Data Acquisition from Serial Ports

With Python's pyserial module

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Serial Ports

In computing, a serial port is a serial communication physical interface through which information transfers in or out one bit at a time (in contrast to a parallel port). Throughout most of the history of personal computers, data was transferred through serial ports to devices such as modems, terminals and various peripherals.

(ref: Wikipedia)

- Very basic form of communication. Low power, low CPU.
- Protocol is called “RS-232” or “RS-485”
- In common use on scientific equipment, for example NCAS’s laser ceilometer.
- Usually a 9-pin or 25-pin “D-Sub” port, but sometimes a variety of others
- no longer common on computers. However, USB->Serial adapters are approx £15.

The Papouch temperature probe

- Very basic serial RS232 temp probe
- ~€20
- Measures temperatures from -55°C to +125°C, 0.1°C resolution
- Output is in ASCII format in °C, no conversion needed.
- Port powered so needs no power source
- Datasheet included in your kit

Basic connections

https://pyserial.readthedocs.io

```python
#!/usr/bin/python2.7
import serial

ser = serial.Serial(
   port='/dev/ttyUSB0',
   baudrate=9600,
   bytesize=serial.EIGHTBITS,
   parity=serial.PARITY_NONE,
   stopbits=serial.STOPBITS_ONE
)
```

As well as the pyserial shortintro above, you may find `https://pythonhosted.org/pyserial/pyserial_api.html` and the Papouch thermometer datasheet useful.

Basic connections example

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- The Papouch thermometer 9600 baud, eight bits, no parity checking and one stopbit. ("9600 8N1") (Same as pyserial's defaults!)
- For other parameters, see pyserial's API (https://pythonhosted.org/pyserial/pyserial_api.html)

Basic connections - Port names

- `/dev/ttyUSB0` is Linux's way of referring to the first USB serial port
- subsequent ones `/dev/ttyUSB1`, `/dev/ttyUSB2` and so-on
- Built-in serial ports would be `/dev/ttyS0`, `/dev/ttyS1` etc.
- Windows machines, the portname will be of the form `COM1`, `COM2`, `COM3`, etc. (USB ports *normally* start at `COM3`, but not always)
- Mac OSX machines are different again. It will be something like `/dev/tty.SOMETHING`, e.g. `/dev/tty.PL2303-xxx`
- You may need to experiment to determine which the USB converter has attached to.

Locating your serial port device

- Multiple USB->serial devices on one machine may not come back in the same order on reboot
- You can get multi-port USB->serial devices
- On Linux, there are alternative ways of addressing the device

By USB ID

```
[user01@unst ~]$ ls -F /dev/serial/by-id/*
/dev/serial/by-id/usb-Prolific_Technology_Inc._USB-Serial_Controller_D-if00-port0@
```

- No use if the devices have the same USB ID (e.g. if they are identical)
- Even devices that look different may have the same USB id if they are the same electronically

By Path

```
[user01@unst ~]$ ls -F /dev/serial/by-path/*
/dev/serial/by-path/pci-0000:00:14.0-usb-0:1:1.0-port0@
/dev/serial/by-path/pci-0000:00:14.0-usb-0:2:1.0-port0@
```

- Identifies them by which port they're plugged in to

Reading Data

- `read()` to read a fixed number of bytes
- `readline()` to read a line of data ending in a newline.

For most instruments, `readline()` is easier, but for the temperature probe, you must use `ser.read(size=8)`.

Reading Data - Temperature probe

From the Papouch thermometer datasheet

```
<sign><3 characters – integer °C>
<decimal point><1 character – tenths of °C>
<C><Enter>
```

- In ASCII coding, each character is one byte
- so a temperature from the thermometer is exactly eight bytes
- `readline()` expects *newline* to separate but probe separates by *carriage return*

The `datetime` module

For the data to be useful you need to add a date and time reading. Python includes a standard module for this, `datetime` (`http://docs.python.org/2/library/datetime.html`)

- Can process times in a very wide variety of formats
- Can deal with different timezones (if you ask it to)
- Other date/time modules are available, but `datetime` is always avaiable.

Date and Time formats

- Timezone should be in UTC or TAI in the majority of cases
- Use an unambiguous format
- `isoformat()` produces a standard format by default - rarely is that a problem.
- `strftime()` will do any format you require (e.g. for documents intended to be read by people)

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Date and Time examples

Current time:

```
>>> from datetime import datetime
>>> dt = datetime.now()
>>> print dt
2016-04-12 17:32:38.806353
>>> dt
datetime.datetime(2016, 4, 12, 17, 32, 38, 806353)
```

Custom formats:

```
>>> print dt.strftime('%Y-%m-%d %H:%M:%S')
2016-04-12 17:32:38
>>> print dt.strftime('%A, %B %d, %Y')
Tuesday, April 12, 2016
```

Time and Date example

```python
#!/usr/bin/python2.7

from datetime import datetime
import serial

ser = serial.Serial(
   port='/dev/ttyUSB0',
   baudrate=9600,
)

print datetime.utcnow().isoformat(), ser.read(size=8)

ser.close()
```

Time and Date example

`datetime.utcnow().isoformat()` returns the current UTC in ISO format, e.g.:

```
2014-03-06T11:55:43.852953 +025.3C
```

```
print datetime.utcnow().isoformat(), ser.read(size=8)
```

- `datetime.utcnow()` call can return in advance of the `ser.read()` call
- timestamp and the temperature should be as close as possible
- store the data in a variable and output the variable and the time at the same time

```
datastring = ser.read(size=8)
print datetime.utcnow().isoformat(), datastring
```

`readline()`

- The example thermometer *always* returns exactly eight bytes, and so `ser.read(size=8)` is fine.
- instruments do not always return fixed-length data, and instead separate the readings (or sets of readings) with a special character.
- Usually newline or carriage return
- The pyserial module provides `readline()` to handle this case.
- worked differently prior to python v2.6

Finding out serial connection details

Check the documentation

Most instruments with serial access will have a (possibly quite short) section in the manual detailing the connection settings. Of course, your instrument might be quite old and the manual lost, in which case:

Finding out serial connection details

Ask the manufacturer

With any luck, the manual will be on their website. Of course they might be out of business, or unwilling or unable to help, in which case:

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Finding out serial connection details

Ask the Internet!

Use a search engine of your choice

Finding out serial connection details

Trial and error

As long as you get the voltage right (usually 3.3v or 5v) you **probably** can't damage your instrument by trying various combinations of serial settings until something works. 9600-8N1 is usually the best place to start

Outputting in NetCDF format

Assuming you've got some data of the format:

```
2017-02-22T10:00:08.457120 +019.4C
2017-02-22T10:00:18.438098 +019.4C
2017-02-22T10:00:28.419100 +019.4C
2017-02-22T10:00:38.400093 +019.4C
2017-02-22T10:00:48.381103 +019.3C
2017-02-22T10:00:58.362099 +019.3C
2017-02-22T10:01:08.342102 +019.3C
…
```

You wouldn't really be happy with that as an archive file - if you came back to it in a few years (or someone else did, perhaps after you've moved on) there's several items of missing information.

Converting data from text to Python datatypes.

Before we write a NetCDF file, we must convert the text file to usable data. Our temperature is in a slightly weird format due to the Papouch sensor including the units, so we need functions to convert the string into a number and the time into a Python 'datetime' object.

Exercise

Q1. Write a function to convert the time as written in your datafile and return a Python `datetime` object.

Q2. Write a function to convert the temperature as written in your datafile and return a `float` in Kelvin.
($T_K = T_C + 273.15$)

Converting data from text to Python datatypes - 2

```
def convert_time(tm):
    tm = datetime.strptime(tm, "%Y-%m-%dT%H:%M:%S.%f")
    return tm

def convert_temp(temp):
    value = temp.strip("+").strip("C").lstrip("0")
    return float(value) + 273.15
```

`strptime` is the opposite of `strftime` that we used earlier.

Reading data in with the `csv` module

Python has a module designed for reading in text formats. It's called `csv`, although it also does tab-separated and related structured ASCII formats. We only need the base reader object here. (Other reader objects deal with more complex cases - f.ex. `DictReader`)

https://docs.python.org/2/library/csv.html

Exercise

Q1. Read your datafile into Python using the `csv` module such that you end up with list object(s) containing floating-point temperature in K and timestamps as Python `datetime` objects.

Reading data in with the csv module -2

```
infile='sample-serial-temperature-2h.tsv'
outfile='sensor-data.nc'
from csv import reader

# Parse the data into python lists
times = []
temps = []

#open infile and read data into lists
with open(infile, 'rb') as tsvfile:
   tsvreader = reader(tsvfile, delimiter='\t')
   for row in tsvreader:
      times.append(convert_time(row[0]))
      temps.append(convert_temp(row[1]))
```

The call to `reader` returns an iterator so we can iterate over it with a `for` loop.

Writing NetCDF files with Python

We can write the data from the serial logging exercise to a new NetCDF file.

- Create a `Dataset` (use the format `NETCDF4_CLASSIC`)
- Convert your time series to a suitable CF-compliant series
- Create a suitable `Dimension` for your time series
- Create `Variable` objects for Temp and Time using appropriate units etc.
- Assign appropriate metadata to the Temp `Variable` and and the `Dataset`
- Add your time series and temp values to the `Dataset`
- Close and write your `Dataset`. Test that it parses correctly eith `ncdump`

Time series

NetCDF using CF conventions stores times as an offset from a base time rather than an absolute time, so we first subtract `base_time`, and then convert the resulting `timedelta` object to an offset in seconds.

```
# Set reference time and convert datetime values to offset values from reference time
#reference time is the first time in the input data
base_time = times[0]
time_values = []

for t in times:
    value = t - base_time
    ts = value.total_seconds()
    time_values.append(ts)

time_units = "seconds since " + base_time.strftime('%Y-%m-%d %H:%M:%S')
```

Create the NetCDF dimensions & variables

```
# Create the output file (NetCDF dataset)
dataset = Dataset(outfile, "w", format='NETCDF4_CLASSIC')

# Create the time dimension - with unlimited length
time_dim = dataset.createDimension("time", None)

# Create the time variable
time_var = dataset.createVariable("time", np.float64, ("time",))
time_var[:] = time_values
time_var.units = time_units
time_var.standard_name = "time"
time_var.calendar = "standard"

# Create the temp variable
temp = dataset.createVariable("temp", np.float32, ("time",))
temp[:] = temps
```

Metadata

One of the advantages of NetCDF is that it can contain metadata. We'll set a dictionary to contain it so we don't repeat ourselves.

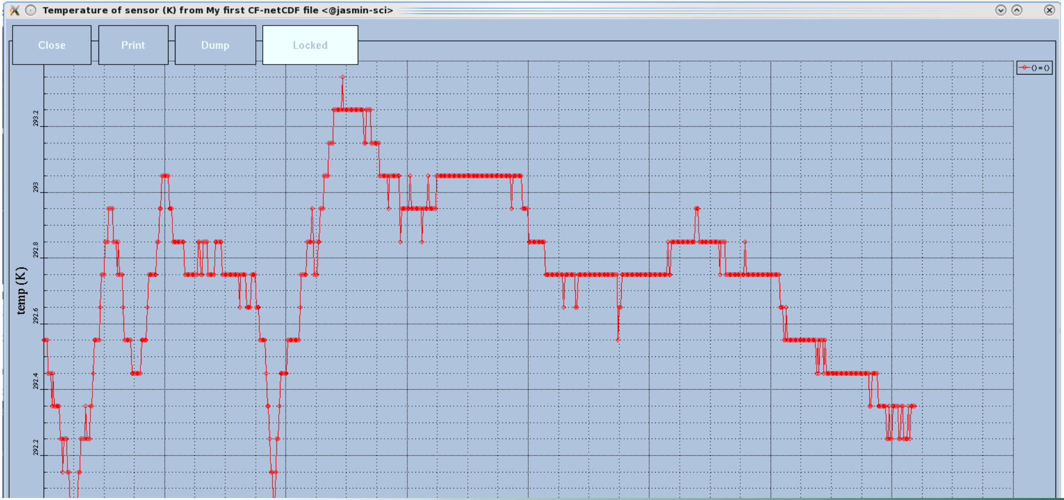
```
# Set the variable attributes
temp.var_id = "temp"
temp.long_name = "Temperature of sensor (K)"
temp.units = "K"
temp.stabdard_name = "air_temperature"

# Set the global attributes
dataset.Conventions = "CF-1.6"
dataset.institution = "NCAS"
dataset.title = "My first CF-netCDF file"
dataset.history = "%s: Written with script: write_sensor_data_to_netcdf.py" % (datetime.now().
```

Plotting data

You can do a quick-and-dirty plot with `ncview`:

```
ncview sensor_data.nc
```



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Plotting data

```
#!/usr/bin/python2.7

''' Plots a line graph from a NetCDF file '''

from netCDF4 import Dataset
import numpy as np

datafile = 'sensor_data.nc'

nc = Dataset(datafile, mode='r')

temps = nc.variables['temp'][:]
times = nc.variables['time'][:]

times = num2date(time[:],units=time.units, calendar=time.calendar)

plt.plot_date(times,temps)
plt.savefig('sensor_data.png')
```

Plotting data - with labels

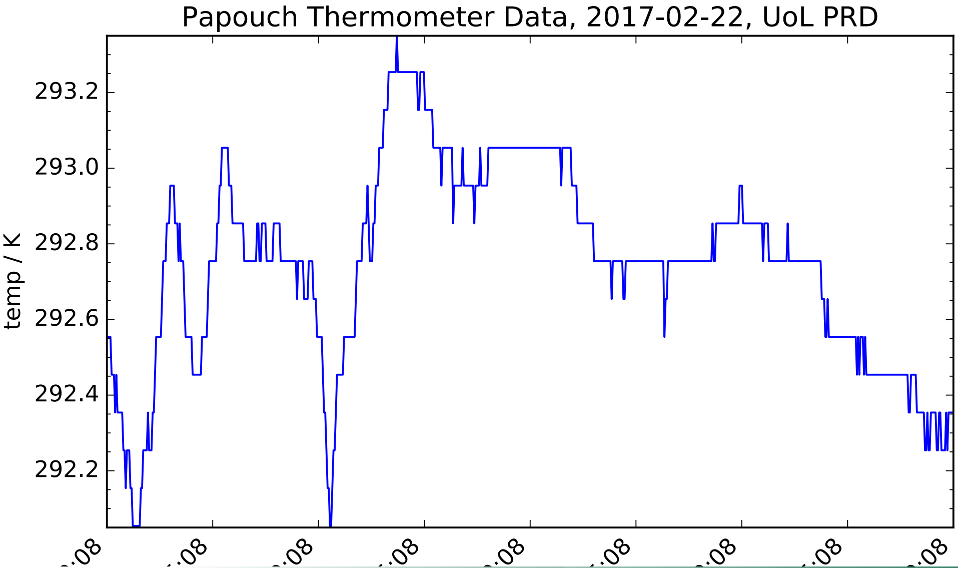
After `times = num2date(time{:},units=time.units, calendar=time.calendar)`

```
#get "handles" to affect plot styling
fig, ax = plt.subplots()
#tick every tenth minute
ax.xaxis.set_major_locator(MinuteLocator(byminute=range(0,60,10)))

#format of date on x-axis (display minutes, uses strftime)
ax.xaxis.set_major_formatter(DateFormatter('%H:%M'))

#tick every minute
ax.xaxis.set_minor_locator(MinuteLocator())
ax.autoscale_view()

#line graph
plt.plot_date(times,temps,'-')
labels = ax.get_xticklabels()
plt.setp(labels, rotation=90, fontsize=10, horizontalalignment='center')
plt.xlabel(time.standard_name)
plt.ylabel(temp.standard_name + ' / ' + temp.units)
```

Plotting data with CIS (Community Intercomparison Suite)

Another option is CIS
"CIS is an open source command-line tool for easy collocation, visualization, analysis, and comparison of diverse gridded and ungridded datasets used in the atmospheric sciences"
It is based on python. Homepage: http://www.cistools.net/

```
cis plot temp:sensor_data.nc --xaxis time --yaxis temp \
    --title "Papouch Thermometer Data, 2017-02-22, UoL PRD" --xstep "0.010416"  \
    --output sensor_data_sample.svg
```


Papouch Thermometer Data, 2017-02-22, UoL PRD
temp / K
293.2
293.0
292.8
292.6
292.4
292.2