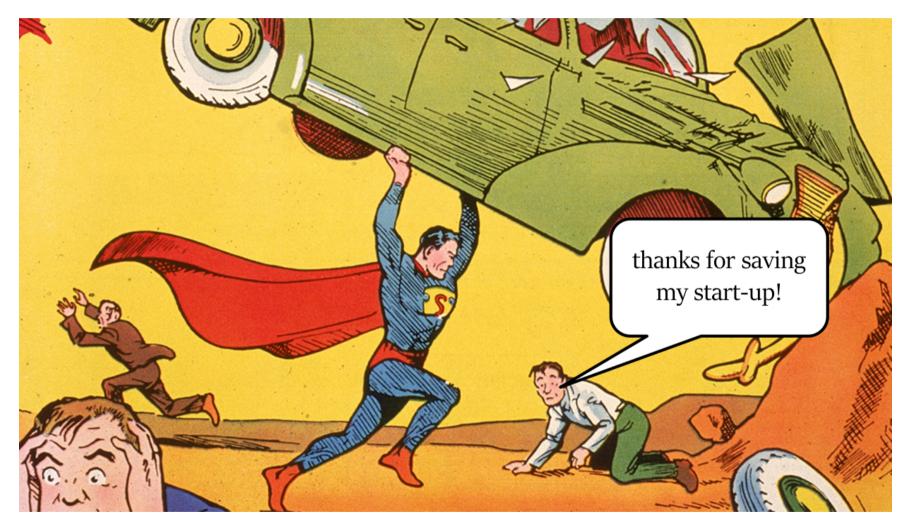# Constraints in Machine Learning

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 maps for attention

- Known connections for GNNs

- ...

Where things 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_j 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 limited 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 AI

- Fairness and trustworthiness in AI

- 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 contains a few relevant examples of such approaches

The lecture consists of a set of tutorials

- We will use (semi) practical examples to discuss the techniques

- Everything is a jupyter notebook (and executable)

> **The lecture is available at:**
> https://github.com/eBISS2022/constrained-ml