technische universität dortmund

SFB 876 Providing Information by Resource-Constrained Data Analysis

Active Simulation Data Mining

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Interactive Adaptive Learning

Learning from Simulations

A simulation models how a system $\boldsymbol{s}$ evolves over time, given the parameters $\boldsymbol{\rho}$:

$$Sim_{\boldsymbol{\rho}}(\boldsymbol{s}_t, \Delta t) = \boldsymbol{s}_{t+\Delta t}$$

Multiple steps make a black-box data generator:

$$\underset{\text{parameters}}{\boldsymbol{\rho}} \longrightarrow \boxed{\text{simulation}} \longrightarrow \underset{\text{training data}}{(\boldsymbol{x}, y)}$$

- Simulated data replaces data from the real system
- Making predictions is faster than simulating

+

Active Sampling

Goal: Sample $\boldsymbol{\rho}$ for maximal learning efficiency

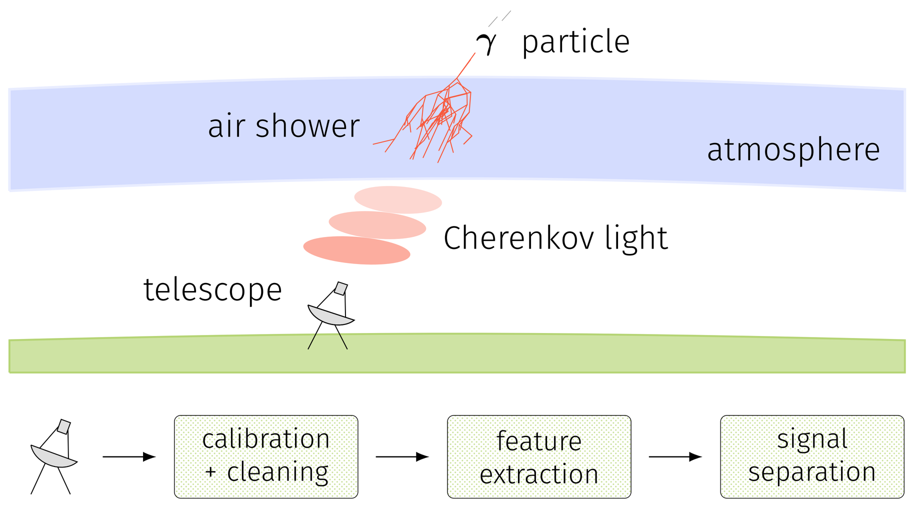
Do so sequentially, monitoring the trained model, and let either $\boldsymbol{x} \in \boldsymbol{\rho}$ or $y \in \boldsymbol{\rho}$, corresponding to the forward/backward distinction.

Cherenkov Astronomy

Labeled data only through simulation!

Simulation input: Label + auxiliary parameters (e.g. energy, direction, ...)

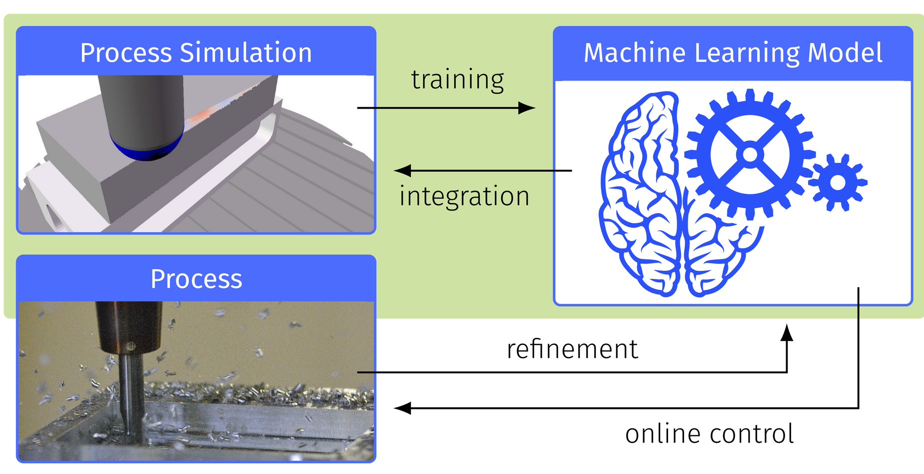
Simulation output: Synthetic observations



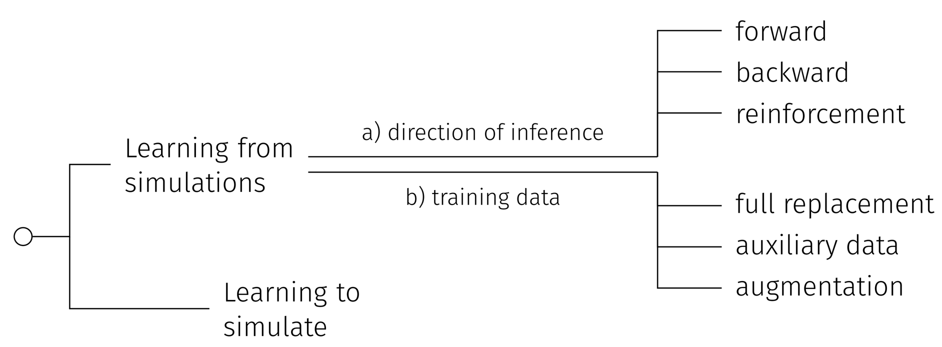
Milling

Simulation input: Process input parameters

Simulation output: Characteristics of the process

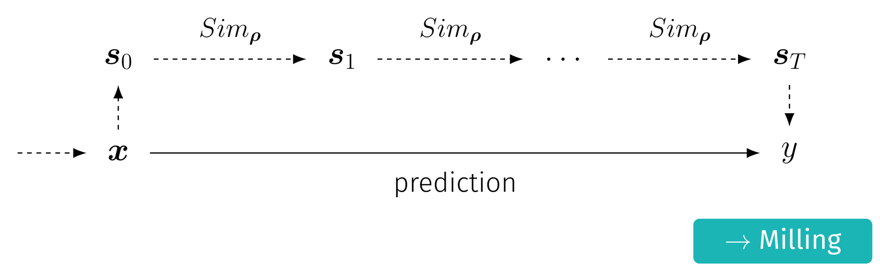


Other integrations of machine learning & simulation:

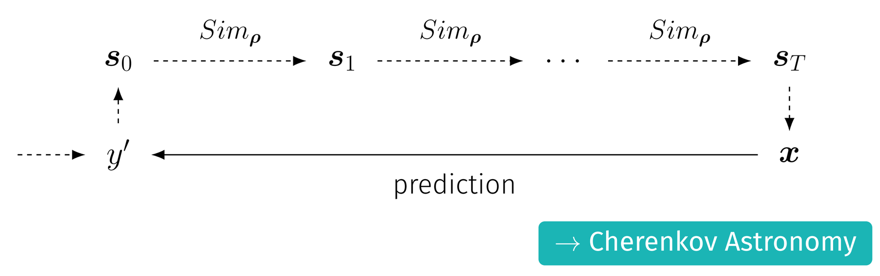


Forward vs. Backward

One may have to predict the **outcome** y...



...or the **cause** y' of an observation $\boldsymbol{x}$.



Example generation is either optimized by active learning (AL) or by active class selection (ACS), depending on the learning scenario.

In particular, the simulation candidates to score are either observations or labels:

$$u_{\text{AL}} : \mathcal{X} \rightarrow \mathbb{R}$$
$$u_{\text{ACS}} : \mathcal{Y} \rightarrow \mathbb{R}$$

Sampling of Parameters

The "pure" AL and ACS are *artificially* limited by neglecting the simulation parameters $\boldsymbol{\rho}$.

We expect that relevant data can be identified more easily by accounting for all parameters:

$$u : \mathcal{P} \rightarrow \mathbb{R}, \qquad \text{where} \begin{cases} \mathcal{X} \subseteq \mathcal{P} & \text{(AL)} \\ \mathcal{Y} \subseteq \mathcal{P} & \text{(ACS)} \end{cases}$$

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Conclusion & Outlook

We distinguish between the *forward* and *backward* learning scenario and propose simulation data mining as a use case for active sampling.

We identify open research issues:

Transfer Learning: The simulation may not exactly picture reality. Domain adaptation makes the two domains—simulation and reality—explicit.

Limits of ACS: In pure ACS, beating a merely random sampling is hard [5]. By accounting for all parameters $\boldsymbol{\rho}$, we hope to find whether this limitation comes from the narrow ACS task itself.

Data Imbalance in ACS: Between-class and within-class imbalances may harm ACS strategies.

Want to Collaborate?

`https://sfb876.tu-dortmund.de/simulation-data-mining`

References

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- Simulation Data Mining
- Deconvolution

...as being applied in Cherenkov astronomy (project SFB 876-C3).

Amal Saadallah

- Ensemble Methods
- Time Series Analyses

...using sensor data of production processes (project SFB 876-B3).

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