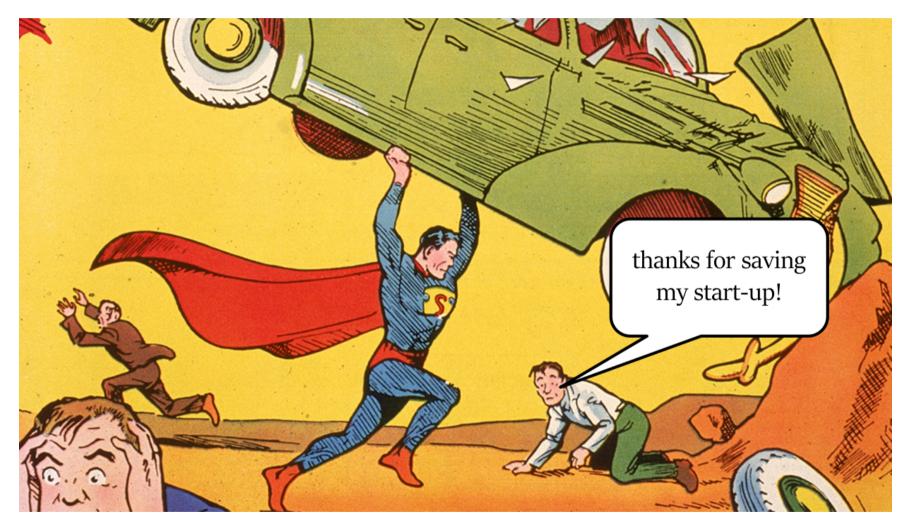


Acknowledging a Fact

ML techniques have reached superhuman performance on many tasks



...All the Facts, Actually

Modern ML method excel at tacking advantage of available data

- They can are robust w.r.t. to noise
- They can approximate highly non-linear relations
- They can handle very large datasets
- ...

However, this is all about implicit information

What about explicit information? E.g.:

- Locality
- Known physical laws
- Regulations
- Intuitive relations
- **...**

Success Stories

Some of the most successful ML methods are based on explicit knowledge

Think of:

- Convolutional networks
- Attention-based architectures (e.g. tranformers)
- Graph neural networks
- •••

They all rely on explict knowledge about the structure of the problem

- Locality for CNNs
- Relevance functions for attention
- Known connections for GNNs
- ...

...And Open Problems

Where thing become trickier is with symbolic information

...Which is typically encoded in the form of (soft of hard) constraints



Let's make a few examples...

Constrained Machine Learning

Example 1: logical rules

E.g. hiearchies in multi-class classification ("A dog is also an animal"):

$$y_{i,dog} \leq y_{i,animal}$$

■ This constraint is defined over individual examples

Example 2: shape constraints

E.g. input x_i cannot cause the output to decrease (monotonicity)

$$y_i \leq y_k \quad \forall i, k : x_{i,j} \leq x_{k,j} \land x_{i,h} = x_{k,h} \forall h \neq j$$

■ This is a relational constraint, i.e. defined over multiple examples

Constrained Machine Learning

Historically, constrained ML has received limitd interest

...But things are changing!

- Symbolic knowledge is available for many practical problems
- Fairness in ML can be though of as a constraints
- Safety in ML can also be stated by means of constraints

Mainstream conferences now often host sessions on related topics:

- Neuro-symbolic Al
- Fairness and trustworthiness in Al
- Hybrid ML-optimization approaches
- ...

About this Lecture

Constraints ML can be taken into account by acting on:

- The architecture
- The training algorithm
- The data

This lecture will containt a few relevant examples of such approaches

The lecture consists of a set of tutorials

- We will use (semi) practical example to discuss the techniques
- Everything is a jupyter notebook (and executable)
- We will reproduce the results in real time
- The code will be made available to you can play with that