E-MOD321 Basic Python coding for subsurface applications

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Learning objectives.

- Create an environment using conda and install required packages
- Use Pandas to combine and manipulate data from different input, Excel and comma separated values (CSV), files.
- Wrap code in functions to reuse them
- Visualize data using `matplotlib`[1] and the Pandas library[2].

Contents

[1] `https://matplotlib.org`
[2] `https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.plot.html`

1 Exercise 1: Matplotlib visualization

In `jotun_data.py` in the `data` folder "official production data":" `https://factpages.sodir.no/en/field/PageView/All/43604`" are available as lists. You can import them as

```
import sys
sys.path.append('../data/')# alternatively put jotun_data.py in your folder
from jotun_data import years, months, oil_gross, gas_gross, oe_gross, wat_prod
```

Question:

- Use matplotlib to plot oil equivalents, `oe_gross` vs the `years` data. Try to make the plot as similar as possible to figure 1.

```
#answer
```

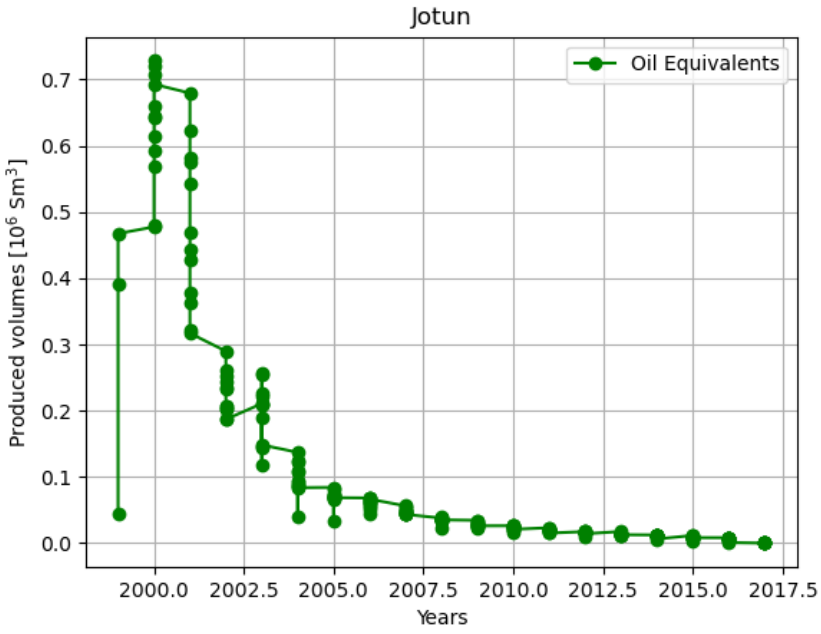

Figure 1: Jotun production data.

2 Exercise 2: Loop over data

Oil equivalents are simply the sum of oil volumes and gas volumes. (Or to be more specific: The convention used when comparing gas volumes with oil volumes is to divide the gas volumes by 1000, see conversion factors[3]. However, we do not need to do anything here because the unit of the gas volumes in `jotun_data.py` is 10^9 Sm^3 and the oil volumes in 10^6 Sm^3.)

Thus, to calculate oil equivalents from our lists that contain oil and gas volumes you just have to add them together.

Question 1: Use vanilla Python to loop over `oil_gross` and `gas_gross`, create a new *list*, which holds your calculated oil equivalents volumes. Note: You can compare with `oe_gross` to check if your calculations are correct.

Question 2: Convert your lists to `numpy.arrays`, by doing e.g. `np.array(oil_gross)`. Perform the same calculation as in Question 1, but this time using Numpy (and no loop).

```
#answer
```

[3] `https://www.sodir.no/en/about-us/use-of-content/conversion-table/`

3 Exercise 3: Boolean masking

Question 1: Use vanilla Python to create a loop and sum up all oil equivalents that was produced for the year 2000. (If you did everything correct you should get 7.529206 $10^6 Sm^3$ for the year 2000.)

Create to new `numpy.arrays`, by

```
years_np=np.array(years)
oe_np=np.array(oe_gross)
```

Question 2: Show how you can use Boolean masking to pick out only produced oil equivalents for the year 2000, without using a loop. Use `np.sum()` to sum all the volumes.

Question 3: Use `np.unique()` to create a unique `np.array()` of years. Loop over this array and use Boolean masking to create a new list (or `np.array()`) that holds the total produced oil equivalents for that year.

Question 4: Use the results in the previous question to create a bar plot and compare with figure 2

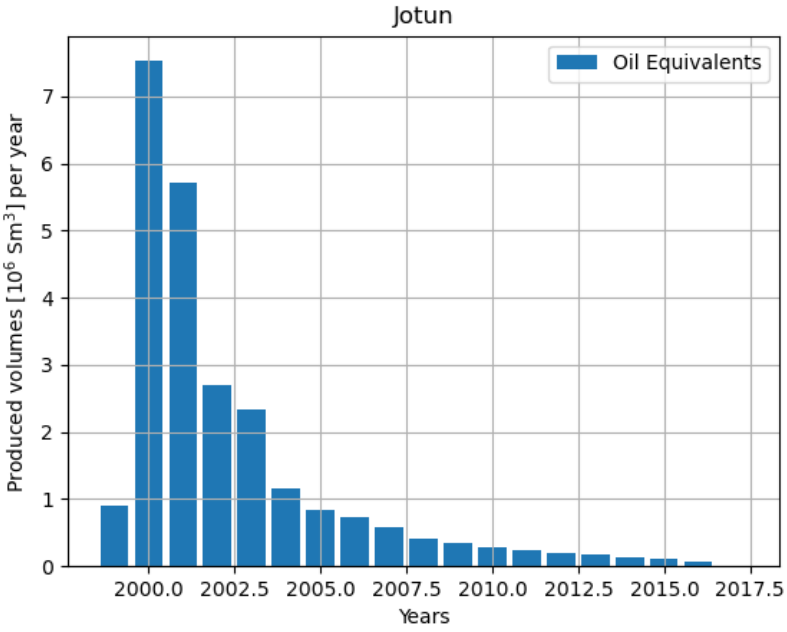

Figure 2: Jotun production data.

4 Exercise 4: Dictionaries and Pandas DataFrame

Question 1: Create a dictionary that holds all the Jotun data you imported in Exercise 1. Choose suitable key names.

Question 2: Create a loop over all the keys in the dictionary and show how you can print out the keys and the values in the dictionary.

Question 3: Create a DataFrame from your dictionary. Show how we can use `DataFrame.groupby().sum()` to find production of oil, gas, water, and oil equivalents per year.

```
#answer
```

5 Exercise 5: Extract data using a function

Question: Create a function from the following code. The function should take as argument the field name and return a DataFrame with field data. Include a docstring in the function.

```
df_prod=pd.read_excel('../data/field_production_gross_monthly.xlsx')
df=df_prod[df_prod['Field (Discovery)'] == 'JOTUN']
```

```
def get_data(field):
    # write code here ..
    return #...
```

Optional: Make the function more robust, by allowing for case insensitive names and/or give a warning if no data was extracted for the field.

```
#answer
```

6 Exercise 6: Create a function for plotting data

Question 1: Create a function that takes as argument the name of a field, and plots oil equivalent production vs time. Hint: you should use the function you wrote in the previous exercise to extract the data.

Question 2: Extend the function such that if no data is extracted from the field, write a warning and do not make the plot. (Note: you can use `DataFrame.empty()` to check if the DataFrame contains data.)

Optional: Extend the function such that it can take in a list of values (e.g. gas, oil, etc.) that should be plotted in the same plot.

```
#answer
```

7 Exercise 7: Write data to files

Question 1: Explain what the following code does. By adding comment lines to each line of the following code.

```
field='JOTUN' # com1
#--------- start --------
df=get_data(field) # com2
data_folder=pt.Path('tmp_data') # com3
data_folder.mkdir(exist_ok=True)# etc.
new_name=str.replace(field,'/','')
new_path=data_folder / new_name
new_path.mkdir(exist_ok=True)
df2=df[df[df.columns[0]]==field]
df2.to_excel(new_path/'production_data.xlsx',index=False)
#-------- stop ----------
```

Question 2: Create a function from the code between `- start -` and `- stop -`. It should take as argument the field name.

```
def write_data(field):
    # ....
    return #optional
```

Question 3: If your Excel file is open in another program, the command `df2.to_excel(new_path/'production_data.xlsx',index=False)`, will fail. Use the `try:` and `except:` commands to try and write the Excel file, and if this fails, give the user a warning.

Optional: Extend the previous function and introduce a default argument, representing `tmp_data` so that the user can specify the directory name.

```
#answer
```

8 Exercise 8: Loop over all fields

The following code writes all field data to separate Excel files.

```
df=pd.read_excel('../data/field_production_gross_monthly.xlsx')
fields=df[df.columns[0]].unique() #skip duplicates
data_folder=pt.Path('tmp_data')
data_folder.mkdir(exist_ok=True)
for field in fields:
    new_name=str.replace(field,'/','')
    new_path=data_folder / new_name
    new_path.mkdir(exist_ok=True)
    df2=df[df[df.columns[0]]==field]
    df2.to_excel(new_path/'production_data.xlsx',index=False)
```

Question: Use one or several functions to achieve the same as the block of code above does. Comment on your choice.

```
#answer
```

9 Exercise 9: lambda functions

Rewrite the following functions, using Pythons `lambda` function

```
def remove_space(x):
    return x.strip()
```

```
def upper_case(x):
    return x.upper()
```

```
#answer
```

10 Exercise 10: Assert your code

Create two assert tests for `remove_space` and `upper_case` defined in the previous exercise.

```
#answer
```

11 Exercise 11: A simple class

Question1: Take a look at the following class, and explain what each line does, by adding comments behind each line.

```
class DeclineCurve:
    def __init__(self,q,tau):
```

```
        self.q=q
        self.tau=tau

    def f(self,t):
        return self.q*np.exp(-t/self.tau)
```

Question2: Add a function to the class, named `plot()`, such that the following code produce the output in figure 3. (To create a suitable list of `t` values you can do `t=np.linspace(0,10,1000)`, or more general `t=np.linspace(0,10*self.tau,1000)`)

```
A=DeclineCurve(1,1)
A.plot()
```

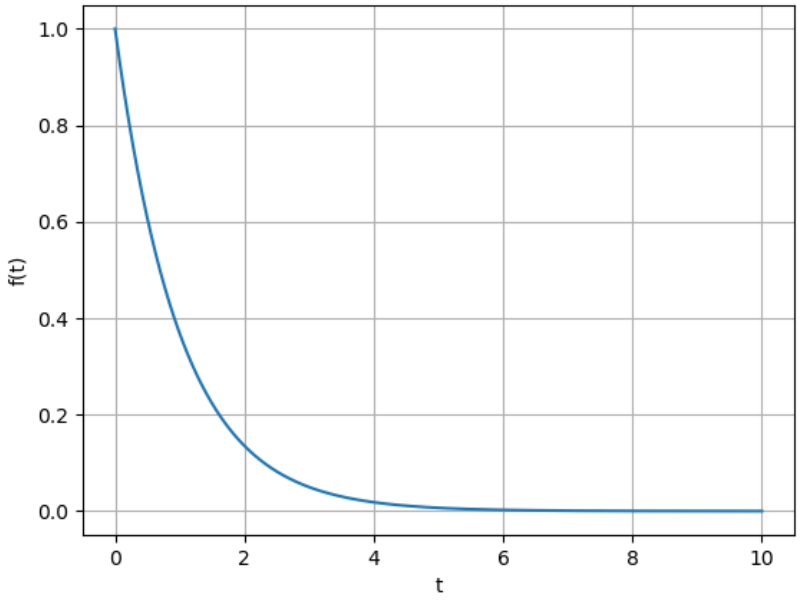

Figure 3: An exponential decline curve.

12 Exercise 12: A more comprehensive class

Inspect the following class

```
class ProdData:
    """
    A class to extract production data from FactPages
```

```
    """
    def __init__(self):
        self.df_prod=pd.read_excel('../data/field_production_gross_monthly.xlsx')

    def get_data(self,field):
        """
        Extracts data for a specific field
        """
        df= self.df_prod[(self.df_prod['Field (Discovery)'] == field)]
        return df
```

Add the following functions to the class:

1. `write_data(field)` write data for a single field to an Excel file
2. `write_all_data()` write an Excel file for each field
3. A function to plot production data for a field

The following is optional:

1. Add some checking to the functions, this could be a sensible error message if e.g. the file `../data/field_production_gross_monthly.xlsx` does not exists or that it is not possible to write data to file.
2. Add some unit tests using assert, this could be to check that the oil produced for a certain year (and month) for a specific field is equal to a specific value.

13 (OPTIONAL) Exercise 13: The Dash library

The Dash library[4] is one of the most popular libraries. Install it by doing

Terminal

```
conda install dash
```

(If this fails, run `pip install dash`). Run the following code, which is copied from a minimal dash app[5].

```
from dash import Dash, html, dcc, callback, Output, Input
import plotly.express as px
import pandas as pd

df = pd.read_csv('https://raw.githubusercontent.com/plotly/datasets/master/gapminder_unfiltered.csv')
```

[4] https://dash.plotly.com/
[5] https://dash.plotly.com/minimal-app

```
app = Dash(__name__)

app.layout = html.Div([
    html.H1(children='Title of Dash App', style={'textAlign':'center'}),
    dcc.Dropdown(df.country.unique(), 'Canada', id='dropdown-selection'),
    dcc.Graph(id='graph-content')
])

@callback(
    Output('graph-content', 'figure'),
    Input('dropdown-selection', 'value')
)
def update_graph(value):
    dff = df[df.country==value]
    return px.line(dff, x='year', y='pop')

if __name__ == '__main__':
    app.run(debug=True)
```

Question: Can you modify the code above to read and plot our data in `../data/field_production_gross_monthly.xlsx`? (Note: you can also download the production data directly by copying the correct address, by right-clicking on the Excel (or csv) tab here[6].)

[6] `https://factpages.sodir.no/en/field/TableView/Production/SumWellbores/Monthly`