Wrangling Formula One Motorsport Data With Python

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Preface

Several years ago, I put together a collection of recipes for analysing and visualising Formula One results and timing data using the R programming language, and published them via the Leanpub self-publishing platform.

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1. Introduction

As many motorsport fans will know, Formula One is a data driven sport.

EXAMPLE REF: See Knuth (1984) for additional discussion of literate programming.

Part I.

Exploring the fast-f1 Python package

2. Getting Started With `FastF1`

The `theOehrly/Fast-F1` Python package [docs] provides a relatively straightforward way of downloading and accessing telemetry data from the Formula One website and the *ergast* historical motor racing results database.

In this chapter, we'll have a quick overview of the package to get a feel for the sorts of things we can do with it, before diving in to more detail in other chapters.

Let's start off by importing the package:

```
#Install with:
# %pip install --upgrade fastf1
# Dev version:
# %pip install --upgrade https://github.com/theOehrly/Fast-F1/archive/refs/heads/master.z
import fastf1 as ff1
```

The package API may change rapidly, and may include breaking changes.

The code used in this chapter relates to version `2.2.9`.

```
# Check the package version
ff1.__version__
```

```
'2.2.9'
```

To minimise the number of calls made to the website, the package can be configured to cache data whenever possible.

```
from pathlib import Path

cachedir = ".cache"
Path(cachedir).mkdir(parents=True, exist_ok=True)

ff1.Cache.enable_cache(cachedir)
```

```
If we request the same data again, the locally cached data will be used, r

This has the advantage that if you have already cached the data, you can l
```

Data can be retrieved for specific sessions of specific races.

As the data is loaded, a diagnostic trace is displayed showing what data has been retrieved, and from where (for example, downloaded from the original API or retrieved from the cache).

```
# Select a wualifying session ("Q") or a race session("R")
monza_quali = ff1.get_session(2019, 'Monza', 'Q')

monza_quali.load()
```

```
core           INFO     Loading data for Italian Grand Prix - Qualifying [v2
api            INFO     Using cached data for driver_info
api            INFO     Using cached data for timing_data
api            INFO     Using cached data for timing_app_data
core           INFO     Processing timing data...
api            INFO     Using cached data for session_status_data
api            INFO     Using cached data for track_status_data
api            INFO     Using cached data for car_data
```

```
api             INFO     Using cached data for position_data
api             INFO     Using cached data for weather_data
api             INFO     Using cached data for race_control_messages
core            INFO     Finished loading data for 20 drivers: ['16', '44', '77', '5', '3', '
```

A good selection of metadata is available to describe the associated event:

```
weekend = monza_quali.event
weekend
```

```
RoundNumber                                                14
Country                                                 Italy
Location                                                Monza
OfficialEventName    FORMULA 1 GRAN PREMIO HEINEKEN D'ITALIA 2019
EventDate                                2019-09-08 00:00:00
EventName                                 Italian Grand Prix
EventFormat                                      conventional
Session1                                          Practice 1
Session1Date                             2019-09-06 00:00:00
Session2                                          Practice 2
Session2Date                             2019-09-06 00:00:00
Session3                                          Practice 3
Session3Date                             2019-09-07 00:00:00
Session4                                          Qualifying
Session4Date                             2019-09-07 00:00:00
Session5                                                Race
Session5Date                             2019-09-08 00:00:00
F1ApiSupport                                            True
Name: Italian Grand Prix, dtype: object
```

2.1. Driver Details

A wide range of data is available, and can be can be explored in several ways.

For example, we can get the data for a particular driver, and identify their fastest lap, along with various summary statistics for it:

Here's an example of the driver details:

```
monza_quali.get_driver('LEC')
```

```
DriverNumber                          16
BroadcastName                  C LECLERC
Abbreviation                         LEC
TeamName                         Ferrari
TeamColor                         dc0000
FirstName                        Charles
LastName                         Leclerc
FullName                  Charles Leclerc
Position                              1.0
GridPosition                          0.0
Q1                0 days 00:01:20.126000
Q2                0 days 00:01:19.553000
Q3                0 days 00:01:19.307000
Time                                 NaT
Status
Points                                0.0
Name: Charles, dtype: object
```

We can retrieve summary data about each lap:

```
monza_quali.laps.head()
```

	Time	DriverNumber	LapTime	LapNumber	Stint	PitOutTime
0	0 days 00:21:01.358000	16	NaT	1	1	0 days 00:19:26.8
1	0 days 00:22:21.775000	16	0 days 00:01:20.417000	2	1	NaT
2	0 days 00:24:03.991000	16	0 days 00:01:42.216000	3	1	NaT
3	0 days 00:25:24.117000	16	0 days 00:01:20.126000	4	1	NaT
4	0 days 00:27:09.461000	16	0 days 00:01:45.344000	5	1	NaT

2.2. Laps Data

A wide range of data is provided as part of the Laps table:

```
monza_quali.laps.columns
```

```
Index(['Time', 'DriverNumber', 'LapTime', 'LapNumber', 'Stint', 'PitOutTime',
       'PitInTime', 'Sector1Time', 'Sector2Time', 'Sector3Time',
       'Sector1SessionTime', 'Sector2SessionTime', 'Sector3SessionTime',
       'SpeedI1', 'SpeedI2', 'SpeedFL', 'SpeedST', 'IsPersonalBest',
       'Compound', 'TyreLife', 'FreshTyre', 'LapStartTime', 'Team', 'Driver',
       'TrackStatus', 'IsAccurate', 'LapStartDate'],
      dtype='object')
```

We can check the laps for a particular car:

```
lec_laps = monza_quali.laps.pick_driver(16)
lec_laps[:5]
```

	Time	DriverNumber	LapTime	LapNumber	Stint	PitOutTime
0	0 days 00:21:01.358000	16	NaT	1	1	0 days 00:19:26.8
1	0 days 00:22:21.775000	16	0 days 00:01:20.417000	2	1	NaT

	Time	DriverNumber	LapTime	LapNumber	Stint
2	0 days 00:24:03.991000	16	0 days 00:01:42.216000	3	1
3	0 days 00:25:24.117000	16	0 days 00:01:20.126000	4	1
4	0 days 00:27:09.461000	16	0 days 00:01:45.344000	5	1

2.3. Car Telemetry Data

Perhaps more interestingly, we can look up regular samples of raw car data for a particular driver:

```
monza_quali.car_data['16'][:5]
```

	Date	RPM	Speed	nGear	Throttle	Brake	DRS	Source	T
0	2019-09-07 12:45:02.230	0	0	0	0	False	0	car	0
1	2019-09-07 12:45:02.470	0	0	0	0	False	0	car	0
2	2019-09-07 12:45:02.710	0	0	0	0	False	0	car	0
3	2019-09-07 12:45:02.990	0	0	0	0	False	0	car	0
4	2019-09-07 12:45:03.230	0	0	0	0	False	0	car	0

An even more helpful telemetry data report includes a derived accumulated distance travelled round the track on each lap, as well as on-track contextual information, such as the distance to, and identity of, the driver ahead on-track.

We can retrieve the telemetry data associated with a particular lap by calling the `get_telemetry()` method on a single lap object:

```
# We need to index to a particular lap record
lec_laps.iloc[1].get_telemetry()
```

	Date	SessionTime	DriverAhead	DistanceToDriverAhead	Time
2	2019-09-07 13:06:02.451	0 days 00:21:01.358000		400.271389	0 days 00:0
3	2019-09-07 13:06:02.521	0 days 00:21:01.428000		400.271389	0 days 00:0
4	2019-09-07 13:06:02.524	0 days 00:21:01.431000		400.271389	0 days 00:0
5	2019-09-07 13:06:02.764	0 days 00:21:01.671000	88	400.271389	0 days 00:0
6	2019-09-07 13:06:02.821	0 days 00:21:01.728000	88	400.671389	0 days 00:0
...	...	...	...	...	...
597	2019-09-07 13:07:22.522	0 days 00:22:21.429000	88	151.229167	0 days 00:0
598	2019-09-07 13:07:22.525	0 days 00:22:21.432000	88	150.462500	0 days 00:0
599	2019-09-07 13:07:22.765	0 days 00:22:21.672000	88	148.795833	0 days 00:0
600	2019-09-07 13:07:22.822	0 days 00:22:21.729000	88	148.795833	0 days 00:0
601	2019-09-07 13:07:22.868	0 days 00:22:21.775000	88	148.795833	0 days 00:0

We can more explicitly return the record for a specific lap by filtering on the `LapNumner`:

```
def onLap(laps, lap):
    """Get record for a particular lap."""
    return laps[laps["LapNumber"]==lap].iloc[0]
```

```
onLap(lec_laps, 2)
```

```
Time                      0 days 00:22:21.775000
DriverNumber                                  16
LapTime                   0 days 00:01:20.417000
LapNumber                                      2
Stint                                          1
PitOutTime                                   NaT
PitInTime                                    NaT
Sector1Time               0 days 00:00:26.982000
Sector2Time               0 days 00:00:26.734000
```

```
Sector3Time               0 days 00:00:26.701000
Sector1SessionTime        0 days 00:21:28.340000
Sector2SessionTime        0 days 00:21:55.074000
Sector3SessionTime        0 days 00:22:21.775000
SpeedI1                                   323.0
SpeedI2                                   342.0
SpeedFL                                   318.0
SpeedST                                   342.0
IsPersonalBest                            False
Compound                                 MEDIUM
TyreLife                                    2.0
FreshTyre                                  True
LapStartTime              0 days 00:21:01.358000
Team                                    Ferrari
Driver                                      LEC
TrackStatus                                   1
IsAccurate                                 True
LapStartDate          2019-09-07 13:06:02.451000
Name: 1, dtype: object
```

We can get then telemetry for the lap by calling the `.get_telemetry()` method on the returned lap object:

```
onLap(lec_laps, 2).get_telemetry()
```

	Date	SessionTime	DriverAhead	DistanceToDriverA
2	2019-09-07 13:06:02.451	0 days 00:21:01.358000		400.271389
3	2019-09-07 13:06:02.521	0 days 00:21:01.428000		400.271389
4	2019-09-07 13:06:02.524	0 days 00:21:01.431000		400.271389
5	2019-09-07 13:06:02.764	0 days 00:21:01.671000	88	400.271389
6	2019-09-07 13:06:02.821	0 days 00:21:01.728000	88	400.671389
...	...	...	...	...

	Date	SessionTime	DriverAhead	DistanceToDriverAhead	Time
597	2019-09-07 13:07:22.522	0 days 00:22:21.429000	88	151.229167	0 days 00:0
598	2019-09-07 13:07:22.525	0 days 00:22:21.432000	88	150.462500	0 days 00:0
599	2019-09-07 13:07:22.765	0 days 00:22:21.672000	88	148.795833	0 days 00:0
600	2019-09-07 13:07:22.822	0 days 00:22:21.729000	88	148.795833	0 days 00:0
601	2019-09-07 13:07:22.868	0 days 00:22:21.775000	88	148.795833	0 days 00:0

Find the fastest lap from a set of laps:

```
lec_fast_lap =  lec_laps.pick_fastest()
lec_fast_lap
```

```
Time                      0 days 01:11:14.868000
DriverNumber                                  16
LapTime                   0 days 00:01:19.307000
LapNumber                                     14
Stint                                          5
PitOutTime                                   NaT
PitInTime                                    NaT
Sector1Time               0 days 00:00:26.469000
Sector2Time               0 days 00:00:26.412000
Sector3Time               0 days 00:00:26.426000
Sector1SessionTime        0 days 01:10:22.030000
Sector2SessionTime        0 days 01:10:48.442000
Sector3SessionTime        0 days 01:11:14.868000
SpeedI1                                    329.0
SpeedI2                                    347.0
SpeedFL                                    321.0
SpeedST                                    349.0
IsPersonalBest                              True
Compound                                    SOFT
TyreLife                                     3.0
```

```
FreshTyre                                  True
LapStartTime              0 days 01:09:55.561000
Team                                      Ferrari
Driver                                        LEC
TrackStatus                                     2
IsAccurate                                 True
LapStartDate          2019-09-07 13:54:56.654000
Name: 13, dtype: object
```

We can also iterate over the laps, for example as `monza_quali.laps.pick_driver(16).iterl` each iteration returns a 2-tuple of the car number and the data for a particular lap.

We can get the telemetry for that driver on each lap by calling the `.get_telemetry()` method on the second (lap) element in the 2-tuple.

2.4. Simple Plots

The `fastf1` package also provides a range of tools to support the plotting of data:

```
from matplotlib import pyplot as plt
from fastf1 import plotting

# Configures timebase for axis ticks
plotting.setup_mpl()
```

For example, a range of labels and colour schemes are defined for enriching displays:

```
ff1.plotting.TEAM_TRANSLATE
```

```
{'MER': 'mercedes',
 'FER': 'ferrari',
 'RBR': 'red bull',
 'MCL': 'mclaren',
 'APN': 'alpine',
 'AMR': 'aston martin',
 'ARR': 'alfa romeo',
 'APT': 'alphatauri',
 'HAA': 'haas',
 'WIL': 'williams'}
```

```
ff1.plotting.TEAM_COLORS
```

```
{'mercedes': '#00d2be',
 'ferrari': '#dc0000',
 'red bull': '#0600ef',
 'mclaren': '#ff8700',
 'alpine': '#0090ff',
 'aston martin': '#006f62',
 'alfa romeo': '#900000',
 'alphatauri': '#2b4562',
 'haas': '#ffffff',
 'williams': '#005aff'}
```

```
ff1.plotting.DRIVER_COLORS
```

```
{'valtteri bottas': '#900000',
 'zhou guanyu': '#500000',
 'pierre gasly': '#2b4562',
 'yuki tsunoda': '#356cac',
 'fernando alonso': '#0090ff',
```

```
 'esteban ocon': '#70c2ff',
 'sebastian vettel': '#006f62',
 'lance stroll': '#25a617',
 'nico hulkenberg': '#2f9b90',
 'charles leclerc': '#dc0000',
 'carlos sainz': '#ff8181',
 'kevin magnussen': '#ffffff',
 'mick schumacher': '#cacaca',
 'daniel ricciardo': '#ff8700',
 'lando norris': '#eeb370',
 'lewis hamilton': '#00d2be',
 'george russell': '#24ffff',
 'max verstappen': '#0600ef',
 'sergio perez': '#716de2',
 'alexander albon': '#005aff',
 'nicholas latifi': '#012564'}
```

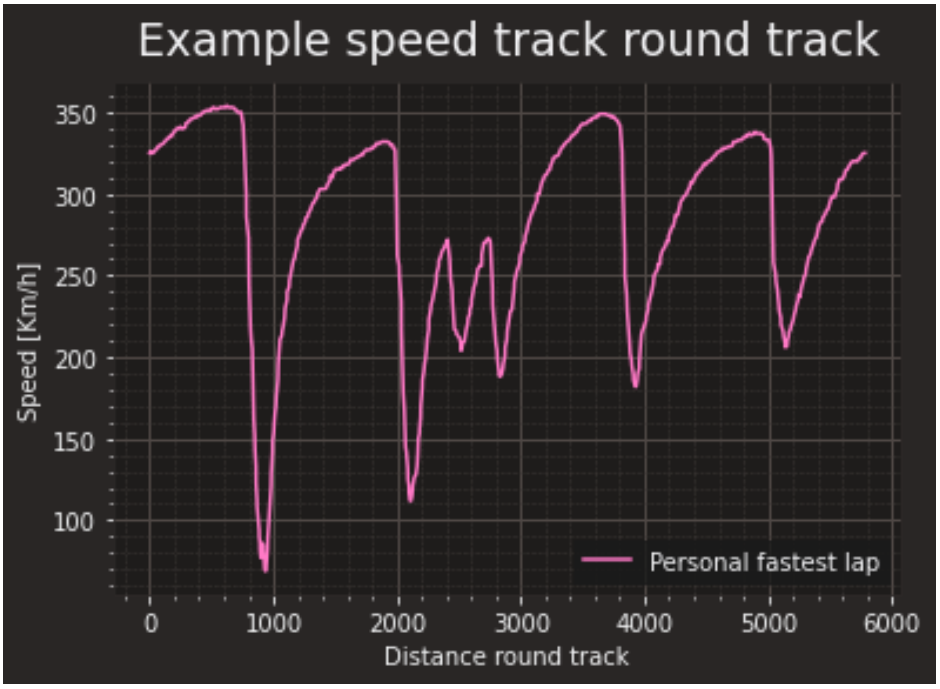
```
ff1.plotting.COLOR_PALETTE
```

```
['#FF79C6', '#50FA7B', '#8BE9FD', '#BD93F9', '#FFB86C', '#FF5555', '#F1FA8C']
```

We can trivially plot the speed against the distance round the track, for example, using telemetry data:

```
#Get the telemetry for a lap
lec_telem = lec_fast_lap.get_telemetry()

t = lec_telem['Distance']
vCar = lec_telem['Speed']

# Create a chart object
fig, ax = plt.subplots()
```

```
# Plot the speed against distance round track
ax.plot(t, vCar, label='Personal fastest lap')

# Add axis labels
ax.set_xlabel('Distance round track')
ax.set_ylabel('Speed [Km/h]')

# Add title
ax.set_title('Example speed track round track')

# Show legend
ax.legend();
```



With access to lap data associated with a session, we can generate a wide range of charts that summarise different aspects of the session.

For example, let's get the data from a particular race:

```
race = ff1.get_session(2020, 'Turkish Grand Prix', 'R')
race.load()
```

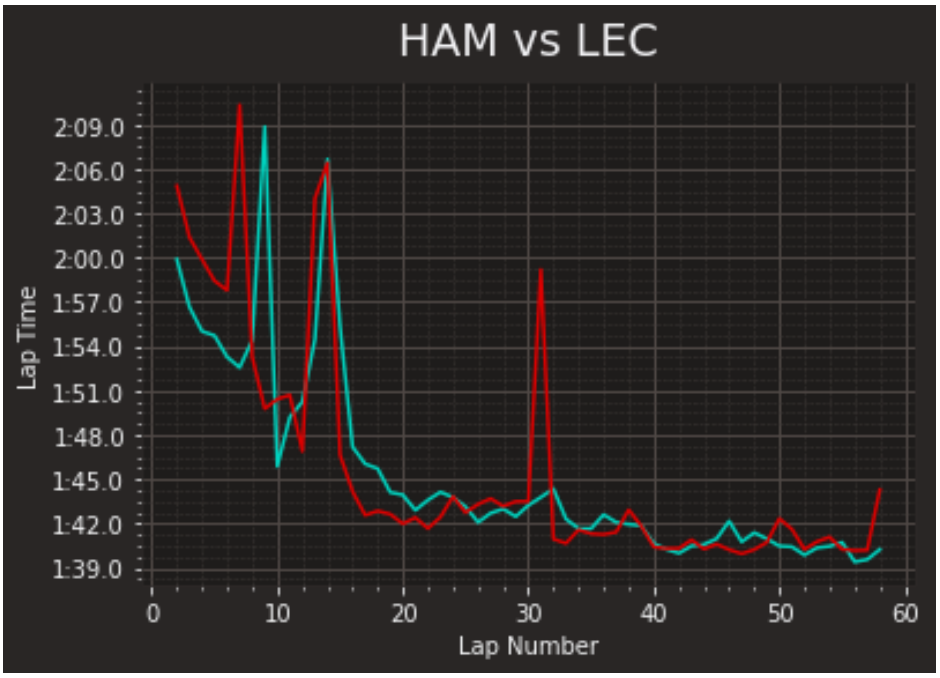
```
core           INFO     Loading data for Turkish Grand Prix - Race [v2.2.9]
api            INFO     Using cached data for driver_info
api            INFO     Using cached data for timing_data
api            INFO     Using cached data for timing_app_data
core           INFO     Processing timing data...
api            INFO     Using cached data for session_status_data
api            INFO     Using cached data for track_status_data
api            INFO     Using cached data for car_data
api            INFO     Using cached data for position_data
api            INFO     Using cached data for weather_data
api            INFO     Using cached data for race_control_messages
core           INFO     Finished loading data for 20 drivers: ['44', '11', '5
```

The following function can be used to plot a chart showing laptimes over the course of a session for one or more drivers.

```
from fastf1.plotting import DRIVER_COLORS, DRIVER_TRANSLATE

def plot_laptimes(race, drivers):
    """Plot laptimes over the course of a race."""
    drivers = [drivers] if isinstance(drivers, str) else drivers
    fig, ax = plt.subplots()
    # Generate an appropriately coloured trace for each driver
    for _driver in drivers:
        driver = race.laps.pick_driver(_driver)
```

```
        ax.plot(driver['LapNumber'], driver['LapTime'],
                color=DRIVER_COLORS[DRIVER_TRANSLATE[_driver]])
    # Annotate the chart with a title and axis labels
    ax.set_title(" vs ".join(drivers))
    ax.set_xlabel("Lap Number")
    ax.set_ylabel("Lap Time")
    return fig, ax
```

We can now compare laptimes over the course of the race in a graphical way:

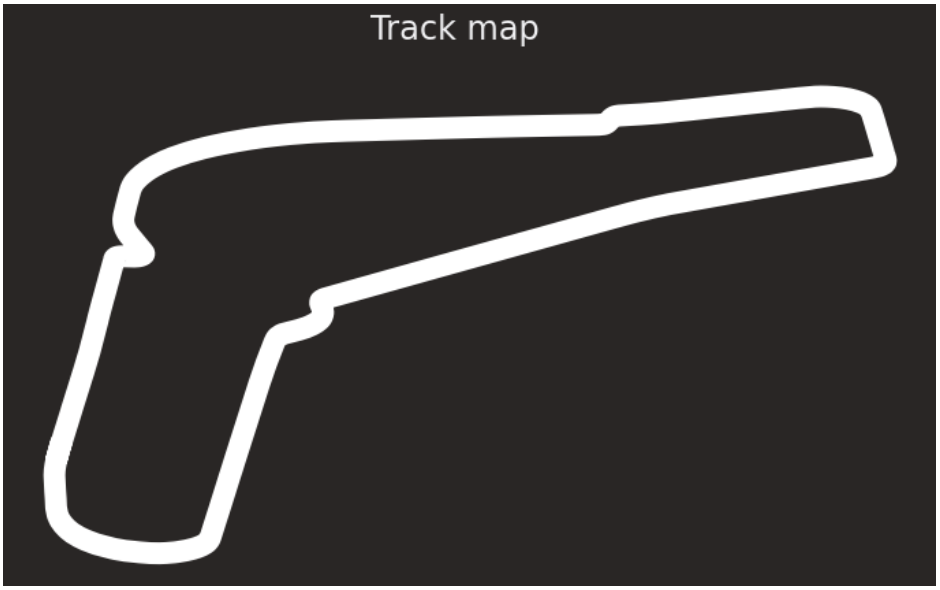


2.5. Telemetry Visualisations via Track Maps

X and Y positions seems to be co-ordinate locations for an on-screen display (https://github.com/theOehrly/Fast-F1/issues/64). This means we probably aren't seeing location data at a resolution good enough to display racing lines on a map, which accurate GPS data *would* give us.

We can create a simple function to display a map of the track as generated from the `X` and `Y` co-ordinates of the sampled telemetry data.

```
def plot_track(lap, linewidth=16, color="white"):
    """Generate a track map from telemetry data co-ordinates."""
    fig, ax = plt.subplots(sharex=True, sharey=True,
                           figsize=(12, 6.75))
    ax.axis('off')

    ax.plot(lap.telemetry['X'], lap.telemetry['Y'],
            color=color, linestyle='-', linewidth=linewidth, zorder=0)
    return fig, ax
fig, ax = plot_track(lec_fast_lap)

# Add a title to the figure object
fig.suptitle(f'Track map', size=24, y=0.97);
```



The `matplotlib` documentation provides an example for generating a multicoloured line from a list of co-ordinates. Consecutive pairs of co-ordinates define consecutive line segments. The line segments are then coloured according to a particular colour mapped value.

The following function will generate a coloured trace overlaying the track map that visualises one of the telemetry measures.

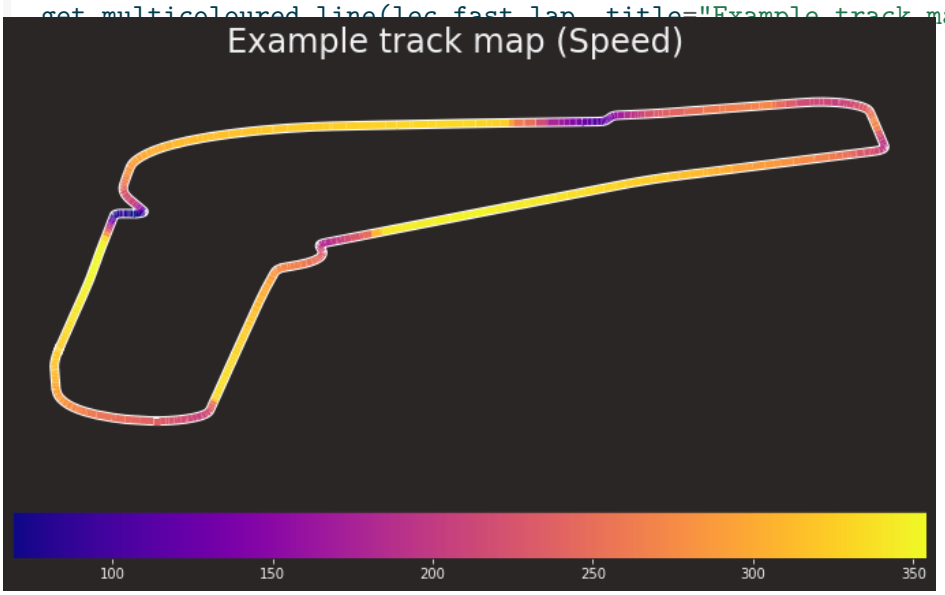
```
from matplotlib.collections import LineCollection
import matplotlib as mpl
import numpy as np

def get_multicoloured_line(lap, color='Speed', title='',
                           colormap=mpl.cm.plasma, linewidth=5, ax=None):
    """Generate a matplotlib plottable mutlicoloured line."""
    if ax is None:
```

```
        fig, ax = plot_track(lap, linewidth=linewidth+2)
    else:
        fig = ax.get_figure()

    ##########################################################################
    # Create a set of line segments so that we can color them
    # individually. This creates the points as a N x 1 x 2 array so that w
    # stack points together easily to get the segments. The segments array
    # line collection needs to be (numlines) x (points per line) x 2 (for
    X = lap.telemetry['X']
    Y = lap.telemetry['Y']

    _color = lap.telemetry[color]

    points = np.array([X, Y]).T.reshape(-1, 1, 2)
    segments = np.concatenate([points[:-1], points[1:]], axis=1)

    if color is not None:
        # Create a continuous norm to map from data points to colors
        norm = plt.Normalize(_color.min(), _color.max())
        lc = LineCollection(segments, cmap=colormap, norm=norm, linestyle=
        # Set the values used for colormapping
        lc.set_array(_color)
    else:
        lc = LineCollection(segments, linestyle='-', linewidth=linewidth)

    line = ax.add_collection(lc)
    # Add color bar legend
    fig.colorbar(line, ax=ax, orientation="horizontal")
    # Add title
    if title:
        fig.suptitle(f"{title} ({color})", size=24, y=0.97)
```

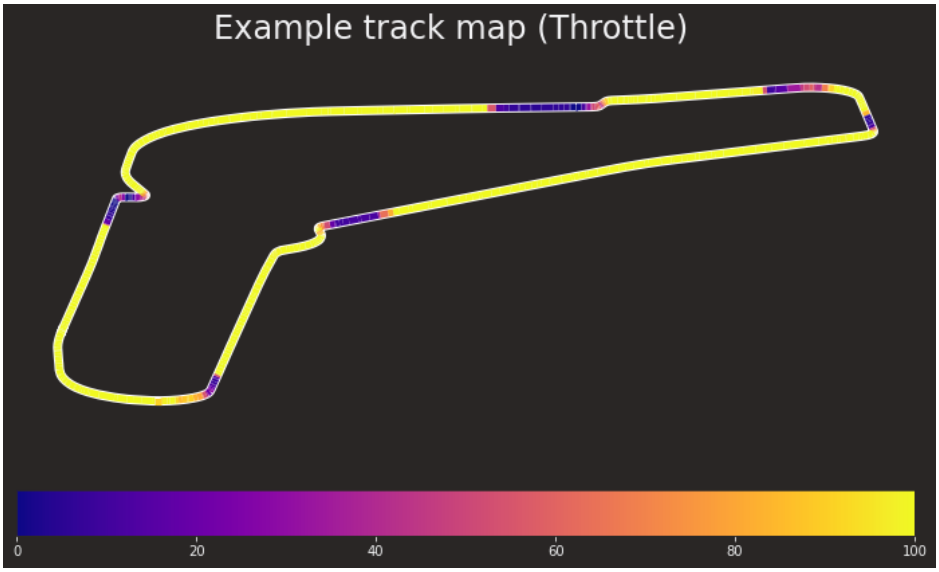
```
    return lc
```

We can now plot telemtry data traces against the position on track at which they we recorded:

```
get_multicoloured_line(lec_fast_lap, title="Example track map");
```




```
get_multicoloured_line(lec_fast_lap, "Throttle", title="Example track map");
```



2.6. Retrieving Data from the ergast API

Basic support for retrieving data from the *ergast* historical motor racing results data API is provided.

For example, we can return summary results data for a particular race (`"Race"`) or qualifying session (`"Qualifying`“) in a particular season:

```
from fastf1 import ergast
import pandas as pd

erd_race = ergast.fetch_results(2022, 2, "Race")

erd_race[:1]
```

```
[{'number': '1',
```

```
 'position': '1',
 'positionText': '1',
 'points': '25',
 'Driver': {'driverId': 'max_verstappen',
  'permanentNumber': '33',
  'code': 'VER',
  'url': 'http://en.wikipedia.org/wiki/Max_Verstappen',
  'givenName': 'Max',
  'familyName': 'Verstappen',
  'dateOfBirth': '1997-09-30',
  'nationality': 'Dutch'},
 'Constructor': {'constructorId': 'red_bull',
  'url': 'http://en.wikipedia.org/wiki/Red_Bull_Racing',
  'name': 'Red Bull',
  'nationality': 'Austrian'},
 'grid': '4',
 'laps': '50',
 'status': 'Finished',
 'Time': {'millis': '5059293', 'time': '1:24:19.293'},
 'FastestLap': {'rank': '2',
  'lap': '50',
  'Time': {'time': '1:31.772'},
  'AverageSpeed': {'units': 'kph', 'speed': '242.191'}}}]
```

We can trivially cast the returned JSON data to a flattened `pandas` dataframe:

```
pd.json_normalize(erd_race).head()
```

	number	position	positionText	points	grid	laps	status	Driver.driverId	Driver.permanentN
0	1	1	1	25	4	50	Finished	max_verstappen	33
1	16	2	2	19	2	50	Finished	leclerc	16

	number	position	positionText	points	grid	laps	status	Driver.driverId	D
2	55	3	3	15	3	50	Finished	sainz	5
3	11	4	4	12	1	50	Finished	perez	1
4	63	5	5	10	6	50	Finished	russell	6

The *ergast* API can also provide season summary information:

```
pd.json_normalize(ergast.fetch_season(2022)).head(2).T
```

	0	1
season	2022	2022
round	1	2
url	http://en.wikipedia.org/wiki/2022_Bahrain_Gran...	http://en
raceName	Bahrain Grand Prix	Saudi Ara
date	2022-03-20	2022-03-2
time	15:00:00Z	17:00:00Z
Circuit.circuitId	bahrain	jeddah
Circuit.url	http://en.wikipedia.org/wiki/Bahrain_Internati...	http://en
Circuit.circuitName	Bahrain International Circuit	Jeddah C
Circuit.Location.lat	26.0325	21.6319
Circuit.Location.long	50.5106	39.1044
Circuit.Location.locality	Sakhir	Jeddah
Circuit.Location.country	Bahrain	Saudi Ara
FirstPractice.date	2022-03-18	2022-03-2
FirstPractice.time	12:00:00Z	14:00:00Z
SecondPractice.date	2022-03-18	2022-03-2
SecondPractice.time	15:00:00Z	17:00:00Z
ThirdPractice.date	2022-03-19	2022-03-2
ThirdPractice.time	12:00:00Z	14:00:00Z
Qualifying.date	2022-03-19	2022-03-2
Qualifying.time	15:00:00Z	17:00:00Z

	0	1
Sprint.date	NaN	NaN
Sprint.time	NaN	NaN

We can also request the metadata describing an event more directly:

```
pd.json_normalize(ergast.fetch_weekend(2022, 2)).T
```

	0
season	2022
round	2
url	http://en.wikipedia.org/wiki/2022_Saudi_Arabia...
raceName	Saudi Arabian Grand Prix
date	2022-03-27
time	17:00:00Z
Circuit.circuitId	jeddah
Circuit.url	http://en.wikipedia.org/wiki/Jeddah_Street_Cir...
Circuit.circuitName	Jeddah Corniche Circuit
Circuit.Location.lat	21.6319
Circuit.Location.long	39.1044
Circuit.Location.locality	Jeddah
Circuit.Location.country	Saudi Arabia
Circuit.Location.alt	5
FirstPractice.date	2022-03-25
FirstPractice.time	14:00:00Z
SecondPractice.date	2022-03-25
SecondPractice.time	17:00:00Z
ThirdPractice.date	2022-03-26
ThirdPractice.time	14:00:00Z
Qualifying.date	2022-03-26

	0
Qualifying.time	17:00:00Z

2.7. Summary

This chapter has provided a brief overview of some of the key features of the `fastf1` API, demonstrating how we can look up event metadata as well as lap information and car telemetry data.

Some support is also provided for improving the quality of data visualisations by setting appropriate colour schemes or configuring `matplotlib` axes, for example.

3. What Next?

Who knows?!

References

Knuth, Donald E. 1984. “Literate Programming.” *Comput. J.* 27 (2): 97–111. https://doi.org/10.1093/comjnl/27.2.97.