Business 4720 - Class 6

Data Management in Python using Pandas

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This Class

What You Will Learn:

- Introduction to Python
- Introduction to the the Numpy package
- Introduction to the Pandas package

Intro to Python

What is Python?

- Readability and simplicity
- Dynamic typing enhancing flexibility
- Extensive libraries
- Procedural, object-oriented, and functional programming
- Widely used in data analysis, AI, scientific computing, etc.
- Easy to learn
- Active community support

Intro Tutorial:

`https://python.swaroopch.com/`

`https://github.com/swaroopch/byte-of-python/releases/`

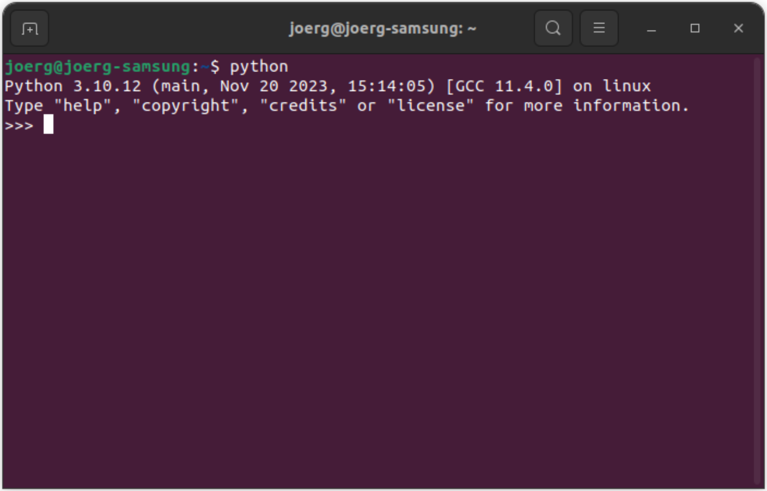
Running Python

1. Interactive Python Shell (command line)
2. Jupyter Notebooks
3. PyCharm IDE

Interactive Python Shell

- Similar to the R shell
- Type ”python” to launch Python interpreter
- Prompt is ”> > >”, type ENTER to execute a command
- Use `quit()` to exit
- Use the up-arrow key to retrieve earlier commands.
- Use the TAB key to auto-complete a command.
- The Ubuntu terminal uses SHIFT-CTRL-X, SHIFT-CTRL-C, SHIFT-CTRL-V for cut/copy/paste.
- **Tip**: Use a notepad app to assemble commands and to keep results

Interactive Python Shell

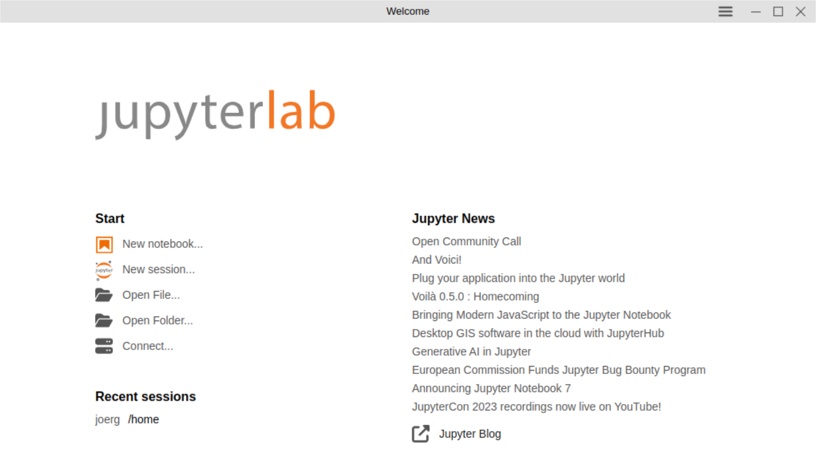


```
joerg@joerg-samsung:~$ python
Python 3.10.12 (main, Nov 20 2023, 15:14:05) [GCC 11.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> 
```

Jupyter Notebooks

- Interactive computing environment
- Notebook Interface
- Combine executable code, text, visualizations
- Create and share documents with live code, equations, and explanatory text
- Collaborative editing of notebooks (on web-based services)
- Popular for Python, but can handle other languages

JupyterLabs Desktop



Welcome

jupyterlab

Start

- New notebook...
- New session...
- Open File...
- Open Folder...
- Connect...

Recent sessions

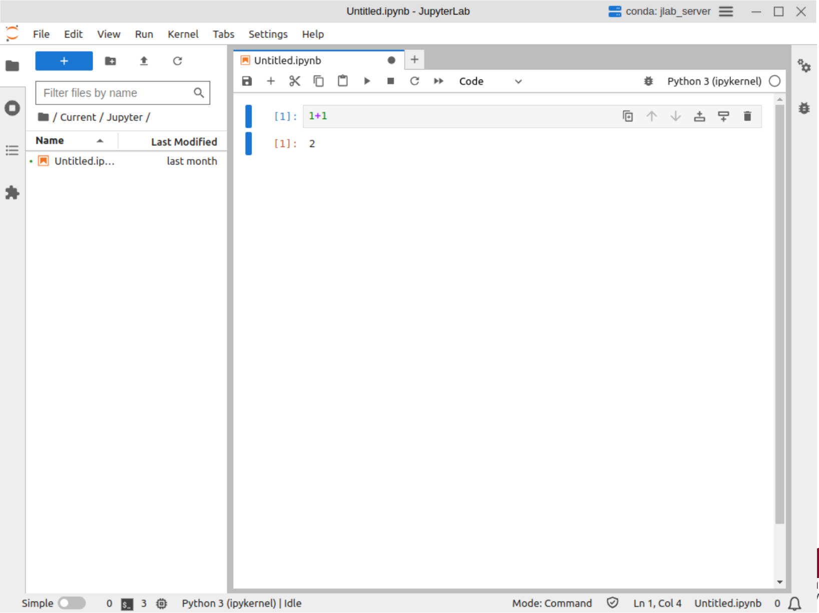
joerg /home

Jupyter News

Open Community Call
And Voici!
Plug your application into the Jupyter world
Voilà 0.5.0 : Homecoming
Bringing Modern JavaScript to the Jupyter Notebook
Desktop GIS software in the cloud with JupyterHub
Generative AI in Jupyter
European Commission Funds Jupyter Bug Bounty Program
Announcing Jupyter Notebook 7
JupyterCon 2023 recordings now live on YouTube!

Jupyter Blog

JupyterLabs Desktop



```
[1]: 1+1
```

```
[1]: 2
```

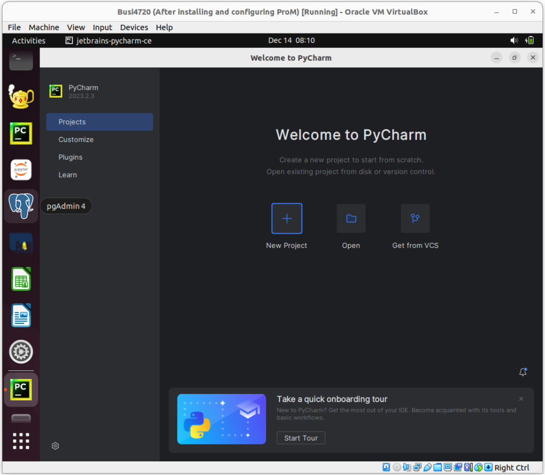
Jupyter Notebooks

- ”Kernel” is the Python interpreter and environment that runs your code
- Enter code into empty cell
- Press CTRL-ENTER to execute a cell
- Merge, split, move, copy, delete cells
- Save, import, export notebooks

PyCharm IDE

- When working with multiple Python files in your project
- Useful for *programming* (defining functions, classes; using control structures, etc.) rather than just *scripting* (executing a few Python commands one after the other)
- Contains built-in debugging tools

PyCharm IDE



Busi4720 (After installing and configuring ProM) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities
jetbrains-pycharm-ce
Dec 14 08:10
Welcome to PyCharm
PyCharm
2023.2.3
Projects
Customize
Plugins
Learn
pgAdmin 4
Welcome to PyCharm
Create a new project to start from scratch.
Open existing project from disk or version control.
New Project
Open
Get from VCS
Take a quick onboarding tour
New to PyCharm? Get the most out of your IDE. Become acquainted with its tools and basic workflows.
Start Tour
Right Ctrl

Basic Python

Python knows math:

```
# Addition
2 + 2
# Exponentiation
2**4
# Integer division
13 // 3
-13 // 3
# Modulus (remainder)
13 % 3
-25.5 % 2.25
# Comparisons
3 < 5
3 > 5
3 == 5
# Logical and, or, not operators
(3 < 5) and (4 < 2)
(3 < 5) or not (4 < 2)
```

Basic Python

String formatting methods:

```python
# Define some variables
age = 19
name = 'Malina'

# Print them in different ways.
# Pick your favourite and stick with it.
print('{0} is {1} years old'.format(name, age))
print('{name} is {age} years old'.format(name=name,age=age))
print('{} is {} years old'.format(name, age))
print(f'{name} is {age} years old')
print(name+' is '+str(age)+' years old')
```

Basic Python

Backslashes split and continue lines:

```
print('This is a very long \
string and needs a second line')
i = \
5
print(i)
```

Python Strings

Python knows strings:

```python
language = 'Innuktitut'

# Check the start of a string
if language.startswith('Innu'):
    print('Yes, the string starts with "Innu"')

# Check if letter contained in string
if 'u' in language:
    print('Yes, it contains the string "u"')

# Find the index of a string in another string
# Returns -1 if not found
if language.find('nuk') != -1:
    print('Yes, it contains the string "nuk"')
```

Note the colon and the indent of exactly 4 significant spaces!

Python Strings

Joining and splitting strings with a delimiter:

```
# Join a list of strings with a delimiter
delimiter = '_*_'
mylist = ['Nain', 'Hopedale', 'Makkovik', 'Rigolet']
mystring = delimiter.join(mylist)
print(mystring)

# Split a string on a delimiter
thelist = mystring.split(delimiter)
print(thelist)
```

Lists

Lists are ordered collections of items:

```python
# Define list (Inuit deities)
gods = ['Sedna', 'Nanook', 'Akna', 'Pinga']

# Length of a list
len(gods)
# Iterate over items
for item in gods:
    print(item, end=' ')

# Append to a list
gods.append('Amaguq')
# Sort a list
gods.sort()
# Retrieve items from list
olditem = gods[0]
# Delete item in list
del gods[0]
```

Note the colon and the indent of exactly 4 significant spaces!

Tuples

Tuples are immutable:

```
# Define a tuple (Inuit Nunangat)
regions = ('Inuvialuit', 'Nunavut', 'Nunavik', 'Nunatsiavut')

# Length of a tuple
len(regions)

# Create a tuple of tuples, NOT flattened
more_regions = ('Kalaallit', 'Inupiaq', regions)

# Retrieve element 1 of element 3 in tuple
more_regions[2][1]
```

Dictionaries

- Key–value pairs
- Associative arrays
- Map

```
# Define a dict (largest citites)
c = {
    'Inuvialuit': 'Inuvik',
    'Nunavut': 'Iqaluit',
    'Nunavik': 'Kuujjuaq',
    'Nunatsiavut': 'Nain'
}
# Get the list of keys
list(c.keys())
# Get the list of values
list(c.values())

# Number of entries in dict
len(c)
```

Dictionaries [cont'd]

```
# Retrieve a value for a key:
c['Nunavik']

# Delete a key-value pair
del c['Nunavut']

# Add a key-value pair
c['Nunavut'] = 'Iqaluit'

# Check for existence of a key
if 'Nunavut' in c:
    print("\nNunavut's largest city is", c['Nunavut'])
```

Structured Data Types

Important

- Indexing begins at 0 (different from R!)
- Can contain any data type

Sequences

- List, tuples, strings are sequences
- Membership tests using `in` or `not in`
- Indexing and slicing

Slicing

```
regions = ('Inuvialuit', 'Nunavut',
           'Nunavik', 'Nunatsiavut')
language = 'Innuktitut'

# Slicing on a tuple
regions[1:3]
regions[2:]
regions[1:-1]
regions[:]

# Slicing with step size
regions[::1]
regions[::2]
regions[::3]
regions[::-1]
```

Hands-On Exercises

Lists

1. Create a list containing the numbers 1 to 10. Use list slicing to create a sublist with only the even numbers.
2. Using a `for` loop, sum all the items in the list.
3. Using a `for` loop, iterate over the list and print each number squared.
4. Write a program to append the square of each number in the range [1:5] to a new list.

Hands-On Exercises

Tuples

1. Create a tuple with different data types (string, int, float).
2. Demonstrate how tuples are immutable by attempting to change its first element.

Dictionaries

1. Create a nested dictionary and demonstrate accessing elements at various levels. A nested dictionary is one in which the values themselves are also dictionaries.

Numerical Data in Python with NumPy

What is Numpy?

- High-performance scientific computing and data analysis.
- Multidimensional arrays
- Comprehensive mathematical function library
- Foundational package for other scientific libraries like SciPy, Pandas, Matplotlib, scikit-learn, scikit-image, etc.

Intro Tutorials

- NumPy Quickstart
- NumPy for Absolute Beginners

NumPy Array

N-Dimensional Array, type ”`ndarray`”

```
# Import the numpy package
import numpy as np

# Create an array
a = np.arange(15).reshape(3, 5)

# Examine its properties
a.shape
a.ndim
a.dtype.name
a.size
```

NumPy Basics

```
# Create an array from Python lists and tuples
b = np.array([(1.5, 2., 3),
              (4.0, 5., 6)])
print(b)

# Elementwise operations
3 * b
b + 5
np.sqrt(b)

# NumPy array functions
np.sum(b)
np.max(b)
# Axis 0 is by column
np.max(b, axis=0)
# Axis 1 is by row
np.max(b, axis=1)
np.std(b, axis=0)
# Transpose
np.transpose(b)
# Cov default by row
np.cov(b)
np.cov(np.transpose(b))
```

NumPy Basics [cont’d]

```python
# Create an array of zeros with shape (3,4)
x = np.zeros((3,4))
print(x)

# Create an array of ones with shape (2,3,4)
y = np.ones((2,3,4))
print(y)
```

Array Slicing

- Each axis can be sliced using `[:]` or `[::]`

```
b = np.array([[ 0,  1,  2,  3],
              [10, 11, 12, 13],
              [20, 21, 22, 23],
              [30, 31, 32, 33],
              [40, 41, 42, 43]])

# One element
b[2, 3]
# Multiple rows, one column
b[0:5, 1]
# Every other row up to 4, one column
b[0:5:2, 1]
# All rows, columns 1 and then every other
b[:, 1::2]
# Two rows, all columns
b[1:3, :]
# Last row
b[-1]
# Last column
b[:,-1]
```

Array Reshaping

```python
# Create 3x4 array of random numbers
a = np.floor(10 * np.random.random((3, 4)))

a.shape
a.flatten()
a.reshape(6, 2)
a.T
a.T.shape

# Create another 3x4 array of random numbers
b = np.floor(5 * np.random.random((3, 4)))
# Vertical stacking
np.vstack((a, b))
# Horizontal stacking
np.hstack((b, a))

# Iterate over rows
for row in b:
    print(row)

# Iterate over all elements
for element in b.flat:
    print(element)
```

Array Indexing with Boolean Arrays

```
a = np.array([[1,  2,  3,  4],
              [5,  6,  7,  8],
              [9, 10, 11, 12]])

# Are entries less than 5?
a < 5
# Entries that are less than 5
a[a < 5]

# Are entries even?
a%2 == 0
# Entries that are even
a[a%2 == 0]
```

Hands-On Exercises

1. Create a four-dimensional array with random numbers in the shape indicated by the last four digits of your student number (if your student number contains a 0, use a 1 instead)
2. Construct a new array by swapping the first half of rows (axis 0) with the second half of rows (axis 0)
3. Calculate all covariance matrices formed by the last two axes of your array. *Tip:* Iterate over the first two axes/dimensions with a `for` loop
4. Subtract the mean of the array from each element in the array (mean normalization)
5. Select all elements that are greater than the overall mean
6. Sort the selected elements from the previous step in ascending order

Data Management with Pandas

What is Pandas?

- Open-source library for data analysis
- High-performance, easy-to-use data structures and data analysis tools
- Can handle tabular data, time series, matrix data, etc.
- Tools for data cleaning, transformation, and preparation
- Importing data from CSV, Excel, SQL databases, etc.
- Functions for aggregating, pivoting, joining, and sorting data

Intro Tutorial: 10 Minutes to Pandas

Pandas Dataframe

- 2-dimensional
- Row labels are called *index*
- Columns may have different data types

```
# Create a dict of two Series
d = {
    "col1": pd.Series([1.0, 2.0, 3.0],
                    index=['a', 'b', 'c']),
    "col2": pd.Series([1.0, 2.0, 3.0, 4.0],
                    index=['a', 'b', 'c', 'd'])
}

# Create a dataframe from dict
df = pd.DataFrame(d)
```

Pandas Dataframe – Basic Information

```
# Dimensions (rows, columns)
df.shape

# Row labels (index)
list(df.index)
# Column labels
list(df.columns)

# Information about columns and data types
df.info()

# First few rows
df.head()
# Last few rows
df.tail()

# Summary of data
df.describe()
```

Pandas Dataframe – Indexing

```
# Select one column
df['col1']

# Select multiple columns (list of columns)
df[['col1', 'col2']]

# Select rows by label, returns Series
df.loc['a']

# Select single row by number
df.iloc[2]

# Select single column by number
df.iloc[:,1]

# Select rows 0 to 3, columns 0 to 1
df.iloc[0:4:2, 0:2]

# Select every other row 0 to 3
df[0:4:2]

# Select rows by boolean array
df[df['col1'] > 2]
```

Pandas Dataframe – Operations

```
# Elementwise operators
df * 5 + 2
1/df
df**4

# Transpose
df.T

# Using Numpy functions on Pandas data frames
np.exp(df)
np.sum(df[['col1', 'col2']], axis=1)
```

Pandas Dataframe – Selection with Query

```python
df = pd.DataFrame(np.random.rand(10, 3),
           columns=['a', 'b', 'c'])

# Pure python
df[(df['a'] < df['b']) & (df['b'] < df['c'])]

# Shorter with Query
df.query('(a < b) & (b < c)')
df.query('a < b & b < c')
df.query('a < b and b < c')
df.query('a < b < c')
```

Easy Pandas – Example Dataset

- Government of Canada, Open Government Portal
- Fuel Consumption Ratings – Battery-electric vehicles – 2012–2023
- https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

Column	**Data Type**
Make	Categorical (string)
Model	Categorical (string)
Year	Numeric
Category	Categorical (string)
City	Numeric
Hwy	Numeric
Comb	Numeric
Range	Numeric

Easy Pandas – Reading CSV Files

```python
# Import pandas
import pandas as pd

# Read CSV into a Pandas data frame
data = pd.read_csv('https://evermann.ca/busi4720/fuel.csv')

# Basic information about data
data.shape
list(data.columns)
data.info()
data.describe()
```

Easy Pandas – Filtering

```
# Filter values
data.query('Make=="Ford" & Year==2023')
```

Equivalent in R:

```
data |>
  filter(Make=='Ford',
         Year==2023) |>
  print()
```

Equivalent in SQL:

```
SELECT *
   FROM data
   WHERE Make=='Ford' AND
         Year==2023;
```

Easy Pandas – Selecting Columns

```
# Filter values and select columns
data.query('Make=="Ford" & Year==2023') \
    [['Model', 'Category', 'Range']]
```

Equivalent in R

```
data |>
  filter(Make=='Ford',
         Year==2023) |>
  select(Model, Category,
            Range) |>
  print()
```

Equivalent in SQL:

```
SELECT Model, Category, Range
   FROM data
   WHERE Make=='Ford' AND
         Year==2023;
```

Easy Pandas – Create New Columns

```python
# Filter values, create new calculated column and select cols
data.query('Make=="Ford" & Year==2023') \
  .assign(HwyRange = data['Range']*data['Comb']/data['Hwy']) \
  [['Model', 'Category', 'Range', 'HwyRange']]
```

Equivalent in R:

```r
data |>
  filter(Make=='Ford',
         Year==2023) |>
  mutate(HwyRange=
            Range*Comb/Hwy) |>
  select(Model, Category,
         Range, HwyRange) |>
  print()
```

Equivalent in SQL:

```sql
SELECT Model, Category, Range,
  (Range*Comb)/Hwy AS HwyRange
   FROM data
   WHERE Make=='Ford' AND
         Year==2023;
```

Easy Pandas – Renaming Columns

```
# Filter values, create two new calculated columns,
# rename a column, and select columns
data.query('Make=="Ford" & Year==2023') \
  .assign(HwyRange = data['Range']*data['Comb']/data['Hwy']) \
  .assign(CityRange = data['Range']*data['Comb']/data['City']) \
  .rename(columns={'Range': 'CombRange'}) \
  [['Model', 'Category', 'CombRange', 'CityRange', 'HwyRange']]
```

Equivalent in R:

```
data |>
  filter(Make=='Ford',
         Year==2023) |>
  mutate(HwyRange =
     Range * Comb / Hwy) |>
  mutate(CityRange =
     Range * Comb / City) |>
  rename(CombRange = Range) |>
  select(Model, Category,
         CombRange, CityRange,
         HwyRange) |>
  print()
```

Equivalent in SQL:

```
SELECT Model, Category,
       Range AS CombRange,
       (Range * Comb) / Hwy
           AS HwyRange,
       (Range * Comb) / City
           As CityRange
   FROM data
   WHERE Make=='Ford' AND
         Year==2023;
```

Easy Pandas – Distinct Values

```python
# Find distinct values
data[['Make', 'Model']].drop_duplicates()
```

Equivalent in R:

```r
data |>
  distinct(Make, Model) |>
  print()
```

Equivalent in SQL:

```sql
SELECT DISTINCT Make, Model
  FROM data;
```

Easy Pandas – Ordering

```
# Filter values, order by values of two columns
# and select columns
data.query('Make=="Ford" & Year==2023') \
  .sort_values(['Category', 'Range'], ascending=[True, False]) \
  [['Model', 'Category', 'Range']]
```

Equivalent in R:

```
data |>
  filter(Make=='Ford',
         Year==2023) |>
  select(Model, Category,
         Range) |>
  arrange(Category,
          desc(Range)) |>
  print()
```

Equivalent in SQL:

```
SELECT Model, Category, Range
   FROM data
   WHERE Make=='Ford' AND
         Year==2023
   ORDER BY Category ASC,
            Range DESC;
```

Easy Pandas – Grouping and Summarizing

```python
# Filter values, group the data,
# calculate aggregates of multiple columns
# filter on aggregate data, order by value
# and select certain columns
data.query('Year==2023') \
    .groupby(['Make', 'Category']) \
    .agg(meanCity = ('City', 'mean'),
         meanHwy = ('Hwy', 'mean'),
         meanComb = ('Comb', 'mean'),
         maxRange = ('Range', 'max'),
         nVehicle = ('Model', 'count')) \
    .query('nVehicle > 1') \
    .sort_values(['Category', 'meanComb']) \
    .reset_index() \
    [['Category', 'meanComb', 'Make', 'meanCity', \
      'meanHwy', 'maxRange', 'nVehicle']]
```

Grouping and Summarizing [cont'd]

Equivalent in R:

```r
data |>
  filter(Year==2023) |>
  group_by(Make, Category) |>
  summarize(
       meanCity = mean(City),
       meanHwy = mean(Hwy),
       meanComb = mean(Comb),
       maxRange = max(Range),
       nVehicle = n()) |>
  filter(nVehicle > 1) |>
  arrange(Category,meanComb) |>
  relocate(Category,meanComb) |>
  print()
```

Equivalent in SQL:

```sql
SELECT Category,
       AVG(Comb) AS meanComb,
       Make,
       AVG(City) AS meanCity,
       AVG(Hwy) AS meanHwy,
       MAX(Range) AS maxRange,
       COUNT(*) AS nVehicle
   FROM data
   WHERE Year==2023
   GROUP BY Make, Category
   HAVING COUNT(*) > 1
   ORDER BY Category ASC,
            meanComb ASC;
```

Advanced Pandas with the Pagila Database

```
rentals = pd.read_csv(
     'http://evermann.ca/busi4720/rentals.csv')

actors = pd.read_csv(
     'https://evermann.ca/busi4720/actors.categories.csv')

addresses = pd.read_csv(
     'https://evermann.ca/busi4720/addresses.csv')
```

Advanced Pandas with the Pagila Database [cont'd]

Find all films and the actors that appeared in them, ordered by film category and year, for those films that are rated PG:

```
data = pd.merge(rentals, actors, on='title',
         suffixes=('_customer', '_actor'), how='outer')
data.query('rating == "PG"') \
    .assign(actor = data['last_name_actor'] + \
                   ', ' + data['first_name_actor']) \
    .rename(columns={'release_year': 'year'}) \
    [['actor', 'title', 'category', 'year']] \
    .drop_duplicates(['actor', 'title', 'category', 'year']) \
    .groupby(['category', 'year', 'title']) \
    ['actor'].apply(list) \
    .reset_index() \
    .sort_values(['category', 'year']) \
```

Advanced Pandas with the Pagila Database [cont'd]

Find the most popular actors in the rentals in each city:

```
full_data = pd.merge(rentals, addresses,
                     left_on='customer_address',
                     right_on='address_id')
full_data = pd.merge(full_data, actors, on='title',
                     suffixes=('_customer', '_actor'))
```

```
full_data \
   .assign(actor=full_data['last_name_actor'] + ', ' +
                 full_data['first_name_actor'] ) \
   .groupby(['city', 'actor']) \
   .agg(count = ('title', 'count')) \
   .reset_index() \
   .assign(ranking=lambda df:
      df.groupby('city')['count']
        .rank(method='min', ascending=False)) \
   .query('ranking <= 3') \
   .sort_values(by=['city', 'ranking', 'actor'])
```

Advanced Pandas with the Pagila Database [cont'd]

Find the customers who spend the most on rentals, and the number of rentals with the higest total rental payments for each category grouped by rental duration.

```
full_data \
   .assign(customer=full_data['last_name_customer'] + ', ' +
                    full_data['first_name_customer'] ) \
   [['customer', 'amount', 'rental_duration', \
     'category', 'phone', 'city']] \
   .groupby(['category', 'rental_duration', 'customer']) \
   .agg(payments =('amount', 'sum'),
        num_rentals=('amount', 'count')) \
   .reset_index() \
   .assign(ranking=lambda df: \
      df.groupby(['category','rental_duration'])['payments'] \
        .rank(method='min', ascending=False)) \
    .loc[lambda df:  \
         df.groupby(['category', 'rental_duration'])
            ['ranking'].idxmin() ]
```

Advanced Pandas with the Pagila Database [cont'd]

Get the top 5 and the bottom 5 grossing customers for each quarter.

```
full_data \
   .assign(customer=full_data['last_name_customer'] + ', ' +
                    full_data['first_name_customer'],
           q=pd.to_datetime(full_data['rental_date'],utc=True)
                 .dt.to_period("Q"))  \
   [['customer', 'q', 'amount', 'rental_date']] \
   .groupby(['q', 'customer']) \
   .agg(payments=('amount', 'sum')) \
   .reset_index() \
   .drop_duplicates(['customer', 'q', 'payments']) \
   .assign(rank_top = lambda df :
              df.groupby('q')['payments']
                .rank(method='min', ascending=False),
           rank_bot = lambda df :
              df.groupby('q')['payments']
              .rank(method='min', ascending=True)) \
    .reset_index() \
    .query('rank_top <= 5 or rank_bot <= 5') \
    .sort_values(by=['q','payments'],ascending=[True,False])
```

Advanced Pandas with the Pagila Database [cont'd]

Find the set of film titles by rental customer and the total number rentals for each customer

```
full_data \
   .assign(customer=full_data['last_name_customer'] + ', ' +
                    full_data['first_name_customer']) \
   [['customer', 'title']] \
   .groupby('customer') \
   ['title'].apply(list) \
   .reset_index(name='titles') \
   .assign(rentals = lambda df :
              df['titles'].apply(len) ,
           unique_titles = lambda df :
              df['titles'].apply(lambda x: list(set(x)))) \
   .drop(columns=['titles']) \
   .sort_values(by='customer')
```

Hands-On Exercises

1. Find all films with a rating of ’PG’
2. List all customers who live in Canada (with their address)
3. Find the average *actual* rental duration for all films
   - This requires date arithmetic
4. Find the average overdue time for each customer
   - This requires date arithmetic
5. List all films that have never been rented
6. List the names of actors who have played in more than 15 films