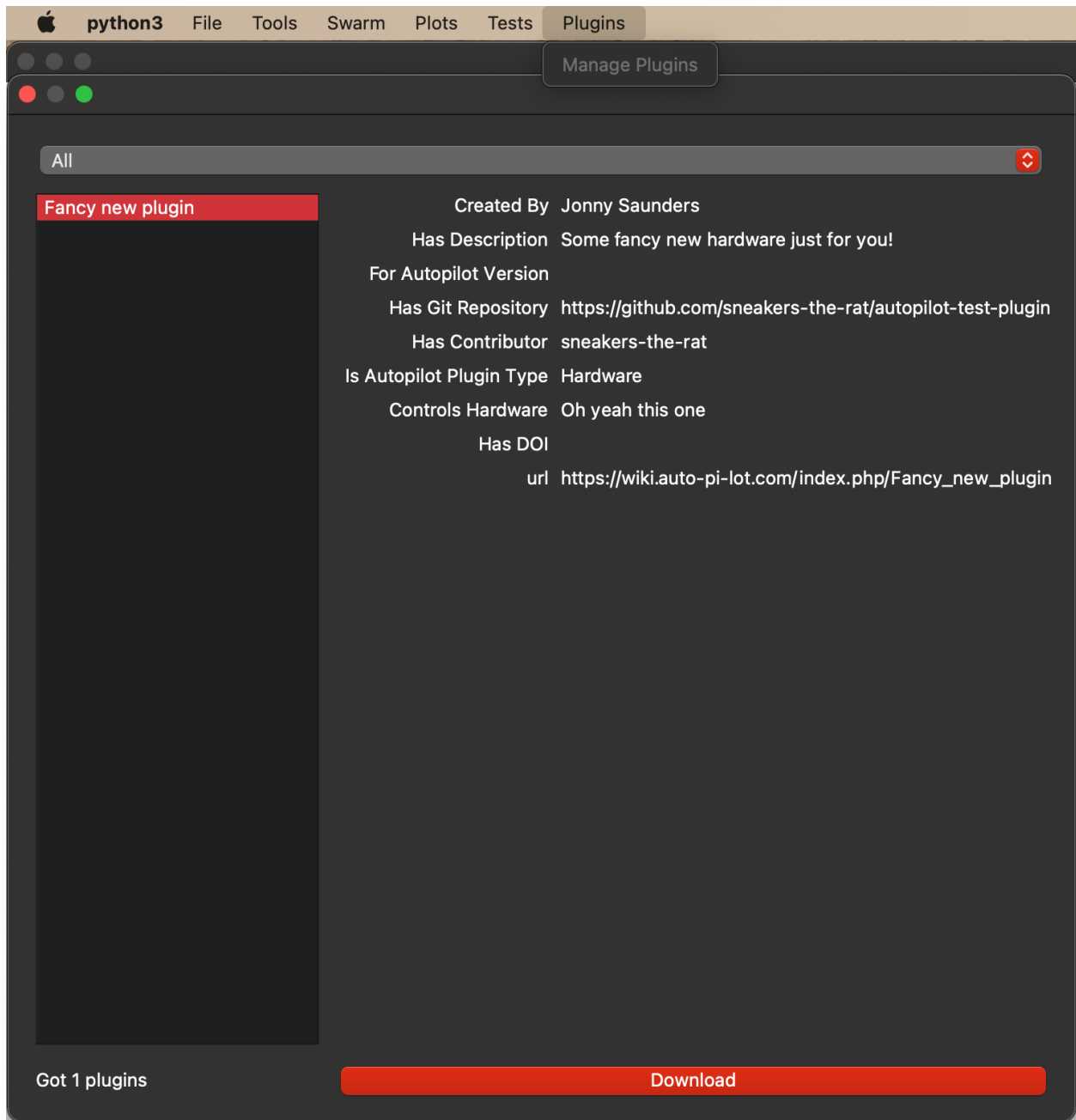
After you submit, it’s immediately available in the `gui.Plugins` manager!

Each plugin has one or multiple Plugin Type(s) that corresponds to a particular entry in [REGISTRIES](#) for filtering plugins that provide different types of objects.



## Edit Autopilot Plugin: Fancy new plugin

<b>Short Description:</b>	<input type="text" value="Some fancy new hardware just for you!"/>
<b>Plugin Type:</b>	<input type="text" value="✕ Hardware"/>
<b>Compatible With Autopilot Version:</b> <small>Expressed as a Python semantic version specifier like &gt;=0.3.0</small>	<input type="text" value=""/>
<b>Git Repository URL:</b>	<input type="text" value="https://github.com/sneakers-the-rat/au"/>
<b>Contributors:</b> <small>Github usernames (preferably), names, email addresses, etc.</small>	<input type="text" value="✕ sneakers-the-rat"/>
<b>Created By:</b>	<input type="text" value="✕ Jonny Saunders"/>
<b>Version:</b>	<input type="text" value="1"/>
<b>DOI (URL) of Related Paper:</b>	<input type="text" value=""/>
<b>Used With Hardware:</b> <small>Hardware that this plugin is used with, but doesn't provide classes to control</small>	<input type="text" value="✕ some new hardware i'll document later"/>
<b>Controls Hardware:</b> <small>Hardware that this plugin provides classes to control</small>	<input type="text" value="✕ oh yeah this one"/>



---

**Todo:** Currently the plugin manager is just a proof of concept, though it would require relatively little to add a routine to clone the git repo into the plugins directory, as mentioned above, we are working on integrating dependency management in a way that's unified throughout the package (instead of, say, needing to manually run `python -m autopilot.setup.run_script picamera` to enable the camera, objects are able to specify and request that their dependencies be met automatically).

For now just `git clone <plugin_url> ~/autopilot/plugins` or wherever your PLUGINDIR is!

---



## EXAMPLES

We're working on writing more examples! Please let us know in the discussion board what you'd like to see :)  
Also see the `examples` folder in the repository for jupyter notebooks we haven't set up Sphinx rendering for yet ;)

### 10.1 Blink

A very simple task: Blink an LED

Written by @mikewehr in the `mike` branch: <https://github.com/wehr-lab/autopilot/blob/mike/autopilot/tasks/blink.py>

Demonstrates the basic structure of a task with one stage, described in the comments throughout the task.

This page is rendered in the docs here in order to provide links to the mentioned objects/classes/etc., but it was written as source code initially and translated to `.rst`, so the narrative flow is often inverted: text follows code as comments, rather than text introducing and narrating code.

#### 10.1.1 Preamble

```
import itertools
import tables
import time
from datetime import datetime

from autopilot.hardware import gpio
from autopilot.tasks import Task
from collections import OrderedDict as odict

class Blink(Task):
    """
    Blink an LED.

    Args:
        pulse_duration (int, float): Duration the LED should be on, in ms
        pulse_interval (int, float): Duration the LED should be off, in ms
    """
```

Note that we subclass the `Task` class (`Blink(Task)`) to provide us with some methods useful for all `Tasks`.

Tasks need to have a few class attributes defined to be integrated into the rest of the system See here for more about class vs. instance attributes <https://www.toptal.com/python/python-class-attributes-an-overly-thorough-guide>

## Params

```
STAGE_NAMES = ["pulse"] # type: list
"""
An (optional) list or tuple of names of methods that will be used as stages for the task.

See ``stages`` for more information
"""

PARAMS = odict()
PARAMS['pulse_duration'] = {'tag': 'LED Pulse Duration (ms)', 'type': 'int'}
PARAMS['pulse_interval'] = {'tag': 'LED Pulse Interval (ms)', 'type': 'int'}
```

PARAMS - A dictionary that specifies the parameters that control the operation of the task – each task presumably has some range of options that allow slight variations (eg. different stimuli, etc.) on a shared task structure. This dictionary specifies each PARAM as a human-readable tag and a type that is used by the gui to create an appropriate input object. For example:

```
PARAMS['pulse_duration'] = {'tag': 'LED Pulse Duration (ms)', 'type': 'int'}
```

When instantiated, these params are passed to the `__init__` method.

A `collections.OrderedDict` is used so that parameters can be presented in a predictable way to users.

## TrialData

```
class TrialData(tables.IsDescription):
    trial_num = tables.Int32Col()
    timestamp_on = tables.StringCol(26)
    timestamp_off = tables.StringCol(26)
```

TrialData declares the data that will be returned for each “trial” – or complete set of executed task stages. It is used by the *Subject* object to make a data table with the correct data types. Declare each piece of data using a pytables Column descriptor (see [https://www.pytables.org/usersguide/libref/declarative\\_classes.html#col-sub-classes](https://www.pytables.org/usersguide/libref/declarative_classes.html#col-sub-classes) for available data types, and the pytables guide: <https://www.pytables.org/usersguide/tutorials.html> for more information)

For each trial, we’ll return two timestamps, the time we turned the LED on, the time we turned it off, and the trial number. Note that we use a 26-character `tables.StringCol` for the timestamps,

## Hardware

```
HARDWARE = {
    'LEDS': {
        'dLED': gpio.Digital_Out
    }
}
```

Declare the hardware that will be used in the task. Each hardware object is specified with a group and an id as nested dictionaries. These descriptions require a set of hardware parameters in the autopilot `prefs.json` (typically generated by `autopilot.setup.setup_autopilot`) with a matching group and id structure. For example, an LED declared like this in the HARDWARE attribute:

```
HARDWARE = {'LEDS': {'dLED': gpio.Digital_Out}}
```

requires an entry in `prefs.json` like this:

```
"HARDWARE": {"LEDS": {"dLED": {
    "pin": 1,
    "polarity": 1
}}}
```

that will be used to instantiate the `hardware.gpio.Digital_Out` object, which is then available for use in the task like:

```
self.hardware['LEDS']['dLED'].set(1)
```

### 10.1.2 Initialization

first we call the superclass ('Task')'s initialization method. All tasks should accept `*args` and `**kwargs` to pass parameters not explicitly specified by subclass up to the superclass.:

```
def __init__(self, stage_block=None, pulse_duration=100, pulse_interval=500, *args,
    ↪ **kwargs):
    super(Blink, self).__init__(*args, **kwargs)

    # store parameters given on instantiation as instance attributes
    self.pulse_duration = int(pulse_duration)
    self.pulse_interval = int(pulse_interval)
    self.stage_block = stage_block # type: "threading.Event"

    # This allows us to cycle through the task by just repeatedly calling self.stages.
    ↪next()
    self.stages = itertools.cycle([self.pulse])
```

Some generator that returns the stage methods that define the operation of the task.

To run a task, the `pilot.Pilot` object will call each stage function, which can return some dictionary of data (see `pulse()`) and wait until some flag (`stage_block`) is set to compute the next stage. Since in this case we want to call the same method (`pulse()`) over and over again, we use an `itertools.cycle` object (if we have more than one stage to call in a cycle, we could provide them like `itertools.cycle([self.stage_method_1, self.stage_method_2])`). More complex tasks can define a custom generator for finer control over stage progression.:

```
self.trial_counter = itertools.count()
"""
Some counter to keep track of the trial number
"""
```

Hardware is initialized by the superclass's `Task.init_hardware()` method, which creates all the hardware objects defined in `HARDWARE` according to their parameterization in `prefs.json`, and makes them available in the `hardware` dictionary.:

```
self.init_hardware()
self.logger.debug('Hardware initialized')
```

All task subclass objects have an `logger` – a `logging.Logger` that allows users to easily debug their tasks and see feedback about their operation. To prevent stdout from getting clogged, logging messages are printed and stored according to the `LOGLEVEL` pref – so this message would only appear if `LOGLEVEL == "DEBUG"`:

```
self.stage_block.set()
```

We set the stage block and never clear it so that the *Pilot* doesn't wait for a trigger to call the next stage – it just does it as soon as the previous one completes.

See `run_task()` for more detail on this loop.

### 10.1.3 Stage Methods

```
def pulse(self, *args, **kwargs):
    """
    Turn an LED on and off according to :attr:`~examples.tasks.Blink.pulse_duration` and
    ↪:attr:`~examples.tasks.Blink.pulse_interval`

    Returns:
        dict: A dictionary containing the trial number and two timestamps.
    """
    # -----
    # turn light on

    # use :meth:`~hardware.gpio.Digital_Out.set` method to turn the LED on
    self.hardware['LEDS']['dLED'].set(1)
    # store the timestamp
    timestamp_on = datetime.now().isoformat()
    # log status as a debug message
    self.logger.debug('light on')
    # sleep for the pulse_duration
    time.sleep(self.pulse_duration / 1000)

    # -----
    # turn light off, same as turning it on.

    self.hardware['LEDS']['dLED'].set(0)
    timestamp_off = datetime.now().isoformat()
    self.logger.debug('light off')
    time.sleep(self.pulse_interval / 1000)

    # count and store the number of the current trial
    self.current_trial = next(self.trial_counter)

    data = {
        'trial_num': self.current_trial,
        'timestamp_on': timestamp_on,
        'timestamp_off': timestamp_off
    }
    return data
```

Create the data dictionary to be returned from the stage. Note that each of the keys in the dictionary must correspond to the names of the columns declared in the `TrialData` descriptor.



At the conclusion of running the task, we will be able to access the data from the run with `Subject.get_trial_data()`, which will be a `pandas.DataFrame` with a row for each trial, and a column for each of the fields here.

### 10.1.4 Full Source

```

1  """
2  A very simple task: Blink an LED
3
4  Written by @mikewehr in the ``mike`` branch: https://github.com/wehr-lab/autopilot/blob/
↳mike/autopilot/tasks/blink.py
5
6  Demonstrates the basic structure of a task with one stage,
7  described in the comments throughout the task.
8
9  See the main tutorial for more detail: https://docs.auto-pi-lot.com/en/latest/guide.task.
↳html#
10
11 This page is rendered in the docs here in order to provide links to the mentioned
↳objects/classes/etc., but
12 this example was intended to be read as source code, as some comments will only be
↳visible there.
13 """
14 import itertools
15 import tables
16 import time
17 from datetime import datetime
18
19 from autopilot.hardware import gpio
20 from autopilot.tasks import Task
21 from collections import OrderedDict as odict
22
23 class Blink(Task):
24     """
25     Blink an LED.
26
27     Note that we subclass the :class:`~autopilot.tasks.Task` class (`Blink(Task)`) to
↳provide us with some methods
28     useful for all Tasks.
29
30     Args:
31         pulse_duration (int, float): Duration the LED should be on, in ms
32         pulse_interval (int, float): Duration the LED should be off, in ms
33
34     """
35     # Tasks need to have a few class attributes defined to be integrated into the rest
↳of the system
36     # See here for more about class vs. instance attributes https://www.toptal.com/
↳python/python-class-attributes-an-overly-thorough-guide
37
38     STAGE_NAMES = ["pulse"] # type: list
39     """

```

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```

40     An (optional) list or tuple of names of methods that will be used as stages for the
41     ↪task.
42
43     See :attr:`~examples.tasks.Blink.stages` for more information
44     """
45
46     PARAMS = odict()
47     """
48     A dictionary that specifies the parameters that control the operation of the task --
49     ↪each task presumably has some
50     ↪range of options that allow slight variations (eg. different stimuli, etc.) on a
51     ↪shared task structure. This
52     ↪dictionary specifies each ``PARAM`` as a human-readable ``tag`` and a ``type`` that is
53     ↪used by the gui to
54     ↪create an appropriate input object. For example::
55
56         PARAMS['pulse_duration'] = {'tag': 'LED Pulse Duration (ms)', 'type': 'int'}
57
58     When instantiated, these params are passed to the ``__init__`` method.
59
60     A :class:`~collections.OrderedDict` is used so that parameters can be presented in a
61     ↪predictable way to users.
62     """
63
64     PARAMS['pulse_duration'] = {'tag': 'LED Pulse Duration (ms)', 'type': 'int'}
65     PARAMS['pulse_interval'] = {'tag': 'LED Pulse Interval (ms)', 'type': 'int'}
66
67     class TrialData(tables.IsDescription):
68         """
69         This class declares the data that will be returned for each "trial" -- or
70         ↪complete set of executed task
71         ↪stages. It is used by the :class:`~autopilot.core.subject.Subject` object to make
72         ↪a data table with the
73         ↪correct data types. Declare each piece of data using a pytables Column descriptor
74         ↪(see https://www.pytables.org/usersguide/libref/declarative\_classes.html#col-sub-
75         ↪classes for available
76         ↪data types, and the pytables guide: https://www.pytables.org/usersguide/
77         ↪tutorials.html for more information)
78
79         For each trial, we'll return two timestamps, the time we turned the LED on, the
80         ↪time we turned it off,
81         ↪and the trial number. Note that we use a 26-character :class:`~tables.StringCol`
82         ↪for the timestamps,
83         ↪which are given as an isoformatted string like ``'2021-02-16T18:11:35.752110'``
84         """
85
86         trial_num = tables.Int32Col()
87         timestamp_on = tables.StringCol(26)
88         timestamp_off = tables.StringCol(26)
89
90     HARDWARE = {
91         'LEDS': {
92             'dLED': gpio.Digital_Out

```

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```

81     }
82 }
83 """
84 Declare the hardware that will be used in the task. Each hardware object is
↳ specified with a ``group`` and
85 an ``id`` as nested dictionaries. These descriptions require a set of hardware
↳ parameters in the autopilot
86 ``prefs.json`` (typically generated by :mod:`autopilot.setup.setup_autopilot` ) with a
↳ matching ``group`` and
87 ``id`` structure. For example, an LED declared like this in the :attr:`~examples.tasks.
↳ Blink.HARDWARE` attribute::

88     HARDWARE = {'LEDS': {'dLED': gpio.Digital_Out}}
89
90 requires an entry in ``prefs.json`` like this::

91     "HARDWARE": {"LEDS": {"dLED": {
92         "pin": 1,
93         "polarity": 1
94     }}}
95
96 that will be used to instantiate the :class:`~hardware.gpio.Digital_Out` object,
↳ which is then available for use
97 in the task like::

98     self.hardware['LEDS']['dLED'].set(1)
99
100 """
101
102 def __init__(self, stage_block=None, pulse_duration=100, pulse_interval=500, *args,
↳ **kwargs):
103     # first we call the superclass ('Task')'s initialization method. All tasks should
↳ accept ``*args``
104     # and ``**kwargs`` to pass parameters not explicitly specified by subclass up to
↳ the superclass.
105     super(Blink, self).__init__(*args, **kwargs)
106
107     # store parameters given on instantiation as instance attributes
108     self.pulse_duration = int(pulse_duration)
109     self.pulse_interval = int(pulse_interval)
110     self.stage_block = stage_block # type: "threading.Event"
111
112     # This allows us to cycle through the task by just repeatedly calling self.
113     stages.next()
114     self.stages = itertools.cycle([self.pulse])
115     """
116     Some generator that returns the stage methods that define the operation of the
↳ task.
117
118     To run a task, the :class:`~pilot.Pilot` object will call each stage function,
↳ which can return some dictionary
119 of data (see :meth:`~examples.tasks.Blink.pulse` ) and wait until some flag
↳ (:attr:`~examples.tasks.Blink.stage_block` ) is set to compute the
120

```

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```

121     next stage. Since in this case we want to call the same method (:meth:`~examples.
↳ tasks.Blink.pulse` ) over and over again,
122     we use an :class:`~itertools.cycle` object (if we have more than one stage to call.
↳ in a cycle, we could provide
123     them like ``itertools.cycle([self.stage_method_1, self.stage_method_2])`` . More
↳ complex tasks can define a custom
124     generator for finer control over stage progression.
125     """
126
127     self.trial_counter = itertools.count()
128     """
129     Some counter to keep track of the trial number
130     """
131
132
133     self.init_hardware()
134
135     """
136     Hardware is initialized by the superclass's :meth:`~Task.init_hardware` method,
↳ which creates all the
137     hardware objects defined in :attr:`~examples.tasks.Blink.HARDWARE` according to
↳ their parameterization in
138     ``prefs.json``, and makes them available in the :attr:`~examples.tasks.Blink.
↳ hardware` dictionary.
139     """
140
141     self.logger.debug('Hardware initialized')
142
143     """
144     All task subclass objects have an :attr:`~autopilot.tasks.Task.logger` -- a
↳ :class:`~logging.Logger` that allows
145     users to easily debug their tasks and see feedback about their operation. To
↳ prevent stdout from
146     getting clogged, logging messages are printed and stored according to the
↳ ``LOGLEVEL`` pref -- so this
147     message would only appear if ``LOGLEVEL == "DEBUG"``
148     """
149
150     self.stage_block.set()
151
152     """
153     We set the stage block and never clear it so that the :class:`~Pilot` doesn't
↳ wait for a trigger
154     to call the next stage -- it just does it as soon as the previous one completes.
155
156     See :meth:`~autopilot.core.pilot.Pilot.run_task` for more detail on this loop.
157     """
158
159
160     #####
161     # Stage Functions
162     #####

```

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```

163     def pulse(self, *args, **kwargs):
164         """
165         Turn an LED on and off according to :attr:`~examples.tasks.Blink.pulse_duration`
166         ↪ and :attr:`~examples.tasks.Blink.pulse_interval`
167
168         Returns:
169             dict: A dictionary containing the trial number and two timestamps.
170             """
171         # -----
172         # turn light on
173
174         # use :meth:`~hardware.gpio.Digital_Out.set` method to turn the LED on
175         self.hardware['LEDS']['dLED'].set(1)
176         # store the timestamp
177         timestamp_on = datetime.now().isoformat()
178         # log status as a debug message
179         self.logger.debug('light on')
180         # sleep for the pulse_duration
181         time.sleep(self.pulse_duration / 1000)
182
183         # -----
184         # turn light off, same as turning it on.
185
186         self.hardware['LEDS']['dLED'].set(0)
187         timestamp_off = datetime.now().isoformat()
188         self.logger.debug('light off')
189         time.sleep(self.pulse_interval / 1000)
190
191         # count and store the number of the current trial
192         self.current_trial = next(self.trial_counter)
193
194         data = {
195             'trial_num': self.current_trial,
196             'timestamp_on': timestamp_on,
197             'timestamp_off': timestamp_off
198         }
199
200         """
201         Create the data dictionary to be returned from the stage. Note that each of the
202         ↪ keys in the dictionary
203         must correspond to the names of the columns declared in the :attr:`~examples.
204         ↪ tasks.Blink.TrialData` descriptor.
205
206         At the conclusion of running the task, we will be able to access the data from
207         ↪ the run with
208         :meth:`~Subject.get_trial_data`, which will be a :class:`~pandas.DataFrame` with a
209         ↪ row for each trial, and
210         a column for each of the fields here.
211         """
212
213         # return the data dictionary from the stage method and yr done :)

```

(continues on next page)

(continued from previous page)

210

```
return data
```

## 11.1 gui

These classes implement the GUI used by the Terminal.

The GUI is built using [PySide2](#), a Python wrapper around Qt5.

These classes are all currently used only by the [Terminal](#).

If performing any GUI operations in another thread (eg. as a callback from a networking object), the method must be decorated with `@gui_event` which will call perform the update in the main thread as required by Qt.

---

**Note:** Currently, the GUI code is some of the oldest code in the library – in particular much of it was developed before the network infrastructure was mature. As a result, a lot of modules are interdependent (eg. pass objects between each other). This will be corrected before v1.0

---

### Data:

---

<code>_MAPS</code>	Maps of shorthand names for objects to the objects themselves.
--------------------	--

---

### Functions:

---

<code>gui_event(fn)</code>	Wrapper/decorator around an event that posts GUI events back to the main thread that our window is running in.
<code>pop_dialog(message[, details, buttons, ...])</code>	Convenience function to pop a :class:`.QtGui.QDialog` window to display a message.

---

### Classes:

---

<code>Control_Panel(subjects, start_fn, ping_fn, ...)</code>	A <code>QtWidgets.QWidget</code> that contains the controls for all pilots.
<code>Subject_List([subjects, drop_fn])</code>	A trivial modification of <code>QListWidget</code> that updates <a href="#">pilots</a> when an item in the list is dragged to another location.
<code>Pilot_Panel([pilot, subject_list, start_fn, ...])</code>	A little panel with
<code>Pilot_Button([pilot, subject_list, ...])</code>	A subclass of (toggled) <code>QtWidgets.QPushButton</code> that incorporates the style logic of a start/stop button - ie.

---

continues on next page

Table 3 – continued from previous page

<code>New_Subject_Wizard()</code>	A popup that prompts you to define variables for a new <code>subject.Subject</code> object
<code>Protocol_Wizard()</code>	A dialog window to create a new protocol.
<code>Graduation_Widget()</code>	A widget used in <code>Protocol_Wizard</code> to define graduation parameters.
<code>Drag_List()</code>	A <code>QtWidgets.QListWidget</code> that is capable of having files dragged & dropped.
<code>Sound_Widget()</code>	A widget that allows sounds to be parameterized.
<code>Bandwidth_Test(pilots)</code>	Test the limits of the rate of messaging from the connected Pilots.
<code>Calibrate_Water(pilots)</code>	A window to calibrate the volume of water dispensed per ms.
<code>Pilot_Ports(pilot[, n_clicks, click_dur])</code>	Created by <code>Calibrate_Water</code> , Each pilot's ports and buttons to control repeated release.
<code>Reassign(subjects, protocols)</code>	A dialog that lets subjects be batch reassigned to new protocols or steps.
<code>Weights(subject_weights, subjects)</code>	A table for viewing and editing the most recent subject weights.
<code>Plugins()</code>	Dialog window that allows plugins to be viewed and installed.
<code>Psychometric(subjects_protocols)</code>	A Dialog to select subjects, steps, and variables to use in a psychometric curve plot.
<code>Stream_Video(pilots, *args, **kwargs)</code>	Dialogue to stream, display, and save video.

```
_MAPS = { 'dialog': { 'icon': { 'error': PySide2.QtWidgets.QMessageBox.Icon.Critical,
'info': PySide2.QtWidgets.QMessageBox.Icon.Information, 'question':
PySide2.QtWidgets.QMessageBox.Icon.Question, 'warning':
PySide2.QtWidgets.QMessageBox.Icon.Warning}, 'modality': { 'modal':
PySide2.QtCore.Qt.WindowModality.NonModal, 'nonmodal':
PySide2.QtCore.Qt.WindowModality.WindowModal}}}
```

Maps of shorthand names for objects to the objects themselves.

Grouped by a rough use case, intended for internal (rather than user-facing) use.

### `gui_event(fn)`

Wrapper/decorator around an event that posts GUI events back to the main thread that our window is running in.

**Parameters** `fn` (*callable*) – a function that does something to the GUI

```
class Control_Panel(subjects, start_fn, ping_fn, pilots)
```

Bases: `PySide2.QtWidgets.QWidget`

A `QtWidgets.QWidget` that contains the controls for all pilots.

### **Parameters**

- **subjects** (*dict*) – See `Control_Panel.subjects`
- **start\_fn** (*toggle\_start()*) – the Terminal's `toggle_start` function, propagated down to each `Pilot_Button`
- **pilots** – Usually the Terminal's `pilots` dict. If not passed, will try to load `params.PILOT_DB`

### **Variables**

- **subjects** (*dict*) – A dictionary with subject ID's as keys and `core.subject.Subject` objects as values. Shared with the Terminal object to manage access conflicts.



- **start\_fn** (*toggle\_start()*) – See `Control_Panel.start_fn`
- **pilots** (*dict*) – A dictionary with pilot ID's as keys and nested dictionaries containing subjects, IP, etc. as values
- **subject\_lists** (*dict*) – A dict mapping subject ID to `subject_List`
- **layout** (`QGridLayout`) – Layout grid for widget
- **panels** (*dict*) – A dict mapping pilot name to the relevant *Pilot\_Panel*

Specifically, for each pilot, it contains

- one `subject_List`: A list of the subjects that run in each pilot.
- one *Pilot\_Panel*: A set of button controls for starting/stopping behavior

This class should not be instantiated outside the context of a *Terminal* object, as they share the subjects dictionary.

#### Methods:

<code>init_ui()</code>	Called on init, creates the UI components.
<code>add_pilot(pilot_id[, subjects])</code>	Add a <i>Pilot_Panel</i> for a new pilot, and populate a <i>Subject_List</i> for it :Parameters: * <b>pilot_id</b> ( <i>str</i> ) -- ID of new pilot * <b>subjects</b> ( <i>list</i> ) -- Optional, list of any subjects that the pilot has.
<code>create_subject(pilot)</code>	Becomes <code>Pilot_Panel.create_fn</code> .
<code>update_db([pilots])</code>	Gathers any changes in <i>Subject_List</i> s and dumps <i>pilots</i> to <code>prefs.get('PILOT_DB')</code>

#### Attributes:

<code>staticMetaObject</code>
-------------------------------

#### `init_ui()`

Called on init, creates the UI components.

Specifically, for each pilot in *pilots*, make a `subject_List`: and *Pilot\_Panel*:, set size policies and connect Qt signals.

#### `add_pilot(pilot_id: str, subjects: Optional[list] = None)`

Add a *Pilot\_Panel* for a new pilot, and populate a *Subject\_List* for it :Parameters: \* **pilot\_id** (*str*) – ID of new pilot

- **subjects** (*list*) – Optional, list of any subjects that the pilot has.

Returns:

#### `create_subject(pilot)`

Becomes `Pilot_Panel.create_fn`. Opens a *New\_Subject\_Wizard* to create a new subject file and assign protocol. Finally, adds the new subject to the *pilots* database and updates it.

**Parameters** **pilot** (*str*) – Pilot name passed from *Pilot\_Panel*, added to the created Subject object.

#### `update_db(pilots: Optional[dict] = None, **kwargs)`

Gathers any changes in *Subject\_List* s and dumps *pilots* to `prefs.get('PILOT_DB')`

**Parameters** **kwargs** – Create new pilots by passing a dictionary with the structure

```
new={'pilot_name': 'pilot_values'}
```

where *'pilot\_values'* can be nothing, a list of subjects, or any other information included in the pilot db

```
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f31930f00>
```

```
class Subject_List(subjects=None, drop_fn=None)
```

Bases: PySide2.QtWidgets.QListWidget

A trivial modification of QListWidget that updates *pilots* when an item in the list is dragged to another location.

Should not be initialized except by *Control\_Panel* .

#### Variables

- **subjects** (*list*) – A list of subjects ID's passed by *Control\_Panel*
- **drop\_fn** (*Control\_Panel.update\_db()*) – called on a drop event

#### Parameters

- **subjects** – see subjects. Can be *None* for an empty list
- **drop\_fn** – see drop\_fn(). Passed from *Control\_Panel*

#### Methods:

populate_list()	Adds each item in Subject_List.subjects to the list.
dropEvent(event)	A trivial redefinition of QtWidgets.QListWidget.dropEvent() that calls the parent <i>dropEvent</i> and then calls <i>drop_fn</i>

#### Attributes:

staticMetaObject
------------------

#### populate\_list()

Adds each item in Subject\_List.subjects to the list.

#### dropEvent(event)

A trivial redefinition of QtWidgets.QListWidget.dropEvent() that calls the parent *dropEvent* and then calls *drop\_fn*

**Parameters** *event* – A QtCore.QEvent simply forwarded to the superclass.

```
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7a9910>
```

```
class Pilot_Panel(pilot=None, subject_list=None, start_fn=None, ping_fn=None, create_fn=None)
```

Bases: PySide2.QtWidgets.QWidget

A little panel with

- the name of a pilot,
- A *Pilot\_Button* to start and stop the task
- Add and remove buttons to *create\_subject()* and *Pilot\_Panel.remove\_subject()*

---

**Note:** This class should not be instantiated except by [Control\\_Panel](#)

---

### Parameters

- **pilot** (*str*) – The name of the pilot this panel controls
- **subject\_list** ([Subject\\_List](#)) – The [Subject\\_List](#) we control
- **start\_fn** ([toggle\\_start\(\)](#)) – Passed by [Control\\_Panel](#)
- **create\_fn** ([Control\\_Panel.create\\_subject\(\)](#)) – Passed by [Control\\_Panel](#)

### Variables

- **layout** (QtWidgets.QGridLayout) – Layout for UI elements
- **button** ([Pilot\\_Button](#)) – button used to control a pilot

### Methods:

<code>init_ui()</code>	Initializes UI elements - creates widgets and adds to <code>Pilot_Panel.layout</code> .
<code>remove_subject()</code>	Remove the currently selected subject in <code>Pilot_Panel.subject_list</code> , and calls the <a href="#">Control_Panel.update_db()</a> method.
<code>create_subject()</code>	Just calls <a href="#">Control_Panel.create_subject()</a> with our <i>pilot</i> as the argument

### Attributes:

---

`staticMetaObject`

---

### `init_ui()`

Initializes UI elements - creates widgets and adds to `Pilot_Panel.layout`. Called on init.

### `remove_subject()`

Remove the currently selected subject in `Pilot_Panel.subject_list`, and calls the [Control\\_Panel.update\\_db\(\)](#) method.

### `create_subject()`

Just calls [Control\\_Panel.create\\_subject\(\)](#) with our *pilot* as the argument

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7a9960>`

**class** `Pilot_Button`(*pilot=None, subject\_list=None, start\_fn=None, ping\_fn=None*)

Bases: `PySide2.QtWidgets.QPushButton`

A subclass of (toggled) `QtWidgets.QPushButton` that incorporates the style logic of a start/stop button - ie. color, text.

Starts grayed out, turns green if contact with a pilot is made.

### Parameters

- **pilot** (*str*) – The ID of the pilot that this button controls
- **subject\_list** ([Subject\\_List](#)) – The Subject list used to determine which subject is starting/stopping

- **start\_fn** (*toggle\_start()*) – The final resting place of the toggle\_start method

**Variables** **state** (*str*) – The state of our pilot, reflected in our graphical properties. Mirrors **state**, with an additional “DISCONNECTED” state for before contact is made with the pilot.

**Methods:**

toggle_start()	Minor window dressing to call the start_fn() with the appropriate pilot, subject, and whether the task is starting or stopping
set_state(state)	Set the button's appearance and state

**Attributes:**

staticMetaObject
------------------

**toggle\_start()**

Minor window dressing to call the start\_fn() with the appropriate pilot, subject, and whether the task is starting or stopping

**set\_state**(*state*)

Set the button's appearance and state

**Parameters** **state** (*str*) – one of `‘IDLE’, ‘RUNNING’, ‘STOPPING’, ‘DISCONNECTED’`

---

**Todo:** There is some logic duplication in this class, ie. if the button state is changed it also emits a start/stop signal to the pi, which is undesirable. This class needs to be reworked.

---

Returns:

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7a98c0>

**class New\_Subject\_Wizard**

Bases: PySide2.QtWidgets.QDialog

A popup that prompts you to define variables for a new *subject.Subject* object

Called by *Control\_Panel.create\_subject()*, which handles actually creating the subject file and updating the *Terminal.pilots* dict and file.

Contains two tabs - *Biography\_Tab* - to set basic biographical information about a subject - *Task\_Tab* - to set the protocol and step to start the subject on

**Variables**

- **protocol\_dir** (*str*) – A full path to where protocols are stored, received from `prefs.get('PROTOCOLDIR')`
- **bio\_tab** (*Biography\_Tab*) – Sub-object to set and store biographical variables
- **task\_tab** (*Task\_Tab*) – Sub-object to set and store protocol and step assignment

**Classes:**

Biography_Tab()	A widget that allows defining basic biographical attributes about a subject
-----------------	---

continues on next page

Table 12 – continued from previous page

Task_Tab()	A tab for selecting a task and step to assign to the subject.
------------	---

**Attributes:**


---

staticMetaObject

---

**class Biography\_Tab**

Bases: PySide2.QtWidgets.QWidget

A widget that allows defining basic biographical attributes about a subject

Creates a set of widgets connected to `update_return_dict()` that stores the parameters.

**Warning:** The below attributes are **not** the object attributes, but are descriptions of the parameters available in the values dictionary. The attributes themselves are PySide Widgets that set the values.

**Variables**

- **id** (*str*) – A Subject’s ID or name
- **start\_date** (*str*) – The date the subject started the task. Automatically filled by `datetime.date.today().isoformat()`
- **blmass** (*float*) – The subject’s baseline mass
- **minmass\_pct** (*int*) – The percentage of baseline mass that a water restricted subject is allowed to reach
- **minmass** (*float*) – The subject’s minimum mass, automatically calculated  $blmass * (minmass\_pct / 100.)$
- **genotype** (*str*) – A string describing the subject’s genotype
- **expt** (*str*) – A tag to describe what experiment this subject is a part of

**Methods:**

<code>update_return_dict(key, val)</code>	Called by lambda functions by the widgets, eg..
<code>calc_minmass()</code>	Calculates the minimum mass for a subject based on its baseline mass and the allowable percentage of that baseline

**Attributes:**


---

staticMetaObject

---

**update\_return\_dict(key, val)**

Called by lambda functions by the widgets, eg.:

```
self.id.editingFinished.connect(lambda: self.update_return_dict('id', self.
↪id.text()))
```

**Parameters**

- **key** (*str*) – The key of the value being stored
- **val** – The value being stored.

**calc\_minmass()**

Calculates the minimum mass for a subject based on its baseline mass and the allowable percentage of that baseline

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3500>

**class Task\_Tab**

Bases: PySide2.QtWidgets.QWidget

A tab for selecting a task and step to assign to the subject.

Reads available tasks from *prefs.get('PROTOCOLDIR')* , lists them, and creates a spinbox to select from the available steps.

**Warning:** Like *Biography\_Tab* , these are not the actual instance attributes. Values are stored in a *values* dictionary.

**Variables**

- **protocol** (*str*) – the name of the assigned protocol, filename without .json extension
- **step** (*int*) – current step to assign.

**Methods:**

<code>update_step_box()</code>	Clears any steps that might be in the step selection box, loads the protocol file and repopulates it.
<code>protocol_changed()</code>	When the protocol is changed, save the value and call <code>update_step_box()</code> .
<code>step_changed()</code>	When the step is changed, save it.

**Attributes:**

<code>staticMetaObject</code>
-------------------------------

**update\_step\_box()**

Clears any steps that might be in the step selection box, loads the protocol file and repopulates it.

**protocol\_changed()**

When the protocol is changed, save the value and call `update_step_box()`.

**step\_changed()**

When the step is changed, save it.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c34b0>

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3460>

**class Protocol\_Wizard**

Bases: PySide2.QtWidgets.QDialog

A dialog window to create a new protocol.

**Warning:** This is a heavily overloaded class, and will be split into separate objects to handle parameters separately. For now this is what we got though and it works.

Protocols are collections of multiple tasks (steps) with some graduation criterion for moving between them.

This widget is composed of three windows:

- **left:** possible task types from `autopilot.get_task()`
- **center:** current steps in task
- **right:** Parameters for currently selected step.

The parameters that are used are of the form used by `Task.PARAMS` (see `Nafc.PARAMS` for an example).

---

**Todo:** Make specific parameter class so this definition is less squishy

---

its general structure is:

```
{'parameter_key': {'tag': 'Human Readable Name',
                   'type': 'param_type'}}
```

while some parameter types have extra items, eg.:

```
{'list_param': {'tag': 'Select from a List of Parameters',
                'type': 'list',
                'values': {'First Option': 0, 'Second Option': 1}}}
```

where k:v pairs are still used with lists to allow parameter values (0, 1) be human readable.

The available types include:

- **int** - integer
- **float** - floating point number
- **bool** - boolean boolbox
- **list** - a list of *values* to choose from
- **sounds** - a `Sound_Widget` that allows sounds to be defined.
- **graduation** - a `Graduation_Widget` that allows graduation criteria to be defined

#### Variables

- **task\_list** (QtWidgets.QListWidget) – The leftmost window, lists available tasks
- **step\_list** (QtWidgets.QListWidget) – The center window, lists tasks currently in protocol
- **param\_layout** (QtWidgets.QFormLayout) – The right window, allows changing available parameters for currently selected step.
- **steps** (*list*) – A list of dictionaries defining the protocol.

#### Methods:

<code>add_step()</code>	Loads <i>PARAMS</i> from task object, adds base parameters to <i>steps</i> list
<code>rename_step()</code>	When the step name widget's text is changed, fire this function to update <i>step_list</i> which updates <i>steps</i>
<code>remove_step()</code>	Remove step from <i>step_list</i> and <i>steps</i>
<code>populate_params()</code>	Calls <i>clear_params()</i> and then creates widgets to edit parameter values.
<code>clear_params()</code>	Clears widgets from parameter window
<code>reorder_steps(*args)</code>	When steps are dragged into a different order, update the step dictionary
<code>set_param()</code>	Callback function connected to the signal each widget uses to signal it has changed.
<code>set_sounds()</code>	Stores parameters that define sounds.
<code>set_graduation()</code>	Stores parameters that define graduation criteria in <i>self.steps</i>
<code>check_depends()</code>	Handle dependencies between parameters, eg.

**Attributes:**

---

`staticMetaObject`

---

**`add_step()`**

Loads *PARAMS* from task object, adds base parameters to *steps* list

**`rename_step()`**

When the step name widget's text is changed, fire this function to update *step\_list* which updates *steps*

**`remove_step()`**

Remove step from *step\_list* and *steps*

**`populate_params()`**

Calls *clear\_params()* and then creates widgets to edit parameter values. Returns:

**`clear_params()`**

Clears widgets from parameter window

**`reorder_steps(*args)`**

When steps are dragged into a different order, update the step dictionary

**Parameters** *\*args* – Input from our *step\_list* 's `QtWidgets.QListModel` 's reorder signal.

**`set_param()`**

Callback function connected to the signal each widget uses to signal it has changed.

Identifies the param that was changed, gets the current value, and updates *self.steps*

**`set_sounds()`**

Stores parameters that define sounds.

Sound parameters work a bit differently, specifically we have to retrieve `Sound_Widget.sound_dict`.

**`set_graduation()`**

Stores parameters that define graduation criteria in *self.steps*



Graduation parameters work a bit differently, specifically we have to retrieve `Graduation_Widget.param_dict`.

#### **check\_depends()**

Handle dependencies between parameters, eg. if “correction trials” are unchecked, the box that defines the correction trial percentage should be grayed out.

---

**Todo:** Not implemented.

---

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3410>`

#### **class Graduation\_Widget**

Bases: `PySide2.QtWidgets.QWidget`

A widget used in *Protocol\_Wizard* to define graduation parameters.

See *tasks.graduation*.

A protocol is composed of multiple tasks (steps), and graduation criteria define when a subject should progress through those steps.

eg. a subject should graduate one stage after 300 trials, or after it reaches 75% accuracy over the last 500 trials.

#### **Variables**

- **type\_selection** (`QtWidgets.QComboBox`) – A box to select from the available graduation types listed in `autopilot.get_task()`. Has its *currentIndexChanged* signal connected to *Graduation\_Widget.populate\_params()*
- **param\_dict** (*dict*) – Stores the type of graduation and the relevant params, fetched by *Protocol\_Wizard* when defining a protocol.
- **set\_graduation** (*Protocol\_Wizard.set\_graduation()*) – Passed to us after we’re initied.

#### **Methods:**

<code>populate_params([params])</code>	Repopulate the widget with fields to edit graduation parameters, fill fields if we are passed <i>params</i> .
<code>clear_params()</code>	Clear any parameter widgets we have.
<code>store_param()</code>	When a parameter is edited, save it in our <code>param_dict</code> , and also call our <i>set_graduation</i> method, which should be <i>Protocol_Wizard.set_graduation()</i> passed to us after instantiation.

#### **Attributes:**

---

`staticMetaObject`

---

#### **populate\_params(params=None)**

Repopulate the widget with fields to edit graduation parameters, fill fields if we are passed *params*.

Each `QtWidgets.QLineEdit` ‘s `QLineEdit.editingFinished()` signal is connected to *Graduation\_Widget.store\_param()*.

---

**Todo:** For now we assume all parameters are defined with a text edit box, so it’s not clear how we’d do

boolean parameters for example. This will be fixed with refactoring the parameter scheme.

---

**Parameters** **params** (*dict*) – In the case that *Protocol\_Wizard* switches us back to a step where we have already defined graduation parameters, it will pass them so we can repopulate the relevant widgets with them.

**clear\_params()**

Clear any parameter widgets we have.

**store\_param()**

When a parameter is edited, save it in our *param\_dict*, and also call our *set\_graduation* method, which should be *Protocol\_Wizard.set\_graduation()* passed to us after instantiation.

If we were not passed *set\_graduation*, just saves in *param\_dict*.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c33c0>

**class Drag\_List**

Bases: PySide2.QtWidgets.QListWidget

A QtWidgets.QListWidget that is capable of having files dragged & dropped.

copied with much gratitude from [stackoverflow](#)

Primarily used in *Sound\_Widget* to be able to drop sound files.

To use: connect *fileDropped* to a method, that method will receive a list of files dragged onto this widget.

**Variables** **fileDropped** (QtCore.Signal) – A Qt signal that takes a list

**Attributes:**

---

**fileDropped**(\*args, \*\*kwargs)

Call self as a function.

---

**staticMetaObject**

---

**Methods:**

---

**dragEnterEvent**(e)

When files are dragged over us, if they have paths in them, accept the event.

---

**dragMoveEvent**(event)

If the *dragEnterEvent* was accepted, while the drag is being moved within us, *setDropAction* to *QtCore.Qt.CopyAction*

---

**dropEvent**(event)

When the files are finally dropped, if they contain paths, emit the list of paths through the *fileDropped* signal.

---

**fileDropped**(\*args, \*\*kwargs)

Call self as a function.

**dragEnterEvent**(e)

When files are dragged over us, if they have paths in them, accept the event.

**Parameters** **e** (QtCore.QEvent) – containing the drag information.

**dragMoveEvent**(event)

If the *dragEnterEvent* was accepted, while the drag is being moved within us, *setDropAction* to *QtCore.Qt.CopyAction*

**Parameters** `event` (`QtCore.QEvent`) – containing the drag information.

**dropEvent**(*event*)

When the files are finally dropped, if they contain paths, emit the list of paths through the *fileDropped* signal.

**Parameters** `event` (`QtCore.QEvent`) – containing the drag information.

**staticMetaObject** = `<PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3370>`

**class** `Sound_Widget`

Bases: `PySide2.QtWidgets.QWidget`

A widget that allows sounds to be parameterized.

Used in *Protocol\_Wizard*.

Has two *Drag\_List*s for left and right sounds (for a 2afc task), given Buttons beneath them allow adding and removing sounds.

Adding a sound will open a `Add_SoundDialog`

---

**Todo:** Sounds will eventually be more elegantly managed by a ... sound manager.. For now sound managers are rudimentary and only support random presentation with correction trials and bias correction.

---

**Variables** `sound_dict` (*dict*) – Dictionary with the structure:

```
{'L': [{'param_1': 'param_1', ... }], 'R': [...]}
```

where multiple sounds can be present in either 'L' or 'R' list.

**Methods:**

<code>pass_set_param_function(set_param_fnxn)</code>	Receives <i>Protocol_Wizard.set_sounds()</i>
<code>add_sound(side)</code>	When the "+" button on either side is pressed, open an <i>Add_Sound_Dialog</i> .
<code>remove_sound(side)</code>	When the "-" button is pressed, remove the currently highlighted sound.
<code>populate_lists(sound_dict)</code>	Populates the sound lists after re-selecting a step.
<code>files_dropped(files)</code>	

**Classes:**

<code>Add_Sound_Dialog()</code>	Presents a dialog to define a new sound.
---------------------------------	--

**Attributes:**

<code>staticMetaObject</code>	
-------------------------------	--

**pass\_set\_param\_function**(*set\_param\_fnxn*)

Receives *Protocol\_Wizard.set\_sounds()*

**Parameters** `set_param_fnxn` (*Protocol\_Wizard.set\_sounds()*) – Called when sounds are

changed.

**add\_sound**(*side*)

When the “+” button on either side is pressed, open an [Add\\_Sound\\_Dialog](#).

**Parameters** *side* (*str*) – The buttons are connected with a lambda function, this will be either ‘L’ or ‘R’. Used to add sounds to the *sound\_dict*

**remove\_sound**(*side*)

When the “-” button is pressed, remove the currently highlighted sound.

**Parameters** *side* (*str*) – The buttons are connected with a lambda function, this will be either ‘L’ or ‘R’. Selects that list so we can remove the currently selected row.

**populate\_lists**(*sound\_dict*)

Populates the sound lists after re-selecting a step.

**Parameters** *sound\_dict* (*dict*) – passed to us by [Protocol\\_Wizard](#) upon reselecting a step.

**files\_dropped**(*files*)

**Warning:** This was programmed hastily and is pretty idiosyncratic to my use.  
It does work for general files but has some extra logic built in to handle my stimuli.  
To be made more general in v0.3

---

**Note:** Sounds must be in the folder specified in *prefs.get(‘SOUNDDIR’)*.

---

When files are dropped on the lists, strips *prefs.get(‘SOUNDDIR’)* from them to make them relative paths, adds them to the *sound\_dict*

**Parameters** *files* (*list*) – List of absolute paths.

**class Add\_Sound\_Dialog**

Bases: `PySide2.QtWidgets.QDialog`

Presents a dialog to define a new sound.

Makes a selection box to choose the sound type from `autopilot.get_names(‘sound’)`, and then populates edit boxes so we can fill in its *PARAMS*.

**Variables**

- **type\_selection** (`QtWidgets.QComboBox`) – Select from a list of available sounds
- **param\_dict** (*dict*) – Parameters that are retrieved by the calling [Sound\\_Widget](#).

**Methods:**

<code>populate_params()</code>	When a sound type is selected, make a <code>QtWidgets.QLineEdit</code> for each <i>PARAM</i> in its definition.
<code>clear_params()</code>	Clear all current widgets
<code>store_param()</code>	When one of our edit boxes is edited, stash the parameter in <i>param_dict</i>

**Attributes:**

---

```
staticMetaObject
```

---

```
populate_params()
```

When a sound type is selected, make a `QtWidgets.QLineEdit` for each *PARAM* in its definition.

```
clear_params()
```

Clear all current widgets

```
store_param()
```

When one of our edit boxes is edited, stash the parameter in *param\_dict*

```
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3320>
```

```
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c32d0>
```

```
class Bandwidth_Test(pilots)
```

Bases: `PySide2.QtWidgets.QDialog`

Test the limits of the rate of messaging from the connected Pilots.

Asks pilots to send messages at varying rates and with varying payload sizes, and with messages with/without receipts.

Measures drop rates and message latency

#### Variables

- **rate\_list** (*list*) – List of rates (Hz) to test
- **payload\_list** (*list*) – List of payload sizes (KB) to test
- **messages** (*list*) – list of messages received during test

#### Methods:

<code>init_ui()</code>	Look we're just making the stuff in the window over here alright? relax.
<code>start()</code>	Start the test!!!
<code>send_test(rate, payload, n_msg, confirm)</code>	Send a message describing the test to each of the pilots in <code>Bandwidth_Test.test_pilots</code>
<code>process_test(rate, n_msg, confirm)</code>	Process the results of the test and update the plot window.
<code>save()</code>	Select save file location for test results (csv) and then save them there
<code>register_msg(value)</code>	Receive message from pilot, stash timestamp, number and pilot
<code>update_pbar(val)</code>	
<code>validate_list()</code>	Checks that the entries in <code>Bandwidth_Test.rates</code> and <code>Bandwidth_Test.payloads</code> are well formed.

#### Attributes:

---

```
staticMetaObject
```

---

**init\_ui()**

Look we're just making the stuff in the window over here alright? relax.

**start()**

Start the test!!!

**send\_test**(*rate, payload, n\_msg, confirm*)

Send a message describing the test to each of the pilots in `Bandwidth_Test.test_pilots`

**Parameters**

- **rate** (*int*) – Rate of message sending in Hz
- **payload** (*int*) – Size of message payload in bytes
- **n\_msg** (*int*) – Number of messages to send
- **confirm** (*bool*) – If True, use message confirmation, if False no confirmation.

Returns:

**process\_test**(*rate, n\_msg, confirm*)

Process the results of the test and update the plot window.

Reads message results from `messages`, appends computed results to `results`, and starts the next test if any remain.

**Parameters**

- **rate** (*int*) – Rate of current test in Hz
- **n\_msg** (*int*) – Number of expected messages in this test
- **confirm** (*bool*) – Whether message confirmations were enabled for this test.

**save()**

Select save file location for test results (csv) and then save them there

**register\_msg**(*value*)

Receive message from pilot, stash timestamp, number and pilot

**Parameters** **value** (*dict*) – Value should contain

- Pilot
- Timestamp
- Message number
- Payload

**update\_pbar**(*val*)

**validate\_list()**

Checks that the entries in `Bandwidth_Test.rates` and `Bandwidth_Test.payloads` are well formed.

ie. that they are of the form 'integer, integer, integer'...

pops a window that warns about ill formed entry and clears line edit if badly formed

If the list validates, stored as either `Bandwidth_Test.rate_list` or `Bandwidth_Test.payload_list`

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3280>

**class Calibrate\_Water**(*pilots*)

Bases: `PySide2.QtWidgets.QDialog`

A window to calibrate the volume of water dispensed per ms.

**Parameters**

- **pilots** (*Terminal.pilots*) – A dictionary of pilots
- **message\_fn** (*Net\_Node.send()*) – The method the Terminal uses to send messages via its net node.

**Methods:**


---

init\_ui()

---

**Attributes:**


---

staticMetaObject

---

init\_ui()

staticMetaObject = &lt;PySide2.QtCore.QMetaObject object at 0x7f6f2f7c31e0&gt;

**class Pilot\_Ports**(pilot, n\_clicks=1000, click\_dur=30)

Bases: PySide2.QtWidgets.QWidget

Created by *Calibrate\_Water*, Each pilot's ports and buttons to control repeated release.
**Parameters**

- **pilot** (*str*) – name of pilot to calibrate
- **n\_clicks** (*int*) – number of times to open the port during calibration
- **click\_dur** (*int*) – how long to open the port (in ms)

**Methods:**

init_ui()	Init the layout for one pilot's ports:
update_volumes()	Store the result of a volume calibration test in volumes
start_calibration()	Send the calibration test parameters to the <i>Pilot</i>
l_progress(value)	Value should contain

**Attributes:**


---

staticMetaObject

---

init\_ui()

Init the layout for one pilot's ports:

- pilot name
- port buttons
- 3 times and vol dispersed

**Returns**

**update\_volumes()**

Store the result of a volume calibration test in `volumes`

**start\_calibration()**

Send the calibration test parameters to the *Pilot*

Sends a message with a 'CALIBRATE\_PORT' key, which is handled by *Pilot.l\_cal\_port()*

**l\_progress(value)**

Value should contain

- Pilot
- Port
- Current Click (click\_num)

**Parameters** `value` –

**Returns**

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3190>`

**class Reassign(subjects, protocols)**

Bases: `PySide2.QtWidgets.QDialog`

A dialog that lets subjects be batch reassigned to new protocols or steps.

**Parameters**

- **subjects** (*dict*) –

A dictionary that contains each subject's protocol and step, ie.:

`{ 'subject_id': ['protocol_name', step_int], ... }`

- **protocols** (*list*) – list of protocol files in the *prefs.get('PROTOCOLDIR')*. Not entirely sure why we don't just list them ourselves here.

**Methods:**

<code>init_ui()</code>	Initializes graphical elements.
<code>populate_steps(subject)</code>	When a protocol is selected, populate the selection box with the steps that can be chosen.
<code>set_protocol()</code>	When the protocol is changed, stash that and call <i>Reassign.populate_steps()</i> .
<code>set_step()</code>	When the step is changed, stash that.

**Attributes:**

---

`staticMetaObject`

---

**init\_ui()**

Initializes graphical elements.

Makes a row for each subject where its protocol and step can be changed.

**populate\_steps(subject)**

When a protocol is selected, populate the selection box with the steps that can be chosen.



**Parameters** **subject** (*str*) – ID of subject whose steps are being populated

**set\_protocol()**

When the protocol is changed, stash that and call [Reassign.populate\\_steps\(\)](#) . Returns:

**set\_step()**

When the step is changed, stash that.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3140>

**class** **Weights**(*subject\_weights*, *subjects*)

Bases: PySide2.QtWidgets.QTableWidget

A table for viewing and editing the most recent subject weights.

**Parameters**

- **subject\_weights** (*list*) – a list of weights of the format returned by [Subject.get\\_weight\(baseline=True\)\(\)](#).
- **subjects** (*dict*) – the Terminal's `Terminal.subjects` dictionary of [Subject](#) objects.

**Methods:**

<code>init_ui()</code>	Initialized graphical elements.
<code>set_weight(row, column)</code>	Updates the most recent weights in <code>gui.Weights.subjects</code> objects.

**Attributes:**

<code>staticMetaObject</code>
-------------------------------

**init\_ui()**

Initialized graphical elements. Literally just filling a table.

**set\_weight**(*row*, *column*)

Updates the most recent weights in `gui.Weights.subjects` objects.

---

**Note:** Only the daily weight measurements can be changed this way - not subject name, baseline weight, etc.

---

**Parameters**

- **row** (*int*) – row of table
- **column** (*int*) – column of table

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c30a0>

**class** **Plugins**

Bases: PySide2.QtWidgets.QDialog

Dialog window that allows plugins to be viewed and installed.

Works by querying the [wiki](#) , find anything in the category `Autopilot Plugins` , clone the related repo, and reload plugins.

At the moment this widget is a proof of concept and will be made functional asap :)

**Methods:**

---

`init_ui()`

---

`list_plugins()`

---

`download_plugin()`

---

`select_plugin_type()`

---

`select_plugin()`

---

**Attributes:**

---

`staticMetaObject`

---

`init_ui()``list_plugins()``download_plugin()``select_plugin_type()``select_plugin()``staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7c3050>`**class** `Psychometric(subjects_protocols)``Bases: PySide2.QtWidgets.QDialog``A Dialog to select subjects, steps, and variables to use in a psychometric curve plot.``See Terminal.plot\_psychometric\(\)`**Parameters** `subjects_protocols` (*dict*) – The Terminals `Terminal.subjects_protocols` dict**Variables** `plot_params` (*list*) – A list of tuples, each consisting of (subject\_id, step, variable) to be given to `viz.plot_psychometric()`**Methods:**

---

`init_ui()`

---

`populate_steps(subject)``When a protocol is selected, populate the selection box with the steps that can be chosen.`

---

`populate_variables()``Fill selection boxes with step and variable names`

---

`check_all()``Toggle all checkboxes on or off`

---

**Attributes:**

---

`plot_params``Generate parameters for plot to be passed to viz.  
plot_psychometric()`

---

`continues on next page`

Table 42 – continued from previous page

staticMetaObject
<p><b>init_ui()</b></p> <p><b>populate_steps(<i>subject</i>)</b> When a protocol is selected, populate the selection box with the steps that can be chosen.</p> <p><b>Parameters</b> <i>subject</i> (<i>str</i>) – ID of subject whose steps are being populated</p> <p><b>populate_variables()</b> Fill selection boxes with step and variable names</p> <p><b>check_all()</b> Toggle all checkboxes on or off</p> <p><b>property plot_params</b> Generate parameters for plot to be passed to <code>viz.plot_psychometric()</code></p> <p><b>Returns</b> (subject_name, step_name, x_var_name, n_trials_back)</p> <p><b>Return type</b> <code>tuple</code></p> <p><b>staticMetaObject</b> = &lt;PySide2.QtCore.QMetaObject object at 0x7f6f2f7bafa0&gt;</p> <p><b>class Stream_Video(<i>pilots: dict, *args, **kwargs</i>)</b> Bases: PySide2.QtWidgets.QDialog</p> <p>Dialogue to stream, display, and save video.</p> <p><b>Parameters</b> <i>pilots</i> (<i>dict</i>) – The <code>Terminal.pilot_db</code> with the prefs of each pilot (given by <i>Pilot.handshake()</i>)</p> <p><b>Methods:</b></p> <p><b>init_ui()</b></p> <p><b>populate_cameras()</b></p> <p><b>camera_selected()</b></p> <p><b>toggle_start()</b></p> <p><b>write_video()</b></p> <p><b>l_frame(value)</b></p> <p><b>closeEvent(self, arg__1)</b></p> <p><b>Attributes:</b></p> <p><b>current_pilot</b></p> <p><b>current_camera</b></p>

continues on next page

Table 44 – continued from previous page

---

staticMetaObject
------------------

---

```

init_ui()
property current_pilot: str
property current_camera: str
populate_cameras()
camera_selected()
toggle_start()
write_video()
l_frame(value)
closeEvent(self, arg__1: PySide2.QtGui.QCloseEvent) → None
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7baf50>
pop_dialog(message: str, details: str = "", buttons: tuple = ('Ok',), modality: str = 'nonmodal', msg_type: str =
'info') → PySide2.QtWidgets.QMessageBox
Convenience function to pop a :class:`.QtGui.QDialog` window to display a message.

```

---

**Note:** This function does *not* call `.exec_` on the dialog so that it can be managed by the caller.

---

## Examples

```
box = pop_dialog( message='Hey what up', details='i got something to tell you', buttons = ('Ok', 'Cancel'))
```

```
ret = box.exec_() if ret == box.Ok:
```

```
    print("user answered 'Ok'")
```

```
else: print("user answered 'Cancel'")
```

### Parameters

- **message** (*str*) – message to be displayed
- **details** (*str*) – Additional detailed to be added to the displayed message
- **buttons** (*list*) – A list specifying which `QtWidgets.QMessageBox.StandardButtons` to display. Use a string matching the button name, eg. “Ok” gives `QtWidgets.QMessageBox.Ok`

The full list of available buttons is:

```
[ 'NoButton', 'Ok', 'Save', 'SaveAll', 'Open', 'Yes', 'YesToAll',
  'No', 'NoToAll', 'Abort', 'Retry', 'Ignore', 'Close', 'Cancel',
  'Discard', 'Help', 'Apply', 'Reset', 'RestoreDefaults',
  'FirstButton', 'LastButton', 'YesAll', 'NoAll', 'Default',
  'Escape', 'FlagMask', 'ButtonMask' ]
```

- **modality** (*str*) – Window modality to use, one of “modal”, “nonmodal” (default). Modal windows block nonmodal windows don’t.
- **msg\_type** (*str*) – “info” (default), “question”, “warning”, or “error” to use `QtGui.QMessageBox.information()`, `QtGui.QMessageBox.question()`, `QtGui.QMessageBox.warning()`, or `QtGui.QMessageBox.error()`, respectively

**Returns** `QtWidgets.QMessageBox`

## 11.2 loggers

### Data:

<code>_LOGGERS</code>	List of instantiated loggers, used in <code>init_logger()</code> to return existing loggers without modification
-----------------------	--

### Functions:

<code>init_logger(instance, module_name, ...)</code>	Initialize a logger
--	---------------------

`_LOGGERS = []`

List of instantiated loggers, used in `init_logger()` to return existing loggers without modification

**init\_logger**(*instance=None, module\_name=None, class\_name=None, object\_name=None*) → `logging.Logger`  
Initialize a logger

Loggers are created such that...

- There is one logger per module (eg. all gpio objects will log to `hardware.gpio`)
- If the passed object has a `name` attribute, that name will be prefixed to its log messages in the file
- The loglevel for the file handler and the stdout is determined by `prefs.get('LOGLEVEL')`, and if none is provided `WARNING` is used by default
- logs are rotated according to `prefs.get('LOGSIZE')` (in bytes) and `prefs.get('LOGNUM')` (number of backups of `prefs.get('LOGSIZE')` to cycle through)

Logs are stored in `prefs.get('LOGDIR')`, and are formatted like:

```
"%(asctime)s - %(name)s - %(levelname)s : %(message)s"
```

Loggers can be initialized either by passing an object to the first `instance` argument, or by specifying any of `module_name`, `class_name`, or `object_name` (at least one must be specified) which are combined with periods like `module.class_name.object_name`

### Parameters

- **instance** – The object that we are creating a logger for! if `None`, at least one of `module`, `class_name`, or `object_name` must be passed
- **module\_name** (*None, str*) – If no `instance` passed, the module name to create a logger for
- **class\_name** (*None, str*) – If no `instance` passed, the class name to create a logger for
- **object\_name** (*None, str*) – If no `instance` passed, the object name/id to create a logger for

**Returns** `logging.logger`

## 11.3 pilot

Classes:

Pilot([splash])	Drives the Raspberry Pi
-----------------	-------------------------

**class** `Pilot`(*splash=True*)

Bases: `object`

Drives the Raspberry Pi

Coordinates the hardware and networking objects to run tasks.

Typically used with a connection to a [Terminal](#) object to coordinate multiple subjects and tasks, but a high priority for future releases is to do the (trivial amount of) work to make this class optionally standalone.

Called as a module with the `-f` flag to give the location of a prefs file, eg:

```
python pilot.py -f prefs_file.json
```

if the `-f` flag is not passed, looks in the default location for prefs (ie. `/usr/autopilot/prefs.json`)

Needs the following prefs (typically established by `setup.setup_pilot`):

- **NAME** - The name used by networking objects to address this Pilot
- **BASEDIR** - The base directory for autopilot files (`/usr/autopilot`)
- **PUSHPORT** - Router port used by the Terminal we connect to.
- **TERMINALIP** - IP Address of our upstream Terminal.
- **MSGPORT** - Port used by our own networking object
- **HARDWARE** - Any hardware and its mapping to GPIO pins. No pins are required to be set, instead each task defines which pins it needs. Currently the default configuration asks for
  - **POKES** - `hardware.Beambreak`
  - **LEDS** - `hardware.LED_RGB`
  - **PORTS** - `hardware.Solenoid`
- **AUDIOSERVER** - Which type, if any, audio server to use (`'jack'`, `'pyo'`, or `'none'`)
- **NCHANNELS** - Number of audio channels
- **FS** - Sampling rate of audio output
- **JACKDSTRING** - string used to start the jackd server, see [the jack manpages](#) eg:

```
jackd -P75 -p16 -t2000 -dalsa -dhw:sndrpihifiberry -P -rfs -n3 -s &
```

- **PIGPIMASK** - Binary mask of pins for pigpio to control, see [the pigpio docs](#) , eg:

```
111111000011111111111110000
```

- **PULLUPS** - Pin (board) numbers to pull up on boot
- **PULLDOWNS** - Pin (board) numbers to pull down on boot.

**Variables**

- **name** (*str*) – The name used to identify ourselves in *networking*
- **task** (`tasks.Task`) – The currently instantiated task
- **running** (`threading.Event`) – Flag used to control task running state
- **stage\_block** (`threading.Event`) – Flag given to a task to signal when task stages finish
- **file\_block** (`threading.Event`) – Flag used to wait for file transfers
- **state** (*str*) – ‘RUNNING’, ‘STOPPING’, ‘IDLE’ - signals what this pilot is up to
- **pulls** (*list*) – list of `Pull` objects to keep pins pulled up or down
- **server** – Either a *pyo\_server()* or *JackClient* , sound server.
- **node** (`networking.Net_Node`) – Our `Net_Node` we use to communicate with our main networking object
- **networking** (`networking.Pilot_Station`) – Our networking object to communicate with the outside world
- **ip** (*str*) – Our IPv4 address
- **listens** (*dict*) – Dictionary mapping message keys to methods used to process them.
- **logger** (`logging.Logger`) – Used to log messages and network events.

**Attributes:**

server	
logger	
running	
stage_block	
file_block	
quitting	mp.Event to signal when process is quitting
networking	
node	

**Methods:**

get_ip()	Get our IP
handshake()	Send the terminal our name and IP to signal that we are alive
update_state()	Send our current state to the Terminal, our Station object will cache this and will handle any future requests.
l_start(value)	Start running a task.
l_stop(value)	Stop the task.
l_param(value)	Change a task parameter mid-run
l_cal_port(value)	Initiate the <i>calibrate_port()</i> routine.

continues on next page

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<code>calibrate_port(port_name, n_clicks, ...)</code>	Run port calibration routine
<code>l_cal_result(value)</code>	Save the results of a port calibration
<code>l_bandwidth(value)</code>	Send messages with a poissonian process according to the settings in value
<code>l_stream_video(value)</code>	Start or stop video streaming
<code>calibration_curve([path, calibration])</code>	# compute curve to compute duration from desired volume
<code>init_pigpio()</code>	
<code>init_audio()</code>	Initialize an audio server depending on the value of <i>prefs.get('AUDIOSERVER')</i>
<code>blank_LEDs()</code>	If any 'LEDS' are defined in <i>prefs.get('HARDWARE')</i> , instantiate them, set their color to [0,0,0], and then release them.
<code>open_file()</code>	Setup a table to store data locally.
<code>run_task(task_class, task_params)</code>	Called in a new thread, run the task.

**server** = None

**logger** = None

**running** = None

**stage\_block** = None

**file\_block** = None

**quitting** = None

mp.Event to signal when process is quitting

**networking** = None

**node** = None

**get\_ip()**

Get our IP

**handshake()**

Send the terminal our name and IP to signal that we are alive

**update\_state()**

Send our current state to the Terminal, our Station object will cache this and will handle any future requests.

**l\_start(value)**

Start running a task.

Get the task object by using *value['task\_type']* to select from `autopilot.get_task()`, then feed the rest of *value* as kwargs into the task object.

Calls `autopilot.run_task()` in a new thread

**Parameters** *value* (*dict*) – A dictionary of task parameters

**l\_stop(value)**

Stop the task.

Clear the running event, set the stage block.

---

**Todo:** Do a coherence check between our local file and the Terminal's data.

---



**Parameters** *value* – ignored

**l\_param**(*value*)

Change a task parameter mid-run

**Warning:** Not Implemented

**Parameters** *value*

**l\_cal\_port**(*value*)

Initiate the `calibrate_port()` routine.

**Parameters** *value* (*dict*) – Dictionary of values defining the port calibration to be run, including

- `port` - which port to calibrate - `n_clicks` - how many openings should be performed -
- `open_dur` - how long the valve should be open - `iti` - ‘inter-trial interval’, or how long should we wait between valve openings.

**calibrate\_port**(*port\_name*, *n\_clicks*, *open\_dur*, *iti*)

Run port calibration routine

Open a `hardware.gpio.Solenoid` repeatedly, measure volume of water dispersed, compute lookup table mapping valve open times to volume.

Continuously sends progress of test with CAL\_PROGRESS messages

**Parameters**

- **port\_name** (*str*) – Port name as specified in `prefs`
- **n\_clicks** (*int*) – number of times the valve should be opened
- **open\_dur** (*int*, *float*) – how long the valve should be opened for in ms
- **iti** (*int*, *float*) – how long we should `sleep()` between openings

**l\_cal\_result**(*value*)

Save the results of a port calibration

**l\_bandwidth**(*value*)

Send messages with a poissonian process according to the settings in *value*

**l\_stream\_video**(*value*)

Start or stop video streaming

**Parameters** *value* (*dict*) –

a dictionary of the form:

```
{
  'starting': bool, # whether we're starting (True) or stopping
  'camera': str, # the camera to start/stop, of form 'group.camera_
    ↪ id'
  'stream_to': node id that the camera should send to
}
```

**calibration\_curve**(*path=None*, *calibration=None*)

# compute curve to compute duration from desired volume

**Parameters**

- **calibration**

- **path** – If present, use calibration file specified, otherwise use default.

**init\_pigpio()**

**init\_audio()**

Initialize an audio server depending on the value of *prefs.get('AUDIOSERVER')*

- 'pyo' = *pyoserver.pyo\_server()*
- 'jack' = *jackclient.JackClient*

**blank\_LEDs()**

If any 'LEDS' are defined in *prefs.get('HARDWARE')* , instantiate them, set their color to [0,0,0], and then release them.

**open\_file()**

Setup a table to store data locally.

Opens *prefs.get('DATADIR')/local.h5*, creates a group for the current subject, a new table for the current day.

---

**Todo:** This needs to be unified with a general file constructor abstracted from *Subject* so it doesn't reimplement file creation!!

---

**Returns** (*tables.File*, *tables.Table*, *tables.tableextension.Row*): The file, table, and row for the local data table

**run\_task**(*task\_class*, *task\_params*)

Called in a new thread, run the task.

Opens a file with *open\_file()* , then continually calls *task.stages.next* to process stages.

Sends data back to the terminal between every stage.

Waits for the task to clear *stage\_block* between stages.

## 11.4 plots

Classes to plot data in the GUI.

---

**Todo:** Add all possible plot objects and options in list.

---

---

**Note:** Plot objects need to be added to *PLOT\_LIST* in order to be reachable.

---

### Functions:

---

*gui\_event*(fn)

Wrapper/decorator around an event that posts GUI events back to the main thread that our window is running in.

---

### Classes:

<code>Plot_Widget()</code>	Main plot widget that holds plots for all pilots
<code>Plot(pilot[, x_width, parent])</code>	Widget that hosts a <code>pyqtgraph.PlotWidget</code> and manages graphical objects for one pilot depending on the task.
<code>Point([color, size])</code>	A simple point.
<code>Line([color, size])</code>	A simple line
<code>Segment(**kwargs)</code>	A line segment that draws from 0.5 to some endpoint.
<code>Roll_Mean([winsize])</code>	Shaded area underneath a rolling average.
<code>Shaded(**kwargs)</code>	Shaded area for a continuous plot
<code>Timer()</code>	A simple timer that counts.
<code>Video(videos[, fps])</code>	Display Video data as it is collected.
<code>HLine()</code>	A Horizontal line.
<code>ImageItem_TimedUpdate(*args, **kwargs)</code>	Reclass of <code>pyqtgraph.ImageItem</code> to update with a fixed fps.

**Data:**

<code>PLOT_LIST</code>	A dictionary connecting plot keys to objects.
------------------------	---

**gui\_event** (*fn*)

Wrapper/decorator around an event that posts GUI events back to the main thread that our window is running in.

**Parameters** *fn* (*callable*) – a function that does something to the GUI

**class Plot\_Widget**

Bases: `PySide2.QtWidgets.QWidget`

Main plot widget that holds plots for all pilots

Essentially just a container to give plots a layout and handle any logic that should apply to all plots.

**Variables**

- **logger** (*logging.Logger*) – The ‘main’ logger
- **plots** (*dict*) – mapping from pilot name to *Plot*

**Methods:**

<code>init_plots(pilot_list)</code>	For each pilot, instantiate a <i>Plot</i> and add to layout.
-------------------------------------	--

**Attributes:**

<code>staticMetaObject</code>
-------------------------------

**init\_plots** (*pilot\_list*)

For each pilot, instantiate a *Plot* and add to layout.

**Parameters** *pilot\_list* (*list*) – the keys from *Terminal.pilots*

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f32f8aa50>`

**class Plot** (*pilot, x\_width=50, parent=None*)

Bases: `PySide2.QtWidgets.QWidget`

Widget that hosts a `pyqtgraph.PlotWidget` and manages graphical objects for one pilot depending on the task.

listens

Key	Method	Description
'START'	<a href="#">l_start()</a>	starting a new task
'DATA'	<a href="#">l_data()</a>	getting a new datapoint
'STOP'	<a href="#">l_stop()</a>	stop the task
'PARAM'	<a href="#">l_param()</a>	change some parameter

### Plot Parameters

The plot is built from the `PLOT={data:plot_element}` mappings described in the [Task](#) class. Additional parameters can be specified in the PLOT dictionary. Currently:

- **continuous** (bool): whether the data should be plotted against the trial number (False or NA) or against time (True)
- **chance\_bar** (bool): Whether to draw a red horizontal line at chance level (default: 0.5)
- **chance\_level** (float): The position in the y-axis at which the `chance_bar` should be drawn
- **roll\_window** (int): The number of trials [Roll\\_Mean](#) take the average over.

### Variables

- **pilot** (*str*) – The name of our pilot, used to set the identity of our socket, specifically:

```
'P_{pilot}'
```

- **infobox** (`QtWidgets.QFormLayout`) – Box to plot basic task information like trial number, etc.
- **info** (*dict*) – Widgets in infobox:
  - 'N Trials': `QtWidgets.QLabel`,
  - 'Runtime' : [Timer](#),
  - 'Session' : `QtWidgets.QLabel`,
  - 'Protocol': `QtWidgets.QLabel`,
  - 'Step' : `QtWidgets.QLabel`
- **plot** (`pyqtgraph.PlotWidget`) – The widget where we draw our plots
- **plot\_params** (*dict*) – A dictionary of plot parameters we receive from the Task class
- **data** (*dict*) – A dictionary of the data we've received
- **plots** (*dict*) – The collection of plots we instantiate based on *plot\_params*
- **node** ([Net\\_Node](#)) – Our local net node where we listen for data.
- **state** (*str*) – state of the pilot, used to keep plot synchronized.

### Parameters

- **pilot** (*str*) – The name of our pilot
- **x\_width** (*int*) – How many trials in the past should we plot?

Methods:

<code>init_plots()</code>	Make pre-task GUI objects and set basic visual parameters of <i>self.plot</i>
<code>l_start(value)</code>	Starting a task, initialize task-specific plot objects described in the <i>Task.PLOT</i> attribute.
<code>l_data(value)</code>	Receive some data, if we were told to plot it, stash the data and update the assigned plot.
<code>l_stop(value)</code>	Clean up the plot objects.
<code>l_param(value)</code>	

**Warning:**

Not  
im-  
ple-  
mented

<code>l_state(value)</code>	Pilot letting us know its state has changed.
-----------------------------	--

**Attributes:**

<code>staticMetaObject</code>
-------------------------------

**init\_plots()**

Make pre-task GUI objects and set basic visual parameters of *self.plot*

**l\_start(value)**

Starting a task, initialize task-specific plot objects described in the *Task.PLOT* attribute.

Matches the data field name (keys of *Task.PLOT* ) to the plot object that represents it, eg, to make the standard nafc plot:

```
{'target'   : 'point',
 'response' : 'segment',
 'correct'  : 'rollmean'}
```

**Parameters** *value* (*dict*) – The same parameter dictionary sent by *Terminal.toggle\_start()*, including

- `current_trial`
- `step`
- `session`
- `step_name`
- `task_type`

**l\_data(value)**

Receive some data, if we were told to plot it, stash the data and update the assigned plot.

**Parameters** *value* (*dict*) – Value field of a data message sent during a task.

**l\_stop(value)**

Clean up the plot objects.

**Parameters** *value* (*dict*) – if “graduation” is a key, don’t stop the timer.

`l_param(value)`

**Warning:** Not implemented

**Parameters** *value*

`l_state(value)`

Pilot letting us know its state has changed. Mostly for the case where we think we’re running but the pi doesn’t.

**Parameters** *value* (`Pilot.state`) – the state of our pilot

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f31d3d870>`

**class** `Point`(*color*=(0, 0, 0), *size*=5, *\*\*kwargs*)

Bases: `pyqtgraph.graphicsItems.PlotDataItem.PlotDataItem`

A simple point.

**Variables**

- **brush** (`QtWidgets.QBrush`) –
- **pen** (`QtWidgets.QPen`) –

**Parameters**

- **color** (*tuple*) – RGB color of points
- **size** (*int*) – width in px.

**Methods:**

---

`update(data)`

**Parameters** *data* (`numpy.ndarray`) --  
an *x\_width* x 2 array where

---

**Attributes:**

---

`staticMetaObject`

---

`update(data)`

**Parameters** *data* (`numpy.ndarray`) – an *x\_width* x 2 array where column 0 is trial number and column 1 is the value, where value can be “L”, “C”, “R” or a float.

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1820>`

**class** `Line`(*color*=(0, 0, 0), *size*=1, *\*\*kwargs*)

Bases: `pyqtgraph.graphicsItems.PlotDataItem.PlotDataItem`

A simple line

There are many different ways to create a `PlotDataItem`:

**Data initialization arguments:** (x,y data only)

PlotDataItem(xValues, yValues)	x and y values may be any sequence (including ndarray) of real numbers
PlotDataItem(yValues)	y values only – x will be automatically set to range(len(y))
PlotDataItem(x=xValues, y=yValues)	x and y given by keyword arguments
PlotDataItem(ndarray(Nx2))	numpy array with shape (N, 2) where <code>x=data[:,0]</code> and <code>y=data[:,1]</code>

**Data initialization arguments:** (x,y data AND may include spot style)

Plot-DataItem(recarray)	numpy array with dtype=[('x', float), ('y', float), ...]
PlotDataItem(list-of-dicts)	[{'x': x, 'y': y, ...}, ...]
PlotDataItem(dict-of-lists)	{'x': [...], 'y': [...], ...}
Plot-DataItem(MetaArray)	1D array of Y values with X sepecified as axis values OR 2D array with a column 'y' and extra columns as needed.

**Line style keyword arguments:**

connect	Specifies how / whether vertexes should be connected. See <a href="#">arrayToQPath()</a>
pen	Pen to use for drawing line between points. Default is solid grey, 1px width. Use None to disable line drawing. May be any single argument accepted by <a href="#">mkPen()</a>
shadow-Pen	Pen for secondary line to draw behind the primary line. disabled by default. May be any single argument accepted by <a href="#">mkPen()</a>
fillLevel	Fill the area between the curve and fillLevel
fill-Outline	(bool) If True, an outline surrounding the <i>fillLevel</i> area is drawn.
fill-Brush	Fill to use when fillLevel is specified. May be any single argument accepted by <a href="#">mkBrush()</a>
step-Mode	If True, two orthogonal lines are drawn for each sample as steps. This is commonly used when drawing histograms. Note that in this case, <code>len(x) == len(y) + 1</code> (added in version 0.9.9)

**Point style keyword arguments:** (see `ScatterPlotItem.setData()` for more information)

symbol	Symbol to use for drawing points OR list of symbols, one per point. Default is no symbol. Options are o, s, t, d, +, or any QPainterPath
symbol-Pen	Outline pen for drawing points OR list of pens, one per point. May be any single argument accepted by <code>mkPen()</code>
symbol-Brush	Brush for filling points OR list of brushes, one per point. May be any single argument accepted by <code>mkBrush()</code>
symbol-Size	Diameter of symbols OR list of diameters.
pxMode	(bool) If True, then symbolSize is specified in pixels. If False, then symbolSize is specified in data coordinates.

**Optimization keyword arguments:**

an-tialias	(bool) By default, antialiasing is disabled to improve performance. Note that in some cases (in particular, when <code>pxMode=True</code> ), points will be rendered antialiased even if this is set to False.
deci-mate	deprecated.
down-sam-ple	(int) Reduce the number of samples displayed by this value
down-sam-pleMethod	'subsample': Downsample by taking the first of N samples. This method is fastest and least accurate. 'mean': Downsample by taking the mean of N samples. 'peak': Downsample by drawing a saw wave that follows the min and max of the original data. This method produces the best visual representation of the data but is slower.
autoDown-sam-ple	(bool) If True, resample the data before plotting to avoid plotting multiple line segments per pixel. This can improve performance when viewing very high-density data, but increases the initial overhead and memory usage.
clip-ToView	(bool) If True, only plot data that is visible within the X range of the containing ViewBox. This can improve performance when plotting very large data sets where only a fraction of the data is visible at any time.
iden-tical	<i>deprecated</i>

**Meta-info keyword arguments:**

name	name of dataset. This would appear in a legend
------	--

**Methods:**

---

`update() -> None`

---

**Attributes:**

---

`staticMetaObject`

---

`update(self, rect: PySide2.QtCore.QRectF = Default(QRectF)) -> None``update(self, x: float, y: float, width: float, height: float) -> None`



`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1780>`

**class Segment**(\*\*kwargs)

Bases: `pyqtgraph.graphicsItems.PlotDataItem.PlotDataItem`

A line segment that draws from 0.5 to some endpoint.

There are many different ways to create a `PlotDataItem`:

**Data initialization arguments:** (x,y data only)

<code>PlotDataItem(xValues, yValues)</code>	x and y values may be any sequence (including ndarray) of real numbers
<code>PlotDataItem(yValues)</code>	y values only – x will be automatically set to <code>range(len(y))</code>
<code>PlotDataItem(x=xValues, y=yValues)</code>	x and y given by keyword arguments
<code>PlotDataItem(ndarray(Nx2))</code>	numpy array with shape (N, 2) where <code>x=data[:,0]</code> and <code>y=data[:,1]</code>

**Data initialization arguments:** (x,y data AND may include spot style)

<code>PlotDataItem(recarray)</code>	numpy array with dtype=[('x', float), ('y', float), ...]
<code>PlotDataItem(list-of-dicts)</code>	[{'x': x, 'y': y, ...}, ...]
<code>PlotDataItem(dict-of-lists)</code>	{'x': [...], 'y': [...], ...}
<code>PlotDataItem(MetaArray)</code>	1D array of Y values with X specified as axis values OR 2D array with a column 'y' and extra columns as needed.

**Line style keyword arguments:**

<code>connect</code>	Specifies how / whether vertexes should be connected. See <code>arrayToQPath()</code>
<code>pen</code>	Pen to use for drawing line between points. Default is solid grey, 1px width. Use None to disable line drawing. May be any single argument accepted by <code>mkPen()</code>
<code>shadow-Pen</code>	Pen for secondary line to draw behind the primary line. disabled by default. May be any single argument accepted by <code>mkPen()</code>
<code>fillLevel</code>	Fill the area between the curve and <code>fillLevel</code>
<code>fill-Outline</code>	(bool) If True, an outline surrounding the <code>fillLevel</code> area is drawn.
<code>fill-Brush</code>	Fill to use when <code>fillLevel</code> is specified. May be any single argument accepted by <code>mkBrush()</code>
<code>step-Mode</code>	If True, two orthogonal lines are drawn for each sample as steps. This is commonly used when drawing histograms. Note that in this case, <code>len(x) == len(y) + 1</code> (added in version 0.9.9)

**Point style keyword arguments:** (see `ScatterPlotItem.setData()` for more information)

symbol	Symbol to use for drawing points OR list of symbols, one per point. Default is no symbol. Options are o, s, t, d, +, or any QPainterPath
symbol-Pen	Outline pen for drawing points OR list of pens, one per point. May be any single argument accepted by <code>mkPen()</code>
symbol-Brush	Brush for filling points OR list of brushes, one per point. May be any single argument accepted by <code>mkBrush()</code>
symbol-Size	Diameter of symbols OR list of diameters.
pxMode	(bool) If True, then <code>symbolSize</code> is specified in pixels. If False, then <code>symbolSize</code> is specified in data coordinates.

**Optimization keyword arguments:**

an-tialias	(bool) By default, antialiasing is disabled to improve performance. Note that in some cases (in particular, when <code>pxMode=True</code> ), points will be rendered antialiased even if this is set to False.
deci-mate	deprecated.
down-sam-ple	(int) Reduce the number of samples displayed by this value
down-sam-pleMethod	'subsample': Downsample by taking the first of N samples. This method is fastest and least accurate. 'mean': Downsample by taking the mean of N samples. 'peak': Downsample by drawing a saw wave that follows the min and max of the original data. This method produces the best visual representation of the data but is slower.
autoDown-sam-ple	(bool) If True, resample the data before plotting to avoid plotting multiple line segments per pixel. This can improve performance when viewing very high-density data, but increases the initial overhead and memory usage.
clip-ToView	(bool) If True, only plot data that is visible within the X range of the containing ViewBox. This can improve performance when plotting very large data sets where only a fraction of the data is visible at any time.
iden-tical	<i>deprecated</i>

**Meta-info keyword arguments:**

name	name of dataset. This would appear in a legend
------	--

**Methods:**

---

<code>update(data)</code>	data is doubled and then every other value is set to 0.5, then <code>setData()</code> is used with <i>connect='pairs'</i> to make line segments.
---------------------------	--

---

**Attributes:**

---

<code>staticMetaObject</code>
-------------------------------

---

**update(data)**

data is doubled and then every other value is set to 0.5, then setData() is used with *connect='pairs'* to make line segments.

**Parameters data** (`numpy.ndarray`) – an x\_width x 2 array where column 0 is trial number and column 1 is the value, where value can be “L”, “C”, “R” or a float.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1af0>

**class Roll\_Mean**(*winsize=10, \*\*kwargs*)

Bases: `pyqtgraph.graphicsItems.PlotDataItem.PlotDataItem`

Shaded area underneath a rolling average.

Typically used as a rolling mean of corrects, so area above and below 0.5 is drawn.

**Parameters winsize** (*int*) – number of trials in the past to take a rolling mean of

**Methods:**


---

update(data)

**Parameters data** (`numpy.ndarray`) --  
an x\_width x 2 array where

---

**Attributes:**


---

staticMetaObject

---

**update(data)**

**Parameters data** (`numpy.ndarray`) – an x\_width x 2 array where column 0 is trial number and column 1 is the value.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1b40>

**class Shaded**(*\*\*kwargs*)

Bases: `pyqtgraph.graphicsItems.PlotDataItem.PlotDataItem`

Shaded area for a continuous plot

There are many different ways to create a PlotDataItem:

**Data initialization arguments:** (x,y data only)

PlotDataItem(xValues, yValues)	x and y values may be any sequence (including ndarray) of real numbers
PlotDataItem(yValues)	y values only – x will be automatically set to range(len(y))
PlotDataItem(x=xValues, y=yValues)	x and y given by keyword arguments
PlotDataItem(ndarray(Nx2))	numpy array with shape (N, 2) where x=data[:,0] and y=data[:,1]

**Data initialization arguments:** (x,y data AND may include spot style)

Plot-DataItem(recarray)	numpy array with dtype=[('x', float), ('y', float), ...]
PlotDataItem(list-of-dicts)	[{'x': x, 'y': y, ...}, ...]
PlotDataItem(dict-of-lists)	{'x': [...], 'y': [...], ...}
Plot-DataItem(MetaArray)	1D array of Y values with X specified as axis values OR 2D array with a column 'y' and extra columns as needed.

**Line style keyword arguments:**

connect	Specifies how / whether vertexes should be connected. See <a href="#">arrayToQPath()</a>
pen	Pen to use for drawing line between points. Default is solid grey, 1px width. Use None to disable line drawing. May be any single argument accepted by <a href="#">mkPen()</a>
shadow-Pen	Pen for secondary line to draw behind the primary line. disabled by default. May be any single argument accepted by <a href="#">mkPen()</a>
fillLevel	Fill the area between the curve and fillLevel
fill-Outline	(bool) If True, an outline surrounding the <i>fillLevel</i> area is drawn.
fill-Brush	Fill to use when fillLevel is specified. May be any single argument accepted by <a href="#">mkBrush()</a>
step-Mode	If True, two orthogonal lines are drawn for each sample as steps. This is commonly used when drawing histograms. Note that in this case, <code>len(x) == len(y) + 1</code> (added in version 0.9.9)

**Point style keyword arguments:** (see `ScatterPlotItem.setData()` for more information)

symbol	Symbol to use for drawing points OR list of symbols, one per point. Default is no symbol. Options are o, s, t, d, +, or any QPainterPath
symbol-Pen	Outline pen for drawing points OR list of pens, one per point. May be any single argument accepted by <a href="#">mkPen()</a>
symbol-Brush	Brush for filling points OR list of brushes, one per point. May be any single argument accepted by <a href="#">mkBrush()</a>
symbol-Size	Diameter of symbols OR list of diameters.
pxMode	(bool) If True, then symbolSize is specified in pixels. If False, then symbolSize is specified in data coordinates.

**Optimization keyword arguments:**

an-alias	(bool) By default, antialiasing is disabled to improve performance. Note that in some cases (in particular, when pxMode=True), points will be rendered antialiased even if this is set to False.
decimate	deprecated.
down-sample	(int) Reduce the number of samples displayed by this value
down-sampleMethod	'subsample': Downsample by taking the first of N samples. This method is fastest and least accurate. 'mean': Downsample by taking the mean of N samples. 'peak': Downsample by drawing a saw wave that follows the min and max of the original data. This method produces the best visual representation of the data but is slower.
autoDown-sample	(bool) If True, resample the data before plotting to avoid plotting multiple line segments per pixel. This can improve performance when viewing very high-density data, but increases the initial overhead and memory usage.
clip-ToView	(bool) If True, only plot data that is visible within the X range of the containing ViewBox. This can improve performance when plotting very large data sets where only a fraction of the data is visible at any time.
identical	<i>deprecated</i>

**Meta-info keyword arguments:**

name	name of dataset. This would appear in a legend
------	--

**Methods:**


---

update(data)

**Parameters** data (`numpy.ndarray`) --  
an x\_width x 2 array where

---

**Attributes:**


---

staticMetaObject

---

**update(data)**

**Parameters** data (`numpy.ndarray`) – an x\_width x 2 array where column 0 is time and column 1 is the value.

**staticMetaObject** = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1b90>

**class Timer**

Bases: PySide2.QtWidgets.QLabel

A simple timer that counts... time...

Uses a QtCore.QTimer connected to `Timer.update_time()`.

**Methods:**

---

```
start_timer([update_interval])
```

**Parameters** `update_interval` (*float*) --  
How often (in ms) the timer should  
be updated.

---

```
stop_timer()
```

you can read the sign ya punk

---

```
update_time()
```

Called every (update\_interval) milliseconds to set the  
text of the timer.

---

#### Attributes:

---

```
staticMetaObject
```

---

```
start_timer(update_interval=1000)
```

**Parameters** `update_interval` (*float*) – How often (in ms) the timer should be updated.

```
stop_timer()
```

you can read the sign ya punk

```
update_time()
```

Called every (update\_interval) milliseconds to set the text of the timer.

```
staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1be0>
```

```
class Video(videos, fps=None)
```

Bases: PySide2.QtWidgets.QWidget

Display Video data as it is collected.

Uses the [ImageItem\\_TimedUpdate](#) class to do timed frame updates.

#### Parameters

- **videos** (*list, tuple*) – Names of video streams that will be displayed
- **fps** (*int*) – if None, draw according to `prefs.get('DRAWFPS')`. Otherwise frequency of widget update

#### Variables

- **videos** (*list, tuple*) – Names of video streams that will be displayed
- **fps** (*int*) – if None, draw according to `prefs.get('DRAWFPS')`. Otherwise frequency of widget update
- **ifps** (*int*) – 1/fps, duration of frame in s
- **qs** (*dict*) – Dictionary of :class:`~queue.Queue`'s in which frames will be dumped
- **quitting** ([threading.Event](#)) – Signal to quit drawing
- **update\_thread** ([threading.Thread](#)) – Thread with target=`meth:~.Video._update_frame`
- **layout** ([PySide2.QtWidgets.QGridLayout](#)) – Widget layout
- **vid\_widgets** (*dict*) – dict containing widgets for each of the individual video streams.

**Methods:**

---

`init_gui()`

---

`_update_frame()`Pulls frames from `Video.qs` and feeds them to the video widgets.

---

`update_frame(video, data)`

Put a frame for a video stream into its queue.

---

`release()`

---

**Attributes:**

---

`staticMetaObject`

---

`init_gui()``_update_frame()`Pulls frames from `Video.qs` and feeds them to the video widgets.

Internal method, run in thread.

`update_frame(video, data)`

Put a frame for a video stream into its queue.

If there is a waiting frame, pull it from the queue first – it's old now.

**Parameters**

- **video** (*str*) – name of video stream
- **data** (`numpy.ndarray`) – video frame

`release()``staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1c30>``class HLine`Bases: `PySide2.QtWidgets.QFrame`

A Horizontal line.

**Attributes:**

---

`staticMetaObject`

---

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1c80>``class ImageItem_TimedUpdate(*args, **kwargs)`Bases: `pyqtgraph.graphicsItems.ImageItem.ImageItem`Reclass of `pyqtgraph.ImageItem` to update with a fixed fps.Rather than calling `update()` every time a frame is updated, call it according to the timer.fps is set according to `prefs.get('DRAWFPS')`, if not available, draw at 10fps**Variables** `timer` (`QTimer`) – Timer held in `globals()` that synchronizes frame updates across image items

See `setImage` for all allowed initialization arguments.

**Methods:**

<code>setImage([image, autoLevels])</code>	Update the image displayed by this item.
<code>update_img()</code>	Call <code>update()</code>

**Attributes:**

<code>staticMetaObject</code>
-------------------------------

**setImage**(*image=None, autoLevels=None, \*\*kwargs*)

Update the image displayed by this item. For more information on how the image is processed before displaying, see [makeARGB](#)

Ar-gu-ments:	
<code>image</code>	(numpy array) Specifies the image data. May be 2D (width, height) or 3D (width, height, RGBa). The array dtype must be integer or floating point of any bit depth. For 3D arrays, the third dimension must be of length 3 (RGB) or 4 (RGBA). See <i>notes</i> below.
<code>autoLevels</code>	(bool) If True, this forces the image to automatically select levels based on the maximum and minimum values in the data. By default, this argument is true unless the levels argument is given.
<code>lut</code>	(numpy array) The color lookup table to use when displaying the image. See <code>setLookupTable</code> .
<code>levels</code>	(min, max) The minimum and maximum values to use when rescaling the image data. By default, this will be set to the minimum and maximum values in the image. If the image array has dtype uint8, no rescaling is necessary.
<code>opacity</code>	(float 0.0-1.0)
<code>composition-Mode</code>	See <code>setCompositionMode</code>
<code>border</code>	Sets the pen used when drawing the image border. Default is None.
<code>autoDownsample</code>	(bool) If True, the image is automatically downsampled to match the screen resolution. This improves performance for large images and reduces aliasing. If <code>autoDownsample</code> is not specified, then <code>ImageItem</code> will choose whether to downsample the image based on its size.

**Notes:**

For backward compatibility, image data is assumed to be in column-major order (column, row). However, most image data is stored in row-major order (row, column) and will need to be transposed before calling `setImage()`:

```
imageitem.setImage(imagedata.T)
```

This requirement can be changed by calling `image.setOpts(axisOrder='row-major')` or by changing the `imageAxisOrder` [global configuration option](#).

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f2f7b1cd0>`



```
update_img()
    Call update()
```

```
PLOT_LIST = { 'line': <class 'autopilot.core.plots.Line'>, 'point': <class
'autopilot.core.plots.Point'>, 'rollmean': <class 'autopilot.core.plots.Roll_Mean'>,
'segment': <class 'autopilot.core.plots.Segment'>, 'shaded': <class
'autopilot.core.plots.Shaded'>}
```

A dictionary connecting plot keys to objects.

---

**Todo:** Just reference the plot objects.

---

## 11.5 styles

Qt Stylesheets for Autopilot GUI widgets

See: <https://doc.qt.io/qt-5/stylesheet-reference.html#>

## 11.6 subject

Classes for managing data and protocol access and storage.

Currently named subject, but will likely be refactored to include other data models should the need arise.

**Classes:**

Subject([name, dir, file, new, biography])	Class for managing one subject's data and protocol.
--	---

```
class Subject(name: Optional[str] = None, dir: Optional[str] = None, file: Optional[str] = None, new: bool =
False, biography: Optional[dict] = None)
```

Bases: `object`

Class for managing one subject's data and protocol.

Creates a tables hdf5 file in `prefs.get('DATADIR')` with the general structure:

```
/ root
|--- current (tables.filename) storing the current task as serialized JSON
|--- data (group)
|   |--- task_name (group)
|       |--- S##_step_name
|           |--- trial_data
|           |--- continuous_data
|           |--- ...
|--- history (group)
|   |--- hashes - history of git commit hashes
|   |--- history - history of changes: protocols assigned, params changed, etc.
|   |--- weights - history of pre and post-task weights
|   |--- past_protocols (group) - stash past protocol params on reassign
|       |--- date_protocol_name - tables.filename of a previous protocol's params.
|       |--- ...
|--- info - group with biographical information as attributes
```

### Variables

- **lock** (`threading.Lock`) – manages access to the hdf5 file
- **name** (`str`) – Subject ID
- **file** (`str`) – Path to hdf5 file - usually `{prefs.get('DATADIR')}/{self.name}.h5`
- **current** (`dict`) – current task parameters. loaded from the 'current' filenode of the h5 file
- **step** (`int`) – current step
- **protocol\_name** (`str`) – name of currently assigned protocol
- **current\_trial** (`int`) – number of current trial
- **running** (`bool`) – Flag that signals whether the subject is currently running a task or not.
- **data\_queue** (`queue.Queue`) – Queue to dump data while running task
- **thread** (`threading.Thread`) – thread used to keep file open while running task
- **did\_graduate** (`threading.Event`) – Event used to signal if the subject has graduated the current step
- **STRUCTURE** (`list`) – list of tuples with order:
  - full path, eg. `'/history/weights'`
  - relative path, eg. `'/history'`
  - name, eg. `'weights'`
  - type, eg. `Subject.Weight_Table` or `'group'`
- **locations** (`node`) – `tables.IsDescriptor` for tables.

### Parameters

- **name** (`str`) – subject ID
- **dir** (`str`) – path where the .h5 file is located, if *None*, `prefs.get('DATADIR')` is used
- **file** (`str`) – load a subject from a filename. if *None*, ignored.
- **new** (`bool`) – if True, a new file is made (a new file is made if one does not exist anyway)
- **biography** (`dict`) – If making a new subject file, a dictionary with biographical data can be passed

### Methods:

<code>open_hdf([mode])</code>	Opens the hdf5 file.
<code>close_hdf(h5f)</code>	Flushes & closes the open hdf file.
<code>new_subject_file(biography)</code>	Create a new subject file and make the general filestructure.
<code>ensure_structure()</code>	Ensure that our h5f has the appropriate baseline structure as defined in <code>self.STRUCTURE</code>
<code>update_biography(params)</code>	Change or make a new biographical attribute, stored as attributes of the <i>info</i> group.
<code>update_history(type, name, value[, step])</code>	Update the history table when changes are made to the subject's protocol.
<code>assign_protocol(protocol[, step_n])</code>	Assign a protocol to the subject.

continues on next page

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<code>flush_current()</code>	Flushes the 'current' attribute in the subject object to the current filenode in the .h5
<code>stash_current()</code>	Save the current protocol in the history group and delete the node
<code>prepare_run()</code>	Prepares the Subject object to receive data while running the task.
<code>data_thread(queue)</code>	Thread that keeps hdf file open and receives data while task is running.
<code>save_data(data)</code>	Alternate and equivalent method of putting data in the queue as <i>Subject.data_queue.put(data)</i>
<code>stop_run()</code>	puts 'END' in the data_queue, which causes <i>data_thread()</i> to end.
<code>to_csv(path[, task, step])</code>	Export trial data to .csv
<code>get_trial_data([step, what])</code>	Get trial data from the current task.
<code>apply_along([along, step])</code>	
<code>get_step_history([use_history])</code>	Gets a dataframe of step numbers, timestamps, and step names as a coarse view of training status.
<code>get_timestamp([simple])</code>	Makes a timestamp.
<code>get_weight([which, include_baseline])</code>	Gets start and stop weights.
<code>set_weight(date, col_name, new_value)</code>	Updates an existing weight in the weight table.
<code>update_weights([start, stop])</code>	Store either a starting or stopping mass.
<code>graduate()</code>	Increase the current step by one, unless it is the last step.

**Classes:**

<code>History_Table()</code>	Class to describe parameter and protocol change history
<code>Weight_Table()</code>	Class to describe table for weight history
<code>Hash_Table()</code>	Class to describe table for hash history

**open\_hdf(mode='r+')**

Opens the hdf5 file.

This should be called at the start of every method that access the h5 file and *close\_hdf()* should be called at the end. Otherwise the file will close and we risk file corruption.

See the pytables docs [here](#) and [here](#)

**Parameters** *mode* (*str*) – a file access mode, can be:

- 'r': Read-only - no data can be modified.
- 'w': Write - a new file is created (an existing file with the same name would be deleted).
- 'a' Append - an existing file is opened for reading and writing, and if the file does not exist it is created.
- 'r+' (default) - Similar to 'a', but file must already exist.

**Returns** Opened hdf file.

**Return type** `tables.File`

**close\_hdf(h5f)**

Flushes & closes the open hdf file. Must be called whenever *open\_hdf()* is used.

**Parameters** `h5f` (`tables.File`) – the hdf file opened by `open_hdf()`

**new\_subject\_file**(*biography*)

Create a new subject file and make the general filestructure.

If a file already exists, open it in append mode, otherwise create it.

**Parameters** `biography` (*dict*) – Biographical details like DOB, mass, etc. Typically created by `Biography_Tab`.

**ensure\_structure**()

Ensure that our h5f has the appropriate baseline structure as defined in `self.STRUCTURE`

Checks that all groups and tables are made, makes them if not

**update\_biography**(*params*)

Change or make a new biographical attribute, stored as attributes of the *info* group.

**Parameters** `params` (*dict*) – biographical attributes to be updated.

**update\_history**(*type, name, value, step=None*)

Update the history table when changes are made to the subject's protocol.

The current protocol is flushed to the `past_protocols` group and an updated `filenode` is created.

---

**Note:** This **only** updates the history table, and does not make the changes itself.

---

#### Parameters

- **type** (*str*) – What type of change is being made? Can be one of
  - ‘param’ - a parameter of one task stage
  - ‘step’ - the step of the current protocol
  - ‘protocol’ - the whole protocol is being updated.
- **name** (*str*) – the name of either the parameter being changed or the new protocol
- **value** (*str*) – the value that the parameter or step is being changed to, or the protocol dictionary flattened to a string.
- **step** (*int*) – When type is ‘param’, changes the parameter at a particular step, otherwise the current step is used.

**assign\_protocol**(*protocol, step\_n=0*)

Assign a protocol to the subject.

If the subject has a currently assigned task, stashes it with `stash_current()`

Creates groups and tables according to the data descriptions in the task class being assigned. eg. as described in `Task.TrialData`.

Updates the history table.

#### Parameters

- **protocol** (*str*) – the protocol to be assigned. Can be one of
  - the name of the protocol (its filename minus .json) if it is in `prefs.get('PROTOCOLDIR')`
  - filename of the protocol (its filename with .json) if it is in the `prefs.get('PROTOCOLDIR')`

- the full path and filename of the protocol.

- **step\_n** (*int*) – Which step is being assigned?

#### **flush\_current()**

Flushes the ‘current’ attribute in the subject object to the current filenode in the .h5

Used to make sure the stored .json representation of the current task stays up to date with the params set in the subject object

#### **stash\_current()**

Save the current protocol in the history group and delete the node

Typically this is called when assigning a new protocol.

Stored as the date that it was changed followed by its name if it has one

#### **prepare\_run()**

Prepares the Subject object to receive data while running the task.

Gets information about current task, trial number, spawns *Graduation* object, spawns *data\_queue* and calls *data\_thread()*.

#### **Returns**

**the parameters for the current step, with subject id, step number,** current trial, and session number included.

**Return type** Dict

#### **data\_thread(queue)**

Thread that keeps hdf file open and receives data while task is running.

receives data through queue as dictionaries. Data can be partial-trial data (eg. each phase of a trial) as long as the task returns a dict with ‘TRIAL\_END’ as a key at the end of each trial.

each dict given to the queue should have the *trial\_num*, and this method can properly store data without passing *TRIAL\_END* if so. I recommend being explicit, however.

Checks graduation state at the end of each trial.

**Parameters** *queue* (*queue.Queue*) – passed by *prepare\_run()* and used by other objects to pass data to be stored.

#### **save\_data(data)**

Alternate and equivalent method of putting data in the queue as *Subject.data\_queue.put(data)*

**Parameters** *data* (*dict*) – trial data. each should have a ‘trial\_num’, and a dictionary with key ‘TRIAL\_END’ should be passed at the end of each trial.

#### **stop\_run()**

puts ‘END’ in the data\_queue, which causes *data\_thread()* to end.

#### **to\_csv(path, task='current', step='all')**

Export trial data to .csv

#### **Parameters**

- **path** (*str*) – output path of .csv
- **task** (*str, int*) – not implemented, but in the future pull data from ‘current’ or other named task
- **step** (*str, int, list, tuple*) – Step to select, see *Subject.get\_trial\_data()*

**get\_trial\_data**(*step: Union[int, list, str] = -1, what: str = 'data'*)

Get trial data from the current task.

**Parameters**

- **step** (*int, list, 'all'*) – Step that should be returned, can be one of
  - -1: most recent step
  - int: a single step
  - list of two integers eg. [0, 5], an inclusive range of steps.
  - string: the name of a step (excluding S##\_)
  - 'all': all steps.
- **what** (*str*) – What should be returned?
  - 'data' : Dataframe of requested steps' trial data
  - 'variables': dict of variables *without* loading data into memory

**Returns** DataFrame of requested steps' trial data.

**Return type** pandas.DataFrame

**apply\_along**(*along='session', step=-1*)

**get\_step\_history**(*use\_history=True*)

Gets a dataframe of step numbers, timestamps, and step names as a coarse view of training status.

**Parameters** **use\_history** (*bool*) – whether to use the history table or to reconstruct steps and dates from the trial table itself. compatibility fix for old versions that didn't stash step changes when the whole protocol was updated.

**Returns** pandas.DataFrame

**get\_timestamp**(*simple=False*)

Makes a timestamp.

**Parameters** **simple** (*bool*) –

**if True:** returns as format '%y%m%d-%H%M%S', eg '190201-170811'

**if False:** returns in isoformat, eg. '2019-02-01T17:08:02.058808'

**Returns** basestring

**get\_weight**(*which='last', include\_baseline=False*)

Gets start and stop weights.

---

**Todo:** add ability to get weights by session number, dates, and ranges.

---

**Parameters**

- **which** (*str*) – if 'last', gets most recent weights. Otherwise returns all weights.
- **include\_baseline** (*bool*) – if True, includes baseline and minimum mass.

**Returns** dict

**set\_weight**(*date*, *col\_name*, *new\_value*)

Updates an existing weight in the weight table.

---

**Todo:** Yes, i know this is bad. Merge with update\_weights

---

#### Parameters

- **date** (*str*) – date in the ‘simple’ format, %y%m%d-%H%M%S
- **col\_name** (*‘start’*, *‘stop’*) – are we updating a pre-task or post-task weight?
- **new\_value** (*float*) – New mass.

**update\_weights**(*start=None*, *stop=None*)

Store either a starting or stopping mass.

*start* and *stop* can be passed simultaneously, *start* can be given in one call and *stop* in a later call, but *stop* should not be given before *start*.

#### Parameters

- **start** (*float*) – Mass before running task in grams
- **stop** (*float*) – Mass after running task in grams.

**graduate**()

Increase the current step by one, unless it is the last step.

**class History\_Table**

Bases: `tables.description.IsDescription`

Class to describe parameter and protocol change history

#### Variables

- **time** (*str*) – timestamps
- **type** (*str*) – Type of change - protocol, parameter, step
- **name** (*str*) – Name - Which parameter was changed, name of protocol, manual vs. graduation step change
- **value** (*str*) – Value - What was the parameter/protocol/etc. changed to, step if protocol.

#### Attributes:

---

columns

---

```
columns = { 'name': StringCol(itemsized=256, shape=(), dflt=b'', pos=None),
            'time': StringCol(itemsized=256, shape=(), dflt=b'', pos=None), 'type':
            StringCol(itemsized=256, shape=(), dflt=b'', pos=None), 'value':
            StringCol(itemsized=4028, shape=(), dflt=b'', pos=None)}
```

**class Weight\_Table**

Bases: `tables.description.IsDescription`

Class to describe table for weight history

#### Variables

- **start** (*float*) – Pre-task mass

- **stop** (*float*) – Post-task mass
- **date** (*str*) – Timestamp in simple format
- **session** (*int*) – Session number

**Attributes:**

---

columns

---

```
columns = { 'date': StringCol(itemsize=256, shape=(), dflt=b'', pos=None),
            'session': Int32Col(shape=(), dflt=0, pos=None), 'start': Float32Col(shape=(),
dflt=0.0, pos=None), 'stop': Float32Col(shape=(), dflt=0.0, pos=None)}
```

**class Hash\_Table**

Bases: tables.description.IsDescription

Class to describe table for hash history

**Variables**

- **time** (*str*) – Timestamps
- **hash** (*str*) – Hash of the currently checked out commit of the git repository.

**Attributes:**

---

columns

---

```
columns = { 'hash': StringCol(itemsize=40, shape=(), dflt=b'', pos=None),
            'time': StringCol(itemsize=256, shape=(), dflt=b'', pos=None)}
```

## 11.7 terminal

Methods for running the Terminal GUI

**Classes:**

---

<i>Terminal</i> ()	Central host to a swarm of <i>Pilot</i> s and user-facing <i>gui</i> objects.
--------------------	---

---

**class Terminal**

Bases: PySide2.QtWidgets.QMainWindow

Central host to a swarm of *Pilot* s and user-facing *gui* objects.

Called as a module with the -f flag to give the location of a prefs file, eg:

```
python terminal.py -f prefs_file.json
```

if the -f flag is not passed, looks in the default location for prefs (ie. */usr/autopilot/prefs.json*)

**\*\***Listens used by the internal *Net\_Node* **\*\***



Key	Method	Description
'STATE'	<code>l_state()</code>	A Pi has changed state
'PING'	<code>l_ping()</code>	Someone wants to know if we're alive
'DATA'	<code>l_data()</code>	Receiving data to store
'HANDSHAKE'	<code>l_handshake()</code>	Pilot first contact, telling us it's alive and its IP

---

**Note:** See `autopilot.prefs` for full list of prefs needed by terminal!

---

### Variables

- **node** (`Net_Node`) – Our `Net_Node` we use to communicate with our main networking object
- **networking** (`Terminal_Station`) – Our networking object to communicate with the outside world
- **subjects** (`dict`) – A dictionary mapping subject ID to `Subject` object.
- **layout** (`QtWidgets.QGridLayout`) – Layout used to organize widgets
- **control\_panel** (`Control_Panel`) – Control Panel to manage pilots and subjects
- **data\_panel** (`Plot_Widget`) – Plots for each pilot and subject.
- **logo** (`QtWidgets.QLabel`) – Label holding our beautiful logo ;X
- **logger** (`logging.Logger`) – Used to log messages and network events.
- **settings** (`PySide2.QtCore.QSettings`) – `QSettings` used to store pyside configuration like window size, stored in `prefs.get("TERMINAL_SETTINGS_FN")`

### Methods:

<code>initUI()</code>	Initializes graphical elements of Terminal.
<code>reset_ui()</code>	Clear Layout and call <code>initUI()</code> again
<code>ping_pilot(pilot)</code>	
<code>heartbeat([once])</code>	Perioducally send an INIT message that checks the status of connected pilots
<code>toggle_start(starting, pilot[, subject])</code>	Start or Stop running the currently selected subject's task.
<code>l_data(value)</code>	A Pilot has sent us data.
<code>l_ping(value)</code>	
<b>Todo:</b> Reminder to implement heartbeating.	
<code>l_state(value)</code>	A Pilot has changed state, keep track of it.
<code>l_handshake(value)</code>	Pilot is sending its IP and state on startup.
<code>new_pilot([name, ip, pilot_prefs])</code>	Make a new entry in <code>Terminal.pilots</code> and make appropriate GUI elements.
<code>new_protocol()</code>	Open a <code>gui.Protocol_Wizard</code> to create a new protocol.
<code>subject_weights()</code>	Gets recent weights from all subjects and open a <code>gui.Weights</code> window to view or set weights.

continues on next page

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<code>update_protocols()</code>	If we change the protocol file, update the stored version in subject files
<code>reassign_protocols()</code>	Batch reassign protocols and steps.
<code>calibrate_ports()</code>	Calibrate <code>hardware.gpio.Solenoid</code> objects.
<code>test_bandwidth()</code>	Test bandwidth of Pilot connection with variable sized arrays as payloads
<code>plot_psychometric()</code>	Select subject, step, and variables to plot a psychometric curve
<code>manage_plugins()</code>	
<code>stream_video()</code>	Open a window to stream videos from a connected pilot.
<code>closeEvent(event)</code>	When Closing the Terminal Window, close any running subject objects, 'KILL' our networking object.

**Attributes:**

<code>pilots</code>	A dictionary mapping pilot ID to its attributes, including a list of its subjects assigned to it, its IP, etc.
<code>protocols</code>	List of protocol names available in PROTOCOLDIR
<code>subject_protocols</code>	Returns: <code>subject_protocols</code> (dict): a dictionary of subjects: [protocol, step]
<code>subject_list</code>	Get a list of all subject IDs
<code>staticMetaObject</code>	

**initUI()**

Initializes graphical elements of Terminal.

Including...

- `Toolbar`
- `gui.Control_Panel`
- `plots.Plot_Widget`

**reset\_ui()**

Clear Layout and call `initUI()` again

**property pilots: collections.OrderedDict**

A dictionary mapping pilot ID to its attributes, including a list of its subjects assigned to it, its IP, etc.

**Returns** like `self.pilots['pilot_id'] = {'subjects': ['subject_0', 'subject_1'], 'ip': '192.168.0.101'}`

**Return type** `dict`

**property protocols: list**

List of protocol names available in PROTOCOLDIR

**Returns** list of protocol names in `prefs.get('PROTOCOLDIR')`

**Return type** `list`

**property subject\_protocols: dict**

Returns: `subject_protocols` (dict): a dictionary of subjects: [protocol, step]

**property subject\_list:** `list`

Get a list of all subject IDs

**Returns** list of all subject IDs present in `Terminal.pilots`

**Return type** `list`

**ping\_pilot**(*pilot*)

**heartbeat**(*once=False*)

Perioducally send an INIT message that checks the status of connected pilots

sent with frequency according to `Terminal.heartbeat_dur`

**Parameters** *once* (*bool*) – if True, do a single heartbeat but don't start a thread to do more.

**toggle\_start**(*starting, pilot, subject=None*)

Start or Stop running the currently selected subject's task. Sends a message containing the task information to the concerned pilot.

Each Pilot\_Panel is given a lambda function that calls this one with the arguments specified See Pilot\_Button, as it is what calls this function.

**Parameters**

- **starting** (*bool*) – Does this button press mean we are starting (True) or stopping (False) the task?
- **pilot** – Which Pilot is starting or stopping?
- **subject** – Which Subject is currently selected?

**l\_data**(*value*)

A Pilot has sent us data.

*value* field of message should have *subject* and *pilot* added to dictionary for identification.

Any key in *value* that matches a column in the subject's trial data table will be saved.

If the subject graduates after receiving this piece of data, stop the current task running on the Pilot and send the new one.

**Parameters** *value* (*dict*) – A dict of field-value pairs to save

**l\_ping**(*value*)

---

**Todo:** Reminder to implement heartbeating.

---



---

**Note:** Currently unused, as Terminal Net\_Node stability hasn't been a problem and no universal system of heartbeating has been established (global stability has not been an issue).

---

**Parameters** *value* – (unused)

**l\_state**(*value*)

A Pilot has changed state, keep track of it.

**Parameters** *value* (*dict*) – dict containing *state* .

**l\_handshake(value)**

Pilot is sending its IP and state on startup.

If we haven't heard of this pilot before, make a new entry in `pilots` and `gui.Control_Panel.update_db()`.

**Parameters** `value` (*dict*) – dict containing *ip* and *state*

**new\_pilot(name: Optional[str] = None, ip: str = "", pilot\_prefs: Optional[dict] = None)**

Make a new entry in `Terminal.pilots` and make appropriate GUI elements.

**Parameters**

- **ip** (*str*) – Optional. if given, stored in db.
- **name** (*str*) – If None, prompted for a name, otherwise used for entry in pilot DB.

**new\_protocol()**

Open a `gui.Protocol_Wizard` to create a new protocol.

Prompts for name of protocol, then saves in `prefs.get('PROTOCOLDIR')`

**subject\_weights()**

Gets recent weights from all subjects and open a `gui.Weights` window to view or set weights.

**update\_protocols()**

If we change the protocol file, update the stored version in subject files

**reassign\_protocols()**

Batch reassign protocols and steps.

Opens a `gui.Reassign` window after getting protocol data, and applies any changes made in the window.

**calibrate\_ports()**

Calibrate `hardware.gpio.Solenoid` objects.

See `gui.Calibrate_Water`.

After calibration routine, send results to pilot for storage.

**test\_bandwidth()**

Test bandwidth of Pilot connection with variable sized arrays as payloads

See `gui.Bandwidth_Test`

**plot\_psychometric()**

Select subject, step, and variables to plot a psychometric curve

**manage\_plugins()**

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f501171e0>`

**stream\_video()**

Open a window to stream videos from a connected pilot.

Choose from connected pilots and configured `Camera` objects (`prefs.json` sent by Pilots in `Pilot.handshake()`). Stream video, save to file.

---

**Todo:** Configure camera parameters!!!

---

**closeEvent(event)**

When Closing the Terminal Window, close any running subject objects, 'KILL' our networking object.

Since the `:class:Net_Node`` keeping us alive is a *daemon*, no need to explicitly kill it.

## HARDWARE

Classes that manage hardware logic.

Each hardware class should be able to operate independently - ie. not be dependent on a particular task class, etc. Other than that there are very few design requirements:

- Every class should have a `.release()` method that releases any system resources in use by the object, eg. objects that use `pigpio` must have their `pigpio.pi` client stopped; LEDs should be explicitly turned off.
- The very minimal class attributes are described in the [Hardware](#) metaclass.
- Hardware methods are typically called in their own threads, so care should be taken to make any long-running operations internally threadsafe.

---

**Note:** This software was primarily developed for the Raspberry Pi, which has [two types of numbering schemes](#), “board” numbering based on physical position (e.g. pins 1-40, in 2 rows of 20 pins) and “bcm” numbering based on the broadcom chip numbering scheme (e.g. GPIO2, GPIO27).

Board numbering is easier to use, but [pigpio](#), which we use as a bridge between Python and the GPIOs, uses the BCM scheme. As such each class that uses the GPIOs takes a board number as its argument and converts it to a BCM number in the `__init__` method.

If there is sufficient demand to make this more flexible, we can implement an additional *pref* to set the numbering scheme, but the current solution works without getting too muddy.

---

**Warning:** In order to use `pigpio`, the `pigpio` daemon must be running. See [the docs](#) Usually *Pilot* s should be started by the bash script or systemd service generated by `setup.setup_pilot`, which starts `pigpiod`.

### Data:

<a href="#">BOARD_TO_BCM</a>	Mapping from board (physical) numbering to BCM numbering.
<a href="#">BCM_TO_BOARD</a>	The inverse of <a href="#">BOARD_TO_BCM</a> .

### Classes:

<a href="#">Hardware</a> ([name, group])	Generic class inherited by all hardware.
--	--

```
BOARD_TO_BCM = { 3: 2, 5: 3, 7: 4, 8: 14, 10: 15, 11: 17, 12: 18, 13: 27, 15: 22, 16: 23, 18: 24, 19: 10, 21: 9, 22: 25, 23: 11, 24: 8, 26: 7, 29: 5, 31: 6, 32: 12, 33: 13, 35: 19, 36: 16, 37: 26, 38: 20, 40: 21}
```

Mapping from board (physical) numbering to BCM numbering.

See [this pinout](#).

Hardware objects take board numbered pins and convert them to BCM numbers for use with *pigpio*.

**Type** dict

```
BCM_TO_BOARD = { 2: 3, 3: 5, 4: 7, 5: 29, 6: 31, 7: 26, 8: 24, 9: 21, 10: 19,
11: 23, 12: 32, 13: 33, 14: 8, 15: 10, 16: 36, 17: 11, 18: 12, 19: 35, 20: 38,
21: 40, 22: 15, 23: 16, 24: 18, 25: 22, 26: 37, 27: 13}
```

The inverse of [BOARD\\_TO\\_BCM](#).

**Type** dict

**class Hardware**(*name=None, group=None, \*\*kwargs*)

Bases: [object](#)

Generic class inherited by all hardware. Should not be instantiated on its own (but it won't do anything bad so go nuts i guess).

Primarily for the purpose of defining necessary attributes.

Also defines `__del__` to call *release()* so objects are always released even if not explicitly.

**Variables**

- **name** ([str](#)) – unique name used to identify this object within its group.
- **group** ([str](#)) – hardware group, corresponds to key in `prefs.json` "HARDWARE": {"GROUP": {"ID": {"\*\*params}}}
- **is\_trigger** ([bool](#)) – Is this object a discrete event input device? or, will this device be used to trigger some event? If *True*, will be given a callback by [Task](#), and [assign\\_cb\(\)](#) must be redefined.
- **pin** ([int](#)) – The BCM pin used by this device, or None if no pin is used.
- **type** ([str](#)) – What is this device known as in *.prefs*? Not required.
- **input** ([bool](#)) – Is this an input device?
- **output** ([bool](#)) – Is this an output device?

**Attributes:**

---

[is\\_trigger](#)

---

[pin](#)

---

[type](#)

---

[input](#)

---

[output](#)

---

[calibration](#)

Calibration used by the hardware object.

---

**Methods:**

---

<code>release()</code>	Every hardware device needs to redefine <code>release()</code> , and must
<code>assign_cb(trigger_fn)</code>	Every hardware device that is a <code>trigger</code> must redefine this to accept a function (typically <code>Task.handle_trigger()</code> ) that is called when that trigger is activated.
<code>get_name()</code>	Usually Hardware is only instantiated with its pin number, but we can get its name from prefs
<code>init_networking([listens])</code>	Spawn a <code>Net_Node</code> to <code>Hardware.node</code> for streaming or networked command

---

`is_trigger = False`

`pin = None`

`type = ''`

`input = False`

`output = False`

`release()`

Every hardware device needs to redefine `release()`, and must

- Safely unload any system resources used by the object, and
- Return the object to a neutral state - eg. LEDs turn off.

When not redefined, a warning is given.

`assign_cb(trigger_fn)`

Every hardware device that is a `trigger` must redefine this to accept a function (typically `Task.handle_trigger()`) that is called when that trigger is activated.

When not redefined, a warning is given.

`get_name()`

Usually Hardware is only instantiated with its pin number, but we can get its name from prefs

`init_networking(listens=None, **kwargs)`

Spawn a `Net_Node` to `Hardware.node` for streaming or networked command

#### Parameters

- `listens (dict)` – Dictionary mapping message keys to handling methods
- `**kwargs` – Passed to `Net_Node`

Returns:

**property calibration:** `Optional[dict]`

Calibration used by the hardware object.

Attempt to read from `prefs.get('CALIBRATIONDIR')/group.name.json`, if `Hardware.group` is `None`, attempt to read from `prefs.get('CALIBRATIONDIR')/name.json`

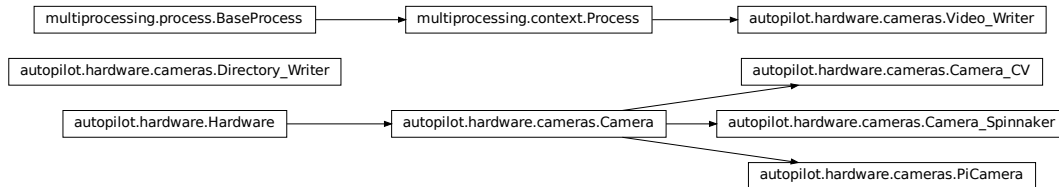
Setting the attribute (over)writes the calibration to disk as a `.json` file

Will be different for each hardware type, subclasses should document this property separately (eg. by overwriting `Hardware.calibration.__doc__`)

**Returns** if calibration is found, a dictionary of calibration for each property. `None` if no calibration found

Return type (dict)

## 12.1 cameras



### Classes:

<code>Camera([fps, timed, crop, rotate])</code>	Metaclass for Camera objects.
<code>PiCamera([camera_idx, sensor_mode, ...])</code>	Interface to the <a href="#">Raspberry Pi Camera Module</a> via <a href="#">picamera</a>
<code>Camera_CV([camera_idx])</code>	Capture Video from a webcam with OpenCV
<code>Camera_Spinnaker([serial, camera_idx])</code>	Capture video from a FLIR brand camera with the Spinnaker SDK.
<code>Video_Writer(q, path[, fps, timestamps, blosc])</code>	Encode frames as they are acquired in a separate process.

### Functions:

<code>list_spinnaker_cameras()</code>	List all available Spinnaker cameras and their DeviceInformation
---------------------------------------	--

**OPENCV\_LAST\_INIT\_TIME = <Synchronized wrapper for c\_double(0.0)>**

Time the last OpenCV camera was initialized (seconds, from `time.time()`).

v4l2 has an extraordinarily obnoxious ... feature – if you try to initialize two cameras at ~the same time, you will get a neverending stream of informative error messages: `VIDIOC_QBUF: Invalid argument`

The workaround seems to be relatively simple, we just wait ~2 seconds if another camera was just initialized.

**class Camera**(*fps=None, timed=False, crop=None, rotate: int = 0, \*\*kwargs*)

Bases: [autopilot.hardware.Hardware](#)

Metaclass for Camera objects. Should not be instantiated on its own.

#### Parameters

- **fps** (*int*) – Framerate of video capture
- **timed** (*bool, int, float*) – If False (default), camera captures indefinitely. If int or float, captures for this many seconds
- **rotate** (*int*) – Number of times to rotate image clockwise (default 0). Note that image rotation should happen in `_grab()` or be otherwise implemented in each camera subclass, because it's a common enough operation many cameras have some optimized way of doing it.



- **\*\*kwargs** –

Arguments to `stream()`, `write()`, and `queue()` can be passed as dictionaries, eg.:

```
stream={'to':'T', 'ip':'localhost'}
```

When the camera is instantiated and `capture()` is called, the class uses a series of methods that should be overwritten in subclasses. Further details for each can be found in the relevant method documentation.

It is highly recommended to instantiate Cameras with a `Hardware.name`, as it is used in `output_filename` and to identify the network stream

Three methods are required to be overwritten by all subclasses:

- `init_cam()` - **required** - used by `cam`, instantiating the camera object so that it can be queried and configured
- `_grab()` - **required** - grab a frame from the `cam`
- `_timestamp()` - **required** - get a timestamp for the frame

The other methods are optional and depend on the particular camera:

- `capture_init()` - *optional* - any required routine to prepare the camera after it is instantiated but before it begins to capture
- `_process()` - *optional* - the wrapper around a full acquisition cycle, including streaming, writing, and queueing frames
- `_write_frame()` - *optional* - how to write an individual frame to disk
- `_write_deinit()` - *optional* - any required routine to finish writing to disk after acquisition
- `capture_deinit()` - *optional* - any required routine to stop acquisition but not release the camera instance.

### Variables

- **frame** (*tuple*) – The current captured frame as a tuple (timestamp, frame).
- **shape** (*tuple*) – Shape of captured frames (height, width, channels)
- **blosc** (*bool*) – If True (default), use blosc compression when
- **cam** – The object used to interact with the camera
- **fps** (*int*) – Framerate of video capture
- **timed** (*bool, int, float*) – If False (default), camera captures indefinitely. If int or float, captures for this many seconds
- **q** (*Queue*) – Queue that allows frames to be pulled by other objects
- **queue\_size** (*int*) – How many frames should be buffered in the queue.
- **initialized** (*threading.Event*) – Called in `init_cam()` to indicate the camera has been initialized
- **stopping** (*threading.Event*) – Called to signal that capturing should stop. when set, ends the threaded capture loop
- **capturing** (*threading.Event*) – Set when camera is actively capturing
- **streaming** (*threading.Event*) – Set to indicate that the camera is streaming data over the network
- **writing** (*threading.Event*) – Set to indicate that the camera is writing video locally

- **queueing** (*threading.Event*) – Indicates whether frames are being put into q
- **indicating** (*threading.Event*) – Set to indicate that capture progress is being indicated in stdout by tqdm

**Parameters**

- **fps**
- **timed**
- **crop** (*tuple*) – (x, y of top left corner, width, height)
- **\*\*kwargs**

**Attributes:**

<i>input</i>	test documenting input
<i>type</i>	what are we anyway?
<i>cam</i>	Camera object.
<i>output_filename</i>	Filename given to video writer.

**Methods:**

<i>capture</i> ([timed])	Spawn a thread to begin capturing.
<i>_capture</i> ()	Threaded capture method started by <i>capture</i> ().
<i>_process</i> ()	A full frame capture cycle.
<i>stream</i> ([to, ip, port, min_size])	Enable streaming frames on capture.
<i>l_start</i> (val)	Begin capturing by calling <i>Camera.capture()</i>
<i>l_stop</i> (val)	Stop capture by calling <i>Camera.release()</i>
<i>write</i> ([output_filename, timestamps, blocs])	Enable writing frames locally on capture
<i>_write_frame</i> ()	Put frame into the <i>_write_q</i> , optionally compressing it with <i>blosc.pack_array()</i>
<i>_write_deinit</i> ()	End the <i>Video_Writer</i> .
<i>queue</i> ([queue_size])	Enable stashing frames in a queue for a local consumer.
<i>_grab</i> ()	Capture a frame and timestamp.
<i>_timestamp</i> ([frame])	Generate a timestamp for each <i>_grab()</i>
<i>init_cam</i> ()	Method to initialize camera object
<i>capture_init</i> ()	Optional: Prepare <i>cam</i> after initialization, but before capture
<i>capture_deinit</i> ()	Optional: Return <i>cam</i> to an idle state after capturing, but before releasing
<i>stop</i> ()	Stop capture by setting <i>stopping</i>
<i>release</i> ()	Release resources held by Camera.

**input = True**

test documenting input

**type = 'CAMERA'**

what are we anyway?

**Type** (*str*)

**capture**(*timed=None*)

Spawn a thread to begin capturing.

**Parameters** `timed` (*None, int, float*) – if *None*, record according to `timed` (default). If numeric, record for `timed` seconds.

### `_capture()`

Threaded capture method started by `capture()`.

Captures until `stopping` is set.

Calls capture methods, in order:

- `capture_init()` - any required routine to prepare the camera after it is instantiated but before it begins to capture
- `_process()` - the wrapper around a full acquisition cycle, including streaming, writing, and queueing frames
- `_grab()` - grab a frame from the `cam`
- `_timestamp()` - get a timestamp for the frame
- `_write_frame()` - how to write an individual frame to disk
- `_write_deinit()` - any required routine to finish writing to disk after acquisition
- `capture_deinit()` - any required routine to stop acquisition but not release the camera instance.

### `_process()`

A full frame capture cycle.

`_grab`'s the `:attr:().frame`, then handles streaming, writing, queueing, and indicating according to `stream()`, `write()`, `queue()`, and `indicating`, respectively.

### `stream(to='T', ip=None, port=None, min_size=5, **kwargs)`

Enable streaming frames on capture.

Spawns a `Net_Node` with `Hardware.init_networking()`, and creates a streaming queue with `Net_Node.get_stream()` according to args.

Sets `Camera.streaming`

#### **Parameters**

- `to` (*str*) – ID of the recipient. Default 'T' for Terminal.
- `ip` (*str*) – IP of recipient. If *None* (default), 'localhost'. If *None* and `to` is 'T', `prefs.get('TERMINALIP')`
- `port` (*int, str*) – Port of recipient socket. If *None* (default), `prefs.get('MSGPORT')`. If *None* and `to` is 'T', `prefs.get('TERMINALPORT')`.
- `min_size` (*int*) – Number of frames to collect before sending (default: 5). use 1 to send frames as soon as they are available, sacrificing the efficiency from compressing multiple frames together
- `**kwargs` – passed to `Hardware.init_networking()` and thus to `Net_Node`

### `l_start(val)`

Begin capturing by calling `Camera.capture()`

**Parameters** `val` – unused

### `l_stop(val)`

Stop capture by calling `Camera.release()`

**Parameters** `val` – unused

**write**(*output\_filename=None, timestamps=True, blosc=True*)

Enable writing frames locally on capture

Spawns a [Video\\_Writer](#) to encode video, sets writing

**Parameters**

- **output\_filename** (*str*) – path and filename of the output video. extension should be `.mp4`, as videos are encoded with `libx264` by default.
- **timestamps** (*bool*) – if `True`, (timestamp, frame) tuples will be put in the `_write_q`. if `False`, timestamps will be generated by [Video\\_Writer](#) (not recommended at all).
- **blosc** (*bool*) – if `true`, compress frames with `blosc.pack_array()` before putting in `_write_q`.

**\_write\_frame()**

Put frame into the `_write_q`, optionally compressing it with `blosc.pack_array()`

**\_write\_deinit()**

End the [Video\\_Writer](#).

Blocks until the `_write_q` is empty, holding the release of the object.

**queue**(*queue\_size=128*)

Enable stashing frames in a queue for a local consumer.

Other objects can get frames as they are acquired from `q`

**Parameters** **queue\_size** (*int*) – max number of frames that can be held in `q`

**property cam**

Camera object.

If `_cam` hasn't been initialized yet, use [init\\_cam\(\)](#) to do so

**Returns** Camera object, different for each camera.

**property output\_filename**

Filename given to video writer.

If explicitly set, returns as expected.

If `None`, or path already exists while the camera isn't capturing, a new filename is generated in the user directory.

**Returns** (*str*) `_output_filename`

**\_grab()**

Capture a frame and timestamp.

Method must be overridden by subclass

**Returns**

(*str*, [numpy.ndarray](#)) Tuple of isoformatted (*str*) or numeric timestamp returned by [\\_timestamp\(\)](#), and captured frame

**\_timestamp**(*frame=None*)

Generate a timestamp for each [\\_grab\(\)](#)

Must be overridden by subclass

**Parameters** **frame** – If needed by camera subclass, pass the frame or image object to get timestamp

**Returns** (*str*, *int*, *float*) Either an isoformatted (*str*) or numeric timestamp

**init\_cam()**

Method to initialize camera object

Must be overridden by camera subclass

**Returns** camera object

**capture\_init()**

Optional: Prepare [cam](#) after initialization, but before capture

**Returns** None

**capture\_deinit()**

Optional: Return [cam](#) to an idle state after capturing, but before releasing

**Returns** None

**stop()**

Stop capture by setting stopping

**release()**

Release resources held by Camera.

Must be overridden by subclass.

Does not raise exception in case some general camera release logic should be put here...

```
class PiCamera(camera_idx: int = 0, sensor_mode: int = 0, resolution: Tuple[int, int] = (1280, 720), fps: int =
    30, format: str = 'rgb', *args, **kwargs)
```

Bases: [autopilot.hardware.cameras.Camera](#)

Interface to the [Raspberry Pi Camera Module](#) via [picamera](#)

Parameters of the [picamera.PiCamera](#) class can be set after initialization by modifying the `PiCamera.cam` attribute, eg `PiCamera().cam.exposure_mode = 'fixedfps'` – see the [picamera.PiCamera](#) documentation for full documentation.

Note that some parameters, like resolution, can't be changed after starting `capture()` .

The Camera Module is a slippery little thing, and `fps` and `resolution` are just requests to the camera, and aren't necessarily followed with 100% fidelity. The possible framerates and resolutions are determined by the `sensor_mode` parameter, which by default tries to guess the best sensor mode based on the `fps` and `resolution`. See the [Sensor Modes](#) documentation for more details.

This wrapper uses a subclass, [PiCamera.PiCamera\\_Writer](#) to capture frames decoded by the gpu directly from the preallocated buffer object. Currently the restoration from the buffer assumes that RGB, or generally `shape[2] == 3`, images are being captured. See [this stackexchange post](#) by Dave Jones, author of the `picamera` module, for a strategy for capturing grayscale images quickly.

This class also currently uses the default [Video\\_Writer](#) object, but it could be more performant to use the [picamera.PiCamera.start\\_recording\(\)](#) method's built-in ability to record video to a file — try it out!

---

**Todo:** Currently timestamps are constructed with `datetime.datetime.now.isoformat()`, which is not altogether accurate. Timestamps should be gotten from the `frame` attribute, which depends on the `clock_mode`

---

## References

- <https://blog.robertelder.org/recording-660-fps-on-raspberry-pi-camera/>
- Fast capture from the author of picamera - <https://raspberrypi.stackexchange.com/a/58941/112948>
- More on fast capture and processing, see last example in section - <https://picamera.readthedocs.io/en/release-1.12/recipes2.html#rapid-capture>

## Parameters

- **camera\_idx** (*int*) – Index of picamera (default: 0, >=1 only supported on compute module)
- **sensor\_mode** (*int*) – Sensor mode, default 0 detects automatically from resolution and fps, note that sensor\_mode will affect the available resolutions and framerates, see [Sensor Modes](#) for more information
- **resolution** (*tuple*) – a tuple of (width, height) integers, but mind the note in the above documentation regarding the sensor\_mode property and resolution
- **fps** (*int*) – frames per second, but again mind the note on sensor\_mode
- **format** (*str*) – Format passed to :class`picamera.PiCamera.start\_recording` one of ('rgb' (default), 'grayscale') The 'grayscale' format uses the 'yuv' format, and extracts the luminance channel
- **\*args** () – passed to superclass
- **\*\*kwargs** () – passed to superclass

## Attributes:

<i>sensor_mode</i>	Sensor mode, default 0 detects automatically from resolution and fps, note that sensor_mode will affect the available resolutions and framerates, see <a href="#">Sensor Modes</a> for more information.
<i>resolution</i>	A tuple of ints, (width, height).
<i>fps</i>	Frames per second
<i>rotation</i>	Rotation of the captured image, derived from <code>Camera.rotate * 90</code> .

## Methods:

<i>init_cam()</i>	Initialize and return the <code>picamera.PiCamera</code> object.
<i>capture_init()</i>	Spawn a <code>PiCamera.PiCamera_Writer</code> object to <code>PiCamera._picam_writer</code> and <code>start_recording()</code> in the set format
<i>_grab()</i>	Wait on the grab_event to be set, then clear it before returning the frame.
<i>capture_deinit()</i>	<code>stop_recording()</code> and <code>close()</code> the camera, releasing its resources.
<i>release()</i>	Release resources held by Camera.

## Classes:

---

<code>PiCamera_Writer(resolution[, format])</code>	Writer object for processing individual frames, see: <a href="https://raspberrypi.stackexchange.com/a/58941/112948">https://raspberrypi.stackexchange.com/a/58941/112948</a>
--	---

---

**property sensor\_mode: int**

Sensor mode, default 0 detects automatically from resolution and fps, note that sensor\_mode will affect the available resolutions and framerates, see [Sensor Modes](#) for more information.

When set, if the camera has been initialized, will change the attribute in `PiCamera.cam`

**Returns** int

**property resolution: Tuple[int, int]**

A tuple of ints, (width, height).

Resolution can't be changed while the camera is capturing.

See [Sensor Modes](#) for more information re: how resolution relates to `picamera.PiCamera.sensor_mode`

**Returns** tuple of ints, (width, height)

**property fps: int**

Frames per second

See [Sensor Modes](#) for more information re: how fps relates to `picamera.PiCamera.sensor_mode`

**Returns** int - fps

**property rotation: int**

Rotation of the captured image, derived from `Camera.rotate * 90`.

Must be one of (0, 90, 180, 270)

Rotation can be changed during capture

**Returns** int - Current rotation

**init\_cam() → picamera.PiCamera**

Initialize and return the `picamera.PiCamera` object.

Uses the stored `camera_idx`, `resolution`, `fps`, and `sensor_mode` attributes on init.

**Returns** `picamera.PiCamera`

**capture\_init()**

Spawn a `PiCamera.PiCamera_Writer` object to `PiCamera._picam_writer` and `start_recording()` in the set `format`

**\_grab() → Tuple[str, numpy.ndarray]**

Wait on the `grab_event` to be set, then clear it before returning the frame.

**Returns** (timestamp, frame) tuple

**capture\_deinit()**

`stop_recording()` and `close()` the camera, releasing its resources.

**release()**

Release resources held by Camera.

Must be overridden by subclass.

Does not raise exception in case some general camera release logic should be put here...

```
class PiCamera_Writer(resolution: Tuple[int, int], format: str = 'rgb')
```

Bases: `object`

Writer object for processing individual frames, see: <https://raspberrypi.stackexchange.com/a/58941/112948>

**Parameters** `resolution` (*tuple*) – (width, height) tuple used when making numpy array from buffer

**Variables**

- **grab\_event** (`threading.Event`) – Event set whenever a new frame is captured, cleared by the parent class when the frame is consumed.
- **frame** (`numpy.ndarray`) – Captured frame
- **timestamp** (*str*) – Isoformatted timestamp of time of capture.

**Methods:**

---

<code>write(buf)</code>	Reconstitute the buffer into a numpy array in <code>PiCamera_Writer.frame</code> and make a timestamp in <code>PiCamera_Writer.timestamp</code> , then set the <code>PiCamera_Writer.grab_event</code>
-------------------------	--

---

**write(buf)**

Reconstitute the buffer into a numpy array in `PiCamera_Writer.frame` and make a timestamp in `PiCamera_Writer.timestamp`, then set the `PiCamera_Writer.grab_event`

**Parameters** `buf` () – Buffer given by PiCamera

```
class Camera_CV(camera_idx=0, **kwargs)
```

Bases: `autopilot.hardware.cameras.Camera`

Capture Video from a webcam with OpenCV

By default, OpenCV will select a suitable backend for the indicated camera. Some backends have difficulty operating multiple cameras at once, so the performance of this class will be variable depending on camera type.

**Parameters**

- **camera\_idx** (*int*) – The index of the desired camera
- **\*\*kwargs** – Passed to the `Camera` metaclass.

**Variables**

- **camera\_idx** (*int*) – The index of the desired camera
- **last\_opencv\_init** (*float*) – See `OPENCV_LAST_INIT_TIME`
- **last\_init\_lock** (`threading.Lock`) – Lock for setting `last_opencv_init`

---

**Note:** OpenCV must be installed to use this class! A Prebuilt opencv binary is available for the raspberry pi, but it doesn't take advantage of some performance-enhancements available to OpenCV. Use the `install_opencv.sh` script in the `setup` directory to compile OpenCV with these enhancements.

---

If your camera isn't working, to print debugging information you can run:

```
echo 3 > /sys/class/video4linux/videox/dev_debug
```

(continues on next page)



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```
# check logs
dmesg
```

**Attributes:**

<code>fps</code>	Attempts to get FPS with <code>cv2.CAP_PROP_FPS</code> , uses 30fps as a default
<code>shape</code>	Attempts to get image shape from <code>cv2.CAP_PROP_FRAME_WIDTH</code> and <code>HEIGHT</code> :returns: (width, height) :rtype: tuple
<code>backend</code>	capture backend used by OpenCV for this camera
<code>v4l_info</code>	Device information from <code>v4l2-ctl</code>

**Methods:**

<code>_grab()</code>	Reads a frame with <code>cam.read()</code>
<code>_timestamp([frame])</code>	Attempts to get timestamp with <code>cv2.CAP_PROP_POS_MSEC</code> .
<code>init_cam()</code>	Initializes OpenCV Camera
<code>release()</code>	Release resources held by Camera.

**property fps**Attempts to get FPS with `cv2.CAP_PROP_FPS`, uses 30fps as a default**Returns** framerate**Return type** `int`**property shape**Attempts to get image shape from `cv2.CAP_PROP_FRAME_WIDTH` and `HEIGHT` :returns: (width, height)  
:rtype: tuple**\_grab()**Reads a frame with `cam.read()`**Returns** (timestamp, frame)**Return type** `tuple`**\_timestamp(*frame=None*)**Attempts to get timestamp with `cv2.CAP_PROP_POS_MSEC`. Frame does not need to be passed to this method, as timestamps are retrieved from `cam`**Todo:** Convert this float timestamp to an isoformatted system timestamp**Returns** milliseconds since capture start**Return type** `float`**property backend**

capture backend used by OpenCV for this camera

**Returns** name of capture backend used by OpenCV for this camera**Return type** `str`

**init\_cam()**

Initializes OpenCV Camera

To avoid overlapping resource allocation requests, checks the last time any `Camera_CV` object was instantiated and makes sure it has been at least 2 seconds since then.

**Returns** camera object

**Return type** `cv2.VideoCapture`

**release()**

Release resources held by Camera.

Must be overridden by subclass.

Does not raise exception in case some general camera release logic should be put here...

**property v4l\_info**

Device information from `v4l2-ctl`

**Returns** Information for all devices available through `v4l2`

**Return type** `dict`

**class Camera\_Spinnaker**(*serial=None, camera\_idx=None, \*\*kwargs*)

Bases: `autopilot.hardware.cameras.Camera`

Capture video from a FLIR brand camera with the Spinnaker SDK.

**Parameters**

- **serial** (*str*) – Serial number of desired camera
- **camera\_idx** (*int*) – If no serial provided, select camera by index. Using **serial** is HIGHLY RECOMMENDED.
- **\*\*kwargs** – passed to `Camera` metaclass

---

**Note:** PySpin and the Spinnaker SDK must be installed to use this class. Please use the `install_pyspin.sh` script in setup

---

See the documentation for the Spinnaker SDK and PySpin here:

<https://www.flir.com/products/spinnaker-sdk/>

**Variables**

- **serial** (*str*) – Serial number of desired camera
- **camera\_idx** (*int*) – If no serial provided, select camera by index. Using **serial** is HIGHLY RECOMMENDED.
- **system** (`PySpin.System`) – The PySpin System object
- **cam\_list** (`PySpin.CameraList`) – The list of PySpin Cameras available to the system
- **nmap** – A reference to the nodemap from the GenICam XML description of the device
- **base\_path** (*str*) – The directory and base filename that images will be written to if object is writing. eg:  

```
base_path = '/home/user/capture_directory/capture_'
image_path = base_path + 'image1.png'
```
- **img\_opts** (`PySpin.PNGOption`) – Options for saving .png images, made by `write()`

**Attributes:**

<i>ATTR_TYPES</i>	Conversion from data types to pointer types
<i>ATTR_TYPE_NAMES</i>	Conversion from data types to human-readable names
<i>RW_MODES</i>	bool, 'write':bool} descriptor
<i>bin</i>	Camera Binning.
<i>exposure</i>	Set Exposure of camera
<i>fps</i>	Acquisition Framerate
<i>frame_trigger</i>	Set camera to lead or follow hardware triggers
<i>acquisition_mode</i>	Image acquisition mode
<i>readable_attributes</i>	All device attributes that are currently readable with <i>get()</i>
<i>writable_attributes</i>	All device attributes that are currently writeable with <i>set()</i>
<i>device_info</i>	Get all information about the camera

**Methods:**

<i>init_cam()</i>	Initialize the Spinnaker Camera
<i>capture_init()</i>	Prepare the camera for acquisition
<i>capture_deinit()</i>	De-initializes the camera after acquisition
<i>_process()</i>	Modification of the <i>Camera._process()</i> method for Spinnaker cameras
<i>_grab()</i>	Get next timestamp and PySpin Image
<i>_timestamp([frame])</i>	Get the timestamp from the passed image
<i>write([output_filename, timestamps, blosc])</i>	Sets camera to save acquired images to a directory for later encoding.
<i>_write_frame()</i>	Write frame to base_path + timestamp + '.png' with <i>PySpin.Image.Save()</i>
<i>_write_deinit()</i>	After capture, write images in base_path to video with <i>Directory_Writer</i>
<i>get(attr)</i>	Get a camera attribute.
<i>set(attr, val)</i>	Set a camera attribute
<i>list_options(name)</i>	List the possible values of a camera attribute.
<i>release()</i>	Release all PySpin objects and wait on writer, if still active.

**ATTR\_TYPES = {}**

Conversion from data types to pointer types

**ATTR\_TYPE\_NAMES = {}**

Conversion from data types to human-readable names

**RW\_MODES = {}**

bool, 'write':bool} descriptor

**Type** Conversion from read/write mode to {'read'}

**init\_cam()**

Initialize the Spinnaker Camera

Initializes the camera, system, cam\_list, node map, and the camera methods and attributes used by *get()* and *set()*

**Returns** The Spinnaker camera object

**Return type** `PySpin.Camera`

**capture\_init()**

Prepare the camera for acquisition

calls the camera's `BeginAcquisition` method and populate *shape*

**capture\_deinit()**

De-initializes the camera after acquisition

**\_process()**

Modification of the `Camera._process()` method for Spinnaker cameras

Because the objects returned from the `_grab()` method are image *pointers* rather than `:class:`numpy.ndarray``s, they need to be handled differently.

More details on the differences are given in the `_write_frame()`,

**\_grab()**

Get next timestamp and PySpin Image

**Returns** (timestamp, `PySpin.Image`)

**Return type** `tuple`

**\_timestamp(*frame=None*)**

Get the timestamp from the passed image

**Parameters** **frame** (`PySpin.Image`) – Currently grabbed image

**Returns** `PySpin` timestamp

**Return type** `float`

**write(*output\_filename=None, timestamps=True, blocs=True*)**

Sets camera to save acquired images to a directory for later encoding.

For performance, rather than encoding during acquisition, save each image as a (lossless) .png image in a directory generated by *output\_filename*.

After capturing is complete, a `Directory_Writer` encodes the images to an x264 encoded .mp4 video.

**Parameters**

- **output\_filename** (*str*) – Directory to write images to. If None (default), generated by *output\_filename*
- **timestamps** (*bool*) – Not used, timestamps are always appended to filenames.
- **blocs** (*bool*) – Not used, images are directly saved.

**\_write\_frame()**

Write frame to `base_path + timestamp + '.png'` with `PySpin.Image.Save()`

**\_write\_deinit()**

After capture, write images in `base_path` to video with `Directory_Writer`

Camera object will remain open until writer has finished.

**property bin**

Camera Binning.

Attempts to bin on-device, and use averaging if possible. If averaging not available, uses summation.

**Parameters** **tuple** – tuple of integers, (Horizontal, Vertical binning)

**Returns** (Horizontal, Vertical binning)

**Return type** `tuple`

**property exposure**

Set Exposure of camera

Can be set with

- 'auto' - automatic exposure control. note that this will limit framerate
- float from 0-1 - exposure duration proportional to fps. eg. if fps = 10, setting exposure = 0.5 means exposure will be set as 50ms
- float or int >1 - absolute exposure time in microseconds

**Returns** If exposure has been set, return set value. Otherwise return `.get('ExposureTime')`

**Return type** `str, float`

**property fps**

Acquisition Framerate

Set with integer. If set with None, ignored (superclass sets FPS to None on init)

**Returns** from `cam.AcquisitionFrameRate.GetValue()`

**Return type** `int`

**property frame\_trigger**

Set camera to lead or follow hardware triggers

If 'lead', Camera will send TTL pulses from Line 2.

If 'follow', Camera will follow triggers from Line 3.

**See also:**

- <https://www.flir.com/support-center/iis/machine-vision/application-note/configuring-synchronized-capture-with-multiple-cameras>
- <https://www.flir.com/support-center/iis/machine-vision/knowledge-base/what-external-iidc-trigger-modes-are-supported-by-my-camera/>

**property acquisition\_mode**

Image acquisition mode

One of

- 'continuous' - continuously acquire frame camera
- 'single' - acquire a single frame
- 'multi' - acquire a finite number of frames.

**Warning:** Only 'continuous' has been tested.

**property readable\_attributes**

All device attributes that are currently readable with `get()`

**Returns** A dictionary of attributes that are readable and their current values

**Return type** `dict`

**property writable\_attributes**

All device attributes that are currently writeable with `set()`

**Returns** A dictionary of attributes that are writeable and their current values

**Return type** `dict`

**get(attr)**

Get a camera attribute.

Any value in `readable_attributes` can be read. Attempts to get numeric values with `.GetValue`, otherwise gets a string with `.ToString`, so be cautious with types.

If `attr` is a method (ie. in `._camera_methods`, execute the method and return the value

**Parameters** `attr (str)` – Name of a readable attribute or executable method

**Returns** Value of `attr`

**Return type** `float, int, str`

**set(attr, val)**

Set a camera attribute

Any value in `writable_attributes` can be set. If attribute has a `.SetValue` method, (ie. accepts numeric values), attempt to use it, otherwise use `.FromString`.

**Parameters**

- **attr (str)** – Name of attribute to be set
- **val (str, int, float)** – Value to set attribute

**list\_options(name)**

List the possible values of a camera attribute.

**Parameters** `name (str)` – name of attribute to query

**Returns** Dictionary with {available options: descriptions}

**Return type** `dict`

**property device\_info**

Get all information about the camera

Note that this is distinct from camera *attributes* like `fps`, instead this is information like serial number, version, firmware revision, etc.

**Returns** {feature name: feature value}

**Return type** `dict`

**release()**

Release all PySpin objects and wait on writer, if still active.

**class Video\_Writer(q, path, fps=None, timestamps=True, blosc=True)**

Bases: `multiprocessing.context.Process`

Encode frames as they are acquired in a separate process.

Must call `start()` after initialization to begin encoding.

Encoding continues until 'END' is put in `q`.

Timestamps are saved in a `.csv` file with the same path as the video.

**Parameters**

- **q** (*Queue*) – Queue into which frames will be dumped
- **path** (*str*) – output path of video
- **fps** (*int*) – framerate of output video
- **timestamps** (*bool*) – if True (default), input will be of form (timestamp, frame). if False, input will just be frames and timestamps will be generated as the frame is encoded (**not recommended**)
- **blosc** (*bool*) – if True, frames in the q will be compressed with blosc. if False, uncompressed

**Variables** **timestamps** (*list*) – Timestamps for frames, written to .csv on completion of encoding

#### Methods:

<code>run()</code>	Open a <code>skvideo.io.FFmpegWriter</code> and begin processing frames from <code>q</code>
--------------------	---

#### `run()`

Open a `skvideo.io.FFmpegWriter` and begin processing frames from `q`

Should not be called by itself, overwrites the `multiprocessing.Process.run()` method, so should call `Video_Writer.start()`

Continue encoding until 'END' put in queue.

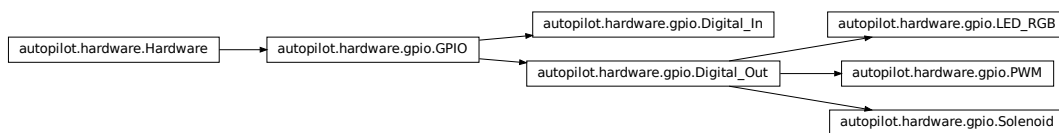
#### `list_spinnaker_cameras()`

List all available Spinnaker cameras and their `DeviceInformation`

**Returns** list of dictionaries of device information for each camera.

**Return type** `list`

## 12.2 gpio



Hardware that uses the GPIO pins of the Raspi. These classes rely on `pigpio`, whose daemon (`pigpiod`) must be running in the background – typically this is handled with a launch script/system daemon (see the `launch_pilot.sh` script generated by `setup_autopilot.py`)

Autopilot uses a custom version of `pigpio` (<https://github.com/sneakers-the-rat/pigpio>) that returns isoformatted timestamps rather than tick numbers in callbacks. See the `setup_pilot.sh` script.

**Note:** Autopilot uses the “Board” rather than “Broadcom” numbering system, see [the numbering note](#). `GPIO` objects convert internally between board and bcm numbers using `GPIO.pin`, `GPIO.pin_bcm`, `BOARD_TO_BCM`, and `BCM_TO_BOARD`.

---

**Note:** This module does not include hardware that uses the GPIO pins over a specific protocol like i2c

---

**Data:**

<i>TRIGGER_MAP</i>	Maps user input descriptions of triggers to the corresponding pigpio object.
<i>INVERSE_TRIGGER_MAP</i>	Inverse of <i>TRIGGER_MAP</i> .
<i>PULL_MAP</i>	Maps user input descriptions of internal resistor pullups/downs to the corresponding pigpio object.
<i>INVERSE_PULL_MAP</i>	Inverse of <i>PULL_MAP</i> , mapping pigpio objects for internal resistor pullups/downs to their canonical form ('U', 'D', None for pullup, pulldown, or no pull)
<i>ENABLED</i>	False if pigpio cannot be imported -- and GPIO devices cannot be used.

---

**Functions:**

<i>clear_scripts</i> ([max_scripts])	Stop and delete all scripts running on the pigpio client.
--------------------------------------	---

---

**Classes:**

<i>GPIO</i> ([pin, polarity, pull, trigger])	Metaclass for hardware that uses GPIO.
<i>Digital_Out</i> ([pin, pulse_width, polarity])	TTL/Digital logic out through a GPIO pin.
<i>Digital_In</i> (pin[, event, record])	Record digital input and call one or more callbacks on logic transition.
<i>PWM</i> (pin[, range])	PWM output from GPIO.
<i>LED_RGB</i> ([pins, r, g, b, polarity, blink])	An RGB LED, wrapper around three <i>PWM</i> objects.
<i>Solenoid</i> (pin[, polarity, duration, vol])	Solenoid valve for water delivery.

---

**TRIGGER\_MAP** = {0: 1, 1: 0, 'B': 2, 'D': 1, 'U': 0, (0, 1): 2}

Maps user input descriptions of triggers to the corresponding pigpio object.

**INVERSE\_TRIGGER\_MAP** = {0: 'U', 1: 'D', 2: 'B'}

Inverse of *TRIGGER\_MAP*. Used to assign canonical references to triggers – ie. it is possible to take multiple params (1, True, 'U') -> pigpio trigger objects, but there is one preferred way to refer to a pigpio object.

**PULL\_MAP** = {None: 0, 0: 1, 1: 2, 'D': 1, 'U': 2}

Maps user input descriptions of internal resistor pullups/downs to the corresponding pigpio object.

**INVERSE\_PULL\_MAP** = {0: None, 1: 'D', 2: 'U'}

Inverse of *PULL\_MAP*, mapping pigpio objects for internal resistor pullups/downs to their canonical form ('U', 'D', None for pullup, pulldown, or no pull)

**ENABLED** = True

False if pigpio cannot be imported – and GPIO devices cannot be used.

True if pigpio can be imported

**clear\_scripts**(max\_scripts=256)

Stop and delete all scripts running on the pigpio client.

To be called, eg. between tasks to ensure none are left hanging by badly behaved GPIO devices

**Parameters** *max\_scripts* (*int*) – maximum number of scripts allowed by pigpio. Set in *pigpio.c*



and not exported to the python module, so have to hardcode it again here, default for pigpio fork is 256

**class** `GPIO(pin=None, polarity=1, pull=None, trigger=None, **kwargs)`

Bases: `autopilot.hardware.Hardware`

Metaclass for hardware that uses GPIO. Should not be instantiated on its own.

Handles initializing pigpio and wraps some of its commonly used methods

#### Parameters

- **pin** (*int*) – The [Board-numbered](#) GPIO pin of this object.
- **polarity** (*int*) – Logic direction. if 1: on=High=1, off=Low=0; if 0: off=Low=0, on=High=1
- **pull** (*str, int*) – state of pullup/down resistor. Can be set as ‘U’/‘D’ or 1/0 to pull up/down. See [PULL\\_MAP](#)
- **trigger** (*str, int, bool*) – whether callbacks are triggered on rising (‘U’, 1, True), falling (‘D’, 0, False), or both edges (‘B’, (0,1))
- **kwargs** – passed to the [Hardware](#) superclass.

#### Variables

- **pig** (`pigpio.pi`) – An object that manages connection to the pigpio daemon. See docs at <http://abyz.me.uk/rpi/pigpio/python.html>
- **CONNECTED** (*bool*) – Whether the connection to pigpio was successful
- **pigpiod** – Reference to the pigpiod process launched by `external.start_pigpiod()`
- **pin** (*int*) – The [Board-numbered](#) GPIO pin of this object.
- **pin\_bcm** (*int*) – The BCM number of the connected pin – used by pigpio. Converted from pin passed as argument on initialization, which is assumed to be the board number.
- **pull** (*str, int*) – state of pullup/down resistor. Can be set as ‘U’/‘D’ or 1/0 to pull up/down
- **polarity** (*int*) – Logic direction. if 1: on=High=1, off=Low=0; if 0: off=Low=0, on=High=1
- **on** (*int*) – if polarity == 1, high/1. if polarity == 0, low/0
- **off** (*int*) – if polarity == 1, low/0. if polarity == 0, high/1
- **trigger** (*str, int, bool*) – whether callbacks are triggered on rising (‘U’, 1, True), falling (‘D’, 0, False), or both edges (‘B’, (0,1))
- **trigger\_edge** – The pigpio object representing RISING\_EDGE, FALLING\_EDGE, BOTH\_EDGES. Set by `:attr`.trigger``

#### Methods:

<code>init_pigpio()</code>	Create a socket connection to the pigpio daemon and set as <code>GPIO.pig</code>
<code>release()</code>	Release the connection to the pigpio daemon.

#### Attributes:

<i>pin</i>	<a href="https://raspberrypi.stackexchange.com/a/12967">//raspberrypi.stackexchange.com/a/12967</a> >`_ GPIO pin.
<i>state</i>	Instantaneous state of GPIO pin, on (True) or off (False)
<i>pull</i>	State of internal pullup/down resistor.
<i>polarity</i>	on=High=1, off=Low=0; if 0: off=Low=0, on=High=1.
<i>trigger</i>	Maps strings (('U',1,True), ('D',0,False), ('B',[0,1])) to pigpio edge types (RISING_EDGE, FALLING_EDGE, EITHER_EDGE), respectively.

**init\_pigpio()** → bool

Create a socket connection to the pigpio daemon and set as GPIO.pig

**Returns** True if connection was successful, False otherwise

**Return type** bool

**property pin**

[//raspberrypi.stackexchange.com/a/12967](https://raspberrypi.stackexchange.com/a/12967)>`\_ GPIO pin.

When assigned, also updates *pin\_bcm* with the BCM-numbered pin.

**Type** `Board-numbered <https

**property state:** bool

Instantaneous state of GPIO pin, on (True) or off (False)

**Returns** bool

**property pull**

State of internal pullup/down resistor.

See [PULL\\_MAP](#) for possible values.

**Returns** 'U'/'D'/None for pulled up, down or not set.

**Return type** int

**property polarity**

on=High=1, off=Low=0; if 0: off=Low=0, on=High=1.

When set, updates on and off accordingly

**Type** Logic direction. if 1

**property trigger**

Maps strings (('U',1,True), ('D',0,False), ('B',[0,1])) to pigpio edge types (RISING\_EDGE, FALLING\_EDGE, EITHER\_EDGE), respectively.

**Type** dict

**release()**

Release the connection to the pigpio daemon.

---

**Note:** the Hardware metaclass will call this method on object deletion.

---

**class Digital\_Out**(pin=None, pulse\_width=100, polarity=1, \*\*kwargs)

Bases: [autopilot.hardware.gpio.GPIO](#)

TTL/Digital logic out through a GPIO pin.

**Parameters**

- **pin** (*int*) – The [Board-numbered](#) GPIO pin of this object
- **pulse\_width** (*int*) – Width of digital output [pulse\(\)](#) (us). range: 1-100
- **polarity** (*bool*) – Whether ‘on’ is High (1, default) and pulses bring the voltage High, or vice versa (0)

**Variables**

- **scripts** (*dict*) – maps script IDs to pigpio script handles
- **pigs\_function** (*bytes*) – when using pigpio scripts, what function is used to set the value of the output? (eg. ‘w’ for digital out, ‘gdc’ for pwm, more info here: <http://abyz.me.uk/rpi/pigpio/pigs.html>)
- **script\_counter** (*itertools.count*) – generate script IDs if not explicitly given to [series\(\)](#). generated IDs are of the form ‘series\_#’

**Attributes:**

---

*output*

---

*type*

---

*pigs\_function*

---

**Methods:**

<a href="#">set</a> (value)	Set pin logic level.
<a href="#">turn</a> ([direction])	Change output state using on/off parlance.
<a href="#">toggle</a> ()	If pin is High, set Low, and vice versa.
<a href="#">pulse</a> ([duration])	Send a timed on pulse.
<a href="#">_series_script</a> (values[, durations, unit, ...])	Create a pigpio script to set a pin to a series of values for a series of durations.
<a href="#">store_series</a> (id, **kwargs)	Create, and store a pigpio script for a series of output values to be called by <a href="#">series()</a>
<a href="#">series</a> ([id, delete])	Execute a script that sets the pin to a series of values for a series of durations.
<a href="#">delete_script</a> (script_id)	spawn a thread to delete a script with id <code>script_id</code>
<a href="#">delete_all_scripts</a> ()	Stop and delete all scripts
<a href="#">stop_script</a> ([id])	Stops a running pigpio script
<a href="#">release</a> ()	Stops and deletes all scripts, sets to off, and calls <a href="#">GPIO.release()</a>

**output** = True**type** = 'DIGITAL\_OUT'**pigs\_function** = b'w'**set**(value: *bool*)

Set pin logic level.

Default uses `pigpio.pi.write()`, but can be overwritten by inheriting classes

Stops the last running script when called.

**Parameters** **value** (*int, bool*) – (1, True) to set High, (0, False) to set Low.

**turn**(*direction='on'*)

Change output state using on/off parlance. logic direction varies based on `Digital_Out.polarity`

Stops the last running script when called.

**Parameters** **direction** (*str, bool*) – ‘on’, 1, or True to turn to on and vice versa for off

**toggle**()

If pin is High, set Low, and vice versa.

Stops the last running script when called.

**pulse**(*duration=None*)

Send a timed on pulse.

**Parameters** **duration** (*int*) – If None (default), uses `duration`, otherwise duration of pulse from 1-100us.

**\_series\_script**(*values, durations=None, unit='ms', repeat=None, finish\_off=True*)

Create a pigpio script to set a pin to a series of values for a series of durations.

Typically shouldn't be called by itself, is used by `series()` or `store_series()`

For more information on pigpio scripts, see: <http://abyz.me.uk/rpi/pigpio/pigs.html#Scripts>

#### Parameters

- **values** (*list*) – A list of tuples of (value, duration) or a list of values in (1,0) to set self.pin\_bcm to.
- **durations** (*list*) – If **values** is not a list of tuples, a list of durations. `len(durations)` must be either `== len(values)` or else `len(durations) == 1`, in which case the duration is repeated.
- **unit** (“*ms*”, “*us*”) – units of durations in milliseconds or microseconds
- **repeat** (*int*) – If the script should be repeated, how many times? A value of 2 results in the script being run 2 times total, not 2 *additional* times (or, 3 total times)
- **finish\_off** (*bool*) – If true, the script ends by turning the pin to off

**Returns** the constructed script string

**Return type** (*str*)

**store\_series**(*id, \*\*kwargs*)

Create, and store a pigpio script for a series of output values to be called by `series()`

#### Parameters

- **id** (*str*) – shorthand key used to call this series with `series()`
- **kwargs** – passed to `_series_script()`

**series**(*id=None, delete=None, \*\*kwargs*)

Execute a script that sets the pin to a series of values for a series of durations.

See `_series_script()` for series parameterization.

Ideally one would use `store_series()` and use the returned id to call this function. Otherwise, this method calls `store_series()` and runs it.

#### Parameters

- **id** (*str, int*) – ID of the script, if not already created, created with `store_script()`. If None (default), an ID is generated with `script_counter` of the form 'script\_#'

- **kwargs** – passed to `_series_script()`

**delete\_script**(*script\_id*)

spawn a thread to delete a script with id `script_id`

This is a ‘soft’ deletion – it checks if the script is running, and waits for up to 10 seconds before actually deleting it.

The script is deleted from the pigpio daemon, from `script_handles` and from `scripts`

**Parameters** `script_id` (*str*) – a script ID in `Digital_Out.script_handles`

**delete\_all\_scripts**()

Stop and delete all scripts

This is a “hard” deletion – the script will be immediately stopped if it’s running.

**stop\_script**(*id=None*)

Stops a running pigpio script

**Parameters** `id` (*str, none*) – If `None`, stops the last run script. if `str`, stops script with that id.

**release**()

Stops and deletes all scripts, sets to `off`, and calls `GPIO.release()`

**class Digital\_In**(*pin, event=None, record=True, \*\*kwargs*)

Bases: `autopilot.hardware.gpio.GPIO`

Record digital input and call one or more callbacks on logic transition.

**Parameters**

- **pin** (*int*) – Board-numbered GPIO pin.
- **event** (`threading.Event`) – For callbacks assigned with `assign_cb()` with `evented = True`, set this event whenever the callback is triggered. Can be used to handle stage transition logic here instead of the `Task` object, as is typical.
- **record** (*bool*) – Whether all logic transitions should be recorded as a list of (‘EVENT’, ‘Timestamp’) tuples.
- **\*\*kwargs** – passed to `GPIO`

Sets the internal pullup/down resistor to `Digital_In.off` and `Digital_In.trigger` to `Digital_In.on` upon instantiation.

---

**Note:** pull and trigger are set by polarity on initialization in digital inputs, unlike other GPIO classes. They are not mutually synchronized however, ie. after initialization if any one of these attributes are changed, the other two will remain the same.

---

**Variables**

- **pi** (`pigpio.pi()`) – The pigpio connection.
- **pin** (*int*) – Broadcom-numbered pin, converted from the argument given on instantiation
- **callbacks** (*list*) – A list of `:meth:`pigpio.callback`’s kept to clear them on exit`
- **polarity** (*int*) – Logic direction, if 1: off=0, on=1, pull=low, trigger=high and vice versa for 0
- **events** (*list*) – if `record` is `True`, a list of (‘EVENT’, ‘TIMESTAMP’) tuples

**Attributes:**

---

*is\_trigger*

---

---

*type*

---

---

*input*

---

**Methods:**

<i>assign_cb</i> (callback_fn[, add, evented, ...])	Sets <i>callback_fn</i> to be called when <i>Digital_In.trigger</i> is detected.
<i>clear_cb</i> ()	Tries to call <i>.cancel()</i> on each of the callbacks in <i>callbacks</i>
<i>record_event</i> (pin, level, timestamp)	On either direction of logic transition, record the time
<i>release</i> ()	Clears any callbacks and calls <i>GPIO.release()</i>

**is\_trigger = True****type = 'DIGI\_IN'****input = True****assign\_cb**(callback\_fn, add=True, evented=False, manual\_trigger=None)Sets *callback\_fn* to be called when *Digital\_In.trigger* is detected.*callback\_fn* must accept three parameters:

- *GPIO* (int, 0-31): the BCM number of the pin that was triggered
- *level* (0-2):
  - 0: change to low (falling)
  - 1: change to high (rising)
  - 2: no change (watchdog timeout)
- *timestamp* (str): If using the Autopilot version of *pigpio*, an isoformatted timestamp

**Parameters**

- **callback\_fn** (*callable*) – The function to be called when triggered
- **add** (*bool*) – Are we adding another callback? If False, the previous callbacks are cleared.
- **evented** (*bool*) – Should triggering this event also set the internal event? Note that *Digital\_In.event* must have been passed.
- **manual\_trigger** ('U', 'D', 'B') – Override *Digital\_In.trigger* if needed.

**clear\_cb()**Tries to call *.cancel()* on each of the callbacks in *callbacks***record\_event**(pin, level, timestamp)

On either direction of logic transition, record the time

**Parameters**

- **pin** (*int*) – BCM numbered pin passed from *pigpio*

- **level** (*bool*) – High/Low status of current pin
- **timestamp** (*str*) – isoformatted timestamp

**release()**

Clears any callbacks and calls `GPIO.release()`

**class** `PWM(pin, range=255, **kwargs)`

Bases: `autopilot.hardware.gpio.Digital_Out`

PWM output from GPIO.

**Parameters**

- **pin** (*int*) – Board numbered GPIO pin
- **range** (*int*) – Maximum value of PWM duty-cycle. Default 255.
- **\*\*kwargs** – passed to `Digital_Out`

**Attributes:**


---

`output`

---

`type`

---

`pigs_function`

---

<code>range</code>	Maximum value of PWM dutycycle.
--------------------	---------------------------------

---

<code>polarity</code>	Logic direction.
-----------------------	------------------

---

**Methods:**


---

<code>set(value)</code>	Sets PWM duty cycle normalized to <code>polarity</code> and transformed by <code>_clean_value()</code>
-------------------------	--

---

<code>release()</code>	Turn off and call <code>Digital_Out.release()</code>
------------------------	--

---

`output = True`

`type = 'PWM'`

`pigs_function = b'pwm'`

**set**(*value*)

Sets PWM duty cycle normalized to `polarity` and transformed by `_clean_value()`

Stops the last running script

**Parameters** **value** (*int, float*) –

- if `int > 1`, sets value (or `PWM.range`-value if `PWM.polarity` is inverted).
- if `0 <= float <= 1`, transforms to a proportion of `range` (inverted if needed as well).

**property** `range`

Maximum value of PWM dutycycle.

Doesn't set duration of PWM, but set values will be divided by this range. eg. if `range == 200`, calling `PWM.set(100)()` would result in a 50% duty cycle

**Parameters** (*int*) – 25-40000

**property polarity**

Logic direction.

- if 1: on=High=:attr:~*PWM.range*, off=Low=0;
- if 0: off=Low=0, on=High=:attr:~*PWM.range*.

When set, updates on and off

**release()**

Turn off and call *Digital\_Out.release()*

Returns:

**class LED\_RGB**(pins=None, r=None, g=None, b=None, polarity=1, blink=True, \*\*kwargs)

Bases: *autopilot.hardware.gpio.Digital\_Out*

An RGB LED, wrapper around three *PWM* objects.

**Parameters**

- **pins** (*list*) – A list of (board) pin numbers. Either *pins* OR all *r*, *g*, *b* must be passed.
- **r** (*int*) – Board number of Red pin - must be passed with *g* and *b*
- **g** (*int*) – Board number of Green pin - must be passed with *r* and *b*
- **b** (*int*) – Board number of Blue pin - must be passed with *r* and *g*:
- **polarity** (*0, 1*) – 0: common anode (low turns LED on) 1: common cathode (low turns LED off)
- **blink** (*bool*) – Flash RGB at the end of init to show we're alive and bc it's real cute.
- **\*\*kwargs** – passed to *Digital\_Out*

**Variables channels** (*dict*) – The three PWM objects, {'r':PWM, ... etc}

**Attributes:**

<i>output</i>	
<i>type</i>	
<i>range</i>	Returns: dict: ranges for each of the LED_RGB. <b>channels</b>
<i>pin</i>	Dict of the board pin number of each channel, ``{'r': self.channels['r'].pin, .
<i>pin_bcm</i>	Dict of the broadcom pin number of each channel, ``{'r': self.channels['r'].pin_bcm, .
<i>pull</i>	State of internal pullup/down resistor.

**Methods:**

<i>set</i> ([value, r, g, b])	Set the color of the LED.
<i>toggle</i> ()	If pin is High, set Low, and vice versa.
<i>pulse</i> ([duration])	Send a timed on pulse.
<i>_series_script</i> (colors[, durations, unit, ...])	Create a script to flash a series of colors.
<i>flash</i> (duration[, frequency, colors])	Specify a color series by total duration and flash frequency.

continues on next page



Table 30 – continued from previous page

<code>release()</code>	Release each channel and stop pig without calling superclass.
<p><b>output</b> = True</p> <p><b>type</b> = 'LEDS'</p> <p><b>property range:</b> <b>dict</b> Returns: dict: ranges for each of the LED_RGB.channels</p> <p><b>set</b>(<i>value=None, r=None, g=None, b=None</i>) Set the color of the LED.</p> <p>Can either pass</p> <ul style="list-style-type: none"> <li>• a full (R, G, B) tuple to <b>value</b>,</li> <li>• a single <b>value</b> that is applied to each channel,</li> <li>• if <b>value</b> is not passed, individual <b>r</b>, <b>g</b>, or <b>b</b> values can be passed (any combination can be set in a single call)</li> </ul> <p>Stops the last run script</p> <p><b>Parameters</b></p> <ul style="list-style-type: none"> <li>• <b>value</b> (<i>int, float, tuple, list</i>) – If list or tuple, an (R, G, B) color. If float or int, applied to each color channe. Can be set with floats 0-1, or ints &gt;= 1 (See <a href="#">PWM.range</a>). If None, use <b>r</b>, <b>g</b>, and <b>b</b>.</li> <li>• <b>r</b> (<i>float, int</i>) – value to set red channel</li> <li>• <b>g</b> (<i>float, int</i>) – value to set green channel</li> <li>• <b>b</b> (<i>float, int</i>) – value to set blue channel</li> </ul> <p><b>toggle()</b> If pin is High, set Low, and vice versa.</p> <p>Stops the last running script when called.</p> <p><b>pulse</b>(<i>duration=None</i>) Send a timed on pulse.</p> <p><b>Parameters</b> <b>duration</b> (<i>int</i>) – If None (default), uses <b>duration</b>, otherwise duration of pulse from 1-100us.</p> <p><b>_series_script</b>(<i>colors, durations=None, unit='ms', repeat=None, finish_off=True</i>) Create a script to flash a series of colors.</p> <p>Like <a href="#">Digital_Out._series_script()</a>, but sets all pins at once.</p> <p><b>Parameters</b></p> <ul style="list-style-type: none"> <li>• <b>colors</b> (<i>list</i>) – a list of (R, G, B) colors, or a list of ((R,G,B),duration) tuples.</li> <li>• <b>durations</b> (<i>int, list</i>) – Duration of each color. if a single value, used for all colors. if a list, len(durations) == len(colors). If None, colors must be ((R,G,B),duration) tuples.</li> <li>• <b>unit</b> (<i>'ms', 'us'</i>) – unit of durations, milliseconds or microseconds</li> <li>• <b>repeat</b> (<i>int</i>) – Number of repetitions. If None, script runs once.</li> <li>• <b>finish_off</b> (<i>bool</i>) – Whether the channels should be set to off when the script completes</li> </ul>	

**Returns** constructed pigpio script string.

**Return type** `str`

**flash**(*duration*, *frequency*=10, *colors*=((1, 1, 1), (0, 0, 0)))

Specify a color series by total duration and flash frequency.

Largely a convenience function for on/off flashes.

**Parameters**

- **duration** (*int*, *float*) – Duration of flash in ms.
- **frequency** (*int*, *float*) – Frequency of flashes in Hz
- **colors** (*list*) –

A list of RGB values 0-255 like:

```
[[255,255,255],[0,0,0]]
```

**release**()

Release each channel and stop pig without calling superclass.

**property pin**

Dict of the board pin number of each channel, {'r' : self.channels['r'].pin, ... }

**property pin\_bcm**

Dict of the broadcom pin number of each channel, {'r' : self.channels['r'].pin\_bcm, ... }

**property pull**

State of internal pullup/down resistor.

See [PULL\\_MAP](#) for possible values.

**Returns** 'U'/'D'/None for pulled up, down or not set.

**Return type** `int`

**class Solenoid**(*pin*, *polarity*=1, *duration*=20, *vol*=None, *\*\*kwargs*)

Bases: [autopilot.hardware.gpio.Digital\\_Out](#)

Solenoid valve for water delivery.

**Parameters**

- **pin** (*int*) – Board pin number, converted to BCM on init.
- **polarity** (0, 1) – Whether HIGH opens the port (1) or closes it (0)
- **duration** (*int*, *float*) – duration of open, ms.
- **vol** (*int*, *float*) – desired volume of reward in uL, must have computed calibration results, see [calibrate\\_ports\(\)](#)
- **\*\*kwargs** – passed to [Digital\\_Out](#)

Only NC solenoids should be used, as there is no way to guarantee that a pin will maintain its voltage when it is released, and you will spill water all over the place.

**Variables**

- **calibration** (*dict*) – Dict with with line coefficients fitting volume to open duration, see [calibrate\\_ports\(\)](#). Retrieved from prefs, specifically `prefs.get('PORT_CALIBRATION')[name]`

- **mode** ('DURATION', 'VOLUME') – Whether open duration is given in ms, or computed from calibration
- **duration** (*int*, *float*) – Duration of valve opening, in ms. When set, creates a script 'open' that is used to open the valve for a precise amount of time

**Attributes:**

---

*output*

---

---

*type*

---

---

*DURATION\_MIN*

---

Minimum allowed duration in ms

---

*duration*

---

**Methods:**

---

*dur\_from\_vol*(vol)

---

Given a desired volume, compute an open duration.

---

*open*([duration])

---

Open the valve.

---

**output** = True**type** = 'SOLENOID'**DURATION\_MIN** = 2

Minimum allowed duration in ms

**property duration****dur\_from\_vol**(vol)

Given a desired volume, compute an open duration.

Must have calibration available in prefs, see *calibrate\_ports()*.**Parameters** **vol** (*float*, *int*) – desired reward volume in uL**Returns** computed opening duration for given volume**Return type** *int***open**(duration=None)

Open the valve.

Uses the 'open' script created when assigning duration.

**Parameters** **duration** (*float*) – If provided, open for this duration instead of the duration stored on instantiation.

## 12.3 i2c

### Classes:

---

<code>I2C_9DOF</code> ([accel, gyro, mag, gyro_hpf, ...])	A <a href="#">Sparkfun 9DOF</a> combined accelerometer, magnetometer, and gyroscope.
<code>MLX90640</code> ([fps, integrate_frames, interpolate])	A MLX90640 Temperature sensor.

---

**class** `I2C_9DOF`(*accel: bool = True*, *gyro: bool = True*, *mag: bool = True*, *gyro\_hpf: float = 0.2*, *accel\_range=16*, *kalman\_mode: str = 'both'*, *invert\_gyro=False*, \*args, \*\*kwargs)

Bases: `autopilot.hardware.Hardware`

A [Sparkfun 9DOF](#) combined accelerometer, magnetometer, and gyroscope.

**Sensor Datasheet:** [https://cdn.sparkfun.com/assets/learn\\_tutorials/3/7/3/LSM9DS1\\_Datasheet.pdf](https://cdn.sparkfun.com/assets/learn_tutorials/3/7/3/LSM9DS1_Datasheet.pdf)

**Hardware Datasheet:** [https://github.com/sparkfun/9DOF\\_Sensor\\_Stick](https://github.com/sparkfun/9DOF_Sensor_Stick)

**Documentation on calculating position values:** <https://arxiv.org/pdf/1704.06053.pdf>

This device uses I2C, so must be connected accordingly:

- VCC: 3.3V (pin 2)
- Ground: (any ground pin)
- SDA: I2C.1 SDA (pin 3)
- SCL: I2C.1 SCL (pin 5)

This class uses code from the [Adafruit Circuitfun](#) library, modified to use pigpio

---

**Note:** use this for processing?? <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6111698/>

---

### Parameters

- **accel** (*bool*) – Whether the accelerometer should be made active (default: True)
- **gyro** (*bool*) – Whether the gyroscope should be made active (default: True) – accel must be true if gyro is true
- **mag** (*bool*) – Whether the magnetometer should be made active (default: True)
- **gyro\_hpf** (*int, float*) – Highpass filter cutoff for onboard gyroscope filter. One of [GYRO\\_HPF\\_CUTOFF](#) (default: 4), or False to disable
- **kalman\_mode** (*'both', 'accel', None*) – Whether to use a kalman filter that integrates accelerometer and gyro readings ('both', default), a kalman filter with just the accelerometer values ('accel'), or just return the raw calculated orientation values from [rotation](#)
- **invert\_gyro** (*list, tuple*) – if not False (default), a list/tuple of the numerical axis index to invert on the gyroscope. eg. passing (1, 2) will invert the y and z axes.

### Attributes:

---

[ACCEL\\_RANGE\\_2G](#)

---

continues on next page

Table 34 – continued from previous page

<i>ACCELRange_16G</i>	
<i>ACCELRange_4G</i>	
<i>ACCELRange_8G</i>	
<i>MAGGAIN_4GAUSS</i>	
<i>MAGGAIN_8GAUSS</i>	
<i>MAGGAIN_12GAUSS</i>	
<i>MAGGAIN_16GAUSS</i>	
<i>GYROSCALE_245DPS</i>	
<i>GYROSCALE_500DPS</i>	
<i>GYROSCALE_2000DPS</i>	
<i>GYRO_HPF_CUTOFF</i>	Highpass-filter cutoff frequencies (keys, in Hz) mapped to binary flag.
<i>accel_range</i>	The accelerometer range.
<i>mag_gain</i>	The magnetometer gain.
<i>gyro_scale</i>	The gyroscope scale.
<i>gyro_filter</i>	Set the high-pass filter for the gyroscope.
<i>gyro_polarity</i>	
<i>acceleration</i>	The calibrated x, y, z acceleration in m/s <sup>2</sup>
<i>magnetic</i>	The magnetometer X, Y, Z axis values as a 3-tuple of gauss values.
<i>gyro</i>	The gyroscope X, Y, Z axis values as a 3-tuple of degrees/second values.
<i>rotation</i>	Return roll (rotation around x axis) and pitch (rotation around y axis) computed from the accelerometer
<i>temperature</i>	Returns: float: Temperature in Degrees C
<b>Methods:</b>	
<i>calibrate</i> ([what, samples, sample_dur])	Calibrate sensor readings to correct for bias and scale errors

**ACCELRange\_2G = 0**

**ACCELRange\_16G = 8**

**ACCELRange\_4G = 16**

**ACCELRange\_8G = 24**

**MAGGAIN\_4GAUSS = 0**

**MAGGAIN\_8GAUSS = 32**

`MAGGAIN_12GAUSS = 64`

`MAGGAIN_16GAUSS = 96`

`GYROSCALE_245DPS = 0`

`GYROSCALE_500DPS = 8`

`GYROSCALE_2000DPS = 24`

`GYRO_HPF_CUTOFF = {0.1: 9, 0.2: 8, 0.5: 7, 1: 6, 2: 5, 4: 4, 8: 3, 15: 2, 30: 1, 57: 0}`

Highpass-filter cutoff frequencies (keys, in Hz) mapped to binary flag.

---

**Note:** the frequency of a given binary flag is dependent on the output frequency (952Hz by default, changing frequency is not currently exposed in this object). See Table 52 of [the sensor datasheet](#) for more.

---

**property `accel_range`**

The accelerometer range. Must be one of: - `I2C_9DOF.ACCELRange_2G` - `I2C_9DOF.ACCELRange_4G` - `I2C_9DOF.ACCELRange_8G` - `I2C_9DOF.ACCELRange_16G`

**property `mag_gain`**

The magnetometer gain. Must be a value of: - `I2C_9DOF.MAGGAIN_4GAUSS` - `I2C_9DOF.MAGGAIN_8GAUSS` - `I2C_9DOF.MAGGAIN_12GAUSS` - `I2C_9DOF.MAGGAIN_16GAUSS`

**property `gyro_scale`**

The gyroscope scale. Must be a value of: - `I2C_9DOF.GYROSCALE_245DPS` - `I2C_9DOF.GYROSCALE_500DPS` - `I2C_9DOF.GYROSCALE_2000DPS`

**property `gyro_filter`: `Union[int, float, bool]`**

Set the high-pass filter for the gyroscope.

---

**Note:** the frequency of a given binary flag is dependent on the output frequency (952Hz by default, changing frequency is not currently exposed in this object). See Table 52 of [the sensor datasheet](#) for more.

---

**Parameters** `gyro_filter` (*int, float, False*) – Filter frequency (in `GYRO_HPF_CUTOFF`) or False to disable

**Returns** current HPF cutoff or False if disabled

**Return type** `float, bool`

**property `gyro_polarity`**

**property `acceleration`**

The calibrated x, y, z acceleration in m/s<sup>2</sup>

**Returns** x, y, z acceleration

**Return type** `accel (tuple)`

**property `magnetic`**

The magnetometer X, Y, Z axis values as a 3-tuple of gauss values.

**Returns** x, y, z gauss values

**Return type** `(tuple)`

**property `gyro`**

The gyroscope X, Y, Z axis values as a 3-tuple of degrees/second values.

**property rotation**

Return roll (rotation around x axis) and pitch (rotation around y axis) computed from the accelerometer

Uses [transform.geometry.IMU\\_Orientation](#) to fuse accelerometer and gyroscope with Kalman filter

**Returns** np.ndarray - [roll, pitch]

**property temperature**

Returns: float: Temperature in Degrees C

**calibrate**(*what*: [str](#) = 'accelerometer', *samples*: [int](#) = 10000, *sample\_dur*: [Optional\[float\]](#) = None) → [dict](#)  
Calibrate sensor readings to correct for bias and scale errors

---

**Note:** Currently only calibrating the accelerometer is implemented.

---

The accelerometer is calibrated by rotating the sensor slowly in all three rotational dimensions in such a way that minimizes linear acceleration (not due to gravity). A perfect sensor would output a sphere of points centered at 0

**Parameters**

- **what** ([str](#)) – which sensor is to be calibrated (currently only “accelerometer” implemented)
- **samples** ([int](#)) – number of samples that should be used to compute the calibration
- **sample\_dur** ([float](#)) – number of seconds to sample for, overrides **samples** if not None (default)

**Returns** calibration dictionary (also saved to disk using [Hardware.calibration](#))

**Return type** [dict](#)

**class MLX90640**(*fps*=64, *integrate\_frames*=64, *interpolate*=3, *\*\*kwargs*)

Bases: [autopilot.hardware.cameras.Camera](#)

A MLX90640 Temperature sensor.

**Parameters**

- **fps** ([int](#)) – Acquisition framerate, must be one of [MLX90640.ALLOWED\\_FPS](#)
- **integrate\_frames** ([int](#)) – Number of frames to average over
- **interpolate** ([int](#)) – Interpolation multiplier – 3 “increases the resolution” 3x
- **\*\*kwargs** – passed to [Camera](#)

**Variables**

- **shape** ([tuple](#)) – :attr:`~MLX90640.SHAPE\_SENSOR`
- **integrate\_frames** ([int](#)) – Number of frames to average over
- **interpolate** ([int](#)) – Interpolation multiplier – 3 “increases the resolution” 3x
- **\_grab\_event** ([threading.Event](#)) – capture thread sets every time it gets a frame, **\_grab** waits every time, keeps us from returning same frame twice

This device uses I2C, so must be connected accordingly:

- VCC: 3.3V (pin 2)
- Ground: (any ground pin)
- SDA: I2C.1 SDA (pin 3)

- SCL: I2C.1 SCL (pin 5)

Uses a modified version of the [MLX90640 Library](#) that is capable of outputting 64fps. You must install the library separately, see the `setup_mlx90640.sh` script.

Capture works a bit differently from other Cameras – the `capture_init()` method spawns a `_threaded_capture()` thread, which continually puts frames in the `_frames` array which serves as a ring buffer. The `_grab()` method then awaits the `_grab_event` to be set by the capture thread, and when it is set returns the mean across frames of the ring buffer.

---

**Note:** The setup script modifies the systemwide i2c baudrate to 1MHz, which may interfere with other I2C devices. It can be returned to 400kHz (default) by editing `/config/boot.txt` to read `dtparam=i2c_arm_baudrate=400000`

---

#### Attributes:

<code>type</code>	what are we anyway?
<code>ALLOWED_FPS</code>	FPS must be one of these
<code>SHAPE_SENSOR</code>	(H, W) Output shape of this sensor is always the same.
<code>fps</code>	
<code>integrate_frames</code>	
<code>interpolate</code>	

#### Methods:

<code>init_cam()</code>	Set the camera object to use our <a href="#">MLX90640</a> . <code>fps</code>
<code>capture_init()</code>	Spawn a <code>_threaded_capture()</code> thread
<code>_threaded_capture()</code>	Continually capture frames into the <code>_frames</code> ring buffer
<code>_grab()</code>	Await the <code>_grab_event</code> and then average over the frames stored in <code>_frames</code>
<code>_timestamp([frame])</code>	Just gets Python timestamps for now...
<code>interpolate_frame(frame)</code>	Interpolate frame according to <a href="#">interpolate</a> using <code>scipy.interpolate.griddata()</code>
<code>release()</code>	Stops the capture thread, cleans up the camera, and calls the superclass release method.

`type = 'MLX90640'`

what are we anyway?

Type (str)

`ALLOWED_FPS = (1, 2, 4, 8, 16, 32, 64)`

FPS must be one of these

`SHAPE_SENSOR = (32, 24)`

(H, W) Output shape of this sensor is always the same. May differ from `MLX90640.shape` if `interpolate > 1`

property `fps`



**property** `integrate_frames`

**property** `interpolate`

**init\_cam()**

Set the camera object to use our [MLX90640.fps](#)

**capture\_init()**

Spawn a `_threaded_capture()` thread

**\_threaded\_capture()**

Continually capture frames into the `_frames` ring buffer

Stops when `stopping` is set.

**\_grab()**

Await the `_grab_event` and then average over the frames stored in `_frames`

**Returns** (`ndarray`) Averaged and interpolated frame

**\_timestamp(*frame=None*)**

Just gets Python timestamps for now...

**Returns** Isoformatted timestamp from datetime

**Return type** `str`

**interpolate\_frame(*frame*)**

Interpolate frame according to [interpolate](#) using `scipy.interpolate.griddata()`

**Parameters** `frame` (`numpy.ndarray`) – Frame to interpolate

**Returns** Interpolated Frame

**Return type** (`numpy.ndarray`)

**release()**

Stops the capture thread, cleans up the camera, and calls the superclass release method.

## 12.4 usb

Hardware that uses USB

**Classes:**

---

<a href="#"><code>Wheel</code></a> ( <code>[mouse_idx, fs, thresh, thresh_type, ...]</code> )	A continuously measured mouse wheel.
---	--------------------------------------

---

<a href="#"><code>Scale</code></a> ( <code>[model, vendor_id, product_id]</code> )
--

---

**class** `Wheel`(`mouse_idx=0, fs=10, thresh=100, thresh_type='dist', start=True, digi_out=False, mode='vel_total', integrate_dur=5`)

Bases: [autopilot.hardware.Hardware](#)

A continuously measured mouse wheel.

Uses a USB computer mouse.

**Warning:** ‘vel’ `thresh_type` not implemented

**Parameters**

- **mouse\_idx** (*int*)
- **fs** (*int*)
- **thresh** (*int*)
- **thresh\_type** ('*dist*')
- **start** (*bool*)
- **digi\_out** (*Digital\_Out*, *bool*)
- **mode** ('*vel\_total*')
- **integrate\_dur** (*int*)

**Attributes:**

---

*input*

---

*type*

---

*trigger*

---

*THRESH\_TYPES*

---

*MODES*

---

*MOVE\_DTYPE*

---

**Methods:**

---

*start()*

---

<i>check_thresh</i> (move)	Updates <i>thresh_val</i> and checks whether it's above/below threshold
----------------------------	---

---

<i>calc_move</i> (move[, <i>thresh_type</i> ])	Calculate distance move depending on type (x, y, total dist)
--	--

---

*thresh\_trig()*

---

<i>assign_cb</i> (trigger_fn)	Every hardware device that is a <b>trigger</b> must re-define this to accept a function (typically <i>Task.handle_trigger()</i> ) that is called when that trigger is activated.
-------------------------------	--

---

<i>l_measure</i> (value)	Task has signaled that we need to start measuring movements for a trigger
--------------------------	---

---

*l\_clear*(value)

---

<i>l_stop</i> (value)	Stop measuring and clear system resources :Parameters: <b>value</b> ()
-----------------------	--

---

<i>release</i> ()	Every hardware device needs to redefine <i>release()</i> , and must
-------------------	---

---

**input = True**

```

type = 'Wheel'
trigger = False
THRESH_TYPES = ['dist', 'x', 'y', 'vel']
MODES = ('vel_total', 'steady', 'dist', 'timed')
MOVE_DTYPE = [('vel', 'i4'), ('dir', 'U5'), ('timestamp', 'f8')]

```

```
start()
```

```
check_thresh(move)
```

Updates thresh\_val and checks whether it's above/below threshold

**Parameters** *move* (*np.array*) – Structured array with fields ('vel', 'dir', 'timestamp')

Returns:

```
calc_move(move, thresh_type=None)
```

Calculate distance move depending on type (x, y, total dist)

**Parameters**

- *move* ()
- *thresh\_type* ()

Returns:

```
thresh_trig()
```

```
assign_cb(trigger_fn)
```

Every hardware device that is a `trigger` must redefine this to accept a function (typically [Task.handle\\_trigger\(\)](#)) that is called when that trigger is activated.

When not redefined, a warning is given.

```
l_measure(value)
```

Task has signaled that we need to start measuring movements for a trigger

**Parameters** *value* ()

```
l_clear(value)
```

Stop measuring!

**Parameters** *value* ()

Returns:

```
l_stop(value)
```

Stop measuring and clear system resources :Parameters: *value* ()

Returns:

```
release()
```

Every hardware device needs to redefine *release()*, and must

- Safely unload any system resources used by the object, and
- Return the object to a neutral state - eg. LEDs turn off.

When not redefined, a warning is given.

```
class Scale(model='stamps.com', vendor_id=None, product_id=None)
```

Bases: [autopilot.hardware.Hardware](#)

---

**Note:** Not implemented, working on using a digital scale to make weighing faster.

---

**Parameters**

- **model**
- **vendor\_id**
- **product\_id**

**Attributes:**

---

*MODEL*

---

```
MODEL = {'stamps.com': {'product_id': 27251, 'vendor_id': 5190}}
```

## NETWORKING

Classes for network communication.

There are two general types of network objects -

- **autopilot.networking.Station and its children are independent processes that should only be instantiated once** per piece of hardware. They are used to distribute messages between *Net\_Node* s, forward messages up the networking tree, and responding to messages that don't need any input from the *Pilot* or *Terminal*.
- ***Net\_Node* is a pop-in networking class that can be given to any other object that** wants to send or receive messages.

The *Message* object is used to serialize and pass messages. When sent, messages are JSON serialized (with some special magic to compress/encode numpy arrays) and sent as zmq multipart messages.

Each serialized message, when sent, can have *n* frames of the format:

`[hop_0, hop_1, ... hop_n, final_recipient, serialized_message]`

Or, messages can have multiple “hops” (a typical message will have one ‘hop’ specified by the *to* field), the second to last frame is always the final intended recipient, and the final frame is the serialized message. Note that the *to* field of a *Message* object will always be the final recipient even if a list is passed for *to* when sending. This lets *Station* objects efficiently forward messages without deserializing them at every hop.

### Functions:

<code>serialize_array(array)</code>	Pack an array with <code>blosc.pack_array()</code> and serialize with <code>base64.b64encode()</code>
-------------------------------------	---

#### **serialize\_array(array)**

Pack an array with `blosc.pack_array()` and serialize with `base64.b64encode()`

**Parameters** *array* (`numpy.ndarray`) – Array to serialize

**Returns** {'NUMPY\_ARRAY': base-64 encoded, blosc-compressed array.}

**Return type** `dict`

## 13.1 station



### Classes:

<code>Station([id, push_ip, push_port, push_id, ...])</code>	Independent networking class used for messaging between computers.
<code>Terminal_Station(pilots)</code>	Station object used by <code>Terminal</code> objects.
<code>Pilot_Station()</code>	Station object used by <code>Pilot</code> objects.

**class** `Station`(*id*: `Optional[str] = None`, *push\_ip*: `Optional[str] = None`, *push\_port*: `Optional[int] = None`, *push\_id*: `Optional[str] = None`, *pusher*: `bool = False`, *listen\_port*: `Optional[int] = None`, *listens*: `Optional[Dict[str, Callable]] = None`)

Bases: `multiprocessing.context.Process`

Independent networking class used for messaging between computers.

These objects send and handle `networking.Message`s by using a dictionary of `listens`, or methods that are called to respond to different types of messages.

Each sent message is given an ID, and a thread is spawned to periodically resend it (up until some time-to-live, typically 5 times) until confirmation is received.

By default, the only listen these objects have is `l_confirm()`, which responds to message confirmations. Accordingly, `listens` should be added by using `dict.update()` rather than reassigning the attribute.

Station objects can be made with or without a `pusher`, a `zmq.DEALER` socket that connects to the `zmq.ROUTER` socket of an upstream Station object.

This class can be instantiated on its own if all of the required arguments are supplied, but the intended pattern of use is to subclass it with any custom `listen` methods for handling message types and other logic that would be specific for an agent type that uses it.

---

**Note:** This object will likely be deprecated in v0.5.0, as the gains of a separate messaging process are not as great as the complications caused by having two different kinds of networking object in the system. In the future we will move to having a single type of networking object that can either be spawned as a separate process or as a thread.

---

Args are similar to the documented Attributes, and so only those that differ from attributes are documented here

**Parameters** `pusher` (*bool*) – If True, create a `zmq.DEALER` socket connected to `push_ip`, `push_port`, and `push_id`. (Default: False).

### Variables

- **context** (`zmq.Context`) – zeromq context
- **loop** (`tornado.ioloop.IOLoop`) – a tornado ioloop
- **pusher** (`zmq.Socket`) – pusher socket - a dealer socket that connects to other routers

- **push\_ip** (*str*) – If we have a dealer, IP to push messages to
- **push\_port** (*str*) – If we have a dealer, port to push messages to
- **push\_id** (*str*) – identity of the Router we push to
- **listener** (*zmq.Socket*) – The main router socket to send/recv messages
- **listen\_port** (*str*) – Port our router listens on
- **logger** (*logging.Logger*) – Used to log messages and network events.
- **id** (*str*) – What are we known as? What do we set our identity as?
- **ip** (*str*) – Device IP
- **listens** (*dict*) – Dictionary of functions to call for different types of messages. keys match the *Message.key*.
- **senders** (*dict*) – Identities of other sockets (keys, ie. directly connected) and their state (values) if they keep one
- **push\_outbox** (*dict*) – Messages that have been sent but have not been confirmed to our *Station.pusher*
- **send\_outbox** (*dict*) – Messages that have been sent but have not been confirmed to our *Station.listener*
- **timers** (*dict*) – dict of *threading.Timer*s that will check in on outbox messages
- **msg\_counter** (*itertools.count*) – counter to index our sent messages
- **file\_block** (*threading.Event*) – Event to signal when a file is being received.

**Attributes:***repeat\_interval***Methods:**

<i>run()</i>	A <i>zmq.Context</i> and <i>tornado.IOLoop</i> are spawned, the listener and optionally the pusher are instantiated and connected to <i>handle_listen()</i> using <i>on_recv()</i> .
<i>prepare_message</i> (to, key, value[, repeat, flags])	If a message originates with us, a <i>Message</i> class is instantiated, given an ID and the rest of its attributes.
<i>send</i> ([to, key, value, msg, repeat, flags])	Send a message via our <i>listener</i> , ROUTER socket.
<i>push</i> ([to, key, value, msg, repeat, flags])	Send a message via our <i>pusher</i> , DEALER socket.
<i>repeat()</i>	Periodically (according to <i>repeat_interval</i> ) re-send messages that haven't been confirmed
<i>l_confirm</i> (msg)	Confirm that a message was received.
<i>l_stream</i> (msg)	Reconstitute the original stream of messages and call their handling methods
<i>handle_listen</i> (msg)	Upon receiving a message, call the appropriate listen method in a new thread.
<i>get_ip</i> ()	Find our IP address
<i>release</i> ()	

continues on next page

Table 4 – continued from previous page

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<code>_check_stop()</code>	periodic callback called by the <code>IOLoop</code> to check if the <i>closing</i> flag has been set, and closing process if so
----------------------------	---

---

`repeat_interval = 5.0`

`run()`

A `zmq.Context` and `tornado.IOLoop` are spawned, the listener and optionally the pusher are instantiated and connected to `handle_listen()` using `on_recv()` .

The process is kept open by the `tornado.IOLoop` .

`prepare_message(to, key, value, repeat=True, flags=None)`

If a message originates with us, a `Message` class is instantiated, given an ID and the rest of its attributes.

#### Parameters

- **flags**
- **repeat**
- **to** (*str*) – The identity of the socket this message is to
- **key** (*str*) – The type of message - used to select which method the receiver uses to process this message.
- **value** – Any information this message should contain. Can be any type, but must be JSON serializable.

`send(to=None, key=None, value=None, msg=None, repeat=True, flags=None)`

Send a message via our listener , ROUTER socket.

Either an already created `Message` should be passed as *msg*, or at least *to* and *key* must be provided for a new message created by `prepare_message()` .

A `threading.Timer` is created to resend the message using `repeat()` unless *repeat* is False.

#### Parameters

- **flags**
- **to** (*str*) – The identity of the socket this message is to
- **key** (*str*) – The type of message - used to select which method the receiver uses to process this message.
- **value** – Any information this message should contain. Can be any type, but must be JSON serializable.
- **msg** (*Message*) – An already created message.
- **repeat** (*bool*) – Should this message be resent if confirmation is not received?

`push(to=None, key=None, value=None, msg=None, repeat=True, flags=None)`

Send a message via our pusher , DEALER socket.

Unlike `send()` , *to* is not required. Every message is always sent to `push_id` . *to* can be included to send a message further up the network tree to a networking object we're not directly connected to.

Either an already created `Message` should be passed as *msg*, or at least *key* must be provided for a new message created by `prepare_message()` .

A `threading.Timer` is created to resend the message using `repeat()` unless *repeat* is False.

#### Parameters



- **flags**
- **to** (*str*) – The identity of the socket this message is to. If not included, sent to `push_id()`.
- **key** (*str*) – The type of message - used to select which method the receiver uses to process this message.
- **value** – Any information this message should contain. Can be any type, but must be JSON serializable.
- **msg** (*Message*) – An already created message.
- **repeat** (*bool*) – Should this message be resent if confirmation is not received?

**repeat()**

Periodically (according to `repeat_interval`) resend messages that haven't been confirmed

TTL is decremented, and messages are resent until their TTL is 0.

**l\_confirm(msg)**

Confirm that a message was received.

**Parameters** `msg` (*Message*) – A confirmation message - note that this message has its own unique ID, so the value of this message contains the ID of the message that is being confirmed

**l\_stream(msg)**

Reconstitute the original stream of messages and call their handling methods

The msg should contain an `inner_key` that indicates the key, and thus the handling method.

**Parameters** `msg` (*dict*) – Compressed stream sent by `Net_Node._stream()`

**handle\_listen(msg: List[bytes])**

Upon receiving a message, call the appropriate listen method in a new thread.

If the message is to us, send confirmation.

If the message is not to us, attempt to forward it.

**Parameters** `msg` (*str*) – JSON `Message.serialize()` d message.

**get\_ip()**

Find our IP address

returns (*str*): our IPv4 address.

**release()****\_check\_stop()**

periodic callback called by the IOloop to check if the `closing` flag has been set, and closing process if so

**class Terminal\_Station(pilots)**

Bases: `autopilot.networking.station.Station`

Station object used by `Terminal` objects.

Spawned without a `pusher`.

**Listens**

Key	Method	Description
'PING'	<code>l_ping()</code>	We are asked to confirm that we are alive
'INIT'	<code>l_init()</code>	Ask all pilots to confirm that they are alive
'CHANGE'	<code>l_change()</code>	Change a parameter on the Pi
'STOPALL'	<code>l_stopall()</code>	Stop all pilots and plots
'KILL'	<code>l_kill()</code>	Terminal wants us to die :(
'DATA'	<code>l_data()</code>	Stash incoming data from a Pilot
'STATE'	<code>l_state()</code>	A Pilot has changed state
'HANDSHAKE'	<code>l_handshake()</code>	A Pi is telling us it's alive and its IP
'FILE'	<code>l_file()</code>	The pi needs some file from us

**Parameters** `pilots` (*dict*) – The `Terminal.pilots` dictionary.

**Attributes:**

---

`plot_timer`

---

`sent_plot`

---

**Methods:**

<code>start_plot_timer()</code>	Start a timer that controls how often streamed video frames are sent to <code>gui.Video</code> plots.
<code>l_ping(msg)</code>	We are asked to confirm that we are alive
<code>l_init(msg)</code>	Ask all pilots to confirm that they are alive
<code>l_change(msg)</code>	Change a parameter on the Pi
<code>l_stopall(msg)</code>	Stop all pilots and plots
<code>l_kill(msg)</code>	Terminal wants us to die :(
<code>l_data(msg)</code>	Stash incoming data from a Pilot
<code>l_continuous(msg)</code>	Handle the storage of continuous data
<code>l_state(msg)</code>	A Pilot has changed state.
<code>l_handshake(msg)</code>	A Pi is telling us it's alive and its IP.
<code>l_file(msg)</code>	A Pilot needs some file from us.

`plot_timer = None`

`sent_plot = {}`

`start_plot_timer()`

Start a timer that controls how often streamed video frames are sent to `gui.Video` plots.

`l_ping(msg: autopilot.networking.message.Message)`

We are asked to confirm that we are alive

Respond with a blank 'STATE' message.

**Parameters** `msg` (*Message*)

`l_init(msg: autopilot.networking.message.Message)`

Ask all pilots to confirm that they are alive

Sends a "PING" to everyone in the pilots dictionary.

**Parameters** `msg` (*Message*)

**l\_change**(*msg*: autopilot.networking.message.Message)

Change a parameter on the Pi

**Warning:** Not Implemented

**Parameters** *msg* (*Message*)

**l\_stopall**(*msg*: autopilot.networking.message.Message)

Stop all pilots and plots

**Parameters** *msg* (*Message*)

**l\_kill**(*msg*: autopilot.networking.message.Message)

Terminal wants us to die :(

Stop the Station.loop

**Parameters** *msg* (*Message*)

**l\_data**(*msg*: autopilot.networking.message.Message)

Stash incoming data from a Pilot

Just forward this along to the internal terminal object (`'_T'`) and a copy to the relevant plot.

**Parameters** *msg* (*Message*)

**l\_continuous**(*msg*: autopilot.networking.message.Message)

Handle the storage of continuous data

Forwards all data on to the Terminal's internal `Net_Node`, send to *Plot* according to update rate in `prefs.get('DRAWFPS')`

**Parameters** *msg* (*Message*) – A continuous data message

**l\_state**(*msg*: autopilot.networking.message.Message)

A Pilot has changed state.

Stash in 'state' field of pilot dict and send along to `_T`

**Parameters** *msg* (*Message*)

**l\_handshake**(*msg*: autopilot.networking.message.Message)

A Pi is telling us it's alive and its IP.

Send along to `_T`

**Parameters** *msg* (*Message*)

**l\_file**(*msg*: autopilot.networking.message.Message)

A Pilot needs some file from us.

Send it back after `base64.b64encode()` ing it.

---

**Todo:** Split large files into multiple messages...

---

**Parameters** *msg* (*Message*) – The value field of the message should contain some relative path to a file contained within `prefs.get('SOUNDDIR')` . eg. `'/songs/sadone.wav'` would return `'os.path.join(prefs.get('SOUNDDIR')/songs.sadone.wav'`

**class Pilot\_Station**

Bases: `autopilot.networking.station.Station`

Station object used by `Pilot` objects.

Spawned with a `pusher` connected back to the `Terminal`.

**Listens**

Key	Method	Description
'STATE' 'CO-HERE' 'PING'	<code>l_state()</code> <code>l_cohere()</code>	Pilot has changed state Make sure our data and the Terminal's match. The Terminal wants to know if we're listening We are being sent a task to start We are being told to stop the current task The Terminal is changing some task parameter We are receiving a file
'START'	<code>l_ping()</code>	
'STOP'	<code>l_start()</code>	
'PARAM'	<code>l_stop()</code>	
'FILE'	<code>l_change()</code> <code>l_file()</code>	

**Methods:**

<code>_pinger()</code>	Periodically ping the terminal with our status
<code>l_noop(msg)</code>	
<code>l_state(msg)</code>	Pilot has changed state
<code>l_cohere(msg)</code>	Send our local version of the data table so the terminal can double check
<code>l_ping([msg])</code>	The Terminal wants to know our status
<code>l_start(msg)</code>	We are being sent a task to start
<code>l_stop(msg)</code>	Tell the pi to stop the task
<code>l_change(msg)</code>	The terminal is changing a parameter
<code>l_file(msg)</code>	We are receiving a file.
<code>l_continuous(msg)</code>	Forwards continuous data sent by children back to terminal.
<code>l_child(msg)</code>	Tell one or more children to start running a task.
<code>l_forward(msg)</code>	Just forward the message to the pi.

**`_pinger()`**

Periodically ping the terminal with our status

Calls its own timer to replace it

Returns:

**`l_noop(msg)`**

**`l_state(msg: autopilot.networking.message.Message)`**

Pilot has changed state

Stash it and alert the Terminal

**Parameters** `msg` (`Message`)

**`l_cohere(msg: autopilot.networking.message.Message)`**

Send our local version of the data table so the terminal can double check

**Warning:** Not Implemented

**Parameters** `msg` (*Message*)

**l\_ping**(*msg: Optional[autopilot.networking.message.Message] = None*)

The Terminal wants to know our status

Push back our current state.

**Parameters** `msg` (*Message*)

**l\_start**(*msg: autopilot.networking.message.Message*)

We are being sent a task to start

If we need any files, request them.

Then send along to the pilot.

**Parameters** `msg` (*Message*) – value will contain a dictionary containing a task description.

**l\_stop**(*msg: autopilot.networking.message.Message*)

Tell the pi to stop the task

**Parameters** `msg` (*Message*)

**l\_change**(*msg: autopilot.networking.message.Message*)

The terminal is changing a parameter

**Warning:** Not implemented

**Parameters** `msg` (*Message*)

**l\_file**(*msg: autopilot.networking.message.Message*)

We are receiving a file.

Decode from b64 and save. Set the file\_block.

**Parameters** `msg` (*Message*) – value will have ‘path’ and ‘file’, where the path determines where in `prefs.get('SOUNDDIR')` the b64 encoded ‘file’ will be saved.

**l\_continuous**(*msg: autopilot.networking.message.Message*)

Forwards continuous data sent by children back to terminal.

Continuous data sources from this pilot should be streamed directly to the terminal.

**Parameters** `msg` (*Message*) – Continuous data message

**l\_child**(*msg: autopilot.networking.message.Message*)

Tell one or more children to start running a task.

By default, the *key* argument passed to `self.send` is ‘START’. However, this can be overridden by providing the desired string as `msg.value[‘KEY’]`.

This checks the pref *CHILDDID* to get the names of one or more children. If that pref is a string, sends the message to just that child. If that pref is a list, sends the message to each child in the list.

**Parameters** `msg` () – A message to send to the child or children.

**Returns** nothing

`l_forward(msg: autopilot.networking.message.Message)`  
Just forward the message to the pi.

## 13.2 node

### Classes:

---

<code>Net_Node(id, upstream, port, listens[, ...])</code>	Drop in networking object to be given to any sub-object behind some external-facing <code>Station</code> object.
---	--

---

**class** `Net_Node`(*id*: `str`, *upstream*: `str`, *port*: `int`, *listens*: `Dict[str, Callable]`, *instance*: `bool` = `True`, *upstream\_ip*: `str` = `'localhost'`, *router\_port*: `Optional[int]` = `None`, *daemon*: `bool` = `True`, *expand\_on\_receive*: `bool` = `True`)

Bases: `object`

Drop in networking object to be given to any sub-object behind some external-facing `Station` object.

**To minimize the complexity of the network topology, the typical way to use ``Net\_Node``s is through a `Station` ROUTER, rather than**

addressing each other directly. Practically, this means that all messages are sent first to the parent `networking.Station` object, which then handles them, forwards them, etc. This proved to be horribly misguided and will be changed in v0.5.0 to support simplified messaging to a `agent_id.netnode_id` address. Until then the networking modules will be in a bit of flux.

To receive messages directly at this `Net_Node`, pass the `router_port` which will bind a `zmq.ROUTER` socket, and messages will be handled as regular ‘listens’ Note that `Net_Nodes` assume that they are the final recipients of messages, and so don’t handle forwarding messages (unless a `listen` method explicitly does so), and will automatically deserialize them on receipt.

---

**Note:** Listen methods currently receive only the value of a message, this will change in v0.5.0, where they will receive the full message like `networking.Station` objects.

---

### Parameters

- **id** (`str`) – What are we known as? What do we set our identity as?
- **upstream** (`str`) – The identity of the ROUTER socket used by our upstream `Station` object.
- **port** (`int`) – The port that our upstream ROUTER socket is bound to
- **listens** (`dict`) – Dictionary of functions to call for different types of messages. keys match the `Message.key`.
- **instance** (`bool`) – Should the node try and use the existing `zmq` context and `tornado` loop?
- **upstream\_ip** (`str`) – If this `Net_Node` is being used on its own (ie. not behind a `Station`), it can directly connect to another node at this IP. Otherwise use ‘localhost’ to connect to a station.
- **router\_port** (`int`) – Typically, `Net_Nodes` only have a single Dealer socket and receive messages from their encapsulating `Station`, but if you want to take this node offroad and use it independently, an int here binds a Router to the port.
- **daemon** (`bool`) – Run the `IOLoop` thread as a daemon (default: `True`)

### Variables

- **context** (`zmq.Context`) – zeromq context
- **loop** (`tornado.ioloop.IOLoop`) – a tornado ioloop
- **sock** (`zmq.Socket`) – Our DEALER socket.
- **id** (`str`) – What are we known as? What do we set our identity as?
- **upstream** (`str`) – The identity of the ROUTER socket used by our upstream *Station* object.
- **port** (`int`) – The port that our upstream ROUTER socket is bound to
- **listens** (`dict`) – Dictionary of functions to call for different types of messages. keys match the `Message.key`.
- **outbox** (`dict`) – Messages that have been sent but have not been confirmed
- **timers** (`dict`) – dict of `threading.Timer`s that will check in on outbox messages
- **logger** (`logging.Logger`) – Used to log messages and network events.
- **msg\_counter** (`itertools.count`) – counter to index our sent messages
- **loop\_thread** (`threading.Thread`) – Thread that holds our loop. initialized with `daemon=True`

**Attributes:**

<code>repeat_interval</code>	
<code>ip</code>	Find our IP address

**Methods:**

<code>init_networking()</code>	Creates socket, connects to specified port on localhost, and starts the <code>threaded_loop()</code> as a daemon thread.
<code>threaded_loop()</code>	Run in a thread, either starts the <code>IOLoop</code> , or if it is already started (ie.
<code>handle_listen(msg)</code>	Upon receiving a message, call the appropriate listen method in a new thread and send confirmation it was received.
<code>send([to, key, value, msg, repeat, flags, ...])</code>	Send a message via our <code>sock</code> , DEALER socket.
<code>repeat()</code>	Periodically (according to <code>repeat_interval</code> ) re-send messages that haven't been confirmed
<code>l_confirm(value)</code>	Confirm that a message was received.
<code>l_stream(msg)</code>	Reconstitute the original stream of messages and call their handling methods
<code>prepare_message(to, key, value, repeat[, flags])</code>	Instantiate a <code>Message</code> class, give it an ID and the rest of its attributes.
<code>get_stream(id, key[, min_size, upstream, ...])</code>	Make a queue that another object can dump data into that sends on its own socket.
<code>release()</code>	

```
repeat_interval = 5
```

**init\_networking()**

Creates socket, connects to specified port on localhost, and starts the `threaded_loop()` as a daemon thread.

**threaded\_loop()**

Run in a thread, either starts the IOloop, or if it is already started (ie. running in another thread), breaks.

**handle\_listen(msg: List[bytes])**

Upon receiving a message, call the appropriate listen method in a new thread and send confirmation it was received.

---

**Note:** Unlike `Station.handle_listen()`, only the `Message.value` is given to listen methods. This was initially intended to simplify these methods, but this might change in the future to unify the messaging system.

---

**Parameters** `msg (list)` – JSON `Message.serialize()` d message.

**send**(*to: Optional[Union[str, list]] = None, key: Optional[str] = None, value: Optional[Any] = None, msg: Optional[autopilot.networking.message.Message] = None, repeat: bool = True, flags=None, force\_to: bool = False*)

Send a message via our sock , DEALER socket.

*to* is not required.

- If the node doesn't have a router, (or the recipient is not in the `Net_Node.senders` dict ) every message is always sent to `upstream` . *to* can be included to send a message further up the network tree to a networking object we're not directly connected to.
- If the node has a router, since messages can only be sent on router sockets after the recipient has first sent us a message, if the *to* is in the `senders` dict, it will be directly sent via `Net_Node.router`
- If the `force_to` arg is True, send to the *to* recipient directly via the dealer `Net_Node.sock`
- If *to* is a list, or is intended to be sent as a multihop message with an explicit path, then networking objects will attempt to forward it along that path (disregarding implicit topology).

Either an already created `Message` should be passed as *msg*, or at least *key* must be provided for a new message created by `prepare_message()` .

A `threading.Timer` is created to resend the message using `repeat()` unless *repeat* is False.

**Parameters**

- **to** (*str, list*) – The identity of the socket this message is to. If not included, sent to `upstream()` .
- **key** (*str*) – The type of message - used to select which method the receiver uses to process this message.
- **value** – Any information this message should contain. Can be any type, but must be JSON serializable.
- **msg** (*Message*) – An already created message.
- **repeat** (*bool*) – Should this message be resent if confirmation is not received?
- **flags** (*dict*)
- **force\_to** (*bool*) – If we really really want to use the 'to' field to address messages (eg. node being used for direct communication), overrides default behavior of sending to upstream.



**repeat()**

Periodically (according to [repeat\\_interval](#)) resend messages that haven't been confirmed

TTL is decremented, and messages are resent until their TTL is 0.

**l\_confirm(value)**

Confirm that a message was received.

**Parameters** **value** (*str*) – The ID of the message we are confirming.

**l\_stream(msg)**

Reconstitute the original stream of messages and call their handling methods

The msg should contain an **inner\_key** that indicates the key, and thus the handling method.

**Parameters** **msg** (*dict*) – Compressed stream sent by `Net_Node._stream()`

**prepare\_message(to, key, value, repeat, flags=None)**

Instantiate a [Message](#) class, give it an ID and the rest of its attributes.

**Parameters**

- **flags**
- **repeat**
- **to** (*str*) – The identity of the socket this message is to
- **key** (*str*) – The type of message - used to select which method the receiver uses to process this message.
- **value** – Any information this message should contain. Can be any type, but must be JSON serializable.

**get\_stream(id, key, min\_size=5, upstream=None, port=None, ip=None, subject=None, q\_size: Optional[int] = None)**

Make a queue that another object can dump data into that sends on its own socket. Smarter handling of continuous data than just hitting 'send' a shitload of times. :returns: Place to dump ur data :rtype: Queue

**property ip: str**

Find our IP address

---

**Todo:** this is a copy of the [Station.get\\_ip\(\)](#) method – unify this in v0.5.0

---

returns (str): our IPv4 address.

**release()**

## 13.3 Message

**Classes:**


---

[Message](#)([msg, expand\_arrays])

A formatted message that takes value, sends it to id, who should call the listen method indicated by the key.

---

**class Message**(msg=None, expand\_arrays=False, \*\*kwargs)

Bases: [object](#)

A formatted message that takes value, sends it to id, who should call the listen method indicated by the key.

Additional message behavior can be indicated by passing `flags`

Numpy arrays given in the value field are automatically serialized and deserialized when sending and receiving using bas64 encoding and blosc compression.

`id`, `to`, `sender`, and `key` are required attributes, but any other key-value pair passed on init is added to the message's attributes and included in the message.

Can be indexed and set like a dictionary (`message['key']`, etc.)

#### Variables

- **id** (*str*) – ID that uniquely identifies a message. format {sender.id}\_{number}
- **to** (*str*) – ID of socket this message is addressed to
- **sender** (*str*) – ID of socket where this message originates
- **key** (*str*) – Type of message, used to select a listen method to process it
- **value** – Body of message, can be any type but must be JSON serializable.
- **timestamp** (*str*) – Timestamp of message creation
- **ttl** (*int*) – Time-To-Live, each message is sent this many times at max, each send decrements ttl.
- **flags** (*dict*) – Flags determine additional message behavior. If a flag has no value associated with it, add it as a key with `None` as the value (eg. `self.flags['MINPRINT'] = None`), the value doesn't matter.
  - MINPRINT - don't print the value in logs (eg. when a large array is being sent)
  - NOPEAT - sender will not seek, and recipients will not attempt to send message receipt confirmations
  - NOLOG - don't log this message! for streaming, or other instances where the constant printing of the logger is performance prohibitive

#### Parameters

- `*args`
- `**kwargs`

#### Methods:

---

<code>__getitem__(key)</code>	<b>Parameters</b> <code>key</code>
<hr/>	
<code>__setitem__(key, value)</code>	<b>Parameters</b> <ul style="list-style-type: none"><li>• <code>key</code></li></ul>
<hr/>	
<code>_serialize_numpy(array)</code>	Serialize a numpy array for sending over the wire
<code>expand()</code>	Don't decompress numpy arrays by default for faster IO, explicitly expand them when needed
<hr/>	
<code>__delitem__(key)</code>	<b>Parameters</b> <code>key</code>

---

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Table 12 – continued from previous page

<code>__contains__(key)</code>	<b>Parameters</b> <code>key</code>
<code>get_timestamp()</code>	Get a Python timestamp
<code>validate()</code>	Checks if <i>id</i> , <i>to</i> , <i>sender</i> , and <i>key</i> are all defined.
<code>serialize()</code>	Serializes all attributes in <code>__dict__</code> using json.
<code>__getitem__(key)</code>	
<b>Parameters</b> <code>key</code>	
<code>__setitem__(key, value)</code>	
<b>Parameters</b>	
• <code>key</code>	
• <code>value</code>	
<code>_serialize_numpy(array)</code>	Serialize a numpy array for sending over the wire
<b>Parameters</b> <code>array</code>	
Returns:	
<code>expand()</code>	Don't decompress numpy arrays by default for faster IO, explicitly expand them when needed
<b>Returns</b>	
<code>__delitem__(key)</code>	
<b>Parameters</b> <code>key</code>	
<code>__contains__(key)</code>	
<b>Parameters</b> <code>key</code>	
<code>get_timestamp()</code>	Get a Python timestamp
<b>Returns</b>	Isoformatted timestamp from datetime
<b>Return type</b>	<code>str</code>
<code>validate()</code>	Checks if <i>id</i> , <i>to</i> , <i>sender</i> , and <i>key</i> are all defined.
<b>Returns</b>	Does message have all required attributes set?
<b>Return type</b>	<code>bool</code> (True)
<code>serialize()</code>	Serializes all attributes in <code>__dict__</code> using json.
<b>Returns</b>	JSON serialized message.
<b>Return type</b>	<code>str</code>



## 14.1 managers

This is a scrappy first draft of a stimulus manager that will be built out to incorporate arbitrary stimulus logic. For now you can subclass *Stim\_Manager* and redefine *next\_stim*

---

**Todo:** Make this more general, for more than just sounds.

---

### Functions:

---

`init_manager(stim)`

---

### Classes:

---

<code>Stim_Manager([stim])</code>	Yield sounds according to some set of rules.
<code>Proportional(stim)</code>	Present groups of stimuli with a particular frequency.
<code>Bias_Correction([mode, thresh, window])</code>	Basic Bias correction module.

---

`init_manager(stim)`

`class Stim_Manager(stim=None)`

Bases: `object`

Yield sounds according to some set of rules.

Currently implemented:

- **correction trials** - If a subject continually answers to one side incorrectly, keep the correct answer on the other side until they answer in that direction
- **bias correction** - above some bias threshold, skew the correct answers to the less-responded side

### Variables

- **stimuli** (*dict*) – Dictionary of instantiated stimuli like:

`{ 'L': [Tone1, Tone2, ...], 'R': [Tone3, Tone4, ...] }`

- **target** ('L', 'R') – What is the correct port?
- **distractor** ('L', 'R') – What is the incorrect port?

- **response** ('L', 'R') – What was the last response?
- **correct** (0, 1) – Was the last response correct?
- **last\_stim** – What was the last stim? (one of *self.stimuli*)
- **correction** (*bool*) – Are we doing correction trials?
- **correction\_trial** (*bool*) – Is this a correction trial?
- **last\_was\_correction** (*bool*) – Was the last trial a correction trial?
- **correction\_pct** (*float*) – proportion of trials that are correction trials
- **bias** – False, or a bias correction mode.

**Parameters** *stim* (*dict*) –

Dictionary describing sound stimuli, in a format like:

```
{
  'L': [{ 'type': 'tone', ... }, { ... } ],
  'R': [{ 'type': 'tone', ... }, { ... } ]
}
```

**Methods:**

<code>do_correction([correction_pct])</code>	Called to set correction trials to True and correction percent.
<code>do_bias(**kwargs)</code>	Instantiate a <i>Bias_Correction</i> module
<code>init_sounds(sound_dict)</code>	Instantiate sound objects, using the 'type' value to choose an object from <code>autopilot.get('sound')</code> .
<code>set_triggers(trig_fn)</code>	Give a callback function to all of our stimuli for when the stimulus ends.
<code>make_punishment(type, duration)</code>	

**Warning:**  
Not  
Im-  
ple-  
mented

---

`play_punishment()`

**Warning:**  
Not  
Im-  
ple-  
mented

<code>next_stim()</code>	Compute and return the next stimulus
<code>compute_correction()</code>	If <i>self.correction</i> is true, compute correction trial logic during <i>next_stim</i> .

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Table 3 – continued from previous page

<code>update(response, correct)</code>	At the end of a trial, update the status of our internal variables with the outcome of the trial.
<code>end()</code>	End all of our stim.

**do\_correction**(*correction\_pct=0.5*)

Called to set correction trials to True and correction percent.

**Parameters** **correction\_pct** (*float*) – Proportion of trials that should randomly be set to be correction trials.

**do\_bias**(*\*\*kwargs*)

Instantiate a *Bias\_Correction* module

**Parameters** **kwargs** – parameters to initialize *Bias\_Correction* with.

**init\_sounds**(*sound\_dict*)

Instantiate sound objects, using the ‘type’ value to choose an object from `autopilot.get('sound')`.

**Parameters** **sound\_dict** (*dict*) –

a dictionary like:: { ‘L’: [{‘type’:‘tone’,...},{...}], ‘R’: [{‘type’:‘tone’,...},{...}] }

**set\_triggers**(*trig\_fn*)

Give a callback function to all of our stimuli for when the stimulus ends.

---

**Note:** Stimuli need a *set\_trigger* method.

---

**Parameters** **trig\_fn** (*callable*) – A function to be given to stimuli via *set\_trigger*

**make\_punishment**(*type, duration*)

**Warning:** Not Implemented

**Parameters**

- **type**
- **duration**

**play\_punishment**()

**Warning:** Not Implemented

**next\_stim**()

Compute and return the next stimulus

If we are doing correction trials, compute that.

Same thing with bias correction.

Otherwise, randomly select a stimulus to present.

**Returns** (‘L’/‘R’ Target, ‘L’/‘R’ distractor, Stimulus to present)

**compute\_correction()**

If *self.correction* is true, compute correction trial logic during *next\_stim*.

- If the last trial was a correction trial and the response to it wasn't correct, return True
- If the last trial was a correction trial and the response was correct, return False
- If the last trial as not a correction trial, but a randomly generated float is less than *correction\_pct*, return True.

**Returns** whether this trial should be a correction trial.

**Return type** `bool`

**update(response, correct)**

At the end of a trial, update the status of our internal variables with the outcome of the trial.

**Parameters**

- **response** ('L', 'R') – How the subject responded
- **correct** (0, 1) – Whether the response was correct.

**end()**

End all of our stim. Stim should have an *.end()* method of their own

**class Proportional(stim)**

Bases: `autopilot.stim.managers.Stim_Manager`

Present groups of stimuli with a particular frequency.

Frequencies do not need to add up to 1, groups will be selected with the frequency (frequency)/(sum(frequencies)).

**Parameters** **stim** (*dict*) – Dictionary with the structure:

```
{'manager': 'proportional',
 'type': 'sounds',
 'groups': (
     {'name': 'group_name',
      'frequency': 0.2,
      'sounds': {
          'L': [{Tone1_params}, {Tone2_params}...],
          'R': [{Tone3_params}, {Tone4_params}...]}
     },
     {'name': 'second_group',
      'frequency': 0.8,
      'sounds': {
          'L': [{Tone1_params}, {Tone2_params}...],
          'R': [{Tone3_params}, {Tone4_params}...]}
     }
 )
}
```

**Variables**

- **stimuli** (*dict*) – A dictionary of stimuli organized into groups
- **groups** (*dict*) – A dictionary mapping group names to frequencies



**Parameters** `stim` (*dict*) –

Dictionary describing sound stimuli, in a format like:

```
{
  'L': [{ 'type': 'tone', ... }, { ... }],
  'R': [{ 'type': 'tone', ... }, { ... }]
}
```

**Methods:**

<code>init_sounds_grouped(sound_stim)</code>	Instantiate sound objects similarly to <a href="#">Stim_Manager</a> , just organizes them into groups.
<code>init_sounds_individual(sound_stim)</code>	Initialize sounds with individually set presentation frequencies.
<code>store_groups(stim)</code>	store groups and frequencies
<code>set_triggers(trig_fn)</code>	Give a callback function to all of our stimuli for when the stimulus ends.
<code>next_stim()</code>	Compute and return the next stimulus

**`init_sounds_grouped(sound_stim)`**

Instantiate sound objects similarly to [Stim\\_Manager](#), just organizes them into groups.

**Parameters** `sound_stim` (*tuple, list*) – an iterator like:

```
(
  { 'name': 'group_name',
    'frequency': 0.2,
    'sounds': {
      'L': [{Tone1_params}, {Tone2_params}...],
      'R': [{Tone3_params}, {Tone4_params}...]
    }
  },
  { 'name': 'second_group',
    'frequency': 0.8,
    'sounds': {
      'L': [{Tone1_params}, {Tone2_params}...],
      'R': [{Tone3_params}, {Tone4_params}...]
    }
  }
})
```

**`init_sounds_individual(sound_stim)`**

Initialize sounds with individually set presentation frequencies.

---

**Todo:** This method reflects the need for managers to have a unified schema, which will be built in a future release of Autopilot.

---

**Parameters** `sound_stim` (*dict*) – Dictionary of { 'side': [sound\_params] } to generate sound stimuli

Returns:

**`store_groups(stim)`**

store groups and frequencies

**set\_triggers**(*trig\_fn*)

Give a callback function to all of our stimuli for when the stimulus ends.

---

**Note:** Stimuli need a *set\_trigger* method.

---

**Parameters** *trig\_fn* (*callable*) – A function to be given to stimuli via *set\_trigger*

**next\_stim**()

Compute and return the next stimulus

If we are doing correction trials, compute that.

Same thing with bias correction.

Otherwise, randomly select a stimulus to present, weighted by its group frequency.

**Returns** ('L'/'R' Target, 'L'/'R' distractor, Stimulus to present)

**class** **Bias\_Correction**(*mode*='thresholded\_linear', *thresh*=0.2, *window*=100)

Bases: `object`

Basic Bias correction module. Modifies the threshold of random stimulus choice based on history of biased responses.

**Variables**

- **responses** (`collections.deque`) – History of prior responses
- **targets** (`collections.deque`) – History of prior targets.

**Parameters**

- **mode** – One of the following:
  - **'thresholded linear'** [above some threshold, do linear bias correction] eg. if response rate 65% left, make correct be right 65% of the time
- **thresh** (*float*) – threshold above chance, ie. 0.2 means has to be 70% biased in window
- **window** (*int*) – number of trials to calculate bias over

**Methods:**

<code>next_bias()</code>	Compute the next bias depending on <i>self.mode</i>
<code>thresholded_linear()</code>	If we are above the threshold, linearly correct the rate of presentation to favor the rarely responded side.
<code>update(response, target)</code>	Store some new response and target values

**next\_bias**()

Compute the next bias depending on *self.mode*

**Returns** Some threshold *Stim\_Manager* uses to decide left vs right.

**Return type** `float`

**thresholded\_linear**()

If we are above the threshold, linearly correct the rate of presentation to favor the rarely responded side.

eg. if response rate 65% left, make correct be right 65% of the time

**Returns** 0.5-bias, where bias is the difference between the mean response and mean target.

**Return type** `float`

**update**(*response*, *target*)

Store some new response and target values

**Parameters**

- **response** ('R', 'L') – Which side the subject responded to
- **target** ('R', 'L') – The correct side.

## 14.2 sound

Module for generating and playing sounds.

This module contains the following files:

`sounds.py` : Defines classes for generating sounds  
`jackclient.py` : Define the interface to the jack client  
`pyoserver.py` : Defines the interface to the pyo server

The use of `pyoserver` is discouraged in favor of `jackclient`. This is controlled by the pref `AUDIOSERVER`.

### 14.2.1 jackclient

Client that dumps samples directly to the jack client with the `jack` package.

**Data:**

<code>SERVER</code>	After initializing, JackClient will register itself with this variable.
<code>FS</code>	Sampling rate of the active server
<code>BLOCKSIZE</code>	Blocksize, or the amount of samples processed by jack per each <code>JackClient.process()</code> call.
<code>QUEUE</code>	Queue to be loaded with frames of <code>BLOCKSIZE</code> audio.
<code>Q_LOCK</code>	Lock that enforces a single writer to the <code>QUEUE</code> at a time.
<code>CONTINUOUS</code>	Event that (when set) signals the sound server should play some sound continuously rather than remain silent by default (eg.
<code>CONTINUOUS_QUEUE</code>	Queue that
<code>CONTINUOUS_LOOP</code>	Event flag that is set when frames dropped into the <code>CONTINUOUS_QUEUE</code> should be looped (eg.

**Classes:**

<code>JackClient</code> ([name])	Client that dumps frames of audio directly into a running jackd client.
----------------------------------	---

**SERVER = None**

After initializing, JackClient will register itself with this variable.

**Type** `JackClient`

**FS = 192000**

Sampling rate of the active server

Type `int`

**BLOCKSIZE = 1024**

Blocksize, or the amount of samples processed by jack per each `JackClient.process()` call.

Type `int`

**QUEUE = None**

Queue to be loaded with frames of BLOCKSIZE audio.

Type `multiprocessing.Queue`

**PLAY = <multiprocessing.synchronize.Event object at 0x7f6f7efdaf10>**

Event used to trigger loading samples from *QUEUE*, ie. playing.

Type `multiprocessing.Event`

**STOP = <multiprocessing.synchronize.Event object at 0x7f6f2a9b5890>**

Event that is triggered on the end of buffered audio.

---

**Note:** NOT an event used to stop audio.

---

Type `multiprocessing.Event`

**Q\_LOCK = None**

Lock that enforces a single writer to the *QUEUE* at a time.

Type `multiprocessing.Lock`

**CONTINUOUS = None**

Event that (when set) signals the sound server should play some sound continuously rather than remain silent by default (eg. play a background sound).

Type `multiprocessing.Event`

**CONTINUOUS\_QUEUE = None**

Queue that

Type `multiprocessing.Queue`

**CONTINUOUS\_LOOP = None**

Event flag that is set when frames dropped into the CONTINUOUS\_QUEUE should be looped (eg. in the case of stationary background noise), otherwise they are played and then discarded (ie. the sound is continuously generating and submitting samples)

Type `multiprocessing.Event`

**class JackClient**(*name='jack\_client'*)

Bases: `multiprocessing.context.Process`

Client that dumps frames of audio directly into a running jackd client.

When first initialized, sets module level variables above.

#### Variables

- **name** (*str*) – name of client, default “jack\_client”
- **q** (*Queue*) – Queue that stores buffered frames of audio
- **q\_lock** (*Lock*) – Lock that manages access to the Queue

- **play\_evt** (`multiprocessing.Event`) – Event used to trigger loading samples from *QUEUE*, ie. playing.
- **stop\_evt** (`multiprocessing.Event`) – Event that is triggered on the end of buffered audio.
- **quit\_evt** (`multiprocessing.Event`) – Event that causes the process to be terminated.
- **client** (`jack.Client`) – Client to interface with jackd
- **blocksize** (`int`) – The blocksize - ie. samples processed per `JackClient.process()` call.
- **fs** (`int`) – Sampling rate of client
- **zero\_arr** (`numpy.ndarray`) – cached array of zeroes used to fill jackd pipe when not processing audio.
- **continuous\_cycle** (`itertools.cycle`) – cycle of frames used for continuous sounds
- **mono\_output** (`bool`) – True or False depending on if the number of output channels is 1 or >1, respectively. detected and set in `JackClient.boot_server()` , initialized to True (which is hopefully harmless)

#### Parameters name

#### Methods:

<code>boot_server()</code>	Called by <code>JackClient.run()</code> to boot the server upon starting the process.
<code>run()</code>	Start the process, boot the server, start processing frames and wait for the end.
<code>quit()</code>	Set the <code>JackClient.quit_evt</code>
<code>process(frames)</code>	Process a frame of audio.
<code>write_to_outputs(data)</code>	Write the sound in <i>data</i> to the output(s).

#### `boot_server()`

Called by `JackClient.run()` to boot the server upon starting the process.

Activates the client and connects it to the physical speaker outputs as determined by `prefs.get('OUTCHANNELS')`.

This is the interpretation of OUTCHANNELS: \* empty string

‘mono’ audio: the same sound is always played to all channels. Connect a single virtual output to every physical channel. If multi-channel sound is provided, raise an error.

- **a single int (example: J)** This is equivalent to [J]. The first virtual output will be connected to physical channel J. Note this is NOT the same as ‘mono’, because only one speaker plays, instead of all speakers.
- **a list (example: [I, J])** The first virtual output will be connected to physical channel I. The second virtual output will be connected to physical channel J. And so on. If 1-dimensional sound is provided, play the same to all speakers (like mono mode). If multi-channel sound is provided and the number of channels is different from the length of this list, raise an error.

`jack.Client`s can’t be kept alive, so this must be called just before processing sample starts.

#### `run()`

Start the process, boot the server, start processing frames and wait for the end.

**quit()**

Set the `JackClient.quit_evt`

**process(*frames*)**

Process a frame of audio.

If the `JackClient.play_evt` is not set, fill port buffers with zeroes.

Otherwise, pull frames of audio from the `JackClient.q` until it's empty.

When it's empty, set the `JackClient.stop_evt` and clear the `JackClient.play_evt`.

**Parameters** `frames` – number of frames (samples) to be processed. unused. passed by jack client

**write\_to\_outports(*data*)**

Write the sound in *data* to the output(s).

**If `self.mono_output`:**

**If `data` is 1-dimensional:** Write that data to the single output, which goes to all speakers.

Otherwise, raise an error.

**If not `self.mono_output`:**

**If `data` is 1-dimensional:** Write that data to every output

**If `data` is 2-dimensional:** Write one column to each output, raising an error if there is a different number of columns than outputs.

## 14.2.2 pyoserver

**Functions:**

---

<code>pyo_server([debug])</code>	Returns a booted and started pyo audio server
----------------------------------	---

---

**pyo\_server(*debug=False*)**

Returns a booted and started pyo audio server

<b>Warning:</b> Use of pyo is generally discouraged due to dropout issues and the general opacity of the module.
--

**Parameters** `debug (bool)` – If true, setVerbosity of pyo server to 8.

## 14.2.3 sounds

This module defines classes to generate different sounds.

These classes are currently implemented: \* Tone : a sinusoidal pure tone \* Noise : a burst of white noise \* File : read from a file \* Speech \* Gap

The behavior of this module depends on `prefs.get('AUDIOSERVER')`. \* If this is 'jack', or True:

Then import jack, define `Jack_Sound`, and all sounds inherit from that.

- **If this is 'pyo':** Then import pyo, define `PyoSound`, and all sounds inherit from that.
- **If this is 'docs':** Then import both jack and pyo, define both `Jack_Sound` and `PyoSound`, and all sounds inherit from *object*.

- **Otherwise:** Then do not import jack or pyo, or define either Jack\_Sound or PyoSound, and all sounds inherit from *object*.

---

**Todo:** Implement sound level and filter calibration

---

**Classes:**

<code>Pyo_Sound()</code>	Metaclass for pyo sound objects.
<code>Jack_Sound()</code>	Base class for sounds that use the <i>JackClient</i> audio server.
<code>Tone(frequency, duration[, amplitude])</code>	The Humble Sine Wave
<code>Noise(duration[, amplitude, channel])</code>	Generates a white noise burst with specified parameters
<code>File(path[, amplitude])</code>	A .wav file.
<code>Gap(duration, **kwargs)</code>	A silent sound that does not pad its final chunk -- used for creating precise silent gaps in a continuous noise.

**Data:**

<code>STRING_PARAMS</code>	These parameters should be given string columns rather than float columns.
----------------------------	--

**Functions:**

<code>int_to_float(audio)</code>	Convert 16 or 32 bit integer audio to 32 bit float.
----------------------------------	---

**class Pyo\_Sound**

Bases: `object`

Metaclass for pyo sound objects.

---

**Note:** Use of pyo is generally discouraged due to dropout issues and the general opacity of the module. As such this object is intentionally left undocumented.

---

**Methods:**

<code>play()</code>	
<code>table_wrap(audio[, duration])</code>	Records a PyoAudio generator into a sound table, returns a tableread object which can play the audio with <code>.out()</code>
<code>set_trigger(trig_fn)</code>	

**Parameters** `trig_fn`

**play()**

**table\_wrap**(*audio*, *duration=None*)

Records a PyoAudio generator into a sound table, returns a tableread object which can play the audio with `.out()`

**Parameters**

- **audio**
- **duration**

**set\_trigger**(*trig\_fn*)

Parameters **trig\_fn**

**class** **Jack\_Sound**

Bases: **object**

Base class for sounds that use the *JackClient* audio server.

**Variables**

- **PARAMS** (*list*) – List of strings of parameters that need to be defined for this sound
- **type** (*str*) – Human readable name of sound type
- **duration** (*float*) – Duration of sound in ms
- **amplitude** (*float*) – Amplitude of sound as proportion of 1 (eg 0.5 is half amplitude)
- **table** (*numpy.ndarray*) – A Numpy array of samples
- **chunks** (*list*) – table split up into chunks of *BLOCKSIZE*
- **trigger** (*callable*) – A function that is called when the sound completes
- **nsamples** (*int*) – Number of samples in the sound
- **padded** (*bool*) – Whether the sound had to be padded with zeros when split into chunks (ie. sound duration was not a multiple of *BLOCKSIZE*).
- **fs** (*int*) – sampling rate of client from *jackclient.FS*
- **blocksize** (*int*) – blocksize of client from *jackclient.BLOCKSIZE*
- **server** (*Jack\_Client*) – Current Jack Client
- **q** (*multiprocessing.Queue*) – Audio Buffer queue from *jackclient.QUEUE*
- **q\_lock** (*multiprocessing.Lock*) – Audio Buffer lock from *jackclient.Q\_LOCK*
- **play\_evt** (*multiprocessing.Event*) – play event from *jackclient.PLAY*
- **stop\_evt** (*multiprocessing.Event*) – stop event from *jackclient.STOP*
- **buffered** (*bool*) – has this sound been dumped into the q ?
- **buffered\_continuous** (*bool*) – Has the sound been dumped into the continuous\_q?

Initialize a new **Jack\_Sound**

This sets sound-specific parameters to None, set jack-specific parameters to their equivalents in *jackclient*, initializes some other flags and a logger.

**Attributes:**

<i>PARAMS</i>	list of strings of parameters to be defined
<i>type</i>	string human readable name of sound
<i>server_type</i>	type of server, always 'jack' for <i>Jack_Sound</i> s.

**Methods:**



<code>chunk([pad])</code>	Split our <i>table</i> up into a list of <code>Jack_Sound.blocksize</code> chunks.
<code>set_trigger(trig_fn)</code>	Set a trigger function to be called when the <code>stop_evt</code> is set.
<code>wait_trigger()</code>	Wait for the <code>stop_evt</code> trigger to be set for at least a second after the sound should have ended.
<code>get_nsamples()</code>	given our <code>fs</code> and <code>duration</code> , how many samples do we need?
<code>quantize_duration([ceiling])</code>	Extend or shorten a sound so that it is a multiple of <code>jackclient.BLOCKSIZE</code>
<code>buffer()</code>	Dump chunks into the sound queue.
<code>buffer_continuous()</code>	Dump chunks into the continuous sound queue for looping.
<code>play()</code>	Play ourselves.
<code>play_continuous([loop])</code>	Play the sound continuously.
<code>stop_continuous()</code>	Stop playing a continuous sound
<code>end()</code>	Release any resources held by this sound

**PARAMS** = []  
list of strings of parameters to be defined

Type `list`

**type** = `None`  
string human readable name of sound

Type `str`

**server\_type** = `'jack'`  
type of server, always 'jack' for *Jack\_Sound* s.

Type `str`

**chunk**(*pad=True*)  
Split our *table* up into a list of `Jack_Sound.blocksize` chunks.

Parameters

- **pad** (*bool*) – If the sound is not evenly divisible into chunks,
- **pad with zeros** (*True, default*)
- **with its continuous sound**

**set\_trigger**(*trig\_fn*)  
Set a trigger function to be called when the `stop_evt` is set.

Parameters **trig\_fn** (*callable*) – Some callable

**wait\_trigger**()  
Wait for the `stop_evt` trigger to be set for at least a second after the sound should have ended.  
Call the trigger when the event is set.

**get\_nsamples**()  
given our `fs` and `duration`, how many samples do we need?  
literally:

```
np.ceil((self.duration/1000.)*self.fs).astype(np.int)
```

**quantize\_duration**(*ceiling=True*)

Extend or shorten a sound so that it is a multiple of `jackclient.BLOCKSIZE`

**Parameters** **ceiling** (*bool*) – If true, extend duration, otherwise decrease duration.

**buffer**()

Dump chunks into the sound queue.

After the last chunk, a *None* is put into the queue. This tells the jack server that the sound is over and that it should clear the play flag.

**buffer\_continuous**()

Dump chunks into the continuous sound queue for looping.

Continuous sounds should always have full frames - ie. the number of samples in a sound should be a multiple of `jackclient.BLOCKSIZE`.

This method will call `quantize_duration()` to force duration such that the sound has full frames.

An exception will be raised if the sound has been padded.

**play**()

Play ourselves.

If we're not buffered, be buffered.

Otherwise, set the play event and clear the stop event.

If we have a trigger, set a Thread to wait on it.

**play\_continuous**(*loop=True*)

Play the sound continuously.

Sound will be paused if another sound has its 'play' method called.

Currently - only looping is implemented: the full sound is loaded by the jack client and repeated indefinitely.

In the future, sound generation methods will be refactored as python generators so sounds can be continuously generated and played.

**Parameters** **loop** (*bool*) – whether the sound will be stored by the jack client and looped (True), or whether the sound will be continuously streamed (False, not implemented)

Returns:

todo:

merge into single play method that changes behavior **if** continuous **or not**

**stop\_continuous**()

Stop playing a continuous sound

Should be merged into a general stop method

**end**()

Release any resources held by this sound

**class Tone**(*frequency, duration, amplitude=0.01, \*\*kwargs*)

Bases: `autopilot.stim.stim.Stim`

The Humble Sine Wave

**Parameters**

- **frequency** (*float*) – frequency of sin in Hz
- **duration** (*float*) – duration of the sin in ms

- **amplitude** (*float*) – amplitude of the sound as a proportion of 1.
- **\*\*kwargs** – extraneous parameters that might come along with instantiating us

**Attributes:**

---

*PARAMS*

---

---

*type*

---

**Methods:**

<i>init_sound()</i>	Create a sine wave table using pyo or numpy, depending on the server type.
---------------------	--

---

**PARAMS** = ['frequency', 'duration', 'amplitude']**type** = 'Tone'**init\_sound()**

Create a sine wave table using pyo or numpy, depending on the server type.

**class Noise**(duration, amplitude=0.01, channel=None, \*\*kwargs)

Bases: autopilot.stim.stim.Stim

Generates a white noise burst with specified parameters

The *type* attribute is always “Noise”.

Initialize a new white noise burst with specified parameters.

The sound itself is stored as the attribute *self.table*. This can be 1-dimensional or 2-dimensional, depending on *channel*. If it is 2-dimensional, then each channel is a column.**Parameters**

- **duration** (*float*) – duration of the noise
- **amplitude** (*float*) – amplitude of the sound as a proportion of 1.
- **channel** (*int or None*) – which channel should be used If 0, play noise from the first channel If 1, play noise from the second channel If None, send the same information to all channels (“mono”)
- **\*\*kwargs** – extraneous parameters that might come along with instantiating us

**Attributes:**

---

*PARAMS*

---

---

*type*

---

**Methods:**

<i>init_sound()</i>	Defines <i>self.table</i> , the waveform that is played.
---------------------	--

---

**PARAMS** = ['duration', 'amplitude', 'channel']

```
type = 'Noise'
```

```
init_sound()
```

Defines *self.table*, the waveform that is played.

The way this is generated depends on *self.server\_type*, because parameters like the sampling rate cannot be known otherwise.

The sound is generated and then it is “chunked” (zero-padded and divided into chunks). Finally *self.initialized* is set True.

```
class File(path, amplitude=0.01, **kwargs)
```

Bases: `autopilot.stim.stim.Stim`

A .wav file.

---

**Todo:** Generalize this to other audio types if needed.

---

#### Parameters

- **path** (*str*) – Path to a .wav file relative to the *prefs.get('SOUNDDIR')*
- **amplitude** (*float*) – amplitude of the sound as a proportion of 1.
- **\*\*kwargs** – extraneous parameters that might come along with instantiating us

#### Attributes:

---

*PARAMS*

---

*type*

---

#### Methods:

---

<i>init_sound()</i>	Load the wavfile with <code>scipy.io.wavfile</code> , converting int to float as needed.
---------------------	--

---

```
PARAMS = ['path', 'amplitude']
```

```
type = 'File'
```

```
init_sound()
```

Load the wavfile with `scipy.io.wavfile`, converting int to float as needed.

Create a sound table, resampling sound if needed.

```
class Gap(duration, **kwargs)
```

Bases: `autopilot.stim.stim.Stim`

A silent sound that does not pad its final chunk – used for creating precise silent gaps in a continuous noise.

**Parameters** **duration** (*float*) – duration of gap in ms

**Variables** **gap\_zero** (*bool*) – True if duration is zero, effectively do nothing on play.

#### Attributes:

---

*type*

---

*PARAMS*

---

#### Methods:

---

*init\_sound()* Create and chunk an array of zeros according to `Gap.duration`

---

*chunk*(*[pad]*) If gap is not `duration == 0`, call parent `chunk`.

---

*buffer()*

---

*play()*

---

**type** = 'Gap'

**PARAMS** = ['duration']

**init\_sound()**

Create and chunk an array of zeros according to `Gap.duration`

**chunk**(*pad=False*)

If gap is not `duration == 0`, call parent `chunk`. :Parameters: **pad** (*bool*) – unused, passed to parent `chunk`

**buffer()**

**play()**

**STRING\_PARAMS** = ['path', 'type']

These parameters should be given string columns rather than float columns.

Bother Jonny to do this better bc it's really bad.

**int\_to\_float**(*audio*)

Convert 16 or 32 bit integer audio to 32 bit float.

**Parameters** **audio** (`numpy.ndarray`) – a numpy array of audio

**Returns** Audio that has been rescaled and converted to a 32 bit float.

**Return type** `numpy.ndarray`



## TASKS

### 15.1 task

Classes:

<code>Task(*args, **kwargs)</code>	Generic Task metaclass
------------------------------------	------------------------

**class** `Task(*args, **kwargs)`

Bases: `object`

Generic Task metaclass

#### Variables

- **PARAMS** (`collections.OrderedDict`) – Params to define task, like:

```
PARAMS = odict()
PARAMS['reward'] = {'tag': 'Reward Duration (ms)',
                   'type': 'int'}
PARAMS['req_reward'] = {'tag': 'Request Rewards',
                       'type': 'bool'}
```

- **HARDWARE** (`dict`) – dict for necessary hardware, like:

```
HARDWARE = {
    'POKES': {
        'L': hardware.Beambreak, ...
    },
    'PORTS': {
        'L': hardware.Solenoid, ...
    }
}
```

- **PLOT** (`dict`) – Dict of plotting parameters, like:

```
PLOT = {
    'data': {
        'target' : 'point',
        'response' : 'segment',
        'correct' : 'rollmean'
    },
    'chance_bar' : True, # Draw a red bar at 50%
```

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```
'roll_window' : 50 # number of trials to roll window over
}
```

- **Trial\_Data** (tables.IsDescription) – Data table description, like:

```
class TrialData(tables.IsDescription):
    trial_num = tables.Int32Col()
    target = tables.StringCol(1)
    response = tables.StringCol(1)
    correct = tables.Int32Col()
    correction = tables.Int32Col()
    RQ_timestamp = tables.StringCol(26)
    DC_timestamp = tables.StringCol(26)
    bailed = tables.Int32Col()
```

- **STAGE\_NAMES** (*list*) – List of stage method names
- **stage\_block** (*threading.Event*) – Signal when task stages complete.
- **punish\_stim** (*bool*) – Do a punishment stimulus
- **stages** (*iterator*) – Some generator or iterator that continuously returns the next stage method of a trial
- **triggers** (*dict*) – Some mapping of some pin to callback methods
- **pins** (*dict*) – Dict to store references to hardware
- **pin\_id** (*dict*) – Reverse dictionary, pin numbers back to pin letters.
- **punish\_block** (*threading.Event*) – Event to mark when punishment is occurring
- **logger** (*logging.Logger*) – gets the ‘main’ logger for now.

#### Parameters

- **subject** (*str*) – Name of subject running the task
- **current\_trial** (*int*) – Current trial number, default 0
- **\*args** ()
- **\*\*kwargs** ()

#### Attributes:

---

PARAMS

---

HARDWARE

---

STAGE\_NAMES

---

PLOT

---

#### Classes:



---

TrialData()

---

### Methods:

<code>init_hardware()</code>	Use the <code>HARDWARE</code> dict that specifies what we need to run the task alongside the <code>HARDWARE</code> subdict in <code>prefs</code> to tell us how they're plugged in to the pi
<code>set_reward([vol, duration, port])</code>	Set the reward value for each of the 'PORTS'.
<code>handle_trigger(pin[, level, tick])</code>	All GPIO triggers call this function with the pin number, level (high, low), and ticks since booting pigpio.
<code>set_leds([color_dict])</code>	Set the color of all LEDs at once.
<code>flash_leds()</code>	flash lights for <code>punish_dir</code>
<code>end()</code>	Release all hardware objects

`PARAMS = OrderedDict()`

`HARDWARE = {}`

`STAGE_NAMES = []`

`PLOT = {}`

`class TrialData`

Bases: `tables.description.IsDescription`

### Attributes:

---

`columns`


---

```
columns = { 'session': Int32Col(shape=(), dflt=0, pos=None), 'trial_num':
Int32Col(shape=(), dflt=0, pos=None)}
```

`init_hardware()`

Use the `HARDWARE` dict that specifies what we need to run the task alongside the `HARDWARE` subdict in `prefs` to tell us how they're plugged in to the pi

Instantiate the hardware, assign it `Task.handle_trigger()` as a callback if it is a trigger.

`set_reward(vol=None, duration=None, port=None)`

Set the reward value for each of the 'PORTS'.

### Parameters

- **vol** (*float, int*) – Volume of reward in uL
- **duration** (*float*) – Duration to open port in ms
- **port** (*None, Port\_ID*) – If *None*, set everything in 'PORTS', otherwise only set *port*

`handle_trigger(pin, level=None, tick=None)`

All GPIO triggers call this function with the pin number, level (high, low), and ticks since booting pigpio.

Calls any trigger assigned to the pin in `self.triggers`, unless during punishment (returns).

### Parameters

- **pin** (*int*) – BCM Pin number
- **level** (*bool*) – True, False high/low
- **tick** (*int*) – ticks since booting pigpio

**set\_leds**(*color\_dict=None*)

Set the color of all LEDs at once.

**Parameters** **color\_dict** (*dict*) – If None, turn LEDs off, otherwise like:

{‘pin’: [R,G,B], ‘pin2: [R,G,B]}

**flash\_leds**()

flash lights for punish\_dir

**end**()

Release all hardware objects

## 15.2 children

Sub-tasks that serve as children to other tasks.

---

**Note:** The Child agent will be formalized in an upcoming release, until then these classes remain relatively undocumented as their design will likely change.

---

### Classes:

Child()	Just a placeholder class for now to work with <code>autopilot.get()</code>
Wheel_Child([stage_block, fs, thresh])	
Video_Child([cams, stage_block, start_now])	<b>Parameters</b> <b>cams</b> ( <i>dict, list</i> ) --
Transformer(transform[, operation, node_id, ...])	<b>Parameters</b> <ul style="list-style-type: none"><li>• <b>transform</b></li></ul>

### class Child

Bases: `object`

Just a placeholder class for now to work with `autopilot.get()`

### class Wheel\_Child(*stage\_block=None, fs=10, thresh=100, \*\*kwargs*)

Bases: `autopilot.tasks.children.Child`

#### Attributes:

---

STAGE\_NAMES

---

PARAMS

---

continues on next page

Table 7 – continued from previous page

---

HARDWARE

---

**Methods:**


---

noop()

---



---

end()

---

```
STAGE_NAMES = ['collect']
```

```
PARAMS = OrderedDict([ ('fs', {'tag': 'Velocity Reporting Rate (Hz)', 'type': 'int'}), ('thresh', {'tag': 'Distance Threshold', 'type': 'int'})])
```

```
HARDWARE = { 'OUTPUT': <class 'autopilot.hardware.gpio.Digital_Out'>, 'WHEEL': <class 'autopilot.hardware.usb.Wheel'>}
```

```
noop()
```

```
end()
```

```
class Video_Child(cams=None, stage_block=None, start_now=True, **kwargs)
```

Bases: [autopilot.tasks.children.Child](#)

**Parameters** *cams* (*dict*, *list*) –

Should be a dictionary of camera parameters or a list of dicts. Dicts should have, at least:

```
{
    'type': 'string_of_camera_class',
    'name': 'name_of_camera_in_task',
    'param1': 'first_param'
}
```

**Attributes:**


---

PARAMS

---

**Methods:**


---

start()

---



---

stop()

---



---

noop()

---

```
PARAMS = OrderedDict([ ('cams', { 'tag': 'Dictionary of camera params, or list of dicts', 'type': ('dict', 'list')})])
```

```
start()
```

```
stop()
```

**noop()**

```
class Transformer(transform, operation: str = 'trigger', node_id=None, return_id='T', return_ip=None,
                  return_port=None, return_key=None, router_port=None, stage_block=None,
                  value_subset=None, forward_id=None, forward_ip=None, forward_port=None,
                  forward_key=None, forward_what='both', **kwargs)
```

Bases: [autopilot.tasks.children.Child](#)

#### Parameters

- **transform**
- **operation** (*str*) – either
  - “trigger”, where the last transform is a [Condition](#)and a trigger is returned to sender only when the return value of the transformation changes, or \* “stream”, where each result of the transformation is returned to sender
- **return\_id**
- **return\_ip**
- **return\_port**
- **return\_key**
- **router\_port** (*None, int*) – If not *None* (default), spawn the node with a route port to receive
- **stage\_block**
- **value\_subset** (*str*) – Optional - subset a value from from a dict/list sent to [l\\_process\(\)](#)
- **forward\_what** (*str*) – one of ‘input’, ‘output’, or ‘both’ (default) that determines what is forwarded
- **\*\*kwargs**

#### Methods:

---

**noop()**

---

**l\_process**(*value*)

---

**forward**([*input, output*])

---

**noop()**

**l\_process**(*value*)

**forward**(*input=None, output=None*)

## 15.3 free\_water

### Classes:

Free_Water([stage_block, current_trial, ...])	Randomly light up one of the ports, then dispense water when the subject pokes there
---	--

**class Free\_Water**(*stage\_block=None, current\_trial=0, reward=50, allow\_repeat=False, \*\*kwargs*)

Bases: `autopilot.tasks.task.Task`

Randomly light up one of the ports, then dispense water when the subject pokes there

Two stages:

- waiting for response, and
- reporting the response afterwards

#### Variables

- **target** ('L', 'C', 'R') – The correct port
- **trial\_counter** (`itertools.count`) – Counts trials starting from *current\_trial* specified as argument
- **triggers** (*dict*) – Dictionary mapping triggered pins to callable methods.
- **num\_stages** (*int*) – number of stages in task (2)
- **stages** (`itertools.cycle`) – iterator to cycle indefinitely through task stages.

#### Parameters

- **stage\_block** (`threading.Event`) – used to signal to the carrying Pilot that the current trial stage is over
- **current\_trial** (*int*) – If not zero, initial number of *trial\_counter*
- **reward** (*int*) – ms to open solenoids
- **allow\_repeat** (*bool*) – Whether the correct port is allowed to repeat between trials
- **\*\*kwargs**

### Attributes:

---

STAGE\_NAMES

---

PARAMS

---

DATA

---

HARDWARE

---

PLOT

---

### Classes:

---

`TrialData()`

---

**Methods:**

<code>water(*args, **kwargs)</code>	First stage of task - open a port if it's poked.
<code>response()</code>	Just have to alert the Terminal that the current trial has ended and turn off any lights.
<code>end()</code>	When shutting down, release all hardware objects and turn LEDs off.

---

```
STAGE_NAMES = ['water', 'response']
```

```
PARAMS = OrderedDict([ ('reward', {'tag': 'Reward Duration (ms)', 'type': 'int'}),  
  ( 'allow_repeat', {'tag': 'Allow Repeated Ports?', 'type': 'bool'})])
```

```
DATA = { 'target': {'plot': 'target', 'type': 'S1'}, 'timestamp': {'type':  
  'S26'}, 'trial_num': {'type': 'i32'}}
```

```
class TrialData
```

```
    Bases: tables.description.IsDescription
```

**Attributes:**

---

`columns`

---

```
    columns = { 'target': StringCol(itemsize=1, shape=(), dflt=b'', pos=None),  
      'timestamp': StringCol(itemsize=26, shape=(), dflt=b'', pos=None), 'trial_num':  
      Int32Col(shape=(), dflt=0, pos=None)}
```

```
HARDWARE = { 'LEDS': { 'C': <class 'autopilot.hardware.gpio.LED_RGB'>, 'L': <class  
  'autopilot.hardware.gpio.LED_RGB'>, 'R': <class 'autopilot.hardware.gpio.LED_RGB'>},  
  'POKES': { 'C': <class 'autopilot.hardware.gpio.Digital_In'>, 'L': <class  
  'autopilot.hardware.gpio.Digital_In'>, 'R': <class  
  'autopilot.hardware.gpio.Digital_In'>}, 'PORTS': { 'C': <class  
  'autopilot.hardware.gpio.Solenoid'>, 'L': <class  
  'autopilot.hardware.gpio.Solenoid'>, 'R': <class  
  'autopilot.hardware.gpio.Solenoid'>}}
```

```
PLOT = {'data': {'target': 'point'}}
```

```
water(*args, **kwargs)
```

```
    First stage of task - open a port if it's poked.
```

**Returns**

```
    Data dictionary containing:
```

```
'target': ('L', 'C', 'R') - correct response  
'timestamp': isoformatted timestamp  
'trial_num': number of current trial
```

**Return type** `dict`

```
response()
```

```
    Just have to alert the Terminal that the current trial has ended and turn off any lights.
```

**end()**

When shutting down, release all hardware objects and turn LEDs off.

## 15.4 graduation

Object that implement Graduation criteria to move between different tasks in a protocol.

**Classes:**

<code>Graduation()</code>	Base Graduation object.
<code>Accuracy([threshold, window])</code>	Graduate stage based on percent accuracy over some window of trials.
<code>NTrials(n_trials[, current_trial])</code>	Graduate after doing n trials

**class Graduation**

Bases: `object`

Base Graduation object.

All Graduation objects need to populate PARAMS, COLS, and define an *update* method.

**Attributes:**

<code>PARAMS</code>	list of parameters to be defined
<code>COLS</code>	list of any data columns that this object should be given.

**Methods:**

`update(row)`

**Parameters**

`:class:`~tables.tableextension.Row``  
-- Trial row

**PARAMS** = []

list of parameters to be defined

**Type** `list`

**COLS** = []

list of any data columns that this object should be given.

**Type** `list`

**update**(*row*)

**Parameters** `:class:`~tables.tableextension.Row`` – Trial row

**class Accuracy**(*threshold=0.75, window=500, \*\*kwargs*)

Bases: `autopilot.tasks.graduation.Graduation`

Graduate stage based on percent accuracy over some window of trials.

**Parameters**

- **threshold** (*float*) – Accuracy above this threshold triggers graduation
- **window** (*int*) – number of trials to consider in the past.
- **\*\*kwargs** – should have ‘correct’ corresponding to the corrects/incorrects of the past.

**Attributes:**

<i>PARAMS</i>	list of parameters to be defined
<i>COLS</i>	list of any data columns that this object should be given.

**Methods:**

<i>update</i> (row)	Get ‘correct’ from the row object.
---------------------	------------------------------------

**PARAMS** = ['threshold', 'window']

list of parameters to be defined

**Type** *list*

**COLS** = ['correct']

list of any data columns that this object should be given.

**Type** *list*

**update**(row)

Get ‘correct’ from the row object. If this trial puts us over the threshold, return True, else False.

**Parameters** row (Row) – Trial row

**Returns** Did we graduate this time or not?

**Return type** *bool*

**class** NTrials(*n\_trials*, *current\_trial*=0, **\*\*kwargs**)

Bases: *autopilot.tasks.graduation.Graduation*

Graduate after doing n trials

**Variables** **counter** (*itertools.count*) – Counts the trials.

**Parameters**

- **n\_trials** (*int*) – Number of trials to graduate after
- **current\_trial** (*int*) – If not starting from zero, start from here
- **\*\*kwargs**

**Attributes:**

<i>PARAMS</i>	list of parameters to be defined
---------------	----------------------------------

**Methods:**

<i>update</i> (row)	If we're past n_trials in this trial, return True, else False.
---------------------	--

**PARAMS** = ['n\_trials', 'current\_trial']

list of parameters to be defined



Type `list`

**update**(*row*)

If we're past `n_trials` in this trial, return `True`, else `False`.

**Parameters** `row` – ignored

**Returns** Did we graduate or not?

**Return type** `bool`

## 15.5 nafc

Classes:

<code>Nafc([stage_block, stim, reward, ...])</code>	A Two-alternative forced choice task.
---	---------------------------------------

```
class Nafc(stage_block=None, stim=None, reward=50, req_reward=False, punish_stim=False, punish_dur=100,
           correction=False, correction_pct=50.0, bias_mode=False, bias_threshold=20, stim_light=True,
           **kwargs)
```

Bases: `autopilot.tasks.task.Task`

A Two-alternative forced choice task.

(can't have number as first character of class.)

**Stages**

- **request** - compute stimulus, set request trigger in center port.
- **discrim** - respond to input, set reward/punishment triggers on target/distractor ports
- **reinforcement** - deliver reward/punishment, end trial.

**Variables**

- **target** (`"L"`, `"R"`) – Correct response
- **distractor** (`"L"`, `"R"`) – Incorrect response
- **stim** – Current stimulus
- **response** (`"L"`, `"R"`) – Response to discriminand
- **correct** (`0`, `1`) – Current trial was correct/incorrect
- **correction\_trial** (`bool`) – If using correction trials, last trial was a correction trial
- **trial\_counter** (`itertools.count`) – Which trial are we on?
- **discrim\_playing** (`bool`) – Is the stimulus playing?
- **bailed** (`0`, `1`) – Subject answered before stimulus was finished playing.
- **current\_stage** (`int`) – As each stage is reached, update for asynchronous event reference

**Parameters**

- **stage\_block** (`threading.Event`) – Signal when task stages complete.
- **stim** (*dict*) –  
Stimuli like:

```
"sounds": {
    "L": [{"type": "Tone", ...}],
    "R": [{"type": "Tone", ...}]
}
```

- **reward** (*float*) – duration of solenoid open in ms
- **req\_reward** (*bool*) – Whether to give a water reward in the center port for requesting trials
- **punish\_stim** (*bool*) – Do a white noise punishment stimulus
- **punish\_dur** (*float*) – Duration of white noise in ms
- **correction** (*bool*) – Should we do correction trials?
- **correction\_pct** (*float*) – (0-1), What proportion of trials should randomly be correction trials?
- **bias\_mode** (*False*, “*thresholded\_linear*”) – False, or some bias correction type (see [managers.Bias\\_Correction](#))
- **bias\_threshold** (*float*) – If using a bias correction mode, what threshold should bias be corrected for?
- **current\_trial** (*int*) – If starting at nonzero trial number, which?
- **stim\_light** (*bool*) – Should the LED be turned blue while the stimulus is playing?
- **\*\*kwargs**

**Attributes:**

---

STAGE\_NAMES

---

---

PARAMS

---

---

PLOT

---

---

HARDWARE

---

**Classes:**

---

TrialData()

---

**Methods:**

<code>request(*args, **kwargs)</code>	Stage 0: compute stimulus, set request trigger in center port.
<code>discrim(*args, **kwargs)</code>	Stage 1: respond to input, set reward/punishment triggers on target/distractor ports
<code>reinforcement(*args, **kwargs)</code>	Stage 2 - deliver reward/punishment, end trial.
<code>punish()</code>	Flash lights, play punishment sound if set
<code>respond(pin)</code>	Set self.response
<code>stim_start()</code>	mark <code>discrim_playing</code> = true

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Table 27 – continued from previous page

stim_end()	called by stimulus callback
flash_leds()	flash lights for punish_dir

```

STAGE_NAMES = ['request', 'discrim', 'reinforcement']

PARAMS = OrderedDict([ ('reward', {'tag': 'Reward Duration (ms)', 'type': 'int'}),
('req_reward', {'tag': 'Request Rewards', 'type': 'bool'}), ('punish_stim',
{'tag': 'White Noise Punishment', 'type': 'bool'}), ('punish_dur', {'tag':
'Punishment Duration (ms)', 'type': 'int'}), ('correction', {'tag': 'Correction
Trials', 'type': 'bool'}), ('correction_pct', {'depends': {'correction': True},
'tag': '% Correction Trials', 'type': 'int'}), ('bias_mode', {'tag': 'Bias
Correction Mode', 'type': 'list', 'values': { 'None': 0, 'Proportional': 1,
'Thresholded Proportional': 2}}), ('bias_threshold', {'depends': {'bias_mode':
2}, 'tag': 'Bias Correction Threshold (%)', 'type': 'int'}), ('stim', {'tag':
'Sounds', 'type': 'sounds'})])

```

```

PLOT = { 'chance_bar': True, 'data': {'correct': 'rollmean', 'response':
'segment', 'target': 'point'}, 'roll_window': 50}

```

**class TrialData**

Bases: tables.description.IsDescription

Attributes:

---

columns

---

```

columns = { 'DC_timestamp': StringCol(itemsized=26, shape=(), dflt=b'',
pos=None), 'RQ_timestamp': StringCol(itemsized=26, shape=(), dflt=b'',
pos=None), 'bailed': Int32Col(shape=(), dflt=0, pos=None), 'correct':
Int32Col(shape=(), dflt=0, pos=None), 'correction': Int32Col(shape=(), dflt=0,
pos=None), 'response': StringCol(itemsized=1, shape=(), dflt=b'', pos=None),
'target': StringCol(itemsized=1, shape=(), dflt=b'', pos=None), 'trial_num':
Int32Col(shape=(), dflt=0, pos=None)}

```

```

HARDWARE = { 'LEDS': {'C': 'LED_RGB', 'L': 'LED_RGB', 'R': 'LED_RGB'}, 'POKES':
{'C': 'Digital_In', 'L': 'Digital_In', 'R': 'Digital_In'}, 'PORTS': {'C':
'Solenoid', 'L': 'Solenoid', 'R': 'Solenoid'}}

```

**request(\*args, \*\*kwargs)**

Stage 0: compute stimulus, set request trigger in center port.

**Returns**

With fields:

```

{
'target': self.target,
'trial_num' : self.current_trial,
'correction': self.correction_trial,
'type': stimulus type,
**stim.PARAMS
}

```

**Return type** data (dict)

**discrim**(\*args, \*\*kwargs)

Stage 1: respond to input, set reward/punishment triggers on target/distractor ports

**Returns**

**With fields::** { 'RQ\_timestamp': datetime.datetime.now().isoformat(), 'trial\_num': self.current\_trial, }

**Return type** data (dict)

**reinforcement**(\*args, \*\*kwargs)

Stage 2 - deliver reward/punishment, end trial.

**Returns**

With fields:

```
{
  'DC_timestamp': datetime.datetime.now().isoformat(),
  'response': self.response,
  'correct': self.correct,
  'bailed': self.bailed,
  'trial_num': self.current_trial,
  'TRIAL_END': True
}
```

**Return type** data (dict)

**punish**()

Flash lights, play punishment sound if set

**respond**(pin)

Set self.response

**Parameters** pin – Pin to set response to

**stim\_start**()

mark discrim\_playing = true

**stim\_end**()

called by stimulus callback

set outside lights blue

**flash\_leds**()

flash lights for punish\_dir

## TRANSFORMATIONS

Data transformations.

Composable transformations from one representation of data to another. Used as the lubricant and glue between hardware objects. Some hardware objects disagree about the way information should be represented – eg. cameras are very partial to letting position information remain latent in a frame of a video, but some other object might want the actual `[x,y]` coordinates. Transformations help negotiate (but don't resolve their irreparably different worldviews :( )

Transformations are organized by modality, but this API is quite immature.

Transformations have a `process` method that accepts and returns a single object. They must also define the format of their inputs and outputs (`format_in` and `format_out`). That API is also a sketch.

The `__add__()` method allows transforms to be combined, eg.:

```
from autopilot import transform as t
transform_me = t.Image.DLC('model_directory')
transform_me += t.selection.DLCSlice('point')
transform_me.process(frame)
# ... etcetera
```

---

**Todo:** This is a first draft of this module and it purely synchronous at the moment. It will be expanded to ... \* support multiple asynchronous processing rhythms \* support automatic value coercion \* make recursion checks – make sure a child hasn't already been added to a processing chain. \* idk participate at home! list your own shortcomings of this module, don't be shy it likes it.

---

### Functions:

---

<code>make_transform(transforms)</code>	Make a transform from a list of iterator specifications.
---	--

---

**make\_transform**(*transforms*: Union[List[dict], Tuple[dict]]) → *autopilot.transform.transforms.Transform*  
Make a transform from a list of iterator specifications.

**Parameters** *transforms* (*list*) –

A list of Transform s and parameterizations in the form:

```
[
    {'transform': Transform,
     'args': (arg1, arg2,), # optional
     'kwargs': {'key1': 'val1', ...}, # optional
     'transform': ...}
]
```

**Returns** Transform

Data transformations.

Experimental module.

Reusable transformations from one representation of data to another. eg. converting frames of a video to locations of objects, or locations of objects to area labels

---

**Todo:** This is a preliminary module and it purely synchronous at the moment. It will be expanded to ... \* support multiple asynchronous processing rhythms \* support automatic value coercion

The following design features need to be added \* recursion checks – make sure a child hasn’t already been added to a processing chain.

---

**Classes:**

---

*TransformRhythm*(value)

**ivar** ~TransformRhythm.FIFO First-in-first-out, process inputs as they are received, potentially slowing down the transformation pipeline

---

*Transform*(rhythm, \*args, \*\*kwargs)

Metaclass for data transformations

---

**class** TransformRhythm(value)

Bases: `enum.Enum`

**Variables**

- **FIFO** – First-in-first-out, process inputs as they are received, potentially slowing down the transformation pipeline
- **FILO** – First-in-last-out, process the most recent input, ignoring previous (lossy transformation)

**Attributes:**

---

*FIFO*

---

*FILO*

---

**FIFO** = 1

**FILO** = 2

**class** Transform(rhythm: autopilot.transform.transforms.TransformRhythm = <TransformRhythm.FILO: 2>, \*args, \*\*kwargs)

Bases: `object`

Metaclass for data transformations

Each subclass should define the following

- *process()* - a method that takes the input of the transformation as its single argument and returns the transformed output
- *format\_in* - a *dict* that specifies the input format

- `format_out` - a *dict* that specifies the output format

**Parameters** `rhythm` (*TransformRhythm*) – A rhythm by which the transformation object processes its inputs

**Variables** (`class` (*child*) – *Transform*): Another Transform object chained after this one

#### Attributes:

<code>rhythm</code>	
<code>format_in</code>	
<code>format_out</code>	
<code>parent</code>	If this Transform is in a chain of transforms, the transform that precedes it

#### Methods:

<code>process(input)</code>	
<code>reset()</code>	If a transformation is stateful, reset state.
<code>check_compatible(child)</code>	Check that this Transformation's <code>format_out</code> is compatible with another's <code>format_in</code>
<code>__add__(other)</code>	Add another Transformation in the chain to make a processing pipeline

**property** `rhythm`: `autopilot.transform.transforms.TransformRhythm`

**property** `format_in`: `dict`

**property** `format_out`: `dict`

**property** `parent`: `Optional[autopilot.transform.transforms.Transform]`

If this Transform is in a chain of transforms, the transform that precedes it

**Returns** *Transform*, None if no parent.

**process**(*input*)

**reset**()

If a transformation is stateful, reset state.

**check\_compatible**(*child*: `autopilot.transform.transforms.Transform`)

Check that this Transformation's `format_out` is compatible with another's `format_in`

---

**Todo:** Check for types that can be automatically coerced into one another and set `_coercion` to appropriate function

---

**Parameters** `child` (*Transform*) – Transformation to check compatibility

**Returns** `bool`

**\_\_add\_\_**(*other*)

Add another Transformation in the chain to make a processing pipeline

**Parameters** **other** (Transformation) – The transformation to be chained

## 16.1 Coercion

placeholder... objects to make type and shape coercion seamless....

## 16.2 Geometry

### Classes:

<code>Distance</code> ([pairwise, n_dim, metric, squareform])	Given an n_samples x n_dimensions array, compute pairwise or mean distances
<code>Angle</code> ([abs, degrees])	Get angle between line formed by two points and horizontal axis
<code>IMU_Orientation</code> ([use_kalman, invert_gyro])	Compute absolute orientation (roll, pitch) from accelerometer and gyroscope measurements (eg from <code>hardware.i2c.I2C_9DOF</code> )
<code>Rotate</code> ([dims, rotation_type, degrees, ...])	Rotate in 3 dimensions using <code>scipy.spatial.transform.Rotation</code>
<code>Spheroid</code> ([target, source, fit])	Fit and transform 3d coordinates according to some spheroid.

### Functions:

<code>_ellipsoid_func</code> (fit, a, b, c, x, y, z)	Ellipsoid equation for use with <code>Ellipsoid.fit()</code>
--	--

**class** `Distance`(pairwise: *bool* = *False*, n\_dim: *int* = 2, metric: *str* = 'euclidean', squareform: *bool* = *True*, \*args, \*\*kwargs)

Bases: `autopilot.transform.transforms.Transform`

Given an n\_samples x n\_dimensions array, compute pairwise or mean distances

#### Parameters

- **pairwise** (*bool*) – If *False* (default), return mean distance. if *True*, return all distances
- **n\_dim** (*int*) – number of dimensions (input array will be filtered like `input[:,0:n_dim]`)
- **metric** (*str*) – any metric acceptable to :func:`scipy.spatial.distance.pdist`
- **squareform** (*bool*) – if pairwise is *True*, if *True* return square distance matrix, otherwise return compressed distance matrix (`dist(X[i], X[j]) = y[i*j]`)
- **\*args**
- **\*\*kwargs**

#### Attributes:

---

`format_in`

---

`format_out`

---



**Methods:**


---

`process(input)`


---

```
format_in = {'type': <class 'numpy.ndarray'>}
```

```
format_out = {'type': <class 'numpy.ndarray'>}
```

```
process(input: numpy.ndarray)
```

```
class Angle(abs=True, degrees=True, *args, **kwargs)
```

Bases: `autopilot.transform.transforms.Transform`

Get angle between line formed by two points and horizontal axis

**Attributes:**


---

`format_in`


---



---

`format_out`


---

**Methods:**


---

`process(input)`


---

```
format_in = {'type': <class 'numpy.ndarray'>}
```

```
format_out = {'type': <class 'float'>}
```

```
process(input)
```

```
class IMU_Orientation(use_kalman: bool = True, invert_gyro: bool = False, *args, **kwargs)
```

Bases: `autopilot.transform.transforms.Transform`

Compute absolute orientation (roll, pitch) from accelerometer and gyroscope measurements (eg from `hardware.i2c.I2C_9DOF`)

Uses a `timeseries.Kalman` filter, and implements [PPT+18] to fuse the sensors

Can be used with accelerometer data only, or with combined accelerometer/gyroscope data for greater accuracy

**Parameters**

- **invert\_gyro** (*bool*) – if the gyroscope’s orientation is inverted from accelerometer measurement, multiply gyro readings by -1 before using
- **use\_kalman** (*bool*) – Whether to use kalman filtering (True, default), or return raw trigonometric transformation of accelerometer readings (if provided, gyroscope readings will be ignored)

**Variables** `kalman` (`transform.timeseries.Kalman`) – If `use_kalman == True`, the Kalman Filter.

## References

[PPT+18] [ABCO15]

### Methods:

---

`process`(`accelgyro`)

**Parameters** `accelgyro` (tuple, `numpy.ndarray`) -- tuple of (accelerometer[x,y,z], gyro[x,y,z]) readings as arrays, or

---

`process`(`accelgyro`: `Union[Tuple[numpy.ndarray, numpy.ndarray], numpy.ndarray]`) → `numpy.ndarray`

**Parameters** `accelgyro` (tuple, `numpy.ndarray`) – tuple of (accelerometer[x,y,z], gyro[x,y,z]) readings as arrays, or an array of just accelerometer[x,y,z]

**Returns** filtered [roll, pitch] calculations in degrees

**Return type** `numpy.ndarray`

**class** `Rotate`(`dims`='xyz', `rotation_type`='euler', `degrees`=True, `inverse`=',', `rotation`=None, \*args, \*\*kwargs)

Bases: `autopilot.transform.transforms.Transform`

Rotate in 3 dimensions using `scipy.spatial.transform.Rotation`

### Parameters

- **dims** ("xyz") – string specifying which axes the rotation will be around, eg "xy", "xyz"
- **rotation\_type** (str) – Format of rotation input, must be one available to the `Rotation` class (but currently only euler angles are supported)
- **degrees** (bool) – whether to output rotation in degrees (True, default) or radians
- **inverse** ("xyz") – dimensions in the “rotation” input to `Rotate.process()` to inverse before applying rotation
- **rotation** (tuple, list, `numpy.ndarray`, None) – If supplied, use the same rotation for all processed data. If None, `Rotate.process()` will expect a tuple of (data, rotation).

### Methods:

---

`process`(`input`)

**Parameters** `input` (tuple, `numpy.ndarray`) -- a tuple of (input[x,y,z], rotation[x,y,z]) where input is to be rotated

---

`process`(`input`)

**Parameters** `input` (tuple, `numpy.ndarray`) – a tuple of (input[x,y,z], rotation[x,y,z]) where input is to be rotated according to the axes in rotation (indicated in `Rotate.dims`). If only an input array is provided, a static rotation array must have been provided in the constructor (otherwise the most recent rotation will be used)

Returns `numpy.ndarray` - rotated input array

**class Spheroid**(*target*=(1, 1, 1, 0, 0, 0), *source*: *tuple* = (None, None, None, None, None, None), *fit*:  
Optional[*numpy.ndarray*] = None, \*args, \*\*kwargs)

Bases: `autopilot.transform.transforms.Transform`

Fit and transform 3d coordinates according to some spheroid.

Eg. for calibrating accelerometer readings by transforming them from their uncalibrated spheroid to the expected sphere with radius == 9.8m/s/s centered at (0,0,0).

Does not estimate/correct for rotation of the spheroid.

## Examples

```
# Calibrate an accelerometer by transforming readings to a 9.8-radius sphere centered at 0 >>> sphere =
Spheroid(target=(9.8,9.8,9.8,0,0,0)) # take some readings... # imagine we're taking them from some sensor
idx # say our sensor slightly exaggerates gravity in the z-axis... >>> readings = np.array((0.,0.,10.5)) # fit our
object (need >>1 sample) >>> sphere.fit(readings) # transform to proper gravity >>> sphere.process(readings)
[0., 0., 9.8]
```

### Parameters

- **target** (*tuple*) – parameterization of spheroid to transform to, if none is passed, transform to unit circle centered at (0,0,0). parameterized as:

(a, # radius of x dimension

b, # radius of y dimension c, # radius of z dimension x, # x-offset y, # y-offset z) # z-offset

- **source** (*tuple*) – parameterization of spheroid to transform from in the same 6-tuple form as **target**, if None is passed, assume we will use `Spheroid.fit()`
- **fit** (None, `numpy.ndarray`) – Initialize with values to fit, if None assume fit will be called later.

## References

- <https://jekel.me/2020/Least-Squares-Ellipsoid-Fit/>
- [http://www.juddzone.com/ALGORITHMS/least\\_squares\\_3D\\_ellipsoid.html](http://www.juddzone.com/ALGORITHMS/least_squares_3D_ellipsoid.html)

### Methods:

<code>fit(points, **kwargs)</code>	Fit a spheroid from a set of noisy measurements
<code>process(input)</code>	Transform input (x,y,z) points such that points in <b>source</b> are mapped to those in <b>target</b>
<code>generate(n[, which, noise])</code>	Generate random points from the ellipsoid

**fit**(*points*, \*\**kwargs*)

Fit a spheroid from a set of noisy measurements

updates the `_scale` and `_offset` private arrays used to manipulate input data

**Note:** It's usually important to pass bounds to `scipy.optimize.curve_fit()` !!! passed as a 2-tuple of ((min\_a, min\_b, ...), (max\_a, max\_b...)) In particular such that a, b, and c are positive. If

no bounds are passed, assume at least that much.

---

**Parameters**

- **points** (`numpy.ndarray`) – (M, 3) array of points to fit
- **\*\*kwargs** () – passed on to `scipy.optimize.curve_fit()`

**Returns** parameters of fit ellipsoid (a,b,c,x,y,z)

**Return type** `tuple`

**process**(*input*: `numpy.ndarray`)

Transform input (x,y,z) points such that points in `source` are mapped to those in `target`

**Parameters** **input** (`numpy.ndarray`) – x, y, and z coordinates

**Returns** coordinates transformed according to the spheroid requested

**Return type** `numpy.ndarray`

**generate**(*n*: `int`, *which*: `str` = 'source', *noise*: `float` = 0)

Generate random points from the ellipsoid

**Parameters**

- **n** (`int`) – number of points to generate
- **which** ('`str`') – which spheroid to generate from? ('source' - default, or 'target')
- **noise** (`float`) – noise to add to points

**Returns** (n, 3) array of generated points

**Return type** `numpy.ndarray`

**\_ellipsoid\_func**(*fit*, *a*, *b*, *c*, *x*, *y*, *z*)

Ellipsoid equation for use with `Ellipsoid.fit()`

**Parameters**

- **fit** (`numpy.ndarray`) – (M, 3) array of x,y,z points to fit
- **a** (`float`) – X-scale parameter to fit
- **b** (`float`) – Y-scale parameter to fit
- **c** (`float`) – Z-scale parameter to fit
- **x** (`float`) – X-offset parameter to fit
- **y** (`float`) – Y-offset parameter to fit
- **z** (`float`) – Z-offset parameter to fit

**Returns** result of ellipsoid function, minimize parameters to == 1

**Return type** `float`

## 16.3 Image

Classes:

<code>Image([shape])</code>	Metaclass for transformations of images
<code>DLC([model_dir, model_zoo])</code>	Do pose estimation with DeepLabCut-Live!!!!

**class** `Image(shape=None, *args, **kwargs)`

Bases: `autopilot.transform.transforms.Transform`

Metaclass for transformations of images

**Attributes:**

---

`format_in`

---

`format_out`

---

`shape`

---

**property** `format_in`: `dict`

**property** `format_out`: `dict`

**property** `shape`: `Tuple[int, int]`

**class** `DLC(model_dir: Optional[str] = None, model_zoo: Optional[str] = None, *args, **kwargs)`

Bases: `autopilot.transform.image.Image`

Do pose estimation with DeepLabCut-Live!!!!

Specify a `model_dir` (relative to <BASEDIR>/dlc or absolute) or a model name from the DLC model zoo.

All other args and kwargs are passed on to `dlclive.DLCLive`, see its documentation for details: <https://github.com/DeepLabCut/DeepLabCut-live>

**Variables**

- **model\_type** (`str`, 'local' or 'zoo') – whether a directory (local) or a modelzoo name (zoo) was passed
- **live** (`dlclive.DLCLive`) – the `DLCLive` object

Must give either `model_dir` or `model_zoo`

**Parameters**

- **model\_dir** (`str`) – directory of model, either absolute or relative to <BASEDIR>/dlc. if `None`, use `model_zoo`
- **model\_zoo** (`str`) – name of modelzoo model. if `None`, use `model_dir`
- **\*args** – passed to `DLCLive` and superclass
- **\*\*kwargs** – passed to `DLCLive` and superclass

**Methods:**

---

`process(input)`

---

`list_modelzoo()` List available modelzoo model names in local  
deeplabcut version

---

`import_dlc()`

---

`create_modelzoo(model)`

---

`load_model()`

---

`export_model()`

---

**Attributes:**

---

`model`

---

`model_dir`

---

`dlc_paths` paths used by dlc in manipulating/using models

---

`dlc_dir` {prefs.get('BASE\_DIR')}/dlc :returns: str

---

`format_in`

---

`format_out`

---

**process**(*input*: *numpy.ndarray*) → *numpy.ndarray*

**property model:** *str*

**property model\_dir:** *str*

**property dlc\_paths:** *dict*

paths used by dlc in manipulating/using models

- config: <model\_dir>/config.yaml
- train\_pose\_cfg: <model\_dir>/dlc-models/iteration-<n>/<name>/train/pose\_cfg.yaml,
- export\_pose\_cfg: <model\_dir>/exported-models/<name>/pose\_cfg.yaml
- export\_dir: <model\_dir>/exported-models/<name>

**Returns** dict

**property dlc\_dir:** *str*

{prefs.get('BASE\_DIR')}/dlc :returns: str

**classmethod list\_modelzoo()**

List available modelzoo model names in local deeplabcut version

**Returns** names of available modelzoo models

**Return type** list

**import\_dlc()**

**create\_modelzoo**(*model*)

```
load_model()
export_model()
property format_in: dict
property format_out: dict
```

## 16.4 Logical

Classes:

<code>Condition</code> ([minimum, maximum, elementwise])	Compare the input against some condition
<code>Compare</code> (compare_fn, *args, **kwargs)	Compare processed values using some function that returns a boolean

**class Condition**(*minimum=None, maximum=None, elementwise=False, \*args, \*\*kwargs*)

Bases: `autopilot.transform.transforms.Transform`

Compare the input against some condition

### Parameters

- **minimum**
- **maximum**
- **elementwise** (*bool*) – if False, return True only if *all* values are within range. otherwise return bool for each tested value
- **\*args**
- **\*\*kwargs**

### Methods:

---

`process`(input)

---

### Attributes:

---

`minimum`

---



---

`maximum`

---



---

`format_in`

---



---

`format_out`

---

`process`(*input*)

property `minimum`

property `maximum`

property `format_in`: dict

property `format_out`: `dict`

**class** `Compare`(*compare\_fn*: callable, \*args, \*\*kwargs)

Bases: `autopilot.transform.transforms.Transform`

Compare processed values using some function that returns a boolean

ie. process will return `compare_fn(*args)` from process.

it is expected that input will be an iterable with `len > 1`

#### Parameters

- **compare\_fn** (callable) – Function used to compare the values given to `Compare.process()`
- **\*args** ()
- **\*\*kwargs** ()

#### Methods:

---

`process`(input)

---

**process**(input)

## 16.5 Selection

#### Classes:

<code>Slice</code> (select, *args, **kwargs)	Generic selection processor
<code>DLCSlice</code> (select[, min_probability])	Select x,y coordinates of <i>DL</i> C output based on the name of the tracked parts

**class** `Slice`(select, \*args, \*\*kwargs)

Bases: `autopilot.transform.transforms.Transform`

Generic selection processor

#### Parameters

- **select** (*slice*, *tuple[slice]*, *int*, *tuple[int]*) – a slice, tuple of slices, int, or tuple of ints! anything you can use inside of a pair of [square brackets].
- **\*args**
- **\*\*kwargs**

#### Attributes:

---

`format_in`

---

---

`format_out`

---

#### Methods:



---

```
process(input)
```

---

```
format_in = {'type': 'any'}
format_out = {'type': 'any'}
process(input)
```

```
class DLCSlice(select: Union[str, tuple, list], min_probability: float = 0, *args, **kwargs)
```

```
Bases: autopilot.transform.selection.Slice
```

Select x,y coordinates of *DLC* output based on the name of the tracked parts

note that *min\_probability* is undefined when a list or tuple of part names are defined: the form of the returned array is ambiguous (how to tell which part is which when some might be excluded?)

#### Parameters

- **select** (*slice*, *tuple[slice]*, *int*, *tuple[int]*) – a slice, tuple of slices, int, or tuple of ints! anything you can use inside of a pair of [square brackets].
- **\*args**
- **\*\*kwargs**

#### Attributes:

---

```
format_in
```

---

```
format_out
```

---

#### Methods:

---

```
check_slice(select)
```

---

```
process(input)
```

---

```
format_in = { 'parent': <class 'autopilot.transform.image.DLC'>, 'type': <class 'numpy.ndarray'>}
```

```
format_out = {'type': <class 'numpy.ndarray'>}
```

```
check_slice(select)
```

```
process(input: numpy.ndarray)
```

## 16.6 Timeseries

Timeseries transformations, filters, etc.

### Classes:

---

<code>Filter_IIR([ftype, buffer_size, coef_type, axis])</code>	Simple wrapper around <code>scipy.signal.iirfilter()</code>
<code>Kalman(dim_state[, dim_measurement, dim_control])</code>	Kalman filter!!!!
<code>Integrate([decay, dt_scale])</code>	

---

**class** `Filter_IIR`(*ftype*='butter', *buffer\_size*=256, *coef\_type*='sos', *axis*=0, \**args*, \*\**kwargs*)

Bases: `autopilot.transform.transforms.Transform`

Simple wrapper around `scipy.signal.iirfilter()`

Creates a streaming filter – takes in single values, stores them, and uses them to filter future values.

#### Parameters

- **ftype** (*str*) – filter type, see *ftype* of `scipy.signal.iirfilter()` for available filters
- **buffer\_size** (*int*) – number of samples to store when filtering
- **coef\_type** (*{'ba', 'sos'}*) – type of filter coefficients to use (see `scipy.signal.sosfilt()` and `scipy.signal.lfilt()`)
- **axis** (*int*) – which axis to filter over? (default: 0 because when passing arrays to filter, want to filter samples over time)
- **\*\*kwargs** – passed on to `scipy.signal.iirfilter()`, eg.
  - *N* - filter order
  - *Wn* - array or scalar giving critical frequencies
  - *btype* - type of band: ['bandpass', 'lowpass', 'highpass', 'bandstop']

#### Variables

- **coefs** (*np.ndarray*) – filter coefficients, depending on *coef\_type*
- **buffer** (*collections.deque*) – buffer of stored values to filter
- **coef\_type** (*str*) – type of filter coefficients to use (see `scipy.signal.sosfilt()` and `scipy.signal.lfilt()`)
- **axis** (*int*) – which axis to filter over? (default: 0 because when passing arrays to filter, want to filter samples over time)
- **ftype** (*str*) – filter type, see *ftype* of `scipy.signal.iirfilter()` for available filters

### Methods:

---

<code>process(input)</code>	Filter the new value based on the values stored in <code>Filter.buffer</code>
-----------------------------	---

---

**process**(*input: float*)

Filter the new value based on the values stored in `Filter.buffer`

**Parameters** *input* (*float*) – new value to filter!

**Returns** the filtered value!

Return type `float`

**class Kalman**(*dim\_state: int, dim\_measurement: Optional[int] = None, dim\_control: int = 0, \*args, \*\*kwargs*)  
 Bases: `autopilot.transform.transforms.Transform`

Kalman filter!!!!

Adapted from [https://github.com/rlabbe/filterpy/blob/master/filterpy/kalman/kalman\\_filter.py](https://github.com/rlabbe/filterpy/blob/master/filterpy/kalman/kalman_filter.py) simplified and optimized lovingly <3

Each of the arrays is named with its canonical letter and a short description, (eg. the `x_state` vector `x_state` is `self.x_state`

#### Parameters

- **dim\_state** (*int*) – Dimensions of the state vector
- **dim\_measurement** (*int*) – Dimensions of the measurement vector
- **dim\_control** (*int*) – Dimensions of the control vector

#### Variables

- **x\_state** (`numpy.ndarray`) – Current state vector
- **P\_cov** (`numpy.ndarray`) – Uncertainty Covariance
- **Q\_proc\_var** (`numpy.ndarray`) – Process Uncertainty
- **B\_control** (`numpy.ndarray`) – Control transition matrix
- **F\_state\_trans** (`numpy.ndarray`) – State transition matrix
- **H\_measure** (`numpy.ndarray`) – Measurement function
- **R\_measure\_var** (`numpy.ndarray`) – Measurement uncertainty
- **M\_proc\_measure\_xcor** (`numpy.ndarray`) – process-measurement cross correlation
- **z\_measure** (`numpy.ndarray`) –
- **K** (`numpy.ndarray`) – Kalman gain
- **y** (`numpy.ndarray`) –
- **S** (`numpy.ndarray`) – System uncertainty
- **SI** (`numpy.ndarray`) – Inverse system uncertainty
- **x\_prior** (`numpy.ndarray`) – State prior
- **P\_prior** (`numpy.ndarray`) – Uncertainty prior
- **x\_post** (`numpy.ndarray`) – State posterior probability
- **P\_post** (`numpy.ndarray`) – Uncertainty posterior probability

## References

Roger Labbe. “Kalman and Bayesian Filters in Python” - <https://github.com/rlabbe/Kalman-and-Bayesian-Filters-in-Python> Roger Labbe. “FilterPy” - <https://github.com/rlabbe/filterpy>

## Methods:

<code>_init_arrays([state])</code>	Initialize the arrays!
<code>predict([u, B, F, Q])</code>	Predict next <code>x_state</code> (prior) using the Kalman filter <code>x_state</code> propagation equations.
<code>update(z[, R, H])</code>	Add a new measurement ( <code>z_measure</code> ) to the Kalman filter.
<code>_reshape_z(z, dim_z, ndim)</code>	ensure <code>z</code> is a <code>(dim_z, 1)</code> shaped vector
<code>process(z, **kwargs)</code>	Call <code>predict</code> and <code>update</code> , passing the relevant kwargs
<code>residual_of(z)</code>	Returns the residual for the given measurement ( <code>z_measure</code> ).
<code>measurement_of_state(x)</code>	Helper function that converts a <code>x_state</code> into a measurement.

## Attributes:

<code>alpha</code>	Fading memory setting.
--------------------	------------------------

`_init_arrays(state=None)`

Initialize the arrays!

`predict(u=None, B=None, F=None, Q=None)`

Predict next `x_state` (prior) using the Kalman filter `x_state` propagation equations.

Update our state and uncertainty priors, `x_prior` and `P_prior`

**u** [np.array, default 0] Optional control vector.

**B** [np.array(dim\_state, dim\_u), or None] Optional control transition matrix; a value of None will cause the filter to use `self.B_control`.

**F** [np.array(dim\_state, dim\_state), or None] Optional `x_state` transition matrix; a value of None will cause the filter to use `self.F_state_trans`.

**Q** [np.array(dim\_state, dim\_state), scalar, or None] Optional process noise matrix; a value of None will cause the filter to use `self.Q_proc_var`.

`update(z: numpy.ndarray, R=None, H=None) → numpy.ndarray`

Add a new measurement (`z_measure`) to the Kalman filter.

If `z_measure` is None, nothing is computed. However, `x_post` and `P_post` are updated with the prior (`x_prior`, `P_prior`), and `self.z_measure` is set to None.

## Parameters

- **z** (`numpy.ndarray`) – measurement for this update. `z_measure` can be a scalar if `dim_measurement` is 1, otherwise it must be convertible to a column vector.

If you pass in a value of `H_measure`, `z_measure` must be a column vector the of the correct size.

- **R** (`numpy.ndarray`, int, None) – Optionally provide `R_measure_var` to override the measurement noise for this one call, otherwise `self.R_measure_var` will be used.

- **H** (`numpy.ndarray`, `None`) – Optionally provide `H_measure` to override the measurement function for this one call, otherwise `self.H_measure` will be used.

**\_reshape\_z**(`z`, `dim_z`, `ndim`)

ensure `z` is a (`dim_z`, 1) shaped vector

**process**(`z`, `**kwargs`)

Call predict and update, passing the relevant kwargs

#### Parameters

- `z` ()
- `**kwargs` ()

**Returns** `self.x_state`

**Return type** `np.ndarray`

**residual\_of**(`z`)

Returns the residual for the given measurement (`z_measure`). Does not alter the `x_state` of the filter.

**measurement\_of\_state**(`x`)

Helper function that converts a `x_state` into a measurement.

**x** [`np.array`] kalman `x_state` vector

**z\_measure** [(`dim_measurement`, 1): `array_like`] measurement for this update. `z_measure` can be a scalar if `dim_measurement` is 1, otherwise it must be convertible to a column vector.

#### property alpha

Fading memory setting. 1.0 gives the normal Kalman filter, and values slightly larger than 1.0 (such as 1.02) give a fading memory effect - previous measurements have less influence on the filter's estimates.

This formulation of the Fading memory filter (there are many) is due to Dan Simon [1].

**class Integrate**(`decay=1`, `dt_scale=False`, `*args`, `**kwargs`)

Bases: `autopilot.transform.transforms.Transform`

#### Methods:

---

`process`(`input`)

---

**process**(`input`)

## 16.7 Units

For converting between things that are the same thing but have different numbers and shapes

#### Classes:

<code>Rescale</code> ( <code>in_range</code> , <code>out_range</code> , <code>clip</code> )	Rescale values from one range to another
<code>Colorspaces</code> ( <code>value</code> )	An enumeration.
<code>Color</code> ( <code>convert_from</code> , <code>convert_to</code> [, <code>output_scale</code> ])	Convert colors using the colorsys module!!

**class Rescale**(`in_range: Tuple[float, float] = (0, 1)`, `out_range: Tuple[float, float] = (0, 1)`, `clip=False`, `*args`, `**kwargs`)

Bases: `autopilot.transform.transforms.Transform`

Rescale values from one range to another

**Attributes:**

---

*format\_in*

---

*format\_out*

---

**Methods:**

---

<i>process</i> (input)	Subtract input minimum, multiple by output/input size ratio, add output minimum
------------------------	---

---

```
format_in = { 'type': ( <class 'numpy.ndarray'>, <class 'float'>, <class 'int'>,  
                      <class 'tuple'>, <class 'list'> ) }
```

```
format_out = { 'type': <class 'numpy.ndarray'> }
```

```
process(input)
```

Subtract input minimum, multiple by output/input size ratio, add output minimum

**class** *Colorspaces*(value)

Bases: *enum.Enum*

An enumeration.

**Attributes:**

---

*HSV*

---

*RGB*

---

*YIQ*

---

*HLS*

---

**HSV** = 1

**RGB** = 2

**YIQ** = 3

**HLS** = 4

```
class Color(convert_from: autopilot.transform.units.Colorspaces = <Colorspaces.HSV: 1>, convert_to:  
             autopilot.transform.units.Colorspaces = <Colorspaces.RGB: 2>, output_scale=255, *args,  
             **kwargs)
```

Bases: *autopilot.transform.transforms.Transform*

Convert colors using the colorsys module!!

---

**Note:** All inputs must be scaled (0,1) and all outputs will be (0,1)

---

**Attributes:**

---

*format\_in*

---

*format\_out*

---

*CONVERSIONS*

---

**Methods:**

---

*process*(input, \*args)

---

```
format_in = {'type': <class 'tuple'>}
```

```
format_out = {'type': <class 'tuple'>}
```

```
CONVERSIONS = { <Colorspaces.RGB: 2>: { <Colorspaces.HSV: 1>: <function rgb_to_hsv  
at 0x7f6f2b837440>, <Colorspaces.YIQ: 3>: <function rgb_to_yiq at 0x7f6f2b836b00>,  
<Colorspaces.HLS: 4>: <function rgb_to_hls at 0x7f6f2b837290>}, <Colorspaces.HSV:  
1>: { <Colorspaces.RGB: 2>: <function hsv_to_rgb at 0x7f6f2b8374d0>},  
<Colorspaces.YIQ: 3>: { <Colorspaces.RGB: 2>: <function yiq_to_rgb at  
0x7f6f2b8369e0>}, <Colorspaces.HLS: 4>: { <Colorspaces.RGB: 2>: <function  
hls_to_rgb at 0x7f6f2b837320>}}
```

```
process(input, *args)
```





## 17.1 trial\_viewer

Tools to visualize data after collection.

**Warning:** this module is unfinished, so it is undocumented.

### Functions:

---

`load_subject_data(data_dir, subject_name[, ...])`

---

`load_subject_dir(data_dir[, steps, grad, which])`

#### Parameters

- **data\_dir** (*str*) -- A path to a directory with *Subject* style hdf5 files

---

`step_viewer(grad_data)`

---

`trial_viewer(step_data[, roll_type, ...])`

#### Parameters

- **bar**

---

`load_subject_data(data_dir, subject_name, steps=True, grad=True)`

`load_subject_dir(data_dir, steps=True, grad=True, which=None)`

#### Parameters

- **data\_dir** (*str*) – A path to a directory with *Subject* style hdf5 files
- **steps** (*bool*) – Whether to return full trial-level data for each step
- **grad** (*bool*) – Whether to return summarized step graduation data.
- **which** (*list*) – A list of subjects to subset the loaded subjects to

`step_viewer(grad_data)`

`trial_viewer(step_data, roll_type='ewm', roll_span=100, bar=False)`

**Parameters**

- **bar**
- **roll\_span**
- **roll\_type**
- **step\_data**

## 17.2 psychometric

**Functions:**

---

<code>calc_psychometric(data, var_x[, var_y])</code>	Calculate a psychometric curve (logistic regression of var_y on var_x)
<code>plot_psychometric(subject_protocols)</code>	Plot psychometric curves for selected subjects, steps, and variables

---

**calc\_psychometric**(*data*, *var\_x*, *var\_y*='response')

Calculate a psychometric curve (logistic regression of var\_y on var\_x)

**Parameters**

- **data** (`pandas.DataFrame`) – Subject data
- **var\_x** (*str*) – name of column to use as the discriminand
- **var\_y** (*str*) – name of the column for the response, usually 'response'

**Returns** parameters for logistic function

**Return type** params (tup)

**plot\_psychometric**(*subject\_protocols*)

Plot psychometric curves for selected subjects, steps, and variables

Typically called by `Terminal.plot_psychometric()`.

**Parameters** **subject\_protocols** (*list*) – A list of tuples, each with

- subject\_id (str)
- step\_name (str)
- variable (str)

**Returns** altair.Chart

Utility functions!

## 18.1 Common Utils

Generic utility functions that are used in multiple places in the library that for now don't have a clear other place to be

### Functions:

<code>list_classes(module)</code>	List all classes within a module/package without importing by parsing the syntax tree directly with <code>ast</code> .
<code>find_class(cls_str)</code>	Given a full <code>package.module.ClassName</code> string, return the relevant class
<code>recurse_subclasses(cls[, leaves_only])</code>	Given some class, find its subclasses recursively
<code>list_subjects([pilot_db])</code>	Given a dictionary of a <code>pilot_db</code> , return the subjects that are in it.
<code>load_pilotdb([file_name, reverse])</code>	Try to load the <code>file_db</code>
<code>coerce_discrete(df, col[, mapping])</code>	Coerce a discrete/string column of a pandas dataframe into numeric values
<code>find_key_recursive(key, dictionary)</code>	Find all instances of a key in a dictionary, recursively.
<code>find_key_value(dicts, key, value[, single])</code>	Find an entry in a list of dictionaries where <code>dict[key] == value</code> .

### Classes:

<code>ReturnThread([group, target, name, args, ...])</code>	Thread whose <code>.join()</code> method returns the value from the function thx to <a href="https://stackoverflow.com/a/6894023">https://stackoverflow.com/a/6894023</a>
<code>NumpyEncoder(*[, skipkeys, ensure_ascii, ...])</code>	Allow json serialization of objects containing numpy arrays.
<code>NumpyDecoder(*args, **kwargs)</code>	Allow json deserialization of objects containing numpy arrays.

**list\_classes**(*module*) → List[Tuple[str, str]]

List all classes within a module/package without importing by parsing the syntax tree directly with `ast`.

**Parameters** **module** (*module*, *str*) – either the imported module to be queried, or its name as a string. if passed a string, attempt to import with `importlib.import_module()`

**Returns** list of tuples [(‘ClassName’, ‘module1.module2.ClassName’)] a la `inspect.getmembers()`

**find\_class**(*cls\_str: str*)

Given a full package.module.ClassName string, return the relevant class

**Parameters** **cls\_str** (*str*) – a full package.module.ClassName string, like 'autopilot.hardware.Hardware'

**Returns** the class indicated by *cls\_str*

**recurse\_subclasses**(*cls, leaves\_only=False*) → *list*

Given some class, find its subclasses recursively

See: <https://stackoverflow.com/a/17246726/13113166>

**Parameters** **leaves\_only** (*bool*) – If True, only include classes that have no further subclasses, if False (default), return all subclasses.

**Returns** list of subclasses

**class ReturnThread**(*group=None, target=None, name=None, args=(), kwargs={}, Verbose=None*)

Bases: `threading.Thread`

Thread whose `.join()` method returns the value from the function thx to <https://stackoverflow.com/a/6894023>

This constructor should always be called with keyword arguments. Arguments are:

*group* should be None; reserved for future extension when a ThreadGroup class is implemented.

*target* is the callable object to be invoked by the `run()` method. Defaults to None, meaning nothing is called.

*name* is the thread name. By default, a unique name is constructed of the form “Thread-N” where N is a small decimal number.

*args* is the argument tuple for the target invocation. Defaults to ().

*kwargs* is a dictionary of keyword arguments for the target invocation. Defaults to {}.

If a subclass overrides the constructor, it must make sure to invoke the base class constructor (`Thread.__init__()`) before doing anything else to the thread.

**Methods:**

<code>run()</code>	Method representing the thread's activity.
<code>join([timeout])</code>	Wait until the thread terminates.

**run()**

Method representing the thread's activity.

You may override this method in a subclass. The standard `run()` method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the *args* and *kwargs* arguments, respectively.

**join**(*timeout=None*)

Wait until the thread terminates.

This blocks the calling thread until the thread whose `join()` method is called terminates – either normally or through an unhandled exception or until the optional timeout occurs.

When the timeout argument is present and not None, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof). As `join()` always returns None, you must call `is_alive()` after `join()` to decide whether a timeout happened – if the thread is still alive, the `join()` call timed out.

When the timeout argument is not present or None, the operation will block until the thread terminates.

A thread can be join()ed many times.

join() raises a RuntimeError if an attempt is made to join the current thread as that would cause a deadlock. It is also an error to join() a thread before it has been started and attempts to do so raises the same exception.

**list\_subjects**(*pilot\_db=None*)

Given a dictionary of a pilot\_db, return the subjects that are in it.

**Parameters** *pilot\_db* (*dict*) – a pilot\_db. if None tried to load pilot\_db with **:method: `load\_pilotdb`**

**Returns** a list of currently active subjects

**Return type** subjects (*list*)

**load\_pilotdb**(*file\_name=None, reverse=False*)

Try to load the file\_db

**Parameters**

- **reverse**
- **file\_name**

Returns:

**coerce\_discrete**(*df, col, mapping={'L': 0, 'R': 1}*)

Coerce a discrete/string column of a pandas dataframe into numeric values

Default is to map 'L' to 0 and 'R' to 1 as in the case of Left/Right 2AFC tasks

**Parameters**

- **df** (*pandas.DataFrame*) – dataframe with the column to transform
- **col** (*str*) – name of column
- **mapping** (*dict*) – mapping of strings to numbers

**Returns** transformed dataframe

**Return type** df (*pandas.DataFrame*)

**find\_key\_recursive**(*key, dictionary*)

Find all instances of a key in a dictionary, recursively.

**Parameters**

- **key**
- **dictionary**

**Returns** list

**find\_key\_value**(*dicts: List[dict], key: str, value: str, single=True*)

Find an entry in a list of dictionaries where dict[key] == value.

**Parameters**

- **dicts** ()
- **key** ()
- **value** ()
- **single** (*bool*) – if True (default), raise an exception if multiple results are matched

```
class NumpyEncoder(*, skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True,
                  sort_keys=False, indent=None, separators=None, default=None)
```

Bases: `json.encoder.JSONEncoder`

Allow json serialization of objects containing numpy arrays.

Use like `json.dump(obj, fp, cls=NumpyEncoder)`

Deserialize with [\*NumpyDecoder\*](#)

## References

- <https://stackoverflow.com/a/49677241/13113166>
- <https://github.com/mpld3/mpld3/issues/434#issuecomment-340255689>
- <https://gist.github.com/massgh/297a73f2dba017ffd28dbc34b9a40e90>

Constructor for JSONEncoder, with sensible defaults.

If skipkeys is false, then it is a `TypeError` to attempt encoding of keys that are not str, int, float or None. If skipkeys is True, such items are simply skipped.

If ensure\_ascii is true, the output is guaranteed to be str objects with all incoming non-ASCII characters escaped. If ensure\_ascii is false, the output can contain non-ASCII characters.

If check\_circular is true, then lists, dicts, and custom encoded objects will be checked for circular references during encoding to prevent an infinite recursion (which would cause an `OverflowError`). Otherwise, no such check takes place.

If allow\_nan is true, then NaN, Infinity, and -Infinity will be encoded as such. This behavior is not JSON specification compliant, but is consistent with most JavaScript based encoders and decoders. Otherwise, it will be a `ValueError` to encode such floats.

If sort\_keys is true, then the output of dictionaries will be sorted by key; this is useful for regression tests to ensure that JSON serializations can be compared on a day-to-day basis.

If indent is a non-negative integer, then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0 will only insert newlines. None is the most compact representation.

If specified, separators should be an (item\_separator, key\_separator) tuple. The default is (', ', ': ') if indent is None and (',', ':') otherwise. To get the most compact JSON representation, you should specify (',', ':') to eliminate whitespace.

If specified, default is a function that gets called for objects that can't otherwise be serialized. It should return a JSON encodable version of the object or raise a `TypeError`.

## Methods:

---

<code>default(obj)</code>	Implement this method in a subclass such that it returns a serializable object for o, or calls the base implementation (to raise a <code>TypeError</code> ).
---------------------------	--

---

## `default(obj)`

Implement this method in a subclass such that it returns a serializable object for o, or calls the base implementation (to raise a `TypeError`).

For example, to support arbitrary iterators, you could implement default like this:

```
def default(self, o):
    try:
        iterable = iter(o)
    except TypeError:
        pass
    else:
        return list(iterable)
    # Let the base class default method raise the TypeError
    return JSONEncoder.default(self, o)
```

**class NumpyDecoder**(\*args, \*\*kwargs)

Bases: `json.decoder.JSONDecoder`

Allow json deserialization of objects containing numpy arrays.

Use like `json.load(fp, cls=NumpyDecoder)`

Serialize with *NumpyEncoder*

## References

- <https://stackoverflow.com/a/49677241/13113166>
- <https://github.com/mpld3/mpld3/issues/434#issuecomment-340255689>
- <https://gist.github.com/massgh/297a73f2dba017ffd28dbc34b9a40e90>

`object_hook`, if specified, will be called with the result of every JSON object decoded and its return value will be used in place of the given dict. This can be used to provide custom deserializations (e.g. to support JSON-RPC class hinting).

`object_pairs_hook`, if specified will be called with the result of every JSON object decoded with an ordered list of pairs. The return value of `object_pairs_hook` will be used instead of the dict. This feature can be used to implement custom decoders. If `object_hook` is also defined, the `object_pairs_hook` takes priority.

`parse_float`, if specified, will be called with the string of every JSON float to be decoded. By default this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON floats (e.g. `decimal.Decimal`).

`parse_int`, if specified, will be called with the string of every JSON int to be decoded. By default this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. `float`).

`parse_constant`, if specified, will be called with one of the following strings: `-Infinity`, `Infinity`, `NaN`. This can be used to raise an exception if invalid JSON numbers are encountered.

If `strict` is false (true is the default), then control characters will be allowed inside strings. Control characters in this context are those with character codes in the 0-31 range, including `'\t'` (tab), `'\n'`, `'\r'` and `'\0'`.

## Methods:

---

*object\_hook*(obj)

---

**object\_hook**(obj)

## 18.2 GUI Invoker

### Classes:

---

<code><i>InvokeEvent</i></code> (fn, *args, **kwargs)	Sends signals to the main QT thread from spawned message threads
<code><i>Invoker</i></code>	Wrapper that calls an evoked event made by <code><i>InvokeEvent</i></code>

---

### Functions:

---

<code><i>get_invoker</i></code> ()
------------------------------------

---

**class** `InvokeEvent`(fn, \*args, \*\*kwargs)

Bases: `PySide2.QtCore.QEvent`

Sends signals to the main QT thread from spawned message threads

See [stackoverflow](#)

Accepts a function, its args and kwargs and wraps them as a `QtCore.QEvent`

#### Attributes:

---

<code><i>EVENT_TYPE</i></code>
--------------------------------

---

`EVENT_TYPE = PySide2.QtCore.QEvent.Type(65533)`

**class** `Invoker`

Bases: `PySide2.QtCore.QObject`

Wrapper that calls an evoked event made by `InvokeEvent`

#### Methods:

---

<code><i>event</i></code> (event)	Parameters event
-----------------------------------	------------------

---

#### Attributes:

---

<code><i>staticMetaObject</i></code>
--------------------------------------

---

`event(event)`

Parameters event

`staticMetaObject = <PySide2.QtCore.QMetaObject object at 0x7f6f32f8ab90>`

`get_invoker()`



## 18.3 Plugins

Utility functions for handling plugins, eg. importing, downloading, listing, confirming, etc.

### Functions:

<code>import_plugins([plugin_dir])</code>	Import all plugins in the plugin (or supplied) directory.
<code>unload_plugins()</code>	Un-import imported plugins (mostly for testing purposes)
<code>list_wiki_plugins()</code>	List plugins available on the wiki using <code>utils.wiki.ask()</code>

**import\_plugins**(*plugin\_dir*: *Optional[pathlib.Path] = None*) → dict

Import all plugins in the plugin (or supplied) directory.

There is no specific form for a plugin at the moment, so this function will recursively import all modules and packages within the directory.

Plugins can then be accessed by the `get()` registry functions.

**Parameters** `plugin_dir` (None, `pathlib.Path`) – Directory to import. if None (default), use `prefs.get('PLUGINDIR')`.

**Returns** of imported objects with form {"class\_name": class\_object}

**Return type** dict

**unload\_plugins()**

Un-import imported plugins (mostly for testing purposes)

**list\_wiki\_plugins()**

List plugins available on the wiki using `utils.wiki.ask()`

**Returns** {'plugin\_name': {'plugin\_prop': 'prop\_value', ...}}

**Return type** dict

## 18.4 Registry

Registry for programmatic access to autopilot classes and plugins

When possible, rather than importing and using an object directly, access it using the `get` methods in this module. This makes it possible for plugins to be integrated across the system.

### Classes:

<code>REGISTRIES(value)</code>	Types of registries that are currently supported, ie.
--------------------------------	---

### Functions:

<code>get(base_class[, class_name, plugins, ast, ...])</code>	Get an autopilot object.
<code>get_names(base_class[, class_name, plugins, ...])</code>	<code>get()</code> but return a list of object names instead of the objects themselves
<code>get_hardware([class_name, plugins, ast])</code>	Get a hardware class by name.
<code>get_task([class_name, plugins, ast])</code>	Get a task class by name.

**class** `REGISTRIES`(*value*)

Bases: `str`, `enum.Enum`

Types of registries that are currently supported, ie. the possible values of the first argument of `registry.get()`

Values are the names of the autopilot classes that are searched for inheriting classes, eg. `HARDWARE == "autopilot.hardware.Hardware"` for `autopilot.Hardware`

**Attributes:**

---

`HARDWARE`

---

`TASK`

---

`GRADUATION`

---

`TRANSFORM`

---

`CHILDREN`

---

`SOUND`

---

`HARDWARE = 'autopilot.hardware.Hardware'`

`TASK = 'autopilot.tasks.Task'`

`GRADUATION = 'autopilot.tasks.graduation.Graduation'`

`TRANSFORM = 'autopilot.transform.transforms.Transform'`

`CHILDREN = 'autopilot.tasks.children.Child'`

`SOUND = 'autopilot.stim.sound.sounds.BASE_CLASS'`

**get**(*base\_class*: `Union[autopilot.utils.registry.REGISTRIES, str, type]`, *class\_name*: `Optional[str] = None`, *plugins*: `bool = True`, *ast*: `bool = True`, *include\_base*: `bool = False`) → `Union[type, List[type]]`

Get an autopilot object.

#### Parameters

**base\_class** (`REGISTRIES`, `str`, `type`) – Class to search its subclasses for the indicated object. One of the values in `REGISTRIES` or else one of its keys (eg. `'HARDWARE'`). If given a full module.ClassName string (eg. `"autopilot.tasks.Task"`) attempt to get the indicated object. If given an object, use that.

**class\_name** (`str`, `None`): Name of class that inherits from `base_class` that is to be returned. if `None` (default), return all found subclasses of `base_class`

**plugins** (`bool`): If `True` (default), ensure contents of `PLUGINDIR` are loaded (with `import_plugins()`) and are included in results. If `False`, plugins are not explicitly imported, but if any have been imported elsewhere, they will be included anyway because we can't control all the different ways to subclass in Python.

**ast** (`bool`): If `True` (default), if an imported object isn't found that matches `class_name`, parse the syntax trees of submodules of `base_class` with `utils.common.list_classes()` without importing to try and find it. If a match is found, it is imported and checked whether or not it is indeed a subclass of the `base_class`. if `False`, do not parse ast trees (will miss any modules that aren't already imported).

**include\_base** (`bool`): If `False` (default), remove the `base_class` before returning

**Returns** Either the requested items, or a list of all the relevant items

**get\_names**(*base\_class*: Union[autopilot.utils.registry.REGISTRIES, *str*, *type*], *class\_name*: Optional[*str*] = None, *plugins*: bool = True, *ast*: bool = True, *full\_name*: bool = False) → List[*str*]

*get()* but return a list of object names instead of the objects themselves

See *get()* for documentation of base arguments.

---

**Note:** While technically you can call this function with a *class\_name*, by default [*class\_name*] == *get\_names*(*base\_class*, *class\_name*), but if *full\_name* == False it could be used to get the fully qualified package.module name in a pretty roundabout way.

---

**Parameters** *full\_name* (bool) – if False (default), return just the class name. if True, return the full package.subpackage.module.Class\_Name name.

**Returns** a list of names

**Return type** List[*str*]

**get\_hardware**(*class\_name*: Optional[*str*] = None, *plugins*: bool = True, *ast*: bool = True) → Union[Type[Hardware], List[Type[Hardware]]]

Get a hardware class by name.

Alias for *registry.get()*

**Parameters**

- **class\_name** (*str*) – Name of hardware class to get
- **plugins** (bool) – If True (default) ensure plugins are loaded and return from them. see *registry.get()* for more details about the behavior of this argument
- **ast** (bool) – If True (default) parse the syntax tree of all modules within *hardware*. see *registry.get()* for more details about the behavior of this argument

**Returns** *Hardware*

**get\_task**(*class\_name*: Optional[*str*] = None, *plugins*: bool = True, *ast*: bool = True) → Union[Type[Task], List[Type[Task]]]

Get a task class by name.

Alias for *registry.get()*

**Parameters**

- **class\_name** (*str*) – Name of task class to get
- **plugins** (bool) – If True (default) ensure plugins are loaded and return from them. see *registry.get()* for more details about the behavior of this argument
- **ast** (bool) – If True (default) parse the syntax tree of all modules within *tasks*. see *registry.get()* for more details about the behavior of this argument

**Returns** *Task*

## 18.5 Wiki

Utility functions for dealing with the wiki (<https://wiki.auto-pi-lot.com>).

See the docstrings of the `ask()` function, as well as the `guide_wiki_plugins` section in the user guide for use.

### Functions:

<code>ask(filters[, properties])</code>	Perform an API call to the wiki using the <a href="#">ask API</a> and simplify to a list of dictionaries
<code>browse(search[, browse_type, params])</code>	Use the <a href="#">browse</a> api of the wiki to search for specific pages, properties, and so on.
<code>make_ask_string(filters[, properties, full_url])</code>	Create a query string to request semantic information from the Autopilot wiki
<code>make_browse_string(search[, browse_type, ...])</code>	

**ask**(*filters*: Union[List[str], str], *properties*: Union[None, List[str], str] = None) → List[dict]  
Perform an API call to the wiki using the [ask API](#) and simplify to a list of dictionaries

#### Parameters

- **filters** (*list*, *str*) – A list of strings or a single string of semantic mediawiki formatted property filters. See [make\\_ask\\_string\(\)](#) for more information
- **properties** (*None*, *list*, *str*) – Properties to return from filtered pages, See [make\\_ask\\_string\(\)](#) for more information

Returns:

**browse**(*search*: str, *browse\_type*: str = 'page', *params*: Optional[dict] = None)  
Use the [browse](#) api of the wiki to search for specific pages, properties, and so on.

#### Parameters

- **search** (*str*) – the search string! \* can be used as a wildcard.
- **browse\_type** (*str*) – The kind of browsing we're doing, one of:
  - page
  - subject
  - property
  - pvalue
  - category
  - concept
- **params** (*dict*) – Additional params for the browse given as a dictionary, see the [smw docs](#) for usage.

**Returns** dict, list of dicts of results

**make\_ask\_string**(*filters*: Union[List[str], str], *properties*: Union[None, List[str], str] = None, *full\_url*: bool = True) → str

Create a query string to request semantic information from the Autopilot wiki

#### Parameters

- **filters** (*list, str*) – A list of strings or a single string of semantic mediawiki formatted property filters, eg "[[Category:Hardware]]" or "[[Has Contributor::sneakers-the-rat]]". Refer to the [semantic mediawiki documentation](#) for more information on syntax
- **properties** (*None, list, str*) – Properties to return from filtered pages, see the [available properties](#) on the wiki and the [semantic mediawiki documentation](#) for more information on syntax. If *None* (default), just return the names of the pages
- **full\_url** (*bool*) – If *True* (default), prepend `f'{WIKI_URL}api.php?action=ask&query='` to the returned string to make it [ready for an API call](#)

**Returns** the formatted query string

**Return type** `str`

`make_browse_string(search, browse_type='page', params=None, full_url: bool = True)`



## SETUP

After initial setup, configure autopilot: create an autopilot directory and a prefs.json file

### Functions:

<code>make_dir(adir[, permissions])</code>	Make a directory if it doesn't exist and set its permissions to 0777
<code>make_alias(launch_script[, bash_profile])</code>	Make an alias so that calling autopilot calls autopilot_dir/launch_autopilot.sh
<code>parse_manual_prefs(manual_prefs)</code>	
<code>parse_args()</code>	
<code>locate_user_dir(args)</code>	
<code>run_form(prefs)</code>	
<code>make_launch_script(prefs[, prefs_fn, ...])</code>	
<code>make_systemd(prefs, launch_file)</code>	
<code>results_string(env_results, config_msgs, ...)</code>	
<code>make_ectopic_dirnames(basedir)</code>	
<code>main()</code>	

**make\_dir**(*adir*: *pathlib.Path*, *permissions*: *int* = 511)

Make a directory if it doesn't exist and set its permissions to 0777

#### Parameters

- **adir** (*str*) – Path to the directory
- **permissions** (*int*) – an octal integer used to set directory permissions (default 0o777)

**make\_alias**(*launch\_script*: *pathlib.Path*, *bash\_profile*: *Optional[str]* = None) → Tuple[bool, str]

Make an alias so that calling autopilot calls autopilot\_dir/launch\_autopilot.sh

#### Parameters

- **launch\_script** (*str*) – the path to the autopilot launch script to be aliased

- **bash\_profile** (*str*, *None*) – Optional, location of shell profile to edit. if *None*, use `.bashrc` then `.bash_profile` if they exist

**parse\_manual\_prefs**(*manual\_prefs*: *List[str]*) → *dict*

**parse\_args**()

**locate\_user\_dir**(*args*) → *pathlib.Path*

**run\_form**(*prefs*: *dict*) → *Tuple[dict, List[str]*

**make\_launch\_script**(*prefs*: *dict*, *prefs\_fn*=*None*, *launch\_file*=*None*, *permissions*: *int* = 509) → *pathlib.Path*

**make\_systemd**(*prefs*: *dict*, *launch\_file*: *pathlib.Path*) → *Tuple[bool, str]*

**results\_string**(*env\_results*: *dict*, *config\_msgs*: *List[str]*, *error\_msgs*: *List[str]*, *prefs\_fn*: *str*, *prefs*) → *str*

**make\_ectopic\_dirnames**(*basedir*: *pathlib.Path*) → *dict*

**main**()

## 19.1 scripts

Scripts used in `run_script` and `setup_autopilot` to install packages and configure the system environment

Scripts are contained in the `scripts.SCRIPTS` dictionary, and each script is of the form:

```
'script_name': {
    'type': 'bool', # always bool, signals that gui elements should present it as a
    ↪checkbox to run or not
    'text': 'human readable description of what the script does',
    'commands': [
        'list of shell commands'
    ]
}
```

The commands in each `commands` list are concatenated with `&&` and run sequentially (see `run_script.call_series()`). Certain commands that are expected to fail but don't impact the outcome of the rest of the script – eg. making a directory that already exists – can be made optional by using the syntax:

```
[
    'required command',
    {'command': 'optional command', 'optional': True}
]
```

This concatenates the command with a ```; ``` which doesn't raise an error if the command fails and allows the rest of the script to proceed.

---

**Note:** The above syntax will be used in the future for additional parameterizations that need to be made to scripts (though being optional is the only parameterization available now).

---

---

**Note:** An unadvertised feature of `raspi-config` is the ability to run commands from the cli – find the name of a command here: <https://github.com/RPi-Distro/raspi-config/blob/master/raspi-config> and then use it like this: `sudo raspi-config nonint function_name argument`, so for example to enable the camera one just calls `sudo`



`raspi-config nonint do_camera 0` (where turning the camera on, perhaps counterintuitively, is `0` which is true for all commands)

---

---

**Todo:** Probably should have these use `prefs.get('S')` copes as well

---

**Data:**

---

*SCRIPTS*

---

```

SCRIPTS = OrderedDict([ ( 'env_pilot', { 'commands': [ 'sudo apt-get update', 'sudo
apt-get install -y ' 'build-essential cmake git python3-dev ' 'libatlas-base-dev
libsamplerate0-dev ' 'libsndfile1-dev libreadline-dev ' 'libasound-dev i2c-tools '
'libportmidi-dev liblo-dev libhdf5-dev ' 'libzmq-dev libffi-dev'], 'text': 'install
system packages necessary for ' 'autopilot Pilots? (required if they arent ' 'already)',
'type': 'bool'}), ( 'env_terminal', { 'commands': [ 'sudo apt-get update', 'sudo
apt-get install ' '-y ' 'libxcb-icc4 ' 'libxcb-image0 ' 'libxcb-keysyms1 '
'libxcb-randr0 ' 'libxcb-render-util0 ' 'libxcb-xinerama0 ' 'libxcb-xf86-dev'], 'text':
'install system packages necessary for ' 'autopilot Terminals? (required if they arent '
'already)', 'type': 'bool'}), ( 'performance', { 'commands': [ 'sudo systemctl disable
raspi-config', "sudo sed -i '/^exit 0/i echo \" \"performance\" | sudo tee '
\"/sys/devices/system/cpu/cpu*/cpufreq/scaling_governor\" \" '/etc/rc.local', 'sudo sh -c
\"echo @audio - memlock ' '256000 >> /etc/security/limits.conf\"", 'sudo sh -c "echo @audio
- rtprio 75 ' '>> /etc/security/limits.conf"', 'sudo sh -c "echo vm.swappiness = 10 ' '>>
/etc/sysctl.conf"', 'text': 'Do performance enhancements? (recommended, ' 'change cpu
governor and give more memory to ' 'audio)', 'type': 'bool'}), ( 'change_pw', {
'commands': ['passwd'], 'text': "If you haven't, you should change the default \"
'rasberry pi password or you _will_ get your ' 'identity stolen. Change it now?",
'type': 'bool'}), ( 'set_locale', { 'commands': [ 'sudo dpkg-reconfigure locales',
'sudo dpkg-reconfigure ' 'keyboard-configuration'], 'text': 'Would you like to set your
locale?', 'type': 'bool'}), ( 'hifiberry', { 'commands': [ { 'command': 'sudo adduser
pi i2c', 'optional': True}, 'sudo sed -i ' ' \"s/^dtparam=audio=on/#dtparam=audio=on/g\" \"
'/boot/config.txt', 'sudo sed -i ' ' \"s/$/\\ndtoverlay=hifiberry-dacplus\\
ndtoverlay=i2s-mmap\\ndtoverlay=i2c-mmap\\ndtparam=i2c1=on\\ndtparam=i2c_arm=on/\" \"
'/boot/config.txt', "echo -e 'pcm.!default {\\n type hw \" 'card 0\\n}\\nctl.!default {\\n
type \"hw card 0\\n\" | sudo tee \" '/etc/asound.conf', 'text': 'Setup Hifiberry
DAC/AMP?', 'type': 'bool'}), ( 'bluetooth', { 'commands': [ "sudo sed -i ' '$s/$/\\n\"
'dtoverlay=pi3-disable-bt/' \" '/boot/config.txt', 'sudo systemctl disable '
'hciuart.service', 'sudo systemctl disable ' 'bluealsa.service', 'sudo systemctl disable
' 'bluetooth.service'], 'text': "Disable Bluetooth? (recommended unless you're \" 'using
it <3\", 'type': 'bool'}), ( 'systemd', { 'text': 'Install Autopilot as a systemd
service?\\n' 'If you are running this command in a virtual ' 'environment it will be used
to launch ' 'Autopilot', 'type': 'bool'}), ( 'alias', { 'text': 'Create an alias to
launch with "autopilot\" ' '(must be run from setup_autopilot, calls ' 'make_alias)',
'type': 'bool'}), ( 'jackd_apt', { 'commands': [ 'sudo apt update && sudo apt install '
'-y jackd2'], 'text': 'Install jack audio from apt repository ' '(required if
AUDIOSERVER = jack)', 'type': 'bool'}), ( 'jackd_source', { 'commands': [ 'git clone '
'git://github.com/jackaudio/jack2 ' '--depth 1', 'cd jack2', './waf configure --alsa=yes
' '--libdir=/usr/lib/arm-linux-gnueabi/hf/', './waf build -j6', 'sudo ./waf install',
'sudo ldconfig', 'sudo sh -c "echo @audio - memlock ' '256000 >>
/etc/security/limits.conf"', 'sudo sh -c "echo @audio - rtprio 75 ' '>>
/etc/security/limits.conf"', 'cd ..', 'rm -rf ./jack2'], 'text': 'Install jack audio
from source, try this if ' 'youre having compatibility or runtime issues ' 'with jack
(required if AUDIOSERVER = jack)', 'type': 'bool'}), ( 'opencv', { 'commands': [ 'sudo
apt-get install -y ' 'build-essential cmake ccache unzip ' 'pkg-config libjpeg-dev
libpng-dev ' 'libtiff-dev libavcodec-dev ' 'libavformat-dev libswscale-dev ' 'libv4l-dev
libxvidcore-dev ' 'libx264-dev ffmpeg libgtk-3-dev ' 'libcanberra-gtk* libatlas-base-dev
' 'gfortran python2-dev python-numpy', 'git clone '
'https://github.com/opencv/opencv.git', 'git clone '
'https://github.com/opencv/opencv_contrib', 'cd opencv', 'mkdir build', 'cd build',
'cmake -D ' 'CMAKE_BUILD_TYPE=RELEASE ' '-D ' 'CMAKE_INSTALL_PREFIX=/usr/local ' '-D '
'OPENCV_EXTRA_MODULES_PATH=/home/pi/git/opencv_contrib/modules ' '-D BUILD_TESTS=OFF -D '
'BUILD_PERF_TESTS=OFF ' '-D BUILD_DOCS=OFF -D ' 'WITH_TBB=ON -D '
'CMAKE_CXX_FLAGS="-DTBB_USE_GCC_BUILTINS=1 ' '-D __TBB_64BIT_ATOMICS=0\" ' '-D
WITH_OPENMP=ON -D ' 'WITH_IPP=OFF -D ' 'WITH_OPENCL=ON -D ' 'WITH_V4L=ON -D '
'WITH_LIBV4L=ON -D ' 'ENABLE_NEON=ON -D ' 'ENABLE_VFPV3=ON -D '
'PYTHON3_EXECUTABLE=/usr/bin/python3 ' '-D ' 'PYTHON_INCLUDE_DIR=/usr/include/python3.7
' '-D ' 'PYTHON_INCLUDE_DIR=/usr/include/arm-linux-gnueabi/hf/python3.7 ' '-D '
'OPENCV_ENABLE_NONFREE=ON ' '-D ' 'INSTALL_PYTHON_EXAMPLES=OFF ' '-D WITH_CAROTENE=ON '
'-D ' 'CMAKE_SHARED_LINKER_FLAGS='-latomic\" \" '-D BUILD_EXAMPLES=OFF ..', 'sudo sed -i '

```

## 19.2 run\_script

Run scripts to setup system dependencies and autopilot plugins

```
> # to list scripts
> python3 -m autopilot.setup.run_script --list

> # to execute one script (setup hifiberry soundcard)
> python3 -m autopilot.setup.run_script hifiberry

> # to execute multiple scripts
> python3 -m autopilot.setup.run_script hifiberry jackd
```

### Functions:

<code>call_series(commands[, series_name])</code>	Call a series of commands, giving a single return code on completion or failure
<code>run_script(script_name)</code>	
<code>run_scripts(scripts[, return_all, print_status])</code>	Run a series of scripts, printing results
<code>list_scripts()</code>	

**call\_series**(*commands*, *series\_name=None*)

Call a series of commands, giving a single return code on completion or failure

**Parameters** *commands* –

**Returns**

**run\_script**(*script\_name*)

**run\_scripts**(*scripts*, *return\_all=False*, *print\_status=True*) → Union[bool, Dict[str, bool]]

Run a series of scripts, printing results

**Parameters** *scripts* (*list*) – list of script names

**Returns** success or failure of scripts - True if all were successful, False otherwise.

**Return type** bool

**list\_scripts**()



## PREFS

Module to hold module-global variables as preferences.

Upon import, `prefs` attempts to import a `prefs.json` file from the default location (see `prefs.init()`).

Prefs are then accessed with `prefs.get()` and `prefs.set()` functions. After initialization, if a pref is set, it is stored in the `prefs.json` file – prefs are semi-durable and persist across sessions.

When attempting to get a pref that is not set, `prefs.get()` will first try to find a default value (set in `_PREFS`), and if none is found return `None` – accordingly no prefs should be intentionally set to `None`, as it signifies that the pref is not set.

Prefs are thread- and process-safe, as they are stored and served by a `multiprocessing.Manager` object.

`prefs.json` is typically generated by running `autopilot.setup.setup_autopilot`, though you can freestyle it if you are so daring.

The ``**HARDWARE**`` pref is a little special. It specifies how each of the `hardware` components connected to the system is configured. It is a dictionary with this general structure:

```
'HARDWARE': {
    'GROUP': {
        'ID': {
            'hardware_arg': 'val'
        }
    }
}
```

where there are user-named 'GROUPS' of hardware objects, like 'LEDS', etc. Within a group, each object has its 'ID' (passed as the name argument to the hardware initialization method) which allows it to be identified from the other components in the group. The intention of this structure is to allow multiple categories of hardware objects to be parameterized and used separately, even though they might be the same object type. Eg. we may have three LEDs in our nosepokes, but also have an LED that serves at the arena light. If we wanted to write a command that turns off all LEDs, we would have to explicitly specify their IDs, making it difficult to re-use very common hardware command patterns within tasks. There are obvious drawbacks to this scheme – clunky, ambiguous, etc. and will be deprecated as parameterization continues to congeal across the library.

The class that each element is used with is determined by the `Task.HARDWARE` dictionary. Specifically, the `Task.init_hardware()` method does something like:

```
self.hardware['GROUP']['ID'] = self.HARDWARE['GROUP']['ID'](**prefs.get('HARDWARE')[
    ↪ 'GROUP']['ID'])
```

**Warning:** These are **not** hard coded prefs. `_DEFAULTS` populates the *default* values for prefs, but local prefs are always restored from and saved to `prefs.json`. If you're editing this file and things aren't changing, you're in the wrong place!

This iteration of prefs with respect to work done on the [People's Ventilator Project](#)

If a pref has a string for a 'deprecation' field in `prefs._DEFAULTS`, a `FutureWarning` will be raised with the string given as the message

#### Classes:

<code>Scopes(value)</code>	Enum that lists available scopes and groups for prefs
----------------------------	---

#### Data:

<code>_DEFAULTS</code>	Ordered Dictionary containing default values for prefs.
------------------------	---

#### Functions:

<code>get([key])</code>	Get a pref!
<code>set(key, val)</code>	Set a pref!
<code>save_prefs([prefs_fn])</code>	Dump prefs into the <code>prefs_fn</code> .json file
<code>init([fn])</code>	Initialize prefs on autopilot start.
<code>add(param, value)</code>	Add a pref after init
<code>git_version(repo_dir)</code>	Get the git hash of the current commit.
<code>compute_calibration([path, calibration, ...])</code>	

#### Parameters

- `path`

<code>clear()</code>	Mostly for use in testing, clear loaded prefs (without deleting <code>prefs.json</code> )
----------------------	---

#### `class Scopes(value)`

Bases: `enum.Enum`

Enum that lists available scopes and groups for prefs

Scope can be an agent type, common (for everyone), or specify some subgroup of prefs that should be presented together (like directories)

COMMON = All Agents DIRECTORY = Prefs group for specifying directory structure TERMINAL = prefs for Terminal Agents Pilot = Prefs for Pilot agents LINEAGE = prefs for networking lineage (until networking becomes more elegant ;) AUDIO = Prefs for configuring the Jackd audio server

#### Attributes:

<code>COMMON</code>	All agents
<code>TERMINAL</code>	Prefs specific to Terminal Agents
<code>PILOT</code>	Prefs specific to Pilot Agents
<code>DIRECTORY</code>	Directory structure
<code>LINEAGE</code>	Prefs for coordinating network between pilots and children

continues on next page

Table 4 – continued from previous page

<i>AUDIO</i>	Audio prefs...
<b>COMMON = 1</b>	All agents
<b>TERMINAL = 2</b>	Prefs specific to Terminal Agents
<b>PILOT = 3</b>	Prefs specific to Pilot Agents
<b>DIRECTORY = 4</b>	Directory structure
<b>LINEAGE = 5</b>	Prefs for coordinating network between pilots and children
<b>AUDIO = 6</b>	Audio prefs...
<b>_PREF_MANAGER = &lt;multiprocessing.managers.SyncManager object at 0x7f6f8550f6d0&gt;</b>	The multiprocessing.Manager that stores prefs during system operation and makes them available and consistent across processes.

```

_DEFAULTS = OrderedDict([ ( 'NAME', { 'scope': <Scopes.COMMON: 1>, 'text': 'Agent
Name:', 'type': 'str'}), ( 'PUSHPORT', { 'default': '5560', 'scope': <Scopes.COMMON:
1>, 'text': 'Push Port - Router port used by the Terminal ' 'or upstream agent:',
'type': 'int'}), ( 'MSGPORT', { 'default': '5565', 'scope': <Scopes.COMMON: 1>,
'text': 'Message Port - Router port used by this agent ' 'to receive messages:',
'type': 'int'}), ( 'TERMINALIP', { 'default': '192.168.0.100', 'scope':
<Scopes.COMMON: 1>, 'text': 'Terminal IP:', 'type': 'str'}), ( 'LOGLEVEL', { 'choices':
('DEBUG', 'INFO', 'WARNING', 'ERROR'), 'default': 'WARNING', 'scope': <Scopes.COMMON:
1>, 'text': 'Log Level:', 'type': 'choice'}), ( 'LOGSIZE', { 'default': 5242880,
'scope': <Scopes.COMMON: 1>, 'text': 'Size of individual log file (in bytes)', 'type':
'int'}), ( 'LOGNUM', { 'default': 4, 'scope': <Scopes.COMMON: 1>, 'text': 'Number of
logging backups to keep of LOGSIZE', 'type': 'int'}), ( 'CONFIG', { 'hidden': True,
'scope': <Scopes.COMMON: 1>, 'text': 'System Configuration', 'type': 'list'}), (
'ENV', { 'default':
'/home/docs/checkouts/readthedocs.org/user_builds/auto-pi-lot/envs/hotfix', 'scope':
<Scopes.COMMON: 1>, 'text': 'Location of virtual environment, if used.', 'type':
'str'}), ( 'AUTOPLUGIN', { 'default': True, 'scope': <Scopes.COMMON: 1>, 'text':
'Attempt to import the contents of the plugin ' 'directory', 'type': 'bool'}), (
'PLUGIN_DB', { 'default': '/home/docs/autopilot/plugin_db.json', 'scope':
<Scopes.COMMON: 1>, 'text': 'filename to use for the .json plugin_db that ' 'keeps track
of installed plugins', 'type': 'str'}), ( 'BASEDIR', { 'default':
'/home/docs/autopilot', 'scope': <Scopes.DIRECTORY: 4>, 'text': 'Base Directory',
'type': 'str'}), ( 'DATADIR', { 'default': '/home/docs/autopilot/data', 'scope':
<Scopes.DIRECTORY: 4>, 'text': 'Data Directory', 'type': 'str'}), ( 'SOUNDDIR', {
'default': '/home/docs/autopilot/sounds', 'scope': <Scopes.DIRECTORY: 4>, 'text':
'Sound file directory', 'type': 'str'}), ( 'LOGDIR', { 'default':
'/home/docs/autopilot/logs', 'scope': <Scopes.DIRECTORY: 4>, 'text': 'Log Directory',
'type': 'str'}), ( 'VIZDIR', { 'default': '/home/docs/autopilot/viz', 'scope':
<Scopes.DIRECTORY: 4>, 'text': 'Directory to store Visualization results', 'type':
'str'}), ( 'PROTOCOLDIR', { 'default': '/home/docs/autopilot/protocols', 'scope':
<Scopes.DIRECTORY: 4>, 'text': 'Protocol Directory', 'type': 'str'}), ( 'PLUGINDIR', {
'default': '/home/docs/autopilot/plugins', 'scope': <Scopes.DIRECTORY: 4>, 'text':
'Directory to import ', 'type': 'str'}), ( 'REPODIR', { 'default': PosixPath('/home/
docs/checkouts/readthedocs.org/user_builds/auto-pi-lot/checkouts/hotfix'), 'scope':
<Scopes.DIRECTORY: 4>, 'text': 'Location of Autopilot repo/library', 'type': 'str'}), (
'CALIBRATIONDIR', { 'default': '/home/docs/autopilot/calibration', 'scope':
<Scopes.DIRECTORY: 4>, 'text': 'Location of calibration files for solenoids, ' 'etc.',
'type': 'str'}), ( 'PIGPIOMASK', { 'default': '1111110000111111111111110000', 'scope':
<Scopes.PILOT: 3>, 'text': 'Binary mask controlling which pins pigpio ' 'controls
according to their BCM numbering, ' 'see the -x parameter of pigpiod', 'type': 'str'}),
( 'PIGPARGS', { 'default': '-t 0 -l', 'scope': <Scopes.PILOT: 3>, 'text': 'Arguments
to pass to pigpiod on startup', 'type': 'str'}), ( 'PULLUPS', { 'scope': <Scopes.PILOT:
3>, 'text': 'Pins to pull up on system startup? (list of ' 'form [1, 2])', 'type':
'list'}), ( 'PULLDOWNS', { 'scope': <Scopes.PILOT: 3>, 'text': 'Pins to pull down on
system startup? (list of ' 'form [1, 2])', 'type': 'list'}), ( 'PING_INTERVAL', {
'default': 5, 'scope': <Scopes.PILOT: 3>, 'text': 'How many seconds should pilots wait
in ' 'between pinging the Terminal?', 'type': 'float'}), ( 'DRAWFPS', { 'default':
'20', 'scope': <Scopes.TERMINAL: 2>, 'text': 'FPS to draw videos displayed during '
'acquisition', 'type': 'int'}), ( 'PILOT_DB', { 'default':
'/home/docs/autopilot/pilot_db.json', 'scope': <Scopes.TERMINAL: 2>, 'text': 'filename
to use for the .json pilot_db that ' 'maps pilots to subjects (relative to BASEDIR)',
'type': 'str'}), ( 'TERMINAL_SETTINGS_FN', { 'default':
'/home/docs/autopilot/terminal.conf', 'scope': <Scopes.TERMINAL: 2>, 'text': 'filename
to store QSettings file for Terminal', 'type': 'str'}), ( 'TERMINAL_WINSIZE_BEHAVIOR', {
'choices': ('remember', 'moderate', 'maximum', 'custom'), 'default': 'remember',
'scope': <Scopes.TERMINAL: 2>, 'text': 'Strategy for resizing terminal window on '
'opening', 'type': 'choice'}), ( 'TERMINAL_CUSTOM_SIZE', { 'default': [Chapter 80, prefs
400], 'depends': ('TERMINAL_WINSIZE_BEHAVIOR', 'custom'), 'scope': <Scopes.TERMINAL:
2>, 'text': 'Custom size for window, specified as [px from ' 'left, px from top, width,
height]', 'type': 'list'}), ( 'LINEAGE', { 'choices': ('NONE', 'PARENT', 'CHILD'),

```



Ordered Dictionary containing default values for prefs.

An Ordered Dictionary lets the prefs be displayed in gui elements in a predictable order, but prefs are stored in `prefs.json` in alphabetical order and the ‘live’ prefs used during runtime are stored in `_PREFS`

Each entry should be a dict with the following structure:

```
"PREF_NAME": {
    "type": (str, int, bool, choice, list) # specify the appropriate GUI input, str,
    or int are validators,
    choices are a
        # dropdown box, and lists allow users to specify lists of values like "[0,
    1]"
    "default": If possible, assign default value, otherwise None
    "text": human-readable text that described the pref
    "scope": to whom does this pref apply? see :class:`.Scopes`
    "depends": name of another pref that needs to be supplied/enabled for this one.
    to be enabled (eg. don't set sampling rate of audio server if audio server
    disabled)
        can also be specified as a tuple like ("LINEAGE", "CHILD") that enables the
    option when prefs[depends[0]] == depends[1]
    "choices": If type=="choice", a tuple of available choices.
}
```

**get**(key: *Optional[str]* = None)

Get a pref!

If a value for the given key can't be found, prefs will attempt to

**Parameters** **key** (*str*, *None*) – get pref of specific key, if *None*, return all prefs

**Returns** value of pref (type variable!), or *None* if no pref of passed key

**set**(key: *str*, *val*)

Set a pref!

---

**Note:** Whenever a pref is set, the prefs file is automatically updated – prefs are system-durable!!

(specifically, whenever the module-level `_INITIALIZED` value is set to `True`, prefs are saved to file to avoid overwriting before loading)

---

#### Parameters

- **key** (*str*) – Name of pref to set
- **val** – Value of pref to set (prefs are not type validated against default types)

**save\_prefs**(*prefs\_fn: Optional[str]* = None)

Dump prefs into the `prefs_fn.json` file

#### Parameters

- **prefs\_fn** (*str*, *None*) – if provided, pathname to `prefs.json` otherwise resolve `prefs.json` according the
- **to the normal methods....**

**init**(*fn=None*)

Initialize prefs on autopilot start.

If passed dict of prefs or location of prefs.json, load and use that

Otherwise

- Look for the autopilot wayfinder `~/ .autopilot` file that tells us where the user directory is
- look in default location `~/autopilot/prefs.json`

---

**Todo:** This function may be deprecated in the future – in its current form it serves to allow the sorta janky launch methods in the headers/footers of `autopilot/core/pilot.py` and `autopilot/core/terminal.py` that will eventually be transformed into a unified agent framework to make launching easier. Ideally one would be able to just import prefs without having to explicitly initialize it, but we need to formalize the full launch process before we make the full lurch to that model.

---

**Parameters** **fn** (*str*, *dict*) – a path to *prefs.json* or a dictionary of preferences

**add**(*param*, *value*)

Add a pref after init

**Parameters**

- **param** (*str*) – Allcaps parameter name
- **value** – Value of the pref

**git\_version**(*repo\_dir*)

Get the git hash of the current commit.

Stolen from [numpy's setup](#)

and linked by ryanjdillon on [SO](#)

**Parameters** **repo\_dir** (*str*) – directory of the git repository.

**Returns** git commit hash.

**Return type** unicode

**compute\_calibration**(*path=None*, *calibration=None*, *do\_return=False*)

**Parameters**

- **path**
- **calibration**
- **do\_return**

Returns:

**clear**()

Mostly for use in testing, clear loaded prefs (without deleting `prefs.json`)

(though you will probably overwrite `prefs.json` if you clear and then set another pref so don't use this except in testing probably)

## EXTERNAL

Autopilot uses two lightly modified versions of existing libraries that are included in the repository as submodules.

- `mlx90640-library` - driver for the `hardware.i2c.MLX90640` that correctly sets the baudrate for 64fps capture
- `pigpio` - pigpio that is capable of returning full timestamps rather than system ticks in gpio callbacks.



## CHANGELOG

For full details, see commit logs and issues at <http://github.com/wehr-lab/autopilot>

### 22.1 Version 0.4

#### 22.1.1 v0.4.2 (August 24th)

##### Minor Improvements

- *Transformer* can now forward processed data and input data in addition to returning the processed data. A lateral improvement until the streaming API is finished.
- *Slice* now accepts arbitrary indexing objects, rather than just `slice` objects. Not sure why this wasn't the case before.

##### Bugfixes

- Fixed a circular import problem that prevented the `stim` module from being imported because the placeholder metaclass was in the `__init__.py` file. Moved it to its own file.
- Fixed another instantiated but not raised value error in `gpio`

##### Documentation

- Documenting flags in networking objects
- Documenting `min_size` in camera stream method
- Documenting `invert_gyro` in `I2C_9DOF`

#### 22.1.2 v0.4.1 (August 17th)

##### Bugfixes

- The `autopilot.setup.forms.HARDWARE_FORM` would incorrectly use the class object itself rather than the class name in a few places which caused hardware names to incorrectly display and be impossible to add!
- Correctly handle module name in loggers when running interactively
- Use accelerometer calibration when computing *rotation()*

- Use `autopilot.get()` in `autopilot.transform.make_transform()`

## Docs

- Document the attributes in `autopilot.transform.timeseries.Kalman`

### 22.1.3 v0.4.0 - Become Multifarious (August 3rd, 2021)

This release is primarily to introduce the new plugin system, the autopilot wiki, and their integration as a way of starting the transformation of Autopilot into a tool with decentralized development and governance (as well as make using the tool a whole lot easier and more powerful).

*With humble thanks to Lucas Ott, Tillie Morris, Chris Rodgers, Arne Meyer, Mikkel Roald-Arbøl, David Robbe, and an anonymous discussion board poster for being part of this release.*

## New Features

- **Registries & Plugins** - Autopilot now supports users writing their code outside of the library as plugins! To support this, a registry system was implemented throughout the program. Plugin objects can be developed as objects that inherit from the Autopilot object tree – eg. implementing a GPIO object by subclassing `hardware.gpio.GPIO`, or a new task by subclassing `Task`. This system is flexible enough to allow any lineage of objects to be included as a plugin – stimuli, tasks, and so on – and we will be working to expand registries to every object in Autopilot, including the ability for plugins to replace core modules to make Autopilot’s flexibility verge on ludicrous. The basic syntax of the registry system is simple and doesn’t require any additional logic beyond inheritance to be implemented on plugin objects – `autopilot.get('object_type', 'object_name')` is the basic method, with a few aliases for specific object types like `autopilot.get_hardware()`. Also thanks to [Arne Meyer](#) for submitting an early draft of the registry system and [Mikkel Roald-Arbøl](#) for raising the issue.
- At long last, the Autopilot Wiki is alive!!!! - <https://wiki.auto-pi-lot.com/> - The wiki is the place for communal preservation of technical knowledge about using Autopilot, like hardware designs, build guides, parameter sets, and beyond! This isn’t any ordinary wiki, though, we got ourselves a *semantic wiki* which augments traditional wikis with a rich system of human and computer-readable linked attributes: a particular type of page will have some set of attributes, like a page about a 3D printed part will have an associated .stl file, but rather than having these be in plaintext they are specified in a format that is queryable, extensible, and infinitely mutable. The vision for the wiki is much grander (but not speculative! very concrete!) than just a place to take notes, but is intended to blend the use of Autopilot as an experimental tool with body of knowledge that supports it. Autopilot can query the wiki with the `wiki` module like `wiki.ask('[[Category:3D_CAD]]', 'Has STL')` to get links to all .stl files for all 3D parts on the wiki. The integration between the two makes using and submitting information trivial, but *also* makes *designing whole new types of community interfaces* completely trivial. As a first pass, the Wiki will be the place to index plugins, the system for submitting them, querying them, and downloading them only took a few hours and few dozen lines of code to implement. The wiki is infinitely malleable – that’s the point – and I am very excited to see how people use it.
- **Tests & Continuous Integration with Travis!** We are on the board with having nonzero tests! The travis page is here: <https://travis-ci.com/github/wehr-lab/autopilot> and the coveralls page is here: <https://coveralls.io/github/wehr-lab/autopilot>. At the moment we have a whopping 27% coverage, but as we build out our testing suite we hope that it will become much easier for people to contribute to Autopilot and be confident that it works!
- **New Hardware Objects**
  - `cameras.PiCamera` - A fast interface to the PiCamera, wrapping the picamera library, and using tips from its developer to juice every bit of speed i could!
  - The `I2C_9DOF` object was massively improved to take better advantage of its onboard DSP and expose more of its i2c commands.

- **New Transforms**

- `timeseries.Kalman` - adapted a Kalman filter from the wonderful filterpy package! it's in the new timeseries transform module
- `geometry.IMU_Orientation` - IMU\_Orientation performs a sensor fusion algorithm with the Kalman Filter class to combine gyroscope and accelerometer measurements into a better estimate of earth-centric roll and pitch. This is used by the IMU class, but is made independent so it can be used without an Autopilot hardware object/post-facto/etc.
- `timeseries.Filter_IIR` - Filter\_IIR implements scipy's IIR filter as a transform object.
- `timeseries.Integrate` - Integrate adds successive numbers together (scaled by dt if requested). not much by itself, but when used with a kalman filter very useful :)
- `geometry.Rotate` - use scipy to rotate a vector by some angle in x, y, and/or z
- `geometry.Spheroid` - fit and transform 3d coordinates according to some spheroid - used in the IMU's accelerometer calibration method: given some target spheroid, and some deformed spheroid (eg. a miscalibrated accelerometer might have the x, y, or z axis scaled or offset) either explicitly set or estimated from a series of point measurements, transform future input given that transformation to correct for the deformed source spheroid.

- **New Prefs**

- 'AUTOPLUGIN' - Attempt to import the contents of the plugin directory,
- 'PLUGIN\_DB' - filename to use for the .json plugin\_db that keeps track of installed plugins',
- 'PING\_INTERVAL' - How many seconds should pilots wait in between pinging the Terminal?',
- 'TERMINAL\_SETTINGS\_FN' - filename to store QSettings file for Terminal',
- 'TERMINAL\_WINSIZE\_BEHAVIOR' - Strategy for resizing terminal window on opening',
- 'TERMINAL\_CUSTOM\_SIZE' - Custom size for window, specified as [px from left, px from top, width, height]',

## Major Improvements

- Stereo Sound (Thank you [Chris Rodgers!](#)) - <https://github.com/wehr-lab/autopilot/pull/102>
- Multihop messages & direct messaging - <https://github.com/wehr-lab/autopilot/pull/99> - it is now possible to send multihop messages through multiple Station objects, as well as easier to send messages directly between net nodes. See the examples in the network tests section of the docs.
- Multiple Children (Thank you [Chris Rodgers!](#)) - <https://github.com/wehr-lab/autopilot/pull/103> - the CHILDDID field now accepts a list, allowing a Pilot to initialize child tasks on multiple children. (this syntax and the hierarchical nature of pilots and children will be deprecated as we refactor the networking modules into a general mesh system, but this is lovely to have for now :)
- Programmatic Setup - <https://github.com/wehr-lab/autopilot/issues/33> - noninteractive setup of prefs and scripts by using `autopilot.setup -f prefs.json -p PREFNAME=VALUE -s scriptname1 -s scriptname2`
- Widget to stream video, en route to more widgets for direct GUI control of hardware objects connected to pilots
- Support python 3.8 and 3.9 essentially by not insisting that the spinnaker SDK be installable by all users (which at the time was only available for 3.7)

## Minor Improvements

- Terminal can be opened maximized, or have its size and position set explicitly, preserve between launches (Thank you Chris Rodgers!) - <https://github.com/wehr-lab/autopilot/pull/70>
- Pilots will periodically ping the Terminal again, Terminal can manually ping Pilots that may have gone silent - <https://github.com/wehr-lab/autopilot/pull/91>
- Pilots share their prefs with the Terminal in their initial handshake - <https://github.com/wehr-lab/autopilot/pull/91>
- Reintroduce router ports for net-nodes to allow them to bind a port to receive messages - <https://github.com/wehr-lab/autopilot/pull/115/commits/35be5d634d98a7983ec3d3d6c5b94da6965a2579>
- Listen methods are now optional for net\_nodes
- Allowed the creation of dataless tasks - <https://github.com/wehr-lab/autopilot/pull/115/commits/628e1fb9c8fcd15399b19b351fed87e4826bc9ab>
- Allowed the creation of plotless tasks - <https://github.com/wehr-lab/autopilot/pull/115/commits/08d99d55a32b45f54e3853813c7c71ea230b25dc>
- The I2C\_9DOF class uses memoryviews rather than buffers for a small performance boost - <https://github.com/wehr-lab/autopilot/pull/115/commits/890f2c500df8010b50d61f64e2755cd2c7a8aeeed>
- Phasing out using Queue s in favor of collections.deque for applications that only need thread and not process safety because they are way faster and what we wanted in the first place anyway.
- New Scripts - i2c, picamera, env\_terminal
- utils.NumpyEncoder and decoder to allow numpy arrays to be json serialized
- calibrations are now loaded by hardware objects themselves instead of the extraordinarily convoluted system in prefs – though some zombie code still remains there.
- Net nodes know their ip now, but this is a lateral improvement pending a reworking of the networking modules.
- performance script now sets swappiness = 10 to discourage the use of swapfiles - see <https://www.raspberrypi.org/forums/viewtopic.php?t=198765>
- Setting a string in the deprecation field of a pref in \_DEFAULTS prints it as a warning to start actually deprecating responsibly.
- Logging in more places like Subject creation, manipulation, protocol assignment.

## Bugfixes

- Loggers would only work for the last object that was instantiated, which was really embarrassing. fixed - <https://github.com/wehr-lab/autopilot/pull/91>
- Graduation criteria were calculated incorrectly when subjects were demoted in stages of a protocol - <https://github.com/wehr-lab/autopilot/pull/91>
- fix durations in solenoid class (Thank you Chris Rodgers!) - <https://github.com/wehr-lab/autopilot/pull/63>
- LED\_RGB ignores zero - <https://github.com/wehr-lab/autopilot/pull/98>
- Fix batch assignment window crashing when there are subjects that are unassigned to a task - <https://github.com/wehr-lab/autopilot/pull/115/commits/e42fc5802792822ff5a53a2379041a4a8b301e9e>
- Catch malformed protocols in batch assignment widget - <https://github.com/wehr-lab/autopilot/pull/115/commits/2cc8508a4bf3a6d49512197dc72433c60d0c656e>



- Remove broken `Terminal.reset_ui` method and made control panel better at adding/removing pilots - <https://github.com/wehr-lab/autopilot/pull/91>
- Subject class handles unexpected state a lot better (eg. no task assigned, no step assigned, tasks with no data.) but is still an absolute travesty that needs to be refactored badly.
- The jackclient would crash with long-running continuous sounds as the thread feeding it samples eventually hiccuped. Made more robust by having jackclient store samples locally in the sound server rather than being continuously streamed from the queue.
- PySide2 references still incorrectly used `QtGui` rather than `QtWidgets`
- pigpio scripts would not be stopped and removed when a task was stopped, the `gpio.clear_scripts()` function now handles that.
- xcb was removed from PySide2 distributions, so it's now listed in the requirements for the Terminal and made available in the `env_terminal` script.
- LED\_RGB didn't appropriately raise a `ValueError` when called with a single pin - <https://github.com/wehr-lab/autopilot/issues/117>
- A fistful of lingering Python 2 artifacts

## Code Structure

- continuing to split out modules in `autopilot.core` - networking this time
- utils is now a separate module instead of being in multiple places
- the npyscreen forms in `setup_autopilot` were moved to a separate module
- `setup_autopilot` was broken into functions instead of a very long and impenetrable script. still a bit of cleaning to do there.
- `autopilot.setup.setup_autopilot` was always extremely awkward, so it's now been aliased as `autopilot.setup`
- the docs have now been split into subfolders rather than period separated names to make urls nicer – eg `/dev/hardware/cameras.htm` rather than `/dev/hardware.cameras.html` . this should break some links when switching between versions on readthedocs but other than that be nondestructive.

## Docs

- new *Quickstart* documentation with lots of quick examples!

## Regressions

- Removed the `check_compatible` method in the `Transforms` class. We will want to make a call at some point if we want to implement a full realtime pipelining framework or if we want to use something like luigi or joblib or etc. for now this is an admission that type and shape checking was never really implemented but it does raise some exceptions sometimes.

## 22.2 Version 0.3

### 22.2.1 v0.3.5 (February 22, 2021)

#### Bugfixes

- Very minor one, fixes to the way *Terminal* accesses the `pilot_db.json` file to use *Terminal.pilots* property that makes a new `pilot_db.json` file if one doesn't exist, but otherwise loads the one that is found in `prefs.get('PILOT_DB')`
- Reorganized *Terminal* source to group properties together & minor additions of type hinting
- Fixed some bad fallback behavior looking for files in old hardcoded default directories, eg. in the ye olde `utils.get_pilotdb()`

### 22.2.2 v0.3.4 (December 13, 2020)

#### Improvements

- Unify the creation of loggers!!!! See the docs ;) *autopilot.core.loggers* : <https://github.com/wehr-lab/autopilot/pull/52/commits/d55638f985ab38044fc95ffeff5945021c2e198e> <https://github.com/wehr-lab/autopilot/issues/38>
- Unify prefs, including sensible defaults, refactoring of scripts into a reasonable format, multiprocessing-safety, and just generally a big weight off my mind. Note that this is a **breaking change** to the way prefs are accessed. Previously one would do `prefs.PREF_NAME`, but that made it very difficult to provide default values or handle missing prefs. the new syntax is `prefs.get('PREF_NAME')` which returns defaults with a warning and *None* if the pref is not set: <https://github.com/wehr-lab/autopilot/pull/52/commits/c40a212bcaf5f184f2a6a606027fe15b1b4df59c> <https://github.com/wehr-lab/autopilot/issues/38>
- completely clean up scripts, and together that opened the path to clean up setup as well. so all things configuration got a major promotion
- We're on the board with CI and automated testing with a positively massive 3% code coverage!!! <https://github.com/wehr-lab/autopilot/pull/52/commits/743bb8fe67a69fcc556fa76e81f72f97f510dff7>
- new scripts to eg. create autopilot alias: <https://github.com/wehr-lab/autopilot/pull/52/commits/211919b05922e18a85d8ef6216973f4000fd32c5>

#### Bugfixes

- cleanup scripts on object deletion: <https://github.com/wehr-lab/autopilot/pull/52/commits/e8218304bd7ef2e13d2adfc236f3e781abea5f78> <https://github.com/wehr-lab/autopilot/issues/41>
- don't drop 'floats' from gui when we say we can use them...: <https://github.com/wehr-lab/autopilot/pull/52/commits/743bb8fe67a69fcc556fa76e81f72f97f510dff7>
- pigpio scripts dont like floats: <https://github.com/wehr-lab/autopilot/pull/52/commits/9f939cd78a5296db3bf318115bee0213bcd1afc0>

## Docs

- Clarification of supported systems: <https://github.com/wehr-lab/autopilot/pull/52/commits/ce0ddf78b7f59f5487fec2ca7e8fb3c0ad162051>
- Solved an ancient sphinx riddle of how to get data objects/constants to pretty-print: <https://github.com/wehr-lab/autopilot/pull/52/commits/ec6d5a75dada05688b6bd3c1a53b3d9e5923870f>
- Clarify hardware prefs <https://github.com/wehr-lab/autopilot/pull/52/commits/f3a7609995c84848004891a0f41c7847cb754aae>
- what numbering system do we use: <https://github.com/wehr-lab/autopilot/pull/52/commits/64267249d7b1ec1040b522308cd60f928f2b2ee6>

## Logging

- catch pigpio script init exception: <https://github.com/wehr-lab/autopilot/pull/52/commits/3743f8abde7bbd3ed7766bdd75aee52afedf47e2>
- more of it idk <https://github.com/wehr-lab/autopilot/pull/52/commits/b682d088dbad0f206c3630543e96a5a00ceabe25>

### 22.2.3 v0.3.3 (October 25, 2020)

#### Bugfixes

- Fix layout in batch reassign gui widget from python 3 float division
- Cleaner close by catching KeyboardInterrupt in networking modules
- Fixing audioserver boot options – if ‘AUDIOSERVER’ is set even if ‘AUDIO’ isn’t set in prefs, should still start server. Not full fixed, need to make single plugin handler, single point of enabling/disabling optional services like audio server
- Fix conflict between polarity and pull in initializing *pulls* in pilot
- Catch `tables.HDF5ExtError` if local `.h5` file corrupt in pilot
- For some reason ‘fs’ wasn’t being replaced in the jackd string, reinstated.
- Fix comparison in `LED_RGB` that caused ‘0’ to turn on full because ‘value’ was being checked for its truth value (0 is false) rather than checking if value is None.
- `obj.next()` to `next(obj)`` in jackdserver

#### Improvements

- Better internal handling of pigpiod – you’re now able to import and use hardware modules without needing to explicitly start pigpiod!!
- Hopefully better killing of processes on exit, though still should work into unified process manager so don’t need to reimplement everything (eg. as is done with launching pigpiod and jackd)
- Environment scripts have been split out into `setup/scripts.py` and you can now run them with `python -m autopilot.setup.run_script` (use `--help` to see how!)
- Informative error when setup is run with too narrow terminal: <https://github.com/wehr-lab/autopilot/issues/23>
- More loggers, but increased need to unify logger creation!!!

## Cleanup

- remove unused imports in main `__init__.py` that made cyclical imports happen more frequently than necessary
- single-sourcing version number from `__init__.py`
- more cleanup of unnecessary meta and header stuff left from early days
- more debugging flags
- filter `NaturalNameWarning` from pytables
- quieter cleanups for hardware objects

## 22.2.4 v0.3.2 (September 28, 2020)

### Bugfixes

- <https://github.com/wehr-lab/autopilot/issues/19> - previously, I attempted to package binaries for the lightly modified pigpio and for jackd (the apt binary used to not work), but after realizing that was the worst possible way of going about it I changed install strategies, but didn't entirely remove the vestiges of the prior attempt. The installation expected certain directories to exist (in autopilot/external) that didn't, which crashed and choked install. Still need to formalize a configuration and plugin system, but getting there.
- <https://github.com/wehr-lab/autopilot/issues/20> - the jackd binary in the apt repos for the raspi used to not work, so i was in the habit of compiling jackd audio from source. I had build that into the install routine, but something about that now causes the JACK-Client python interface to throw segfaults. Somewhere along the line someone fixed the apt repo version of jackd so we use that now.
- previously I had only tested in a virtual environment, but now the installation routine properly handles not being in a venv.

### Cleanup

- remove bulky static files like fonts and css from /docs/ where they were never needed and god knows how they got there
- use a forked sphinx-sass when building docs that doesn't specify a required sphinx version (which breaks sphinx)
- removed skbuild requirements from install
- fixed pigpio install requirement in `requirements_pilot.txt`
- included various previously missed files in `MANIFEST.in`
- added installation of system libraries to the pilot configuration menu

## 22.2.5 v0.3.1 (August 4, 2020)

Practice version!!! still figuring out pypi

## 22.2.6 v0.3.0 (August 4, 2020)

### Major Updates

- **Python 3** - We've finally made it to Python 3! Specifically we have brought Autopilot up to compatibility with Python 3.8 – though the Spinnaker SDK is currently only available through Python 3.7, so we have formally required 3.7 for now while we work on moving acquisition to Aravis. I will *not attempt to keep Autopilot compatible with Python 2*, but no decision has been made about compatibility with other versions of Python 3. Until then, expect that Autopilot will attempt to keep up with major version changes. The switch also let up update PySide (Qt library used for the GUI) to PySide2, which uses Qt5 and has a whole raft of other improvements.
- **Continuous Data Handling** - The `Subject` class and `networking` modules have been improved to handle continuous data (eg. streaming data, generally non-trialwise or non-event-sampled data). Continuous data can be set in a Task description either with a `tables` column descriptor as trial data is, but also can be set as `'infer'`, for which the `Subject` class will wait until it receives the first data and automatically create a `tables` column depending on its type and shape. While previously we intended to nudge users to be explicit about declaring their data, this was necessary to allow for data that might be variable in type and shape to be included in a Task – eg. it should be possible to record video data without needing to specify the resolution or bit depth as a hardcoded parameter in a task class. I have come to like type inference, and may make it a general practice for all types of data. That would potentially allow tasks to be written without explicitly declaring the data that they produce at all, but I haven't decided if that's a good thing or not yet.
- The **GPIO engine** has been rebuilt, relying more on `pigpio`'s function interface. This means that GPIO timing is now ~microsecond precise, important for reward delivery, LED flashing, and a number of other basic infrastructural needs. The reorganization of hardware modules resulted in general `GPIO`, `Digital_In` and `Digital_Out` metaclasses, making common operations like setting polarity, triggers, and pullup/down resistors much easier.
- Setup has been *greatly improved*. This includes proper packaging and installation with `setuptools` & `sk-build`, allowing us to finally join PyPI :) <https://pypi.org/project/auto-pi-lot/> . Setup has been unified into a single `npyscreen`-based set of prompts that allow the user to run scripts to install libraries or configure their environment (also see `run_script()` and `list_scripts()`), set `prefs`, configure hardware objects (based on some very fun signature introspection), setup autopilot as a `systemd` service, etc. Getting started with Autopilot is now three commands!:

```
pip install auto-pi-lot
autopilot.setup.setup_autopilot
~/autopilot/launch_autopilot.sh
```

### Minor Updates

- **Logging** level is now set from `prefs`, so where before, eg. every message through the `networking` modules would be logged to `stdout`, now only warnings and exceptions are. This gives a surprisingly large performance boost.
  - Logging has also been much improved in `networking` modules, where rather than an awkward `do_logging` flag that was used to avoid logging performance-critical events like streaming data, logging is controlled by log level throughout the system. By default, logging of most messages is set at `debug` level so they don't drown out important messages in the logs as they used to.
- **Networking** modules now only deserialize messages if they are the final recipient, saving lots of processing time – particularly with streamed arrays. `Message` objects also only re-serialize messages if they have been changed. Message structure has been changed such that serialized messages are now of the general format:

```
[sender,
 (optional) intermediate_node_1, intermediate_node_2, ...
```

(continues on next page)

(continued from previous page)

```
final_recipient,
message_contents]
```

- Configuration will continue to be a point of improvement, but a few minor updates were made:
  - `prefs.CONFIG` will be used to signal multiple, potentially overlapping agent configurations, each of which may have their own system dependencies, external daemons, etc. Eg. a Pilot could be configured to play audio (which requires a jackd daemon to be started before Autopilot) and video (which requires Autopilot to be started in a X session). Checks of `prefs.CONFIG` are now `in` rather than `==` to reflect that.
  - `prefs.PINS` was renamed `prefs.HARDWARE`, and now allows hardware to be configured with dictionaries rather than integers only. Initially PINS was meant to just contain pin numbering for GPIO objects, but having a single point of hardware configuration is preferable. `Task.init_hardware()` now respects all parameters set in `prefs`.
- Throughout the code, minimal `get_this` type methods have begun to be replaced with `@property` attributes. This is because a) I love them and think they are magical, but b) will also be building Autopilot's closed-loop infrastructure around a Qt-style signal/slot architecture that wraps `@property` attributes so they can be `.connected` to one another easily.
- Previously it was possible to control presentation by *groups* of stimuli, but now it is possible to control the presentation frequency of individual stimuli.
- PySide2 has proper support for CSS Stylesheets, so the design of Autopilot's GUI has been marginally improved, a process that will continue in the ceaseless quest for aesthetic perfection.
- Several setup routines have been added to make installation of `opencv`, `pyspin`, etc. easier. I also wrote a routine to `download_box()` files from a URL, which is mysteriously hard to do.
- The *To-Do* page now reflects the full ambition of Autopilot, where before this vision was contained only in the *whitepaper* and a disorganized *plaintext* file in the repo.
- The *Subject* class can now export trial data `to_csv()`. A very minor update, but one that is the first in a number of planned improvements to data export.
- I have also opened up a message board in google groups to make feature requests and discuss use and development, hope to see you there :)

<https://groups.google.com/forum/#!forum/autopilot-users>

## New Features

- **TRANSFORMS** have been introduced!!! *Transform* objects have a `process()` method that, well, transforms data in some way. Multiple transforms can be added together to make a transformation chain. This module is still very young and doesn't have a developed API, but will be built to to automatic type compatibility checking, coercion, parallelization, and rhythm (FIFO/FILO) control. Transforms are implemented with different modalities (image, selection, logical) that imply different types of input and output data structures, but the hierarchical structure of the modules is still quite flat.
  - Autopilot is now integrated with *DeepLabCut-live*!!!! You can now use realtime pose tracking in your experiments. See the *dlclive\_example*
- **HARDWARE** has been substantially refactored to give objects an appropriate inheritance structure. This substantially reduces effort duplication across hardware objects and makes a bunch of obvious capabilities available to all of them, for example all hardware objects are now network (`init_networking()`) and logging (`init_logging()`) capable.

- **Cameras:** The `cameras.Camera_CV` class allows webcams/other simple cameras to be accessed through OpenCV, and the `cameras.Camera_Spinnaker` class allows FLIR and other cameras to be accessed through the `Spinnaker` SDK. Cameras are capable of encoding videos locally (with x264), streaming frames over the network, and making acquired frames available to other objects on the same computer. The `Camera_Spinnaker` class provides simple `@property` setter/getter methods for common parameters, but also makes all `PySpin` attributes available to the user with its `get()` and `set()` methods. The `cameras.Camera` metaclass is written so that new camera types can be added by overriding a few methods. A new `Video_Child` can be used to run a camera on a `Child` agent.
- **9DOF Motion Sensor:** The `i2c.I2C_9DOF` class can use the LSM9DS1 sensor to collect accelerometer, magnetometer, and gyroscopic data to compute unambiguous position and orientation information. We will be including calibration and computation routines that make it easier to extract properties of interest – eg. computing vertical motion by combining readings from the three sensors.
- **Temperature Sensor:** The `i2c.MLX90640` class can use the `MLX90640` sensor to measure temperature. The sensor is 32x24px, which the class can `interpolate()`. The class also allows frames to be integrated and averaged over time, substantially reducing noise. I modified the driver library to enable capture at the full 64fps on the Raspberry Pi.
- **NETWORKING** modules can stream continuous data better in a few ways:
  - `Net_Node` modules were given a `get_stream()` method that lets objects, well, stream data. Specifically, they are given a `queue.Queue` to shovel data into, which is then picked up by a dedicated `zmq.Socket` in its own thread, which handles batching, serialization, and load balancing. Streamed messages are batched (ie. contain multiple messages), but behave like normal message when received – they are split and contain an `inner_key` that is used to call the `listen` with each message (see `l_stream()`).
  - `networking` objects also now compress arrays-in-transit with the superfast `blosc` compression library. This increases their throughput dramatically, as many data streams in neuroscience are relatively low-entropy (eg. the pixels in a video of a mostly-white arena are mostly unchanged frame-to-frame and are thus highly compressible). See the `Message._serialize_numpy()` and `Message._deserialize_numpy()` methods.
- **STIMULI** - The `JackClient` can now play continuous sounds rather than discrete sounds. An example can be found in the `Nafc_Gap` task, which plays continuous white noise. All sounds now have a `play_continuous()` method, which continually dumps samples in a cycle into a queue for the `JackClient`. The continuous sound will be interrupted if another sound has its `Jack_Sound.play()` method called, but the continuous sound will resume seamlessly even if number of samples in the played sound aren't a multiple of the jack buffer size. We use this for gaps in noise (using the new `Gap` class), which we have confirmed are sample-accurate.
- **UI & VIZ**
  - A `Video` window has been created to display streaming video. The `Terminal_Networking.l_continuous()` method meters frames such that even if high-speed video is being acquired, frames are only sent at a rate of `prefs.DRAWFPS`. The `Video` class uses the `ImageItem_TimedUpdate` object, a slight modification of `pyqtgraph.ImageItem`, that calls its update method according to a `PySide2.QtCore.QTimer`.
  - A `plots_menu` menu has been added to the Terminal, and a GUI dialog (`gui.Psychometric`) has been added to create simple psychometric curves with the `viz.psychometric` module, which uses `altair`. Plans for developing visualization are described in *To-Do*.
  - A general `gui.pop_dialog()` function simplifies displaying messages to the user using the Terminal UI. This was an initial step towards improving status/error reporting from other agents, further detailed in *To-Do*.



## Bugfixes

- Some objects, particularly several *gui* objects, had the old *mouse/mice* terminology updated to *subject/subjects*.
- *Net\_Node* objects were only implicitly destroyed by their *release* method which ends the threaded loop by setting the closing event.
- Embarrassingly, *Pilot* objects were not prevented from running multiple tasks at a time. This led to some very confusing and hard-to-debug problems, as well as frequent conflicts over hardware access and resources. Typically what would happen is the Terminal would send a START message to begin a task, and if it wouldn't receive a message receipt quickly enough would resend it, resulting in two tasks being started – but this would happen whenever two START messages were sent to a pilot. This was fixed with a simple check of *Pilot.state* before a task is initialized. Similar bugs were fixed in *Plot* objects.
- The *Subject* class would sometimes fail to get and increment the trial session. This has been fixed by saving the session number as an attribute in the *info* node.
- The *Subject* class would reset the session counter even when the same task was being reassigned (eg. if updated), now it preserves session number if the protocol name is unchanged.
- The *update\_protocols()* method didn't report which subjects had their protocols updated, and so if there was some exception when setting new protocols it happened silently, making it so a user would never know their task was never updated. This was fixed with a noisier protocol update method for the Subject class and by displaying a list of subjects that were updated after the method is called.
- Correction trials were being calculated incorrectly by the *Stim\_Manager*, such that rather than only repeating a stimulus *if the subject got the previous trial incorrect*, the stimulus was always repeated at least once.

## Code Structure

- Modified versions of external libraries have been added as git submodules in *autopilot/external*.
- Requirements files have been split out to better differentiate between different agents and use-cases. eg. requirements for Terminal agents are in *requirements/requirements\_terminal.txt*, requirements for build the docs are in *requirements/requirements\_docs.txt*, etc. This is a temporary arrangement, as a future design goal is restructuring setup routines so that they can flexibly install components as-needed (see *To-Do*)
- *autopilot.core.hardware* has been refactored into its own module, *autopilot.hardware*, and split by device type, currently...
  - *autopilot.cameras*
  - *autopilot.gpio* - devices that use the GPIO pins for standard digital I/O logic
  - *autopilot.i2c* - devices that use the GPIO pins for I2C
  - *autopilot.usb*
- The docs are hosted on readthedocs again, so the docs structure has been collapsed to a single folder without built documentation
- The autopilot user directory is now *~/autopilot* rather than */usr/autopilot*, which was always a mistake anyway. Autopilot creates a wayfinder *~/autopilot* file that is used to find the user directory if it's set elsewhere



## External Libraries

- External libraries can now be built and packaged along with autopilot using cmake, see CMakeLists.txt. Still uh having a little bit of trouble getting this to work, so code is in place to build and package the custom pigpio repo and jack audio but this will likely need some more work.
- pigpio <https://github.com/sneakers-the-rat/pigpio/>
  - Added the ability to return absolute timestamps rather than system ticks. pigpio typically returns 1 32-bit integer of ticks since the daemon started, absolute timestamps are 64-bit, so the pigpio daemon and python interface (*pi*) were given two new methods:
    - \* *synchronize* gets several (default 5) sets of paired timestamps and ticks using *get\_sync\_time*. It then computes an offset for translating ticks to timestamps
    - \* *ticks\_to\_timestamp* converts ticks to timestamps based on the offset found with *synchronize*
    - \* *get\_current\_time* sends two requests to the daemon to get the seconds and microseconds of the complete timestamp and returns an isoformatted string
- mlx90640-library <https://github.com/pimoroni/mlx90640-library>
  - Removed building examples by default which require additional dependencies
  - When using the raspi I2C driver, the baudrate would never be set to 1MHz, which is necessary to achieve full 64fps. This was fixed to use 1MHz by default.

## Regressions

- Message confirmation (holding a message to resend if confirmation isn't received) was causing a huge amount of problems and needed to be rethought. There are in general very low rates (near-zero) of messages being dropped without some larger bug causing them, so confirmation has been disabled for now.
- The same is true of *heartbeat()* - which polled for status of connected pilots. this will be repaired and restored, as the terminal currently has a pretty bad idea of the status of what's connected to it. this will be part of a broader networking overhaul

## 22.3 Version 0.2

### 22.3.1 v0.2.0 (October 26, 2019)

Can't change what just started existing!

Release version of autopilot consistent with explanation in <https://www.biorxiv.org/content/10.1101/807693v1>

Development Roadmap, Minor To-dos, and all future plans :)



## 23.1 Visions

*The long view: design, ux, and major functionality projects roughly corresponding to minor semantic versions*

### 23.1.1 Integrations

Make autopilot work with...

#### Open Ephys Integration

- write a C extension to the Rhythm API similar to that used by the OpenEphys [Rhythm Node](#).
- Enable existing OE configuration files to be loaded and used to configure plugin, so ephys data can be collected natively alongside behavioral data.

#### Multiphoton & High-performance Image Integration

- Integrate the Thorlabs multiphoton imaging SDK to allow 2p image acquisition during behavior
- Integrate the Aravis camera drivers to get away from the closed-source spinnaker SDK

#### Bonsai Integration

- Write source and sink modules so [Bonsai](#) pipelines can be used within Autopilot for image processing, acquisition etc.

### 23.1.2 Closed-Loop Behavior & Processing Pipelines

- design a signal/slot architecture like Qt so that hardware devices and data streams can be connected with low latency. Ideally something like:

```
# directly connecting acceleration in x direction
# to an LED's brightness
accelerometer.acceleration.connect('x', LED.brightness)

# process some video frame and use it to control task stage logic
camera.frame.transform(
    DLC, **kwargs
).connect(
    task.subject_position
)
```

- The pipelining framework should be concurrent, but shouldn't rely on `multiprocessing.Queue`s and the like for performance, as transferring data between processes requires it to be pickled/unpickled. Instead it should use shared memory, like `multiprocessing.shared_memory` available in Python 3.8
- The pipelining framework should be evented, such that changes in the source parameter are automatically pushed through the pipeline without polling. This could be done with a decorator around the setter method for the sender,
- The pipelining framework need not be written from scratch, and could use one of Python's existing pipelining frameworks, like
  - `Joblib`
  - `Luigi`
  - `pyperator`
  - `streamz` (love the ux of this but doesn't seem v mature)
- **Agents**
  - The Agent infrastructure is still immature—the terminal, pilot, and child agents are written as independent classes, rather than with a shared inheritance structure. The first step is to build a metaclass for autopilot agents that includes the different prefs setups they need and their runtime requirements. Many of the further improvements are discussed in the setup section
  - Child agents need to be easier to spawn and configure, and child tasks lack any formalization at all.
- **Parameters**
  - Autopilot has a lot of types of parameters, and at the moment they all have their own styles. This makes a number of things difficult, but primarily it makes it hard to predict which style is needed at any particular time. Instead Autopilot needs a generalized `Param`eter` class. It should be able to represent the human readable name of that parameter, the parameter's value, the expected data type, whether that parameter is optional, and so on.
  - The parameter class should also be recursive, so parameter sets are not treated distinctly from an individual parameter – eg. a task needs a set of parameters, one of which is a list of hardware. one hardware object in that list will have its own list of parameters, and so forth.
  - The parameter class should operate in both directions – ie. it should be able to represent *set* parameters, as well as be able to be used as a specifier of parameters that *need to be set*

- The parameter class should be cascading, where parameters apply to lower ‘levels’ of parameterization unless specified otherwise. For example, one may want to set `correction_trials` on for all stimuli in a task, but be able to turn them off for one stimulus in particular. To avoid needing to manually implement layered logic for all objects, handlers should be able to assume that a parameter will be passed from parent objects to their children.
- GUI elements should be automatically populating – some GUI elements are, like the protocol wizard is capable of populating a list of parameters from a task description, but it is incapable of choosing different types of stimulus managers, reading all their parameters, and so on. Instead it should be possible to descend through all levels of parameters for all objects in all GUI windows without duplicating the effort of implementing the parameterization logic every time.

#### • Configuration & Setup

- Setup routines and configuration options are currently hard-coded into `npyscreen` forms (see `PilotSetupForm`). `prefs` setup needs to be separated into a model-view-controller type design where the available prefs and values are made separate from their form.
- Setup routines should include both the ability to install necessary resources and the ability to check if those resources have been installed so that hardware objects can be instantiated freely without setup and configuration becoming cumbersome.
- Currently, Autopilot creates a crude bash script with `setup_pilot.sh` to start external processes before Autopilot. This makes handling multiple environment types difficult – ie. one needs to close the program entirely, edit the startup script, and restart in order to switch from a primarily auditory to primarily visual experiment. Management of external processes should be brought into Autopilot, potentially by using [sarge](https://sarge.readthedocs.io/en/latest/index.html)<https://sarge.readthedocs.io/en/latest/index.html> or some other process management tool.
- Autopilot should both install to a virtual environment by default and should have docker containers built for it. Further it should be possible to package up your environment for the purposes of experimental replication.

#### • UI/UX

- The GUI code is now the oldest in the entire library. It needs to be generally overhauled to make use of the tools that have been developed since it was written (eg. use of networking modules rather than passing sets of variables around).
- It should be much easier to read the status of, interact with, and reconfigure agents that are connected to the terminal. Currently control of Pilots is relatively opaque and limited, and often requires the user to go read the logs stored on each individual pilot to determine what is happening with it. Instead Autopilot should have an additional window that can be used to set the parameters, reconfigure, and test each individual Pilot.
- There are some data -> graphical object mappings available to tasks, but Autopilot needs a fuller grammar of graphics. It should be possible to reconfigure plotting in the terminal GUI, and it should be possible to modify short-term parameters like bin widths for rolling means.
- Autopilot shouldn’t sprawl into a data visualization library, but it should have some basic post-experiment plotting features like plotting task performance and stages over time.
- Autopilot should have a web interface for browsing data. We are undecided about building a web interface for controlling tasks, but it should be possible to download data, do basic visualization, and observe the status of the system from a web portal.

#### • Tasks

- Task design is a bit *too* open at the moment. Tasks need to feel like they have more ‘guarantees’ on their operation. eg. there should be a generalized callback api for triggering events. the existing `handle_trigger()` is quite limited. There should be an obvious way for users to implement saving/reporting data from their tasks.

- \* Relatedly, the creation of triggers is pretty awkward and not strictly threadsafe, it should be possible to identify triggers in subclasses (eg. a superclass creates some trigger, a subclass should be able to unambiguously identify it without having to parse method names, etc)
- It's possible already to use a python generator to have more complex ordering of task stages, eg. instead of using an `itertools.cycle` one could write a generator function that yields task stages based on some parameters of the task. There should be an additional manager type, the `Trial_Manager`, that implements some common stage schemes – cycles, yes, but also DAGs, timed switches, etc. This way tasks could blend some intuitive features of finite-state machines while also not being beholden by them.
- **Mesh Networking**
  - Autopilot's networking system at the moment risks either a) being bottlenecked by having to route all data through a hierarchical network tree, or b) being indcipherable and impossible to program with as individual objects and streams are capable of setting up arbitrary connections that need to potentially be manually configured. This goal is very abstract, but Autopilot should have a mesh-networking protocol.
  - It should be possible for any object to communicate with any other object in the network without name collisions
  - It should be possible to stream data efficiently both point-to-point but also from one producer to many consumers.
  - It should be possible for networking connections to be recovered automatically in the case a node temporarily becomes unavailable.
  - Accordingly, Autopilot should adapt `Zyre` for general communications, and improve its file transfer capabilities so that it resembles something like bittorrent.
- **Data**
  - Autopilot's data format shouldn't be yet another standard incompatible with all the others that exist. Autopilot should at least implement data translators for, if not adopt outright the Neurodata Without Borders standard.
  - For distributed data acquisition, it makes sense to use a distributed database, so we should consider switching data collection infrastructure from `.hdf5` files to a database system like PostgreSQL.
- **Hardware Library**
  - Populate <https://auto-pi-lot.com/hardware> with hardware designs, CAD files, BOMs, and assembly instructions
  - Make a 'thingiverse for experimental hardware' that allows users to browse hardware based on application, materials, etc.

## 23.2 Improvements

*The shorter view: smaller, specific tweaks to improve functionality of existing features roughly corresponding to patches in semantic versioning.*

- **Logging**
  - ensure that all events worth logging are logged across all objects.
  - ensure that the structure of logfiles is intuitive – one logfile per object type (networking, hardware rather than one per each hardware device)
  - logging of experimental conditions is incomplete – only the git hash of the pilot is stored, but the git hash of *all* relevant agents should be stored, and logging should be expanded to include params and system configuration (like `pip freeze`)

- logs should also be made both human and machine readable – use `prettyprint` for python objects, and standardize fields present in logger messages.
- File and Console log handlers should be split so that users can configure what they want to *see* vs. what they want *stored* separately (See <https://docs.python.org/3/howto/logging-cookbook.html#multiple-handlers-and-formatters>)

- **UI/UX**

- Batch subject creation.
- Double-clicking a subject should open a window to edit and view task parameters.
- Drag-and-drop subjects between pilots.
- Plot parameters should be editable - window roll size, etc.
- Make a messaging routine where a pilot can display some message on the terminal. this should be used to alert the user about any errors in task operation rather than having to inspect the logs on the pilot.
- The `Subject_List` remains selectable/editable once a subject has started running, making it unclear which subject is running. It should become fixed once a subject is running, or otherwise unambiguously indicate which subject is running.
- Plot elements should have tooltips that give their value – eg. when hovering over a rolling mean, a tooltip should display the current value of the rolling mean as well as other configuration params like how many trials it is being computed over.
- Elements in the GUI should be smarter about resizing, particularly the main window should be able to use a scroll bar once the number of subjects forces them off the screen.

- **Hardware**

- Sound calibration - implement a calibration algorithm that allows speakers to be flattened
- Implement OpenCL for image processing, specifically decoding on acquisition with OpenCV, with VC4CL. See
  - \* <https://github.com/doe300/VC4CL/issues/29>
  - \* <https://github.com/thortex/rpi3-opencv/>
  - \* <https://github.com/thortex/rpi3-vc4cl/>
- Have hardware objects sense if they are configured on instantiation – eg. when an audio device is configured, check if the system has been configured as well as the hifiberry is in `setup/presetup_pilot.sh`

- **Synchronization**

- Autopilot needs a unified system to generate timestamps and synchronize events across pilots. Currently we rely on implicit NTP-based synchronization across Pilots, which has ~ms jitter when configured optimally, but is ultimately not ideal for precise alignment of data streams, eg. ephys sampled at 30kHz. `pigpio` should be extended such that a Pilot can generate a clock signal that its children synchronize to. With the recent addition of timestamp generation within `pigpio`, that would be one parsimonious way of
- In order to synchronize audio events with behavioral events, the `JackClient` needs to add a call to `jack_last_frame_time` in order to get an accurate time of when sound stimuli start and stop (See [https://jackaudio.org/api/group\\_\\_TimeFunctions.html](https://jackaudio.org/api/group__TimeFunctions.html))
- Time synchronization between Terminal and Pilot agents is less important, but having them synchronized as much as possible is good. The Terminal should be set up to be an NTP server that Pilots follow.

- **Networking**

- Multihop messages (eg. send to C through A and B) are clumsy. This may be irrelevant if Autopilot's network infrastructure is converted a true meshnet, but in the meantime networking modules should be better at tracking and using trees of connected nodes.
- The system of zmq routers and dealers is somewhat cumbersome, and the new radio/dish pattern in zmq might be better suited. Previously, we had chosen not to use pub/sub as the publisher is relatively inefficient – it sends every message to every recipient, who filter messages based on their id, but the radio/dish method may be more efficient.
- Network modules should use a thread pool for handling messages, as spawning a new thread for each message is needlessly costly

- **Data**

- Data specification needs to be formalized further – currently data for a task is described with `tables` specifiers, `TrialData` and `ContinuousData`, but there are always additional fields – particularly from stimuli. The `Subject` class should be able to create columns and tables for
  - \* Task data as specified in the task description
  - \* Stimulus data as specified by a stimulus manager that initializes them. eg. the stimulus manager initializes all stimuli for a task, and then is able to yield a description of all columns needed for all initialized stimuli. So, for a task that uses

- **Tests** - Currently Autopilot has *no unit tests* (shocked gasps, monocles falling into brandy glasses). We need to implement an automated test suite and continuous integration system in order to make community development of Autopilot manageable.

- **Configuration**

- Rather than require all tasks be developed within the directory structure of Autopilot, Tasks and hardware objects should be able to be added to the system in a way that mimics `tensor2tensor`'s `registry`. For example, users could specify a list of user directories in `prefs`, and user-created Hardware/Tasks could be decorated with a `@registry.register_task`.
  - \* This would additionally solve the awkward `tasks.TASK_LIST` method of making tasks available by name that is used now by having a more formal task registry.

- **Cleanliness & Beauty**

- Intra-autopilot imports are a bit messy. They should be streamlined so that importing one class from one module doesn't spiral out of control and import literally everything in the package.
- Replace `getter`- and `setter`-type methods throughout with `@properties` when it would improve the object, eg. in the `JackClient`, the storage/retrieval of all the global module variables could be made much neater with `@property` methods.
- Like the `Hardware` class, top-level metaclasses should be moved to the `__init__` file for the module to avoid awkward imports and extra files like `autopilot.tasks.task.Task`
- Use `enum.Enum` s all over! eg. things like `autopilot.hardware.gpio.TRIGGER_MAP` etc.

- **Concurrency**

- Autopilot could be a lot smarter about the way it manages threads and processes! It should have a centralized registry of threads and processes to keep track on their status
- Networking modules and other thread-creating modules should probably create thread pools to avoid the overhead of constantly spawning them

- **Decorators** - specific improvements to make autopilot objects magic!

- `hardware.gpio` - try/catch release decorator so don't have to check for attribute error in every subclass!



## 23.3 Bugs

*Known bugs that have eluded us thus far*

- The `Pilot_Button` doesn't always reflect the availability/unavailability of connected pilots. The button model as well as the general heartbeating/status indication routines need to be made robust.
- The `pilot_db.json` and `Subject_List` doesn't check for duplicate subjects across Pilots. That shouldn't be a problem generally, but if a subject is switched between Pilots that may not be reflected in the generated metadata. Pilot ID needs to be more intimately linked to the `Subject`.
- If Autopilot needs to be quit harshly, some pigpio-based hardware objects don't quit nicely, and the pigpiod service can remain stuck on. Resource release needs to be made more robust
- Network connectivity can be lost if the network hardware is disturbed (in our case the router gets kicked from the network it is connected to) and is only reliably recovered by restarting the system. Network connections should be able to recover disturbance.
- The use of *off* and *on* is inconsistent between `Digital_Out` and `PWM` – since the PWM cleans values (inverts logic, expands range),
- There is ambiguity in setting PWM ranges: using `PWM.set()` with 0-1 uses the whole range off to on, but numbers from 0-`PWM.range` can be used as well – 0-1 is the preferred behavior, but should using 0-range still be supported as well?

## 23.4 Completed

*good god we did it*

- *v0.3.5 (February 22, 2021)* - Integrate DeepLabCut
- *v0.3.5 (February 22, 2021)* - Unify installation
- *v0.3.5 (February 22, 2021)* - Upgrade to Python 3
- *v0.3.5 (February 22, 2021)* - Upgrade to PySide 2 & Qt5
- *v0.3.5 (February 22, 2021)* - Generate full timestamps from pigpio rather than ticks
- *v0.3.5 (February 22, 2021)* - Continuous data handling
- *v0.3.5 (February 22, 2021)* - GPIO uses pigpio functions rather than python timing
- *v0.3.5 (February 22, 2021)* - networking modules compress arrays before transfer
- *v0.3.5 (February 22, 2021)* - Images can be acquired from cameras

## 23.5 Lowest Priority

*Improvements that are very unimportant or strictly for unproductive joy*

- **Classic Mode - in honor of an ancient piece of software that Autopilot may have descended from**, add a hidden key that when pressed causes the entire terminal screen to flicker whenever any subject in any pilot gets a trial incorrect.



---

CHAPTER  
**TWENTYFOUR**

---

**REFERENCES**



## TESTS

### 25.1 Networking

Networking Tests.

#### Assumptions

- In docstring examples, `listens` callbacks are often omitted for clarity

#### Functions:

<code>test_node(node_params)</code>	<code>Net_Node</code> s can be initialized with their default parameters
<code>test_node_to_node(node_params)</code>	<code>Net_Node</code> s can directly send messages to each other with ROUTER/DEALER pairs.
<code>test_multihop(node_params, station_params)</code>	<code>Message</code> s can be routed through multiple <code>Station</code> objects by using a list in the <code>to</code> field

#### `test_node(node_params)`

`Net_Node` s can be initialized with their default parameters

#### `test_node_to_node(node_params)`

`Net_Node` s can directly send messages to each other with ROUTER/DEALER pairs.

```
>>> node_1 = Net_Node(id='a', router_port=5000)
>>> node_2 = Net_Node(id='b', upstream='a', port=5000)
>>> node_2.send('a', 'KEY', 'VALUE')
>>> node_2.send('b', 'KEY', 'VALUE')
```

#### `test_multihop(node_params, station_params)`

`Message` s can be routed through multiple `Station` objects by using a list in the `to` field

```
# send message:
# node_1 -> station_1 -> station_2 -> station_3 -> node_3
>>> station_1 = Station(id='station_1', listen_port=6000,
    pusher=True, push_port=6001, push_id='station_2')
>>> station_2 = Station(id='station_2', listen_port=6001,
    pusher=True, push_port=6002, push_id='station_3',)
>>> station_3 = Station(id='station_3', listen_port=6002)
>>> node_1 = Net_Node(id='node_1',
    upstream='station_1', port=6000)
>>> node_3 = Net_Node(id='node_3',
```

(continues on next page)

(continued from previous page)

```

        upstream='station_3', port=6002)
>>> node_1.send(key='KEY', value='VALUE',
               to=['station_1', 'station_2', 'station_3', 'node_3'])

```

## 25.2 Plugins

### Functions:

<code>hardware_plugin(default_dirs)</code>	Make a basic plugin that inherits from the Hardware class, clean it up on exit
<code>test_hardware_plugin(hardware_plugin)</code>	A subclass of <code>autopilot.hardware.Hardware</code> in the PLUGINDIR can be accessed with <code>autopilot.get()</code> .
<code>test_autoplugin()</code>	the <code>autopilot.utils.registry.get()</code> function should automatically load plugins if the pref AUTOPLUGIN is True and the plugins argument is True

**hardware\_plugin**(*default\_dirs*) → Tuple[pathlib.Path, str]

Make a basic plugin that inherits from the Hardware class, clean it up on exit

**Returns** path to created plugin file

**Return type** Path

**test\_hardware\_plugin**(*hardware\_plugin*)

A subclass of `autopilot.hardware.Hardware` in the PLUGINDIR can be accessed with `autopilot.get()`.

For example, for the following class declared in some .py file in the plugin dir:

```

from autopilot.hardware import Hardware

class Test_Hardware_Plugin(Hardware):
    def __init__(self, *args, **kwargs):
        super(Test_Hardware_Plugin, self).__init__(*args, **kwargs)

    def release(self):
        pass

```

one would be able to access it throughout autopilot with:

```

autopilot.get('hardware', 'Test_Hardware_Plugin')
# or
autopilot.get_hardware('Test_Hardware_Plugin')

```

**test\_autoplugin**()

the `autopilot.utils.registry.get()` function should automatically load plugins if the pref AUTOPLUGIN is True and the plugins argument is True

## 25.3 Prefs

### Functions:

<code>test_prefs_defaults(default_pref)</code>	
<code>test_prefs_deprecation()</code>	If there is a string in the 'deprecation' field of a pref in <code>_DEFAULTS</code> , a warning is raised printing the string.

`test_prefs_defaults(default_pref)`

`test_prefs_deprecation()`

If there is a string in the 'deprecation' field of a pref in `_DEFAULTS`, a warning is raised printing the string.

## 25.4 Registry

### Data:

<code>_EXPECTED_HARDWARE</code>	A list of all the hardware we expect to have at the moment.
---------------------------------	---

### Functions:

<code>logger_registry_get(caplog)</code>	
<code>test_get_one(base_class, class_name)</code>	Get one autopilot object with a specified base class and class name using a string, an enum in <code>autopilot.utils.registry.REGISTRIES</code> , or an object itself
<code>test_get_all(base_class)</code>	Test that calling <code>get</code> with no <code>class_name</code> argument returns all the objects for that registry
<code>test_get_subtree(logger_registry_get, caplog)</code>	Test that calling <code>get</code> with a child of a top-level object (eg <code>GPIO</code> rather than <code>Hardware</code> ) gets all its children, (using <code>GPIO</code> as the test case)
<code>test_get_hardware()</code>	use the <code>autopilot.utils.registry.get_hardware()</code> alias
<code>test_get_task()</code>	use the <code>autopilot.utils.registry.get_task()</code> alias
<code>test_get_equivalence()</code>	Test that the same object is gotten regardless of method of specifying <code>base_class</code>
<code>test_except_on_failure()</code>	Ensure a exceptions are raised for nonsense

```
_EXPECTED_HARDWARE = ( 'autopilot.hardware.cameras.Camera',
'autopilot.hardware.cameras.Camera_CV', 'autopilot.hardware.cameras.Camera_Spinnaker',
'autopilot.hardware.gpio.Digital_In', 'autopilot.hardware.gpio.Digital_Out',
'autopilot.hardware.gpio.GPIO', 'autopilot.hardware.gpio.LED_RGB',
'autopilot.hardware.gpio.PWM', 'autopilot.hardware.gpio.Solenoid',
'autopilot.hardware.i2c.I2C_9DOF', 'autopilot.hardware.i2c.MLX90640',
'autopilot.hardware.usb.Scale', 'autopilot.hardware.usb.Wheel')
```

A list of all the hardware we expect to have at the moment.

This doesn't need to be maintained *exactly*, but is just used as an independent source of expectation for which

Hardware objects we can expect.

So in all tests that use it, this tests a **minimal** expectation, ie. that we get all the values that we should get if this were up to date, knowing that it might not be.

**logger\_registry\_get**(*caplog*)

**test\_get\_one**(*base\_class*, *class\_name*)

Get one autopilot object with a specified base class and class name using a string, an enum in `autopilot.utils.registry.REGISTRIES`, or an object itself

**test\_get\_all**(*base\_class*)

Test that calling `get` with no `class_name` argument returns all the objects for that registry

**test\_get\_subtree**(*logger\_registry\_get*, *caplog*)

Test that calling `get` with a child of a top-level object (eg GPIO rather than Hardware) gets all its children, (using GPIO as the test case)

**test\_get\_hardware**()

use the `autopilot.utils.registry.get_hardware()` alias

mostly a formality to keep it working since the underlying function is tested elsewhere

**test\_get\_task**()

use the `autopilot.utils.registry.get_task()` alias

mostly a formality to keep it working since the underlying function is tested elsewhere

**test\_get\_equivalence**()

Test that the same object is gotten regardless of method of specifying `base_class`

**test\_except\_on\_failure**()

Ensure a exceptions are raised for nonsense

## 25.5 Setup

Functions:

---

`test_make_alias()`

---

`test_quiet_mode()`

---

Autopilot can be setup programmatically by calling `setup_autopilot` with `--quiet` and passing prefs and scripts manually

---

**test\_make\_alias**()

**test\_quiet\_mode**()

Autopilot can be setup programmatically by calling `setup_autopilot` with `-quiet` and passing prefs and scripts manually



## 25.6 Sounds

Tests for generating sound stimuli.

This script runs tests that generate different sound stimuli and verifies that they are initialized correctly.

Currently these only work if AUDIOSERVER is 'jack'. 'pyo' is not tested. 'docs' doesn't actually generate waveforms.

This doesn't require (or test) a running jackd or even a JackClient. Instead, these tests short-circuit those dependencies by manually setting FS and BLOCKSIZE in autopilot.stim.sound.jackclient.

A TODO is to test the JackClient itself.

Currently only the sound Noise is tested.

These tests cover multiple durations and amplitudes of mono and multi-channel Noise, including some edges cases like very short durations or zero amplitude.

The rest of this docstring addresses the workaround used to short-circuit jackd and JackClient.

Here is the sequence of events that leads to FS and BLOCKSIZE. \* If an autopilot.core.pilot.Pilot is initialized: \*\* autopilot.core.pilot.Pilot.\_\_init\_\_ checks prefs.AUDIOSERVER,

and calls autopilot.core.pilot.Pilot.init\_audio.

**\*\* autopilot.core.pilot.Pilot.init\_audio calls autopilot.external.\_\_init\_\_.start\_jackd.**

**\*\* autopilot.external.\_\_init\_\_.start\_jackd takes the JACKDSTRING pref** and replaces the token '-rfs' in it with the FS pref. The jackd process is launched and stored in autopilot.external.JACKD\_PROCESS. That process may fail or not, we continue anyway.

**\*\* Next, autopilot.core.pilot.Pilot.init\_audio instantiates an autopilot.stim.sound.jackclient.JackClient()**

**\*\* autopilot.stim.sound.jackclient.JackClient.\_\_init\_\_** initializes a jack.Client

**\*\* autopilot.stim.sound.jackclient.JackClient.fs** is set to jack.Client.samplerate. Note that this is either the requested sample rate, or some default value from jack (not Autopilot) if the client did not actually succeed in booting.

**\*\* autopilot.stim.sound.jackclient.FS (a global variable) is set to autopilot.stim.sound.jackclient.JackClient.fs**

- Later, a sound (e.g., Noise) is initialized.

**\*\* autopilot.stim.sound.sounds.Noise.\_\_init\_\_** calls **super().\_\_init\_\_**, **\*\* which is autopilot.stim.sound.sounds.Jack\_Sound.\_\_init\_\_** **\*\* autopilot.stim.sound.sounds.Jack\_Sound.\_\_init\_\_**

sets *self.fs* to jackclient.FS

**\*\* autopilot.stim.sound.sounds.Noise.\_\_init\_\_ calls autopilot.stim.sound.sounds.Noise.init\_sound**

**\*\* autopilot.stim.sound.sounds.Noise.init\_sound calls autopilot.stim.sound.sounds.Jack\_Sound.get\_nsamples**

**\*\* autopilot.stim.sound.sounds.Jack\_Sound.get\_nsamples** inspects *self.fs*

To remove the dependence on jackd2 and JackClient, the entire first block of code can be circumvented by setting these: autopilot.stim.sound.jackclient.FS autopilot.stim.sound.jackclient.BLOCKSIZE

### Functions:

---

<code>test_init_noise(duration_ms, amplitude, ...)</code>	Initialize and check a mono (single-channel) noise.
<code>test_init_multichannel_noise(duration_ms, ...)</code>	Initialize and check a multi-channel noise.

---

**test\_init\_noise**(*duration\_ms*, *amplitude*, *check\_duration\_samples*, *check\_n\_chunks\_expected*)

Initialize and check a mono (single-channel) noise.

A mono *Noise* is initialized with specified duration and amplitude. The following things are checked: \* The attributes should be correctly set \* The *table* should be the right dtype and the right duration,

given the sampling rate

- The chunks should be correct, given the block size. The last chunk should be zero-padded.
- The waveform should not exceed amplitude anywhere
- As long as the waveform is sufficiently long, it should exceed 90% of the amplitude somewhere
- Concatenating the chunks should generate a result equal to the table, albeit zero-padded to a multiple of the block size.
- Specifying channel as None should give identical results to leaving it unspecified.

`duration_ms` : passed as *duration* `amplitude` : passed as *amplitude* `check_duration_samples` : int or None

If not None, the length of the sounds *table* should be this

**`check_n_chunks_expected`** [int or None] If not None, the length of the sounds *chunks* should be this

**`test_init_multichannel_noise`**(*duration\_ms*, *amplitude*, *channel*, *check\_duration\_samples*,  
*check\_n\_chunks\_expected*)

Initialize and check a multi-channel noise.

A multi-channel *Noise* is initialized with specified duration, amplitude, and channel. The following things are checked: \* The attributes should be correctly set \* The *table* should be the right dtype and the right duration,

given the sampling rate

- The chunks should be correct, given the block size. The last chunk should be zero-padded.
- The column *channel* should contain non-zero data and all other columns should contain zero data.
- The waveform should not exceed amplitude anywhere
- As long as the waveform is sufficiently long, it should exceed 90% of the amplitude somewhere
- Concatenating the chunks should generate a result equal to the

`duration_ms` : passed to *Noise* as *duration* `amplitude` : passed to *Noise* as *amplitude* `channel` : passed to *Noise* as *channel* `check_duration_samples` : int or None

If not None, the length of the sounds *table* should be this

**`check_n_chunks_expected`** [int or None] If not None, the length of the sounds *chunks* should be this

## 25.7 Terminal

## 25.8 Transforms

## 25.9 Utils

## INDICES AND TABLES

- `genindex`
- `modindex`
- `search`



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