UNIVERSITÉ DE GENÈVE

SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

ESR 3: Real time analysis strategies for reconstruction, exotic physics, and market analysis

Leon Bozianu

Anna Sfyrla, Steven Schramm

27.11.2023

We acknowledge funding by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086 (SMARTHEP).

MARIE CURIE ACTIONS

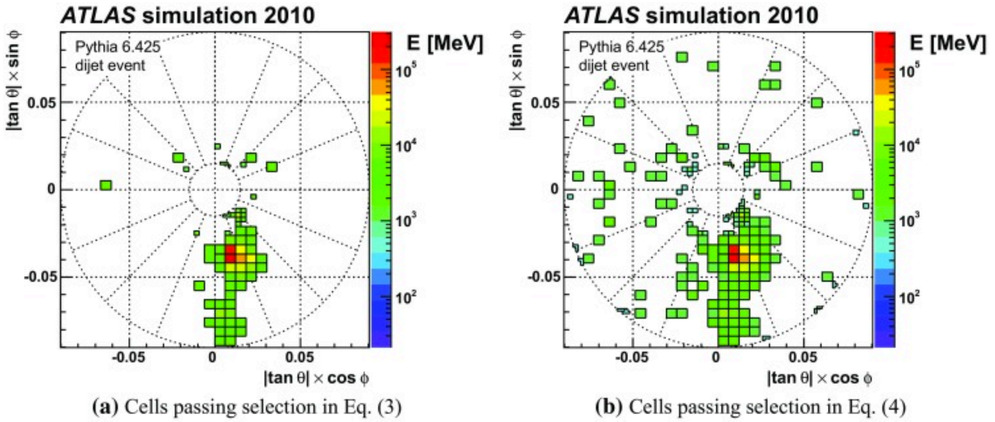
Presentation Outline

- Qualification task
- Secondment project
- Other activities

Qualification Task

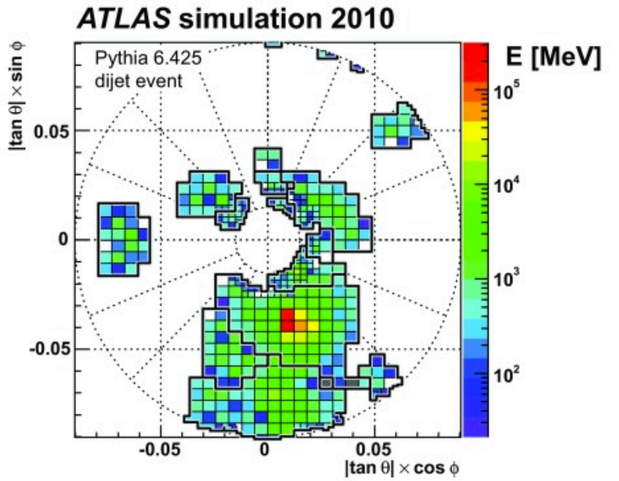
Topoclustering

Making of jet constituents

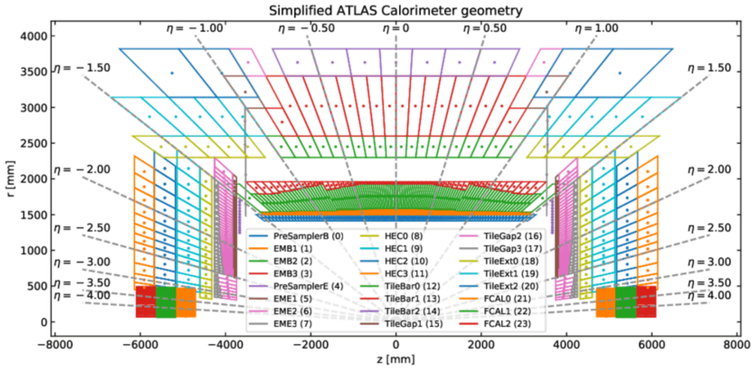


(a) Cells passing selection in Eq. (3) **(b)** Cells passing selection in Eq. (4)

- ATLAS uses the topoclustering algorithm to cluster calorimeter cells together.
- The algorithm is iterative, it checks each cell in turn.
- It then checks all the neighbouring cells.
- This guarantees you “find” everything, but is very slow!
- The clusters go through several post-processing steps and are then used to make jets.



(c) All clustered cells



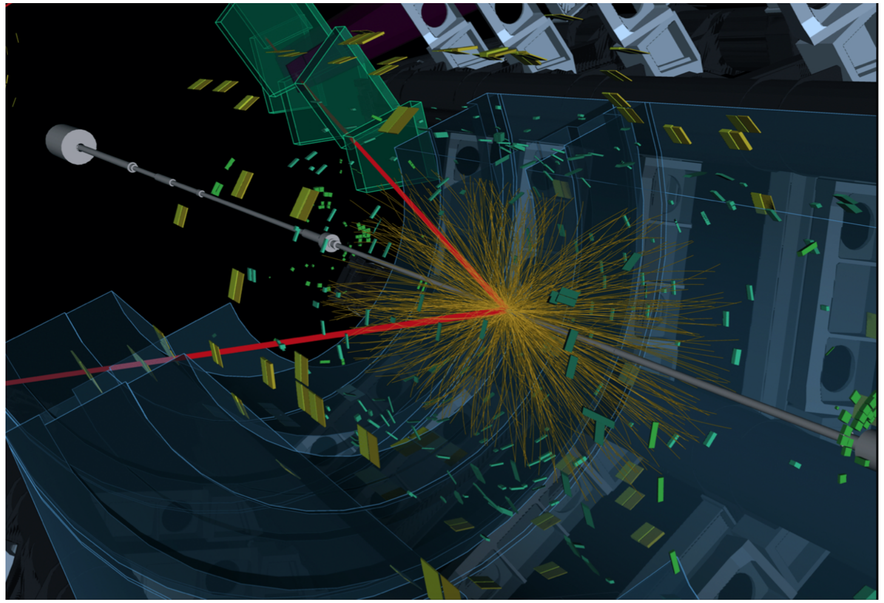
https://www.researchgate.net/publication/346904471_The_Acts_project_track_reconstruction_software_for_HL-LHC_and_beyond

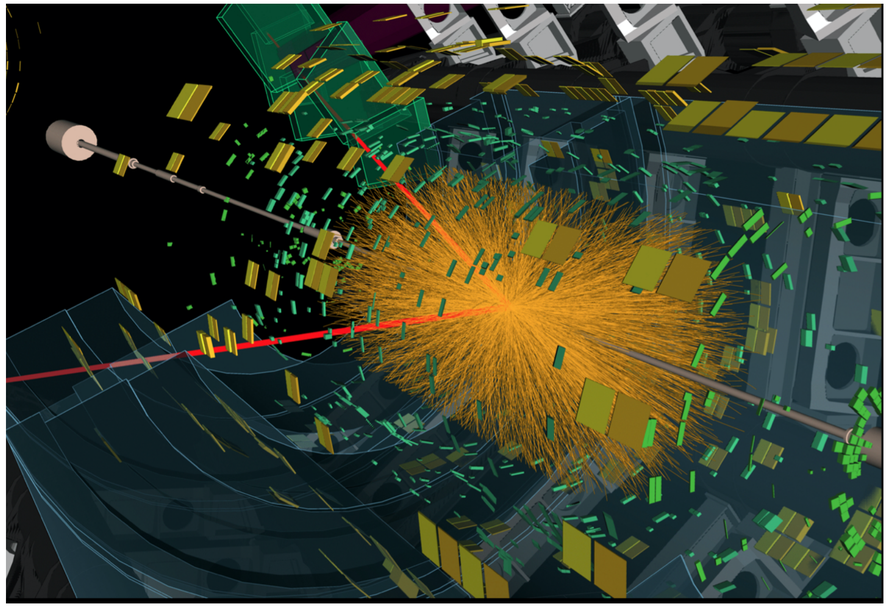
https://arxiv.org/abs/1603.02934

What's the motivation?

Why target this…

- **Topoclustering** is one of the most resource intensive algorithms in use in HLT.
- Crucial role in **jet** and **MET** reconstruction.
- Far worse **pile-up** conditions in HL-LHC.
- We pursue **faster** solutions with similar or improved performance.
- (And also less **energy consumption**).

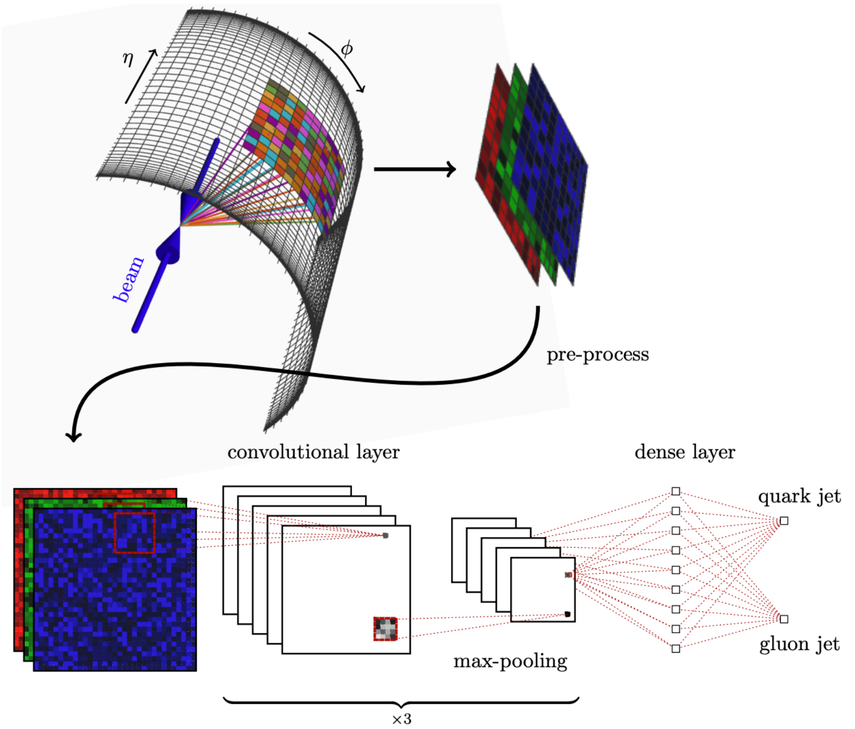


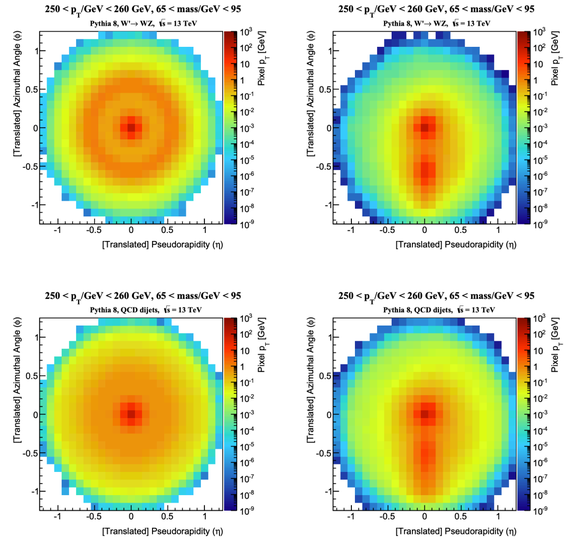


50 vs 200 p-p collisions per bunch crossing.

Can ML help?

- Project has been exploring the use of deep neural networks (CNN/GNN) to replicate the topoclusters.
- Training model weights then using rapid execution speed in inference.
- Possibility to port to other hardware (GPUs, FPGAs) faster and more energy efficient.
- Produce “more accurate” (different) clusters.

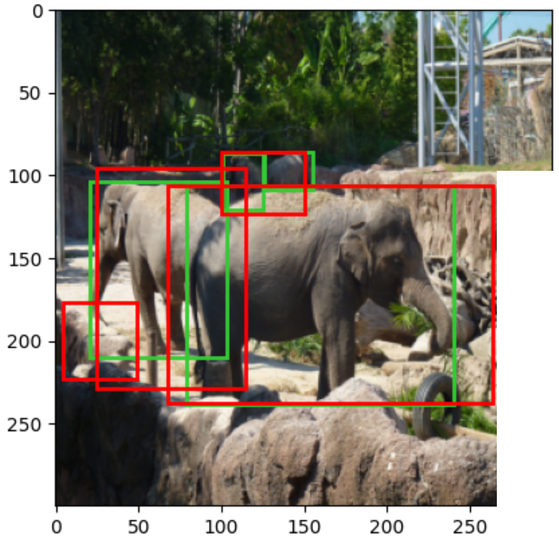


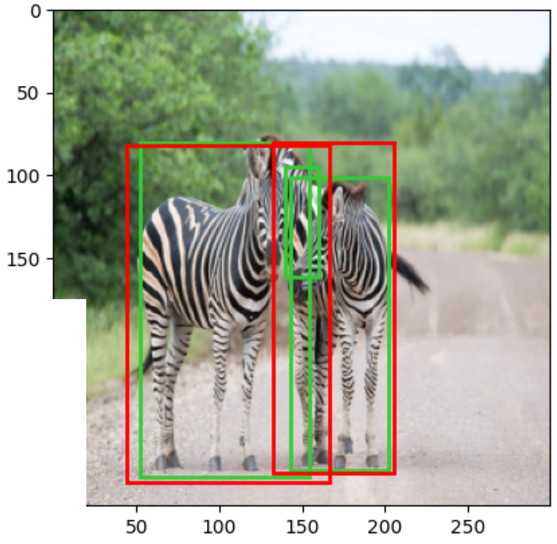


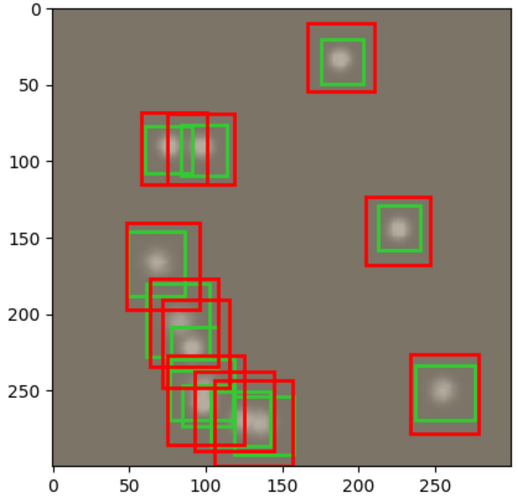
https://arxiv.org/pdf/1612.01551.pdf

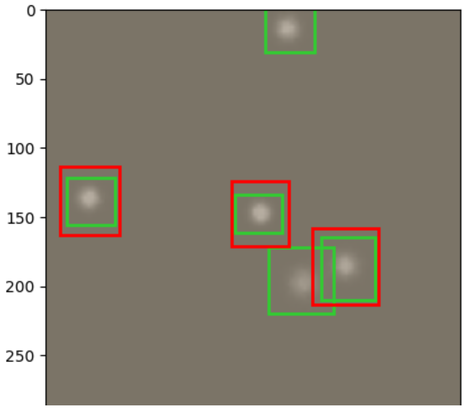
Figure 2: The average jet image for signal W jets (top) and background QCD jets (bottom) before (left) and after (right) applying the rotation, re-pixelation, and inversion steps of the pre-processing. The average is taken over images of jets with 240 GeV $< p_T <$ 260 GeV and 65 GeV $<$ mass $<$ 95 GeV.

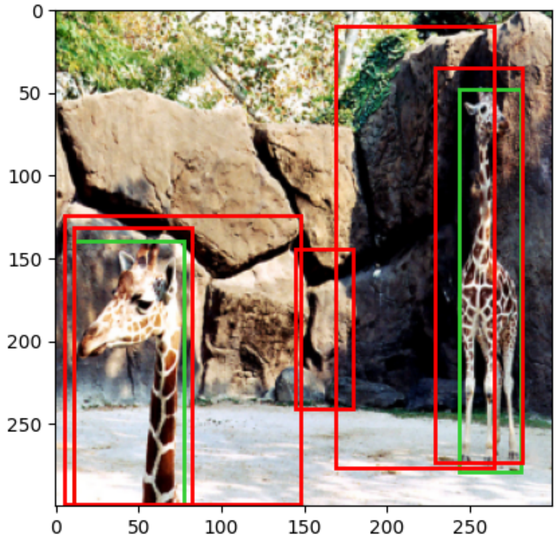
Aside: Animals and Random Gaussian Signals

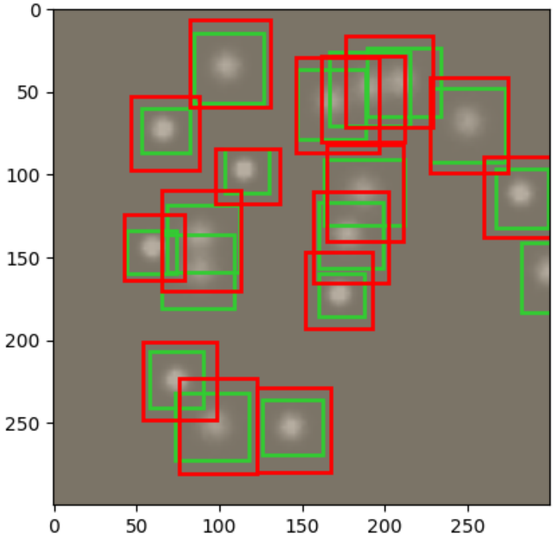


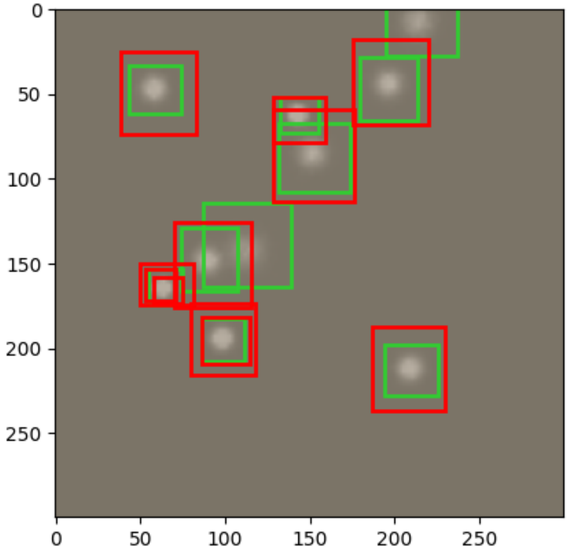






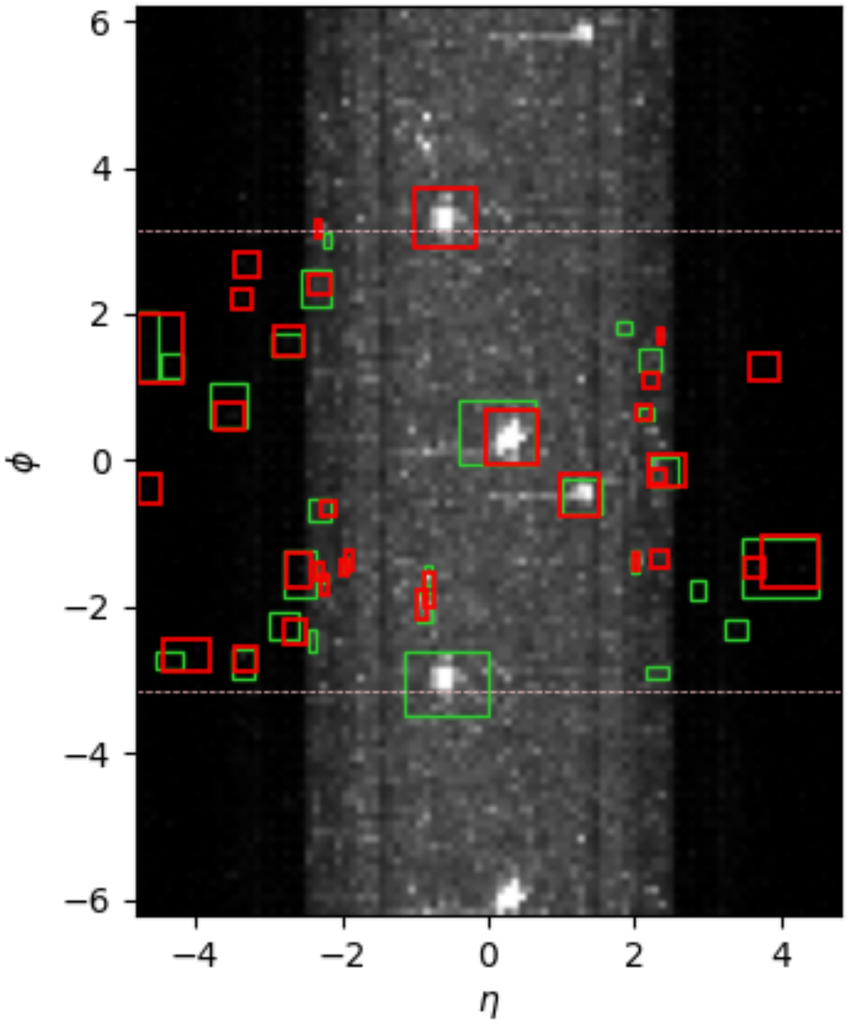


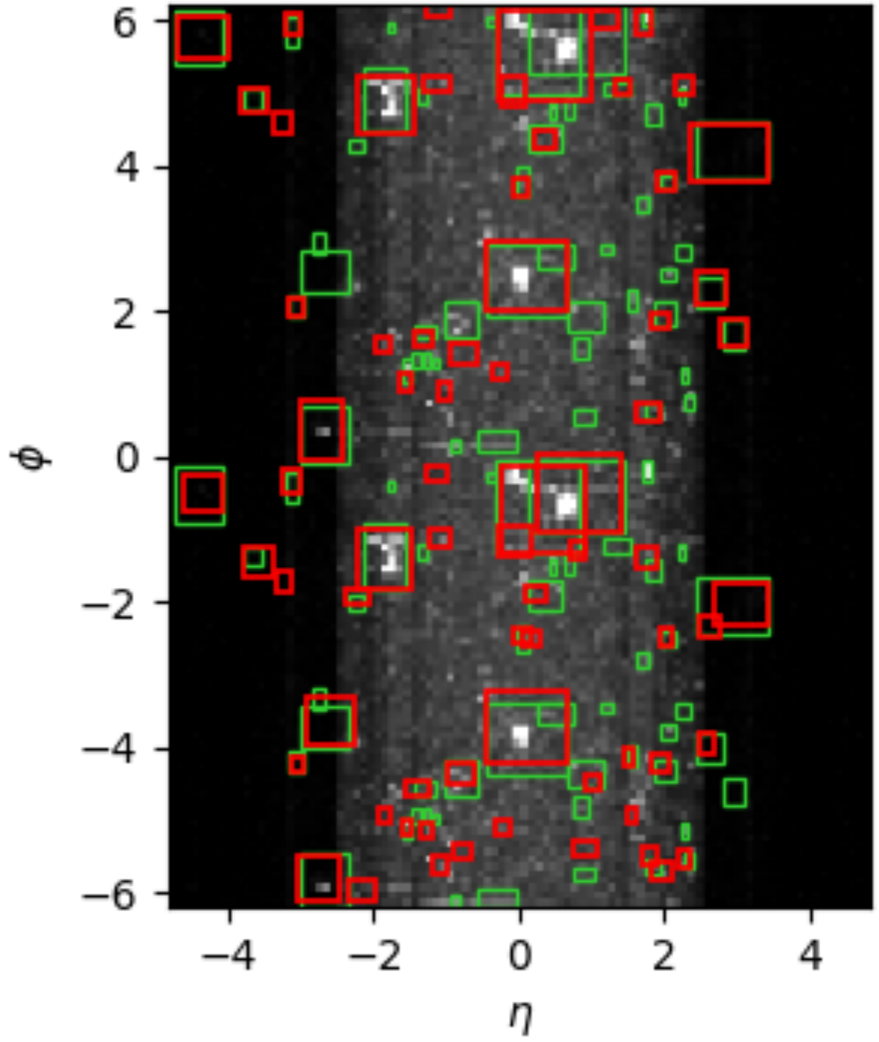




Object Detection in the Detector

“Real life” example





Secondment

Lightbox, Geneva

Market Analysis for Financial Firm

- **NOT prediction of the future!**
- Using ML and other data science tools to give signals/inform a financial strategy.
- Already widely adopted.
- A lot of different advice/practices compared to physics and academia.
- Time series data - handle with care!

https://www.netsuite.com/portal/resource/articles/financial-management/financial-forecast-machine-learning.shtml

https://www.tapinto.net/towns/elizabeth/articles/3-applications-of-machine-learning-and-ai-in-finance-2d5c4825-e0ad-4dda-bec6-22e91842eaa7

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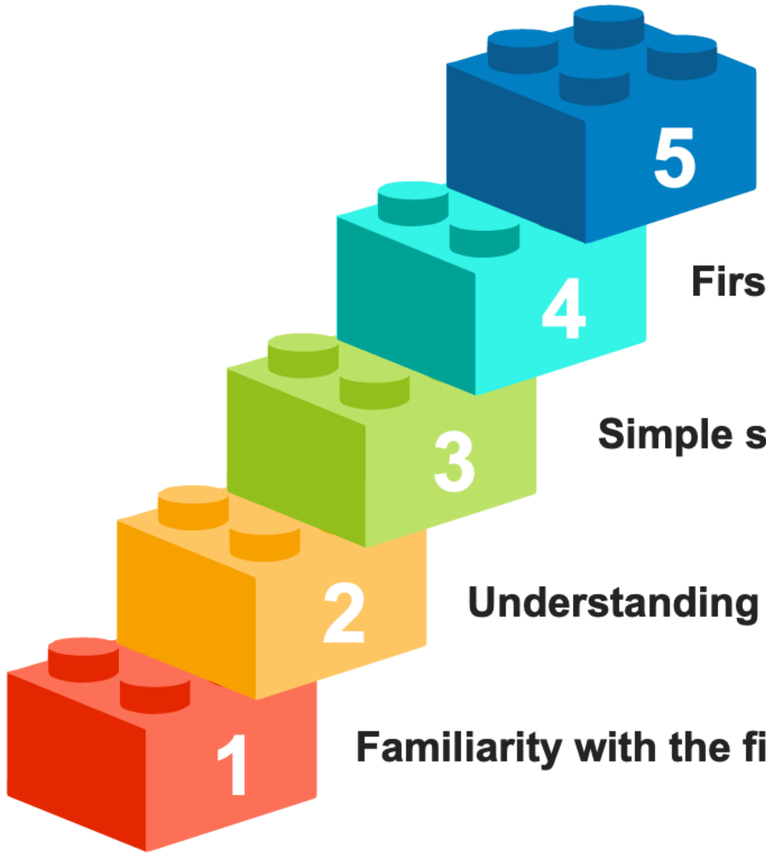
Our work

A bit of trial and error



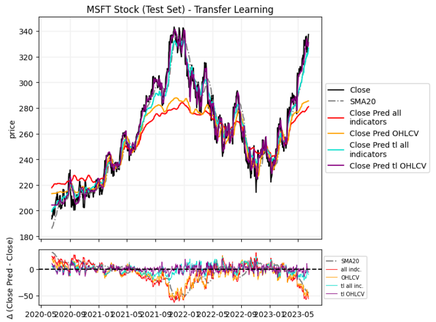
Progress to RNNs (LSTM, GRU,α-RNN)

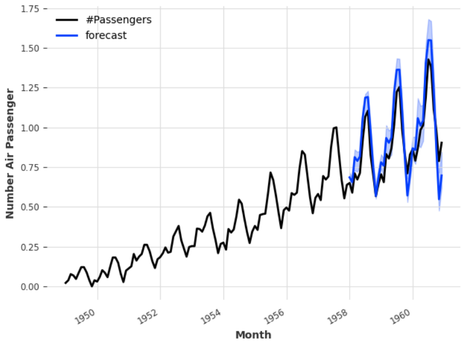
First, straightforward BDTs and FC-NNs

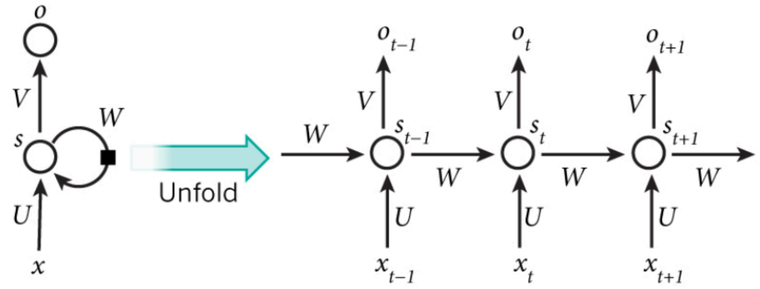
Simple statistical tests (PCA, Autocorr.)

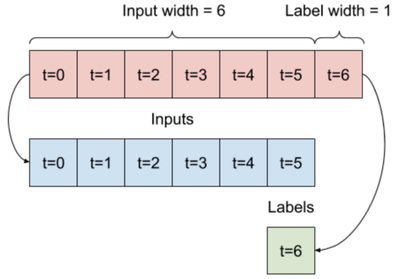
Understanding the technical indicators

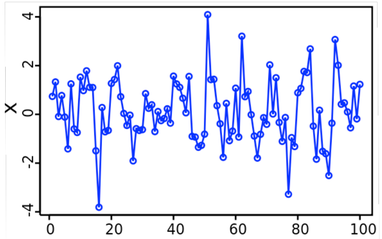
Familiarity with the financial data

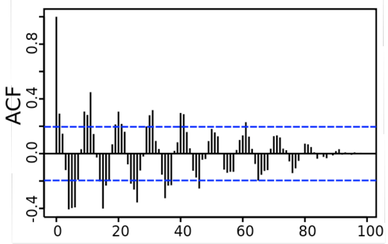












https://otexts.com/fpp3/acf.html

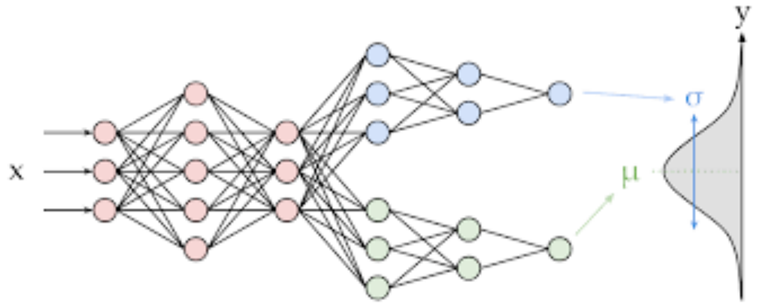
https://www.barchart.com/education/technical-indicators

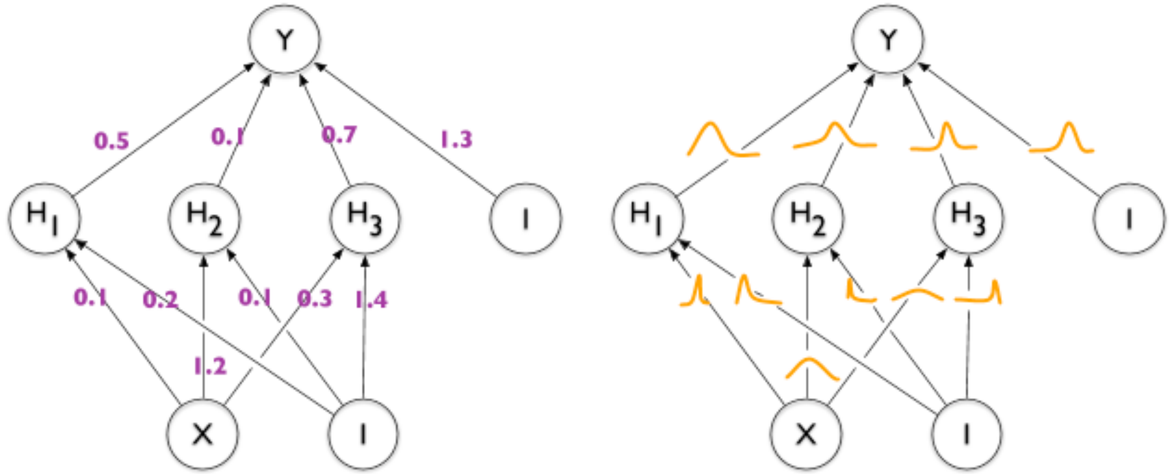
https://arxiv.org/pdf/1412.3555.pdf

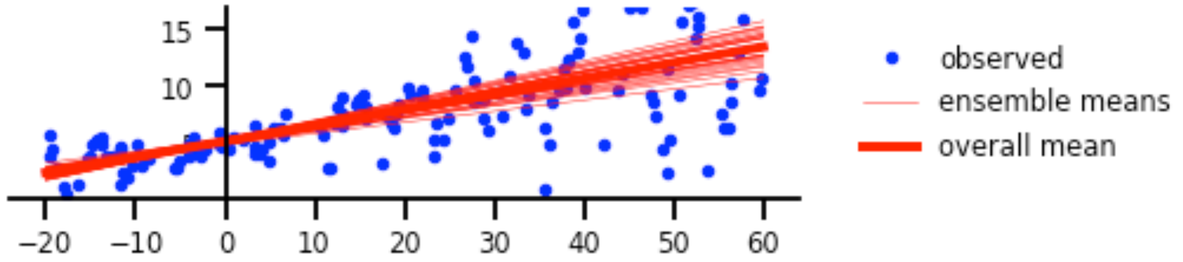
Our work

Detour into Bayesian Neural Networks

- Bayesian neural networks model the uncertainty associated to a prediction.
- Rather than a weights leading to a single deterministic output their weights define PDFs.
- The model output can also be a ‘distribution’.
- Very robust to noisy data, hard to overtrain.







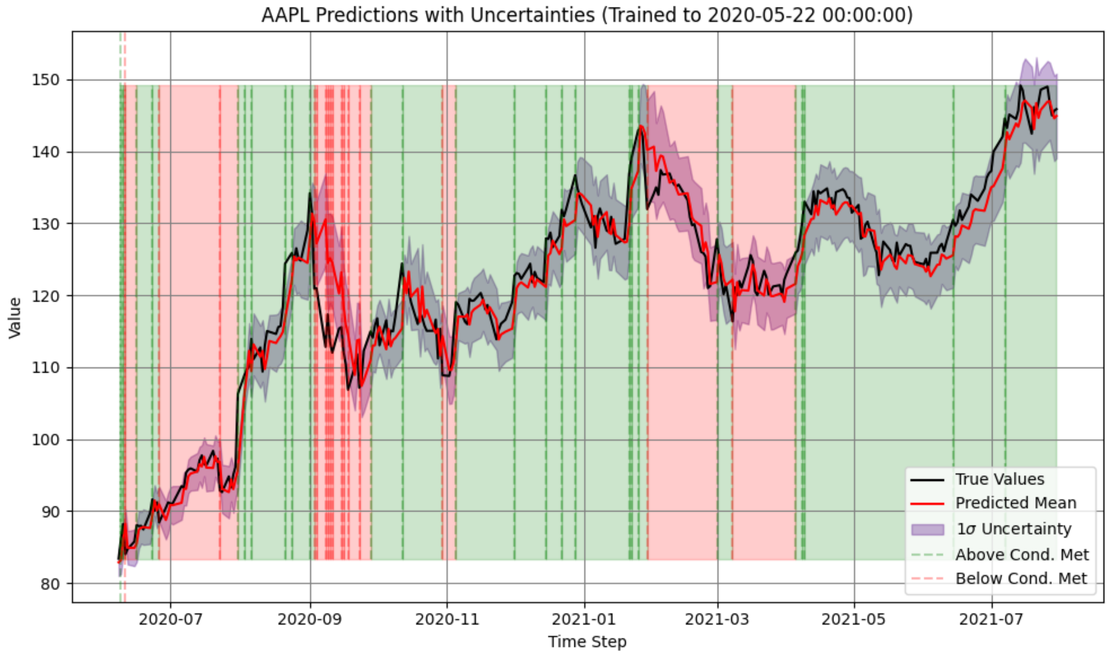
https://www.tensorflow.org/probability/examples/Probabilistic_Layers_Regression

https://brendanhasz.github.io/2019/07/23/bayesian-density-net.html https://neptune.ai/blog/bayesian-neural-networks-with-jax

Our work

Combine LSTM + Bayesian Output

- Can we use the uncertainty estimation of BNNs to guide the LSTM.
- At each time step output a Gaussian (student's-T) distribution.
- Use σ as a quality/confidence score. Use this to filter buy and sell decisions.
- Predictions highly dependent on training size (training sample regime) and forecast window .
- (And a small excursion into transfer learning…)



Miscellaneous activities

Additional engagements

In Geneva:

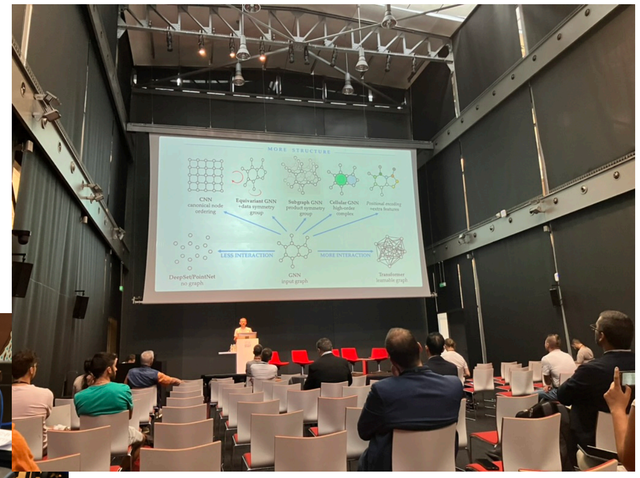
- University course in statistical methods
- University course in scientific computing in physics
- 3rd Symposium on AI for Industry, Science and Society
- High performance computing cluster training

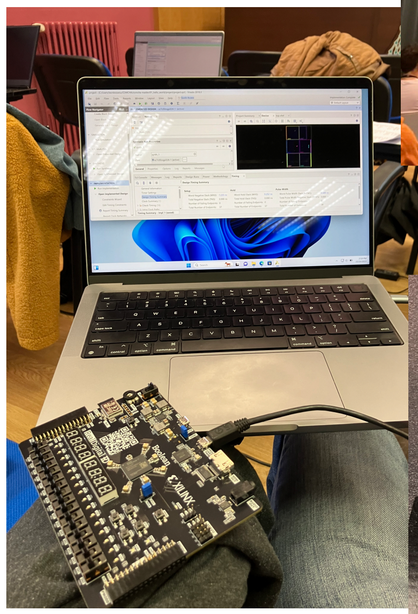
At CERN:

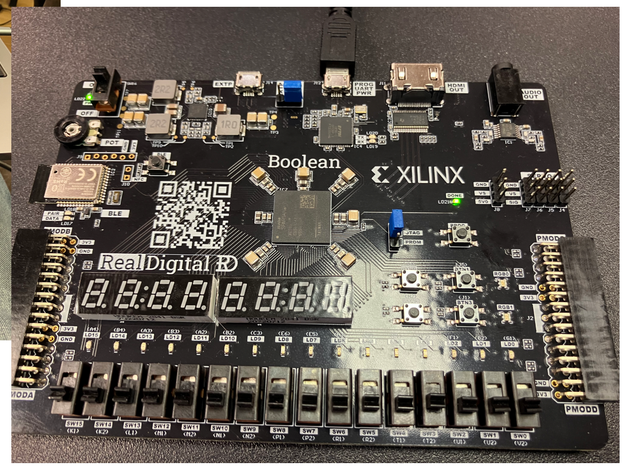
- ATLAS Control Room Shifter Training for trigger + DQ
- PyRoot + Scikit-HEP masterclasses/tutorials
- ECSB Lecture Series
- Radioactivity safety course

Elsewhere:

- CHIPP PhD Winter School, Leukerbad Jan. 2023
- 3rd COMCHA School, Oviedo Oct. 2023







Thanks for listening