Sense-Emu Documentation

Release 1.1

Raspberry Pi Foundation

Jul 09, 2018

Contents

CHAPTER 1

Installation

1.1 Raspbian installation

If you are using the Raspbian[1] distro, it is best to install the Sense HAT Emulator using the system's package manager: apt. This will ensure that the emulator is easy to keep up to date, and easy to remove should you wish to do so. To install using apt simply:

```
$ sudo apt-get update
$ sudo apt-get install python-sense-emu python3-sense-emu sense-emu-tools
```

These three packages contain the following things:

sense-emu-tools This package contains the Sense HAT Emulator application.

python-sense-emu This is the Python 2 version of the Sense HAT Emulator library.

python3-sense-emu This is the Python 3 version of the Sense HAT Emulator library.

To upgrade your installation when new releases are made you can simply use apt's normal upgrade procedure:

```
$ sudo apt-get update
$ sudo apt-get upgrade
```

If you ever need to remove your installation:

```
$ sudo apt-get remove python-sense-emu python3-sense-emu sense-emu-tools
```

1.2 Ubuntu installation

To install from the author's PPA[2]:

```
$ sudo add-apt-repository ppa://waveform/ppa
$ sudo apt-get update
$ sudo apt-get install python-sense-emu python3-sense-emu sense-emu-tools
```

[1] http://www.raspbian.org/
[2] https://launchpad.net/~waveform/+archive/ppa

To upgrade your installation when new releases are made you can simply use apt's normal upgrade procedure:

```
$ sudo apt-get update
$ sudo apt-get upgrade
```

To remove the installation:

```
$ sudo apt-get remove python-sense-emu python3-sense-emu sense-emu-tools
```

1.3 macOS installation

The following installation instructions assume you are using Homebrew[3] as your macOS package manager:

```
$ brew install pygobject3 gtk+3
```

If you are using Python virtual environments for the Sense HAT Emulator, the `system-site-packages` option must be enabled within the virtualenv.

For existing virtual environments:

```
$ rm ${VIRTUAL_ENV}/lib/python*/no-global-site-packages.txt
```

For new virtual environments:

```
$ virtualenv --system-site-packages
```

Activate your virtual environment and install the Sense HAT Emulator:

```
$ pip install sense-emu
```

1.4 Alternate platforms

On platforms other than Raspbian or Ubuntu, it is probably simplest to install system wide using Python's `pip` tool:

```
$ pip install sense-emu
```

To upgrade your installation when new releases are made:

```
$ pip install -U sense-emu
```

If you ever need to remove your installation:

```
$ pip uninstall sense-emu
```

Note: The emulator application requires PyGObject and cairo to be installed (GTK3 bindings for Python), but this cannot be obtained from PyPI; install PyGObject manually from your operating system's package manager (e.g. python-gi, python3-gi, python-gi-cairo, and python3-gi-cairo on Raspbian/Ubuntu).

Also note that installation via `pip` won't create short-cuts for the emulator application in your desktop's start menu. Instead you will have to launch it manually by running `sense_emu_gui` from the command line.

[3] http://brew.sh/

CHAPTER 2

Examples

2.1 Introduction

The Sense HAT emulator exactly mirrors the official Sense HAT API. The only difference (required because both the emulator and actual library can be installed simultaneously on a Pi) is the name: `sense_emu` instead of `sense_hat`. It is recommended to import the library in the following manner at the top of your code:

```
from sense_emu import SenseHat
```

Then, when you want to change your code to run on the actual HAT all you need do is change this line to:

```
from sense_hat import SenseHat
```

To run your scripts under the emulator, first start the emulator application, then start your script.

Several example scripts, with varying degrees of difficulty, are available from the *File* → *Open example* menu within the emulator. Selecting an example from this menu will open it in Python's IDLE environment.

Note: The example will be opened directly from the installation. To edit the example for your own purposes, use *File* → *Save As* in IDLE to save the file under your home directory (e.g. `/home/pi`).

A selection of example scripts is given in the following sections.

2.2 Temperature

Displays the current temperature reading on the Sense HAT's screen:

```
from sense_emu import SenseHat

sense = SenseHat()

red = (255, 0, 0)
blue = (0, 0, 255)

while True:
```

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```
    temp = sense.temp
    pixels = [red if i < temp else blue for i in range(64)]
    sense.set_pixels(pixels)
```

2.3 Humidity

Displays the current humidity reading on the Sense HAT's screen:

```
from sense_emu import SenseHat

sense = SenseHat()

green = (0, 255, 0)
white = (255, 255, 255)

while True:
    humidity = sense.humidity
    humidity_value = 64 * humidity / 100
    pixels = [green if i < humidity_value else white for i in range(64)]
    sense.set_pixels(pixels)
```

2.4 Joystick

Scrolls a blip around the Sense HAT's screen in response to joystick motions:

```
from sense_emu import SenseHat

x = y = 4
hat = SenseHat()

def update_screen():
    hat.clear()
    hat.set_pixel(x, y, 255, 255, 255)

def clamp(value, min_value=0, max_value=7):
    return min(max_value, max(min_value, value))

def move_dot(event):
    global x, y
    if event.action in ('pressed', 'held'):
        x = clamp(x + {
            'left': -1,
            'right': 1,
            }.get(event.direction, 0))
        y = clamp(y + {
            'up': -1,
            'down': 1,
            }.get(event.direction, 0))

update_screen()
while True:
    for event in hat.stick.get_events():
        move_dot(event)
        update_screen()
```

An alternative way to write this example using the joystick's event handler attributes is given below:

```python
from sense_emu import SenseHat
from signal import pause

x = y = 4
hat = SenseHat()

def update_screen():
    hat.clear()
    hat.set_pixel(x, y, 255, 255, 255)

def clamp(value, min_value=0, max_value=7):
    return min(max_value, max(min_value, value))

def move_dot(event):
    global x, y
    if event.action in ('pressed', 'held'):
        x = clamp(x + {
            'left': -1,
            'right': 1,
            }.get(event.direction, 0))
        y = clamp(y + {
            'up': -1,
            'down': 1,
            }.get(event.direction, 0))

update_screen()
hat.stick.direction_up = move_dot
hat.stick.direction_down = move_dot
hat.stick.direction_left = move_dot
hat.stick.direction_right = move_dot
hat.stick.direction_any = update_screen
pause()
```

2.5 Rainbow

Scrolls a rainbow of colours across the Sense HAT's pixels:

```python
from colorsys import hsv_to_rgb
from time import sleep
from sense_emu import SenseHat

# Hues represent the spectrum of colors as values between 0 and 1. The range
# is circular so 0 represents red, ~0.2 is yellow, ~0.33 is green, 0.5 is cyan,
# ~0.66 is blue, ~0.84 is purple, and 1.0 is back to red. These are the initial
# hues for each pixel in the display.
hues = [
    0.00, 0.00, 0.06, 0.13, 0.20, 0.27, 0.34, 0.41,
    0.00, 0.06, 0.13, 0.21, 0.28, 0.35, 0.42, 0.49,
    0.07, 0.14, 0.21, 0.28, 0.35, 0.42, 0.50, 0.57,
    0.15, 0.22, 0.29, 0.36, 0.43, 0.50, 0.57, 0.64,
    0.22, 0.29, 0.36, 0.44, 0.51, 0.58, 0.65, 0.72,
    0.30, 0.37, 0.44, 0.51, 0.58, 0.66, 0.73, 0.80,
    0.38, 0.45, 0.52, 0.59, 0.66, 0.73, 0.80, 0.87,
    0.45, 0.52, 0.60, 0.67, 0.74, 0.81, 0.88, 0.95,
    ]

hat = SenseHat()

def scale(v):
```

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```
    return int(v * 255)

while True:
    # Rotate the hues
    hues = [(h + 0.01) % 1.0 for h in hues]
    # Convert the hues to RGB values
    pixels = [hsv_to_rgb(h, 1.0, 1.0) for h in hues]
    # hsv_to_rgb returns 0..1 floats; convert to ints in the range 0..255
    pixels = [(scale(r), scale(g), scale(b)) for r, g, b in pixels]
    # Update the display
    hat.set_pixels(pixels)
    sleep(0.04)
```

CHAPTER 3

Sense HAT API

The main class which is used to interact with the Sense HAT emulator is `SenseHat` (page 7). This provides accesss to all sensors, the LED pixel display, and the joystick. It is recommended that you import the library using the following idiom:

```
from sense_emu import SenseHat
```

This way, when you wish to deploy your code on an actual Sense HAT the only change you need to make is to this line, changing it to:

```
from sense_hat import SenseHat
```

3.1 SenseHat

class sense_emu.**SenseHat**(*imu_settings_file='RTIMULib'*, *text_assets='sense_hat_text'*)

The main interface the Raspberry Pi Sense HAT.

This class provides properties to query the various sensors on the Sense HAT (`temp`, `pressure`, `humidity`, `gyro`, etc.) and methods to control the LED "screen" on the HAT (`set_pixel()` (page 8), `set_pixels()` (page 8)).

The *imu_settings_file* parameter specifies the base name of the configuration file used to calibrate the sensors on the HAT. An ".ini" suffix will be implicitly added to this filename. If a file with the resulting name is present in `~/.config/sense_hat`, it will be used in the configuration. Otherwise, the file will be located within `/etc`, and will be copied to `~/.config/sense_hat` before use.

The *text_assets* parameter provides the base name of the PNG image and text file which will be used to define the font used by the `show_message()` (page 9) method.

clear(**args*)

Clears the LED matrix with a single colour, default is black / off

e.g. ap.clear() or ap.clear(r, g, b) or colour = (r, g, b) ap.clear(colour)

flip_h(*redraw=True*)

Flip LED matrix horizontal

flip_v(*redraw=True*)

Flip LED matrix vertical

gamma_reset()
Resets the LED matrix gamma correction to default

get_accelerometer()
Gets the orientation in degrees from the accelerometer only

get_accelerometer_raw()
Accelerometer x y z raw data in Gs

get_compass()
Gets the direction of North from the magnetometer in degrees

get_compass_raw()
Magnetometer x y z raw data in uT (micro teslas)

get_gyroscope()
Gets the orientation in degrees from the gyroscope only

get_gyroscope_raw()
Gyroscope x y z raw data in radians per second

get_humidity()
Returns the percentage of relative humidity

get_orientation_degrees()
Returns a dictionary object to represent the current orientation in degrees, 0 to 360, using the aircraft principal axes of pitch, roll and yaw

get_orientation_radians()
Returns a dictionary object to represent the current orientation in radians using the aircraft principal axes of pitch, roll and yaw

get_pixel(*x*, *y*)
Returns a list of [R,G,B] representing the pixel specified by x and y on the LED matrix. Top left = 0,0 Bottom right = 7,7

get_pixels()
Returns a list containing 64 smaller lists of `[R,G,B]` pixels representing what is currently displayed on the LED matrix

get_pressure()
Returns the pressure in Millibars

get_temperature()
Returns the temperature in Celsius

get_temperature_from_humidity()
Returns the temperature in Celsius from the humidity sensor

get_temperature_from_pressure()
Returns the temperature in Celsius from the pressure sensor

load_image(*file_path*, *redraw=True*)
Accepts a path to an 8 x 8 image file and updates the LED matrix with the image

set_imu_config(*compass_enabled*, *gyro_enabled*, *accel_enabled*)
Enables and disables the gyroscope, accelerometer and/or magnetometer input to the orientation functions

set_pixel(*x*, *y*, **args*)
Updates the single `[R,G,B]` pixel specified by x and y on the LED matrix Top left = 0,0 Bottom right = 7,7

e.g. ap.set_pixel(x, y, r, g, b) or pixel = (r, g, b) ap.set_pixel(x, y, pixel)

set_pixels(*pixel_list*)
Accepts a list containing 64 smaller lists of `[R,G,B]` pixels and updates the LED matrix. R,G,B elements must intergers between 0 and 255

set_rotation(*r=0*, *redraw=True*)
Sets the LED matrix rotation for viewing, adjust if the Pi is upside down or sideways. 0 is with the Pi HDMI port facing downwards

show_letter(*s*, *text_colour=[255, 255, 255]*, *back_colour=[0, 0, 0]*)
Displays a single text character on the LED matrix using the specified colours

show_message(*text_string*, *scroll_speed=0.1*, *text_colour=[255, 255, 255]*, *back_colour=[0, 0, 0]*)
Scrolls a string of text across the LED matrix using the specified speed and colours

stick
A `SenseStick` (page 9) object representing the Sense HAT's joystick.

3.2 SenseStick

class sense_emu.**SenseStick**
Represents the joystick on the Sense HAT.

get_events()
Returns a list of all joystick events that have occurred since the last call to `get_events()` (page 9). The list contains events in the order that they occurred. If no events have occurred in the intervening time, the result is an empty list.

wait_for_event(*emptybuffer=False*)
Waits until a joystick event becomes available. Returns the event, as an `InputEvent` (page 10) tuple.

If *emptybuffer* is `True` (it defaults to `False`), any pending events will be thrown away first. This is most useful if you are only interested in "pressed" events.

direction_any
The function to be called when the joystick is used. The function can either take a parameter which will be the `InputEvent` (page 10) tuple that has occurred, or the function can take no parameters at all.

This event will always be called *after* events associated with a specific action. Assign `None` to prevent this event from being fired.

direction_down
The function to be called when the joystick is pushed down. The function can either take a parameter which will be the `InputEvent` (page 10) tuple that has occurred, or the function can take no parameters at all.

Assign `None` to prevent this event from being fired.

direction_left
The function to be called when the joystick is pushed left. The function can either take a parameter which will be the `InputEvent` (page 10) tuple that has occurred, or the function can take no parameters at all.

Assign `None` to prevent this event from being fired.

direction_middle
The function to be called when the joystick middle click is pressed. The function can either take a parameter which will be the `InputEvent` (page 10) tuple that has occurred, or the function can take no parameters at all.

Assign `None` to prevent this event from being fired.

direction_right
The function to be called when the joystick is pushed right. The function can either take a parameter which will be the `InputEvent` (page 10) tuple that has occurred, or the function can take no parameters at all.

Assign `None` to prevent this event from being fired.

direction_up
The function to be called when the joystick is pushed up. The function can either take a parameter which will be the *InputEvent* (page 10) tuple that has occurred, or the function can take no parameters at all.

Assign None to prevent this event from being fired.

3.3 InputEvent

class sense_emu.**InputEvent**
A namedtuple()[4] derivative representing a joystick event. The following attributes are present:

timestamp
The time at which the event occurred, represented as the number of seconds since the UNIX epoch (same output as time()[5]).

direction
The direction in which the joystick was pushed (or released from), as one of the constants *DIRECTION_UP* (page 10), *DIRECTION_DOWN* (page 10), *DIRECTION_LEFT* (page 10), *DIRECTION_RIGHT* (page 10), *DIRECTION_MIDDLE* (page 10)

action
The action that occurred, as one of the constants *ACTION_PRESSED* (page 10), *ACTION_RELEASED* (page 10), or *ACTION_HELD* (page 10).

3.4 Constants

sense_emu.**DIRECTION_UP**

sense_emu.**DIRECTION_DOWN**

sense_emu.**DIRECTION_LEFT**

sense_emu.**DIRECTION_RIGHT**

sense_emu.**DIRECTION_MIDDLE**
Constants representating the direction in which the joystick has been pushed. *DIRECTION_MIDDLE* (page 10) refers to pressing the joystick as a button.

sense_emu.**ACTION_PRESSED**

sense_emu.**ACTION_RELEASED**

sense_emu.**ACTION_HELD**
Constants representing the actions that can be applied to the joystick.

[4] https://docs.python.org/3.5/library/collections.html#collections.namedtuple
[5] https://docs.python.org/3.5/library/time.html#time.time

CHAPTER 4

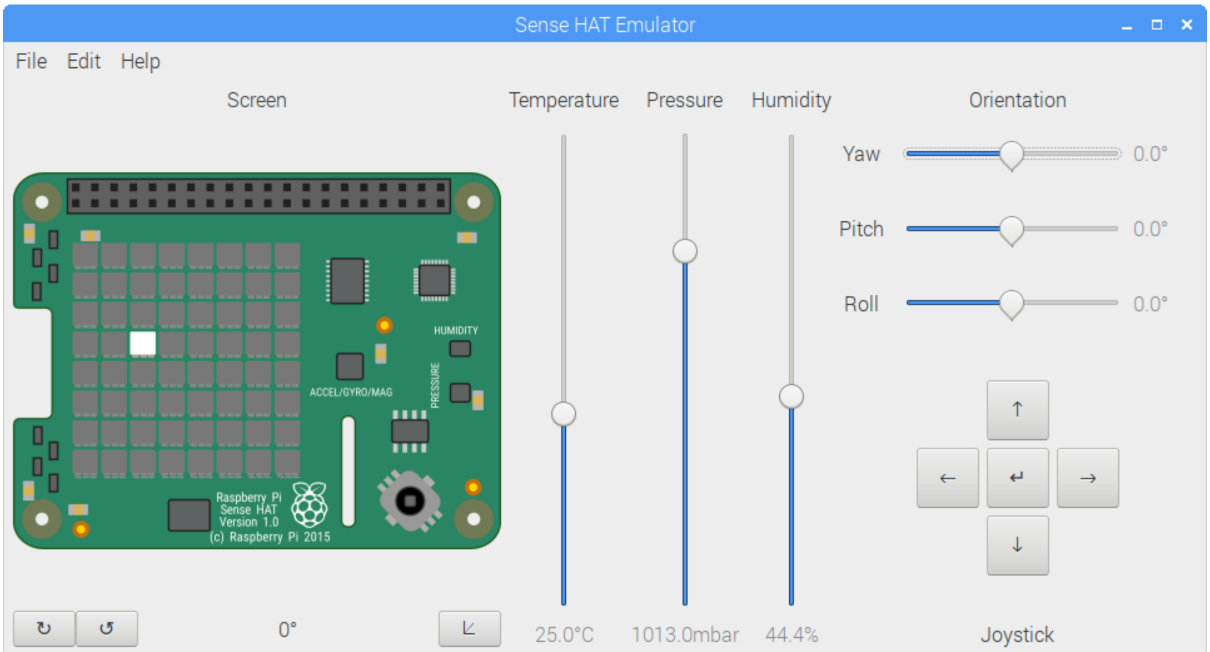
Sense Emulator

The Sense HAT emulator application. This GTK application provides an interactive interface for emulating the Raspberry Pi Sense HAT.

4.1 Synopsis

```
sense_emu_gui
```

4.2 Usage



The main window is divided into four parts. At the left is a visual representation of the Sense HAT. Scripts using the emulator library (sense_emu (page 7)) to set the HAT's LEDs will display the result here. Immediately below the LEDs are the rotation buttons which rotate the view of the HAT. These buttons also affect the action of the joystick buttons (covered below).

To the right of the LEDs are three sliders representing the temperature, pressure, and humidity of the emulated HAT's environment.

Note: The emulation does not *precisely* reflect the settings of the temperature, pressure, and humidity sliders. Random errors are introduced that scale according to the sensor specifications, and as the sliders are adjusted, the sensor value will gradually drift towards the new setting at a similar rate to the sensors on the real HAT.

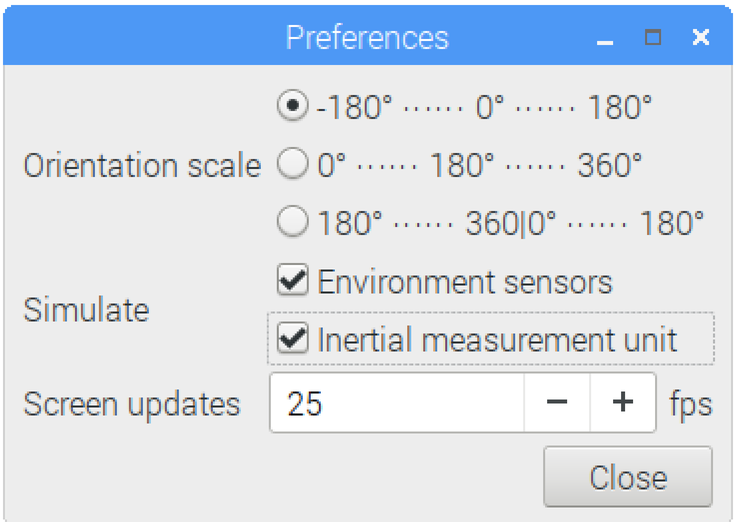
On the far right of the window, three sliders provide the orientation of the emulated HAT in terms of yaw (rotation around the vertical Z axis), pitch (rotation around the Y axis), and roll (rotation around the X axis). Adjusting these sliders affect the accelerometer, gyroscope, and magnetometer (compass) sensors on the emulated HAT. The emulated HAT assumes gravity runs vertically in the direction of the Z axis (as in the real HAT), and that North is in the direction of the X axis.

Finally, at the bottom right of the window, a series of buttons are provided to emulate the joystick on the HAT. The buttons will simulate *press*, *release*, and *hold* events generated by the real joystick. When the view of the HAT is rotated, the joystick buttons will act in the new orientation of the HAT. For example, initially the "up" button will send "up" events. After the HAT is rotated 90° the "up" button will send "right" events. After another 90° rotation, the "up" button will send "down" events, and so on.

Note: The emulator must be run prior to starting any scripts which expect to use the `sense_emu` (page 7) library. However, the emulator can be terminated (and restarted) while scripts using the library are running (obviously, when the emulator isn't running sensor errors can't be emulated and all sensor readings will appear fixed). Attempting to spawn more than one instance of the emulator will simply activate the existing instance.

4.3 Preferences

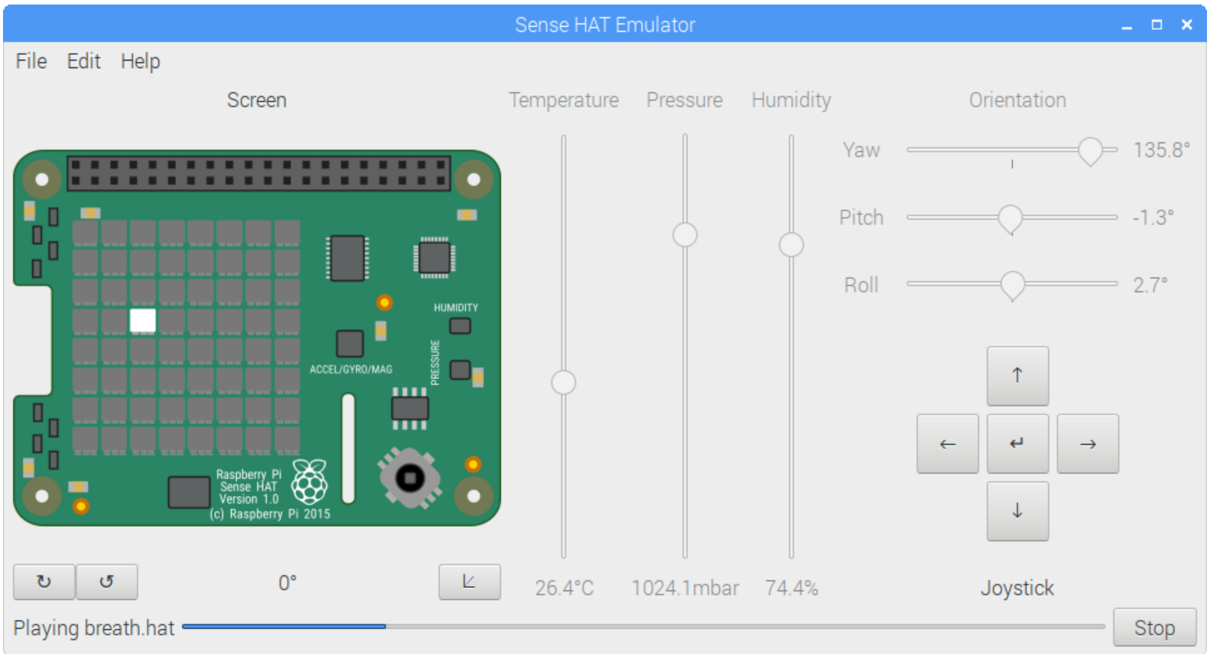
On slower Pis in particular, you may wish to disable some aspects of the emulation for performance purposes. From the "Edit" menu, select "Preferences". In the window that appears you can control which aspects of the emulation are enabled, and what speed the screen updates will be limited to.



You can also control the appearance of angles for the orientation sliders (note that this is a purely visual preference; it doesn't affect the output of the emulated sensors in any way).

4.4 Replay

Recordings of actual sensor readings from a Sense HAT can be replayed within the emulator. From the "File" menu, select "Replay recording". From the file selection dialog that appears, select the recording you wish to replay and click "Open". The replay will immediately begin, with progress displayed in a bar at the bottom of the main window. You can click "Stop" (next to the progress bar) to terminate playback of the recording.



During playback, the sensor sliders will move according to the data in the recording but will be disabled (to prevent the user affecting the replay). At the end of the replay (or immediately after termination of playback), the sliders will be left at their present positions and re-enabled.

CHAPTER 5

sense_rec

Records sensor readings from the Raspberry Pi Sense HAT in real time, outputting the results to a file for later playback or analysis. This is most useful for preparing records of experiments for use with the Sense HAT emulator. For example, a recording of a Sense HAT being dropped, a recording of a HAB[6] flight, a recording of the cycle of temperature over a few days, etc.

5.1 Synopsis

```
sense_rec [-h] [--version] [-q] [-v] [-l FILE] [-P] [-c CONFIG]
          [-d DURATION] [-f] output
```

5.2 Description

-h, --help
show this help message and exit

--version
show this program's version number and exit

-q, --quiet
produce less console output

-v, --verbose
produce more console output

-l FILE**, --log-file** FILE
log messages to the specified file

-P, --pdb
run under PDB (debug mode)

-c FILE**, --config** FILE
the Sense HAT configuration file to use (default: `/etc/RTIMULib.ini`)

-d SECS**, --duration** SECS
the duration to record for in seconds (default: record until terminated with `Control-C`)

[6] https://en.wikipedia.org/wiki/High-altitude_balloon

-i SECS, **--interval** SECS
the delay between each reading in seconds (default: the IMU polling interval, typically 0.003 seconds)

-f, --flush
flush every record to disk immediately; reduces chances of truncated data on power loss, but greatly increases disk activity

5.3 Examples

To record an experiment with the Sense HAT, simply execute **sense_rec** with the filename you wish to record the results:

```
$ sense_rec experiment.hat
```

By default, the recording will continue indefinitely. Press `Control-C` to terminate the recording. If you want to record for a specific duration, you can use the *--duration* (page 15) option to specify the number of seconds:

```
$ sense_rec --duration 10 short_experiment.hat
```

This tool can be run simultaneously with scripts that use the Sense HAT. Simply start your script in one terminal, then open another to start **sense_rec**. Alternatively, you can use the shell's job control facilities to start recording in the background:

```
$ sense_rec experiment.hat &
$ python experiment.py
...
$ kill %1
```

> **Warning:** Be aware that other scripts attempting to use the HAT's sensors will likely obtain different readings than they would have if run standalone. Some of the HAT's sensors are affected by their query-rate, and **sense_rec** drives all sensors at close to their maximum rate.

If – is specified as the output file, **sense_rec** will write its output to stdout. This can be used to reduce the disk space required for long output by piping the output through a compression tool like **gzip**:

```
$ sense_rec - | gzip -c - > experiment.hat.gz
```

When compressed in this manner the data typically uses approximately 3Kb per second (without **gzip** the recording will use approximately 10Kb of disk space per second). Use **gunzip** to de-compress the data for playback or analysis:

```
$ gunzip -c experiment.hat.gz | sense_play -
```

Another method of reducing the data usage is increasing the interval between readings (the default is the IMU polling interval which is an extremely short 3ms). Obviously a longer interval will reduce the "fidelity" of the recording; you will only see the sensors update at each interval during playback, however it can be extremely useful for very long recordings. For example, to record with a 1 second interval between readings for 24 hours:

```
$ sense_rec -i 1 -d $((24*60*60)) one_day_experiment.hat
```

Finally, you can use pipes in conjunction with **sense_csv** to produce CSV output directly:

```
$ sense_rec - | sense_csv - experiment.csv
```

Be warned that CSV data is substantially larger than the binary format (CSV data uses approximately 25Kb per second at the default interval).

CHAPTER 6

sense_play

Replays readings recorded from a Raspberry Pi Sense HAT, via the Sense HAT emulation library.

6.1 Synopsis

```
sense_play [-h] [--version] [-q] [-v] [-l FILE] [-P] input
```

6.2 Description

-h, --help
show this help message and exit

--version
show this program's version number and exit

-q, --quiet
produce less console output

-v, --verbose
produce more console output

-l FILE**, --log-file** FILE
log messages to the specified file

-P, --pdb
run under PDB (debug mode)

6.3 Examples

To play back an experiment recorded from the Sense HAT, simply execute **sense_play** with the filename you wish to play back:

```
$ sense_play experiment.hat
```

Playback will start immediately and continue in real-time (at the recording rate) until the file is exhausted. If you wish to start an emulated script at the same time as playback, you can use the shell's job control facilities:

```
$ sense_play experiment.hat & python experiment.py
```

If - is specified as the input file, **sense_play** will read its from stdin. This can be used to play back compressed recordings (see Examples under **sense_rec**) without using any disk space for decompression:

```
$ gunzip -c experiment.hat.gz | sense_play -
```

Note: If playback is going too slowly (e.g. because the Pi is too busy with other tasks, or because the data cannot be read quickly enough from the SD card), **sense_play** will skip records and print a warning to the console at the end of playback with the number of records skipped.

CHAPTER 7

sense_csv

Converts a Sense HAT recording to CSV format, for the purposes of debugging or analysis.

7.1 Synopsis

```
sense_csv [-h] [--version] [-q] [-v] [-l FILE] [-P]
          [--timestamp-format TIMESTAMP_FORMAT] [--header] input output
```

7.2 Description

-h, --help
show this help message and exit

--version
show this program's version number and exit

-q, --quiet
produce less console output

-v, --verbose
produce more console output

-l FILE**, --log-file** FILE
log messages to the specified file

-P, --pdb
run under PDB (debug mode)

--timestamp-format FMT
the format to use when outputting the record timestamp (default: ISO8601 format, which is "%Y-%m-%dT%H:%M:%S.%f"; see *strftime(3)* for information on valid format parameters)

--header
if specified, output column headers at the start of the output

7.3 Examples

To convert a recording to CSV, simply run **sense_csv** with the recorded file as the first filename, and the output CSV file as the second:

```
$ sense_csv experiment.hat experiment.csv
```

By default, only the data is output, with the columns defined as follows:

1. Timestamp - the moment in time at which the readings were taken (note that as the Pi lacks a real-time clock, this is likely to be inaccurate unless the clock has been set with NTP).
2. Pressure - the reading from the pressure sensor in hectopascals (hPa).
3. Temperature - the temperature reading from the pressure sensor in degrees celsius (°C).
4. Humidity - the reading from the humidity sensor in % humidity.
5. Temperature - the temperature reading from the humidity sensor in degrees celsius (°C).
6. Accelerometer X-axis - the acceleration reading along the X-axis of the HAT in g.
7. Accelerometer Y-axis.
8. Accelerometer Z-axis.
9. Gyroscope X-axis - the angular rate of change around the X-axis of the HAT in degrees per second.
10. Gyroscope Y-axis.
11. Gyroscope Z-axis.
12. Compass X-axis - the magnetometer reading along the X-axis in micro-teslas.
13. Compass Y-axis.
14. Compass Z-axis.
15. Orientation X-axis - the computed orientation of the HAT as radians rotation ($-\pi$ to $+\pi$) about the X-axis.
16. Orientation Y-axis.
17. Orientation Z-axis.

If you wish to include column headers as the first row of data, simply specify the *--header* (page 19) option:

```
$ sense_csv --header experiment.hat experiment.csv
```

If - is specified for either filename, **sense_csv** will read from stdin, or write to stdout. This can be used in conjunction with other standard command line utilities for all sorts of effects. For example, to produce a CSV file containing only the timestamps, humidity, and accelerometer readings:

```
$ sense_csv --header experiment.hat - | cut -d, -f1,4,6-8 > experiment.csv
```

CHAPTER 8

Change log

8.1 Release 1.1 (2018-07-07)

- Enforce a minimum width of window to ensure orientation sliders are never excessively small (#9[7])
- Various documentation updates (#12[8] etc.)
- Resizing of the display for high-resolution displays (#14[9])
- Orientation sliders had no effect when world simulation was disabled (#19[10])
- When the emulator was spawned by instantiating `SenseHat()` in an interpreter, pressing Ctrl+C in the interpreter would affect the emulator (#22[11])
- Make **sense_rec** interval configurable (#24[12])

Many thanks to everyone who reported bugs and provided patches!

8.2 Release 1.0 (2016-08-31)

- Initial release

[7] https://github.com/RPi-Distro/python-sense-emu/issues/9
[8] https://github.com/RPi-Distro/python-sense-emu/issues/12
[9] https://github.com/RPi-Distro/python-sense-emu/issues/14
[10] https://github.com/RPi-Distro/python-sense-emu/issues/19
[11] https://github.com/RPi-Distro/python-sense-emu/issues/22
[12] https://github.com/RPi-Distro/python-sense-emu/issues/24

CHAPTER 9

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