Machine Learning for Constrained Optimization

A Phd Course

Machine Learning for Constrained Optimization

Let's start with an observation:

Machine Learning is Optimization

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Machine Learning is Optimization

- Well, maybe a few exceptions apply (looking at you, non-parametric models...)
- ...But broadly speaking, the statement is true

From an optimization point of view:

- Classical ML has focused on large-scale, unconstrained problems
- ...And for good reason!
  - Large input spaces
  - Large parameter spaces
  - Expensive cost functions

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Let's start with an observation:

Machine Learning is Optimization

However, that's a bit reductive:

- What if our ML problem has a non-trivial structure?
- What if we have external knowledge?
- What if there are physical laws, or regulations?
- What if we want to use data to help with a decision problem?

Then, we may want to take a broader view...

...Since other optimization techniques may be of help!

Machine Learning for Constrained Optimization

This course is about seeing ML and CO as a whole:

- Focus: integration of Machine Learning and Constrained Optimization
  - Emphasis on modeling aspects and knowledge integration
  - No mention of acceleration techniques
- Three parts:
  - Constrained Optimization for Data Mining
  - Handling constraints in Machine Learning
  - Hanlding Machine Learning models in optimization
- It will be far from a complete overview
  - Bias on my own research
  - I'll do my best to provide pointers
  - ...And starting points for related areas

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Course material

- Jupyter notebooks for everything; version 6, for compatibility with...
- RISE plugin for the presentation mode
- Poetry for dependency management and reproducibility
- Each part in different github repository

Lectures are meant to be executed

For doing it locally, you need to:

- Install Poetry using pipx or the native installer
- Clone the git repository
- Open a terminal on the cloned repository
- Run `poetry shell` then `jupyter notebook`

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Let's check our directory structure:

In [4]:
```
!ls ..
```

```
LICENSE.md              data                    poetry.lock
README.md               notebooks               pyproject.toml
assets                  pdfs                    requirements_dev.txt
```

- The `data` folder is meant for datasets & co.
- The pdf folder contains PDF exports for the notebooks
- In the `Dockerfile` you have the container setup instructions
- The `docker-compose.yml` file specifies how to run the container
- The `README.md` file contains instructions on how to run the lectures

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Let's check our directory structure:

In [5]:
```
!ls ../notebooks
```

```
00. Introduction to the Course.ipynb
01. Constraint Optimization for Data Mining.ipynb
02. The Alternating Direction Method of Multipliers.ipynb
03. Solving the Path Formulation.ipynb
04. Consolidation as Regularization.ipynb
05. Mixed Integer Linear Programming.ipynb
06. Solving the Consolidation Problem.ipynb
07. From Pricing....ipynb
08. ...To Column Generation.ipynb
09. Constraints in the Master.ipynb
10. Constraints in the Subproblem.ipynb
11. Maximum Wait Pricing Model.ipynb
print-pdf.sh
rise.css
util
```

- In the `notebooks` folder we have the notebooks themselves
- A `util` folder with a python module for utility functions
- An `assets` folder with pictures, fonts, & co.