Intro & Course Outline

Introduction to Python Programming for Economics & Finance

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Why Python? ... and why not?

Why Python?

- Free and open source
- Easy to learn, yet powerful and flexible syntax
- General-purpose language that can be used to solve many different problems
- Huge ecosystem of libraries and tools
- By now the most popular language overall
  - Most popular in machine learning
  - One of the two most popular in data science (together with R)
- May not be the fastest, but offers easy way to accelerate things (Cython, Numba, JAX, ML libraries)

What can you do with Python?

- Everything. The question is whether you <u>should</u> be using Python!

Why not Python?

- You already know another language that solves your problem reasonably well
- You want to use an estimator/algorithm that is implemented somewhere else (Stata, R), but not in Python

Examples of Python in economics

Solving dynamic programming problems with Python + Numba

- Olsson (2023): Solves Aiyagari model + extensive margin labour supply choice for single and couple households [accepted at AEJ:Macro]
- Foltyn (2020): Household finance model with portfolio choice and learning from experience

Econometrics (custom estimators with Python + Numba)

- Foltyn and Olsson (2023): Implements MLE that keeps track of latent health states [R&R Quant. Econ.]

Dynamic economic models solved with Python + ML

- Maliar, Maliar, and Winant (2021): Solve dynamic problems with TensorFlow; example code here [JME, 2021]
- Duarte (2018): Continuous-time finance models with TensorFlow [R&R Review of Financial Studies]
- Duarte et al. (2021): Solve HH portfolio choice problem with 22 states using JAX

Comparing to other languages (1)

Matlab

- Proprietary, quite expensive
- Shipped as complete software package from one vendor (plus optional toolboxes)
- Industry standard, widely used
- Substantially less powerful syntax
- Pure Matlab is somewhat faster than pure Python, but Python is easier to accelerate

R language

- Free, open source
- Focus on statistics, less on general-purpose computing
- Large ecosystem of packages focus on statistics, econometric modelling, machine learning

Comparing to other languages (2)

Julia

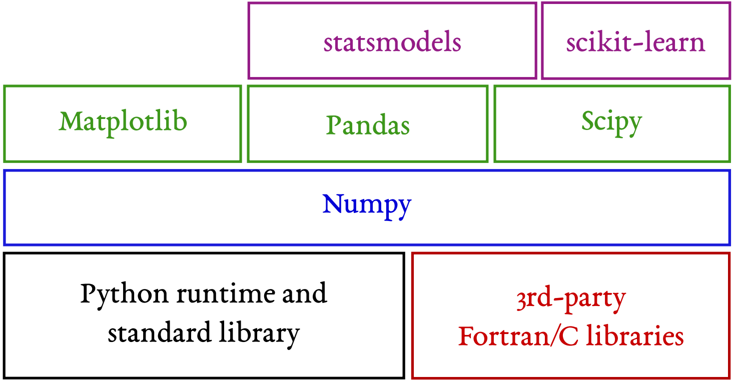
- Free, open source
- Focused on numerical computations, less on general-purpose computing
- Substantially faster than Python, but Python can be accelerated to similar speed (using Numba)
- Smaller ecosystem, still under rapid development

Stata

- Proprietary, quite expensive
- Focused on econometrics, in particular econometrics using large micro data sets
- Syntax was designed to run built-in commands, very inflexible for anything else
- If what you need is implemented, great! If not, it’s very tedious to do it yourself (Mata is not great either).

Python software stack

How things fit together



statsmodels

scikit-learn

Matplotlib

Pandas

Scipy

Numpy

Python runtime and standard library

3rd-party Fortran/C libraries

Python software stack (covered in this course)

Core libraries for quantitative work

- Python language, runtime and standard libraries ("Python")
- NumPy: implements n-dimensional arrays, linear algebra routines, random number generators
- SciPy: Optimisation routines, sparse matrices, integration, interpolation, linear algebra, statistics
- Matplotlib: High-level plotting routines for visualisation
- Pandas: Containers to handle heterogeneous data & routines for data analysis
- scikit-learn: routines used for machine learning (Ridge regression, Lasso, elastic net, etc.)

Python software stack (**not** covered in this course)

Econometrics & Machine learning

- statsmodels: routines for estimating many (linear) models
- TensorFlow: ML library maintained by Google with Python API
- JAX: Low-level API for automatic differentiation and accelerated linear algebra used to build ML models, developed by Google
- PyTorch: Python interface to ML libraries originally developed by Facebook

Frameworks to speed things up

- Numba: compiles Python code to machine code using LLVM
- Cython: converts pseudo-Python to C code (advanced, don't use this)

Jupyter notebooks

This course is mostly based on Jupyter notebooks, not “regular” Python scripts.

Jupyter notebooks

- File extension: `.ipynb`
- Interactive, dynamic notebooks
- Run in web server, displayed in web browser
- Good for exploratory work
- Easy to share work with others, in particular if they are *not* data analysts or programmers
- Can be exported to other formats, e.g., PDFs, LaTeX

Python scripts

- File extension: `.py`
- Interactive only in debugger
- Usually run locally in Python interpreter
- For “serious” programming
- For libraries, reusable code
- Not useful to share with others who don’t know Python

Course outline

Monday, 22 May 2023

- **Lectures 1 & 2**, 9:00–12:15 (15 min break), Room 305AB

  Unit 1: **Language and NumPy basics** [PDF]

  1. Basic syntax
  2. Built-in data types
  3. NumPy arrays
  4. Optional exercises with provided solutions (asynchronous)

  Unit 2: **Control flow and list comprehensions** [PDF]

  1. Conditional execution
  2. Loops
  3. List comprehensions
  4. Optional exercises with provided solutions (asynchronous)

  Unit 3: **Reusing code – Functions, modules and packages** [PDF]

  1. Functions
  2. Modules and packages
  3. Optional exercises with provided solutions (asynchronous)

- **Lab 1**, 13:30–15:00, Room 305AB
  - Lab exercise for units 1–3

Wednesday, 24 May 2023

- **Lectures 3 & 4**, 9:00–12:15 (15 min break), Room 305AB

  Unit 4: **Plotting** [PDF]

  1. Line and scatter plots, categorical data
  2. Labels and annotations
  3. Multiple plots
  4. Optional exercises with provided solutions (asynchronous)

  Unit 5: **Advanced NumPy** [PDF]

  1. Creating and reshaping arrays
  2. Advanced indexing
  3. Numerical operations
  4. Optional exercises with provided solutions (asynchronous)

- **Lab 2**, 13:30–15:00, Room 305AB
  - Lab exercise for units 4–5

Friday, 26 May 2023

- **Lectures 5 & 6**, 9:00–12:15 (15 min break), Room 305AB

  Unit 6: **Handling data with pandas** [PDF]

  1. Creating and viewing DataFrames
  2. Indexing
  3. Aggregation and reduction operations
  4. Working with time series data
  5. Visualisation
  6. Optional exercises with provided solutions (asynchronous)

  Unit 7: **Data input and output** [PDF]

  1. I/O with NumPy
  2. I/O with pandas
  3. Retrieving macroeconomic / financial data from the web

- **Lab 3**, 13:30–15:00, Room 305AB
  - Lab exercise for units 6–7

Thursday, 1 June 2023

- **Lectures 7 & 8**, 9:00–12:15 (15 min break), Room 305AB

  Unit 8: **Random number generation and statistics** [PDF]

  1. NumPy’s RNG routines
  2. Statistics functions in SciPy
  3. Optional exercises with provided solutions (asynchronous)

  Unit 9: **Introduction to unsupervised learning** [PDF]

  1. Principal component analysis (PCA)
  2. Introduction to scikit-learn

  Unit 10: **Introduction to supervised learning** [PDF]

  1. Linear regression models
  2. Ridge regression
  3. Lasso
  4. Hyperparameter tuning

- **Lab 4**, 13:30–15:00, Room 305AB
  - Lab exercise for units 8–10

Friday, 2 June 2023

- **Lectures 9 & 10**, 9:00–12:15 (15 min break), Room 305AB

  Unit 11: **Solving models for macroeconomics and household finance** [TBA]

  1. Setting up consumption/savings household problems
  2. Solving deterministic problems with VFI
  3. Solving stochastic problems with VFI

- **Lab 5**, 13:30–15:00, Room 305AB
  - Lab exercise for unit 11

Course material & additional resources

Course material

- All code can be downloaded from GitHub repository
  https://github.com/richardfoltyn/python-intro-PGR
- Interactive notebooks can be launched directly in the browser (see setup guide)

Additional resources

- Scipy Lecture Notes (http://scipy-lectures.org/index.html)
  Online lecture notes for quantitative work with Python
- Numpy quick start tutorial (https://numpy.org/doc/stable/user/quickstart.html)
- Numpy tutorial for Matlab users
  (https://numpy.org/doc/stable/user/numpy-for-matlab-users.html)
- QuantEcon lectures: mostly Python but also Julia (https://quantecon.org/lectures/)
- QuantEcon library for Python (https://quantecon.org/quantecon-py/)
  Collection of routines and tools for economics
- QuantEcon repository for contributed code solving economic problems in Python
  (https://notes.quantecon.org/)
- Dive Into Python 3 (https://diveintopython3.net/)
  Freely available online book on general Python programming (no focus on scientific computing)
- scikit-learn user guide (https://scikit-learn.org/stable/user_guide.html)

References

Duarte, Victor. 2018. **Machine learning for continuous-time finance.** Technical report. Tech. rep., Gies College of Business.

Duarte, Victor, Julia Fonseca, Aaron S Goodman, and Jonathan A Parker. 2021. **Simple Allocation Rules and Optimal Portfolio Choice Over the Lifecycle.** Working Paper, Working Paper Series 29559. National Bureau of Economic Research.

Foltyn, Richard. 2020. Experience-based Learning, Stock Market Participation and Portfolio Choice. **Available at SSRN 3543442.**

Foltyn, Richard, and Jonna Olsson. 2023. **Subjective Life Expectancies, Time Preference Heterogeneity, and Wealth Inequality.** Technical report.

Maliar, Lilia, Serguei Maliar, and Pablo Winant. 2021. Deep learning for solving dynamic economic models. **Journal of Monetary Economics** 122:76–101.

Olsson, Jonna. 2023. Singles, couples, and their labor supply: long-run trends and short-run fluctuations. **American Economic Journal: Macroeconomics.**