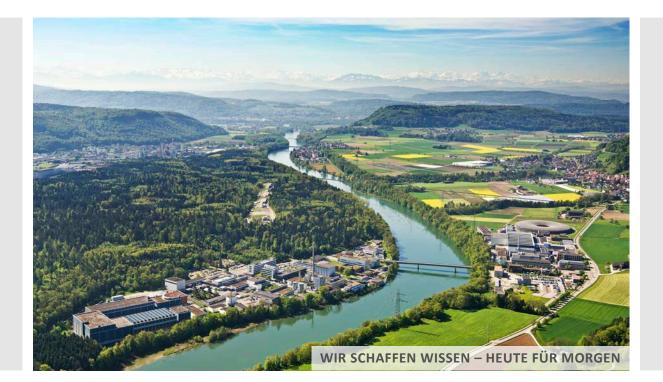
PAUL SCHERRER INSTITUT



Nicole Hiller :: Operation :: Paul Scherrer Institut

Machine Learning at PSI

10th Workshop on Longitudinal Electron Bunch Diagnostics



Machine Learning

wikipedia.org: Machine learning (ML) is the scientific study of algorithms and statistical models that computer systems use to perform a specific task without using explicit instructions, relying on patterns and inference instead. It is seen as a subset of artificial intelligence.



Samuel, Arthur L. (1959).

"Some Studies in Machine Learning Using the Game of Checkers". *IBM Journal of Research and Development*. **44**: 206–226. CiteSeerX 10.1.1.368.2254. doi:10.1147/ rd.441.0206

- Learning: (un-)supervised, reinforcement, self-learning, feature learning, anomaly detection, clustering...
- **Models**: neural networks, decision trees, support vector machines, ...
- Strong ties to: Optimisation, data mining, statistics -> data science



ML at PSI - What for?

- Tuning / Optimisation / Control (e.g. Bayesian optimisation at SwissFEL & HIPA)
- Prognostics / alarm handling / anomaly-breakout detection (e.g. interlock prediction at HIPA, virtual diagnostics -> Photon diagnostics looking into this)

• Data analysis

(e.g. clustering, pattern recognition -> beamline people are looking into this)

• Simulations / Modeling

(e.g. surrogate models when simulations are very time-consuming or there is no clear model -> predicting detector calibration factors; training a fast "online" model of an accelerator)

Other projects in the planning

(e.g. efficient patient scheduling for proton therapy, ...)



Goal: Optimise the FEL pulse intensity -> Many Photons = Happy Users

Challenges:

- Exponential dependence of FEL output on many, coupled machine parameters
- Manual tuning is time consuming & inefficient
- Use many knobs (~40)
- Don't drive the machine into the wall...

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¹ ETH Zürich, Department of Computer Science, Zürich, Switzerland

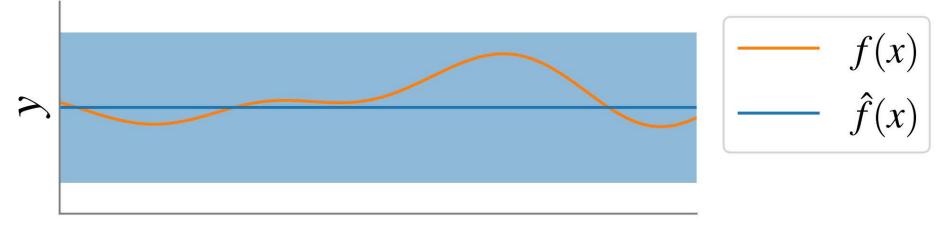
² Paul Scherrer Institut (PSI), CH-5232 Villigen PSI, Switzerland



- The work is supported by the Swiss National Science Foundation under grant 200020_159557

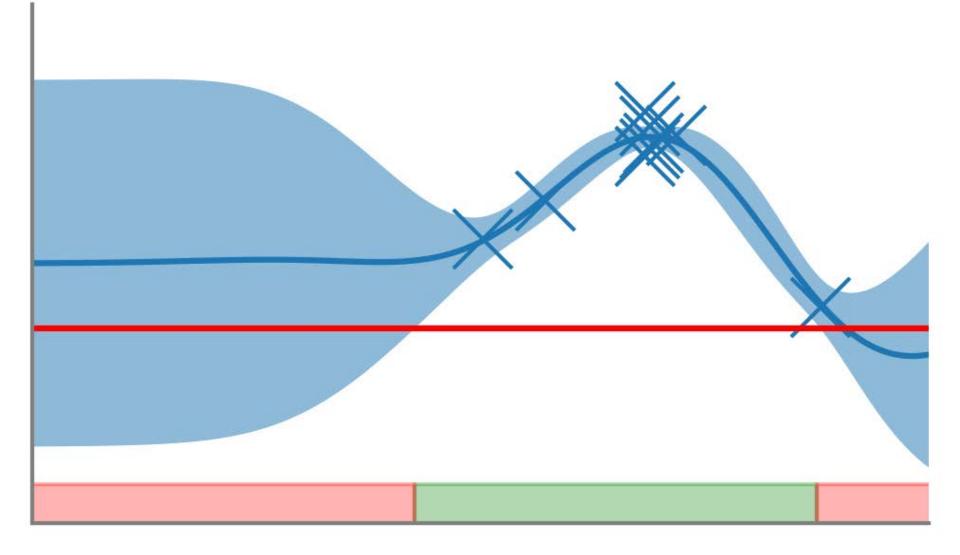


The ML Experts from ETHZ suggested Bayesian Optimisation!
 -> How does this work?



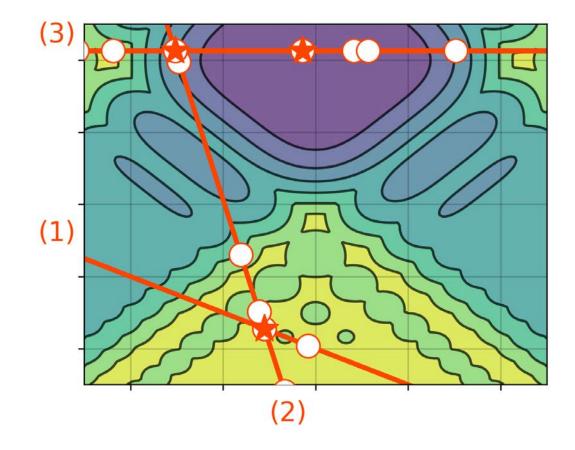
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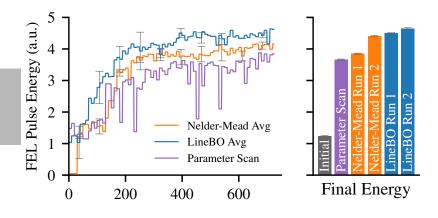




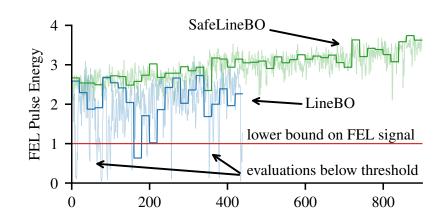
- How does it scale for many parameters? -> Poorly...
- What do we do? -> Combination of gradient method (local sampling) and 1D line approach over several lines



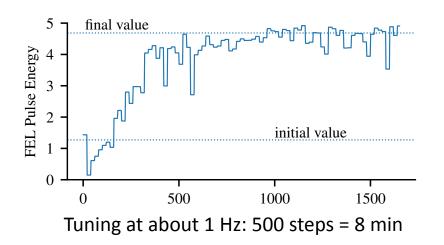




Benchmarking against other algorithms! (24 Parameters)



Adding Safety Constraints (24 Parameters)



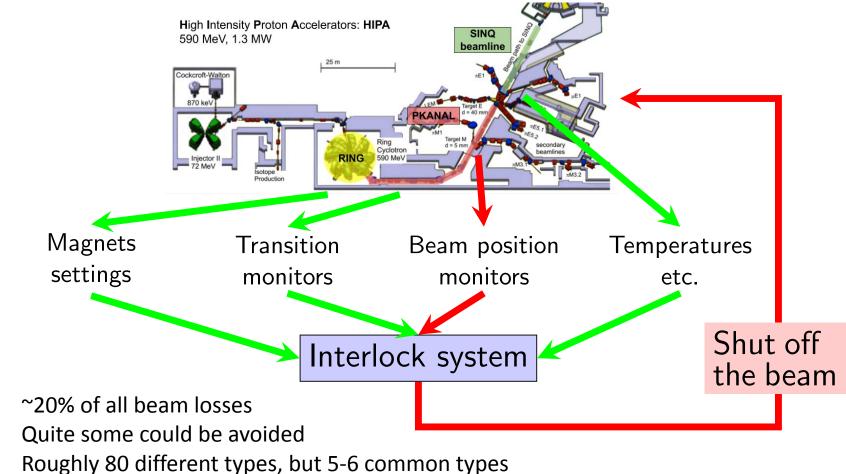
Still works fast with 40 Parameters!



- Where does the journey go to?
 - Versatile Framework with a GUI that
 - can be used by operators
 - can be used at other accelerators -> we are also tuning HIPA with it now!

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Andreas Adelmann, Jaime Coello, Davide Reggiani, Jochem Snuverink, Melissa Zacharias (PSI); Anastasia Pentina (Swiss Data Science Center)



Interlock Prediction at HIPA

•What would be your approach?

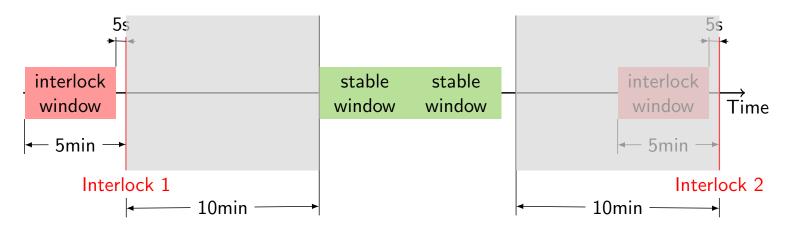


Interlock Prediction at HIPA

Goal: Train a model (supervised learning) that can then predict interlocks and prevent them by lowering the beam current temporarily

Approach:

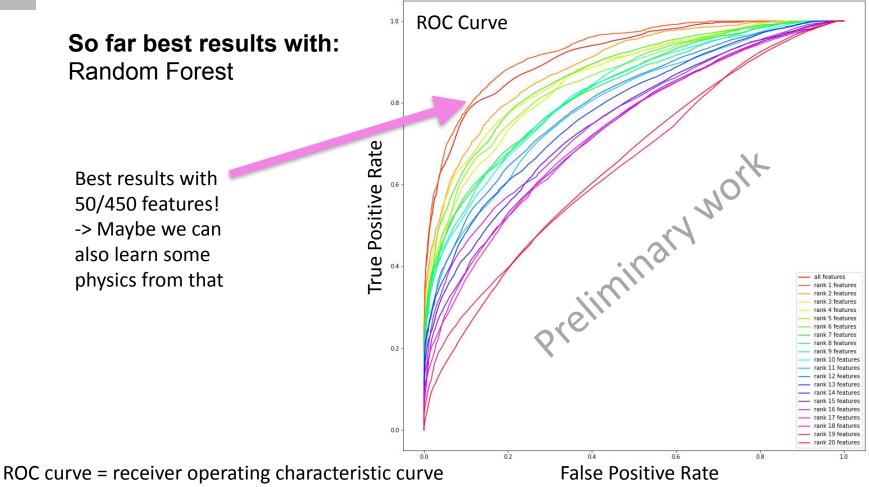
- Training on archived data (450 channels) -> lots of data preparation needed
- Finding the best model
 - Interlock-window: interlock happens in 5 seconds
 - Stable-window: interlocks are far from happening





Interlock Prediction at HIPA

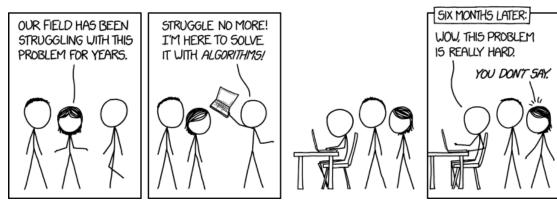
In an interlock happens: 25 s no beam If the charge is temporarily lowered: corresponds to 6 s no beam -> We want a high positive true prediction, but a very low positive false one!





Lessons learned so far

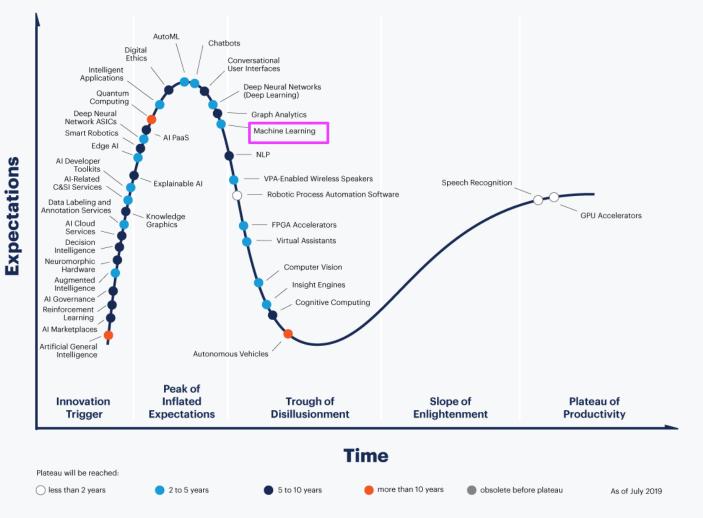
- Machine learning techniques can be great tools especially when
 - Your problem is hard to formulate analytically (pattern recognition,...)
 - You have a lot of data
 - You would have to frequently use very time-consuming simulations
 - Your "standard tools" do not work very well
 - You need a high degree of automation
- but
 - You still need to understand your problem! -> it does not do that for you
 - You still need to prepare your data (data science skills are crucial) -> do not underestimate this part
 - Quite often a lot of "hyper-parameters" are involved -> you will need to learn the "tricks of the trade"





- Regular (every 6 weeks) discussion rounds: ML Luncheons (11:30-13:00 with free sandwiches) -> open discussions, informal presentations
- ML Awareness event -> Half day event with invited speakers
- ML Mailing List & SLACK channel for announcements & discussions
- Collaboration with the Adaptive Systems Group at ETHZ (Prof. Andreas Krause):
 - PhD & Master Students
- Project grants for the Swiss Data Science Center (SDSC)
 - <u>www.datascience.ch</u> -> professional support for projects (e.g. data scientist is at PSI once per week)
 - 3rd ICFA Mini-Workshop on Machine Learning Applications for Charged Particle Accelerators 18-21 Feb 2020 at PAL, Korea <u>https://www.indico.kr/event/5/</u>

Gartner Hype Cycle for Artificial Intelligence, 2019



gartner.com/SmarterWithGartner

Source: Gartner © 2019 Gartner, Inc. and/or its affiliates. All rights reserved.



PAUL SCHERRER INSTITUT

What are your

experiences?

opinions/

© 2014 Ted Goff KDnuggets Cartoon



THIS IS YOUR MACHINE LEARNING SYSTEM? YUP! YOU POUR THE DATA INTO THIS BIG PILE OF LINEAR ALGEBRA, THEN COLLECT THE ANSWERS ON THE OTHER SIDE. WHAT IF THE ANSWERS ARE WRONG? JUST STIR THE PILE UNTIL THEY START LOOKING RIGHT.

"The machine learning algorithm wants to know if we'd like a dozen wireless mice to feed the Python book we just bought."

> How are things at your institute?

www.xkcd.com

OH, HEY, YOU ORGANIZED OUR PHOTO ARCHIVE!

> YEAH, I TRAINED A NEURAL NET TO SORT THE UNLABELED PHOTOS INTO CATEGORIES.

WHOA! NICE WORK!



ENGINEERING TIP: WHEN YOU DO A TASK BY HAND, YOU CAN TECHNICALLY SAY YOU TRAINED A NEURAL NET TO DO IT.