CiML 2019 @NeurIPS : conclusion on TrackML, a Particle Physics Tracking Machine Learning Challenge combining accuracy and inference speed

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The Large Hadron Collider (LHC) located at the European Center for Nuclear Research (CERN, Switzerland) is a unique particle accelerator complex providing proton beams at unprecedented energies. It allowed the Higgs boson discovery in 2012 (acknowledged by the 2013 Nobel prize in physics). Experiments at the LHC are collecting events ($\simeq$ images, see Figure 1) of the proton collisions of increasing complexity at an increasing rate. The CPU time to reconstruct the trajectories (helices) from the measurement (3D points) is increasing year after year faster than the hardware resources. Exploration of completely new approaches to pattern recognition is needed.

To reach out to Computer Science specialists, a Tracking Machine Learning challenge (TrackML[1]) has been run in 2018 and 2019 by a team of particle physicists tracking experts and Computer Scientists, building on the experience of the successful Higgs Machine Learning challenge[2] in 2014 [3]. A dataset consisting of an accurate simulation[4, 5] of a LHC experiment has been created, listing for each event the measured 3D points, and the list of 3D points associated to each true track. The orders of magnitude are : ten thousand events, 100 million tracks, 1 billion points, 100 GB, 10^{500} combinations per event. No limit on the training resources has been imposed. The participants to the challenge should find the tracks in an additional test dataset, meaning building the list of 3D points belonging to each track.

The challenge has been run in two phases:

1. During the first "Accuracy" phase (which has run August to September on Kaggle[6]), a metric reflecting the accuracy of the model at finding the proper point association

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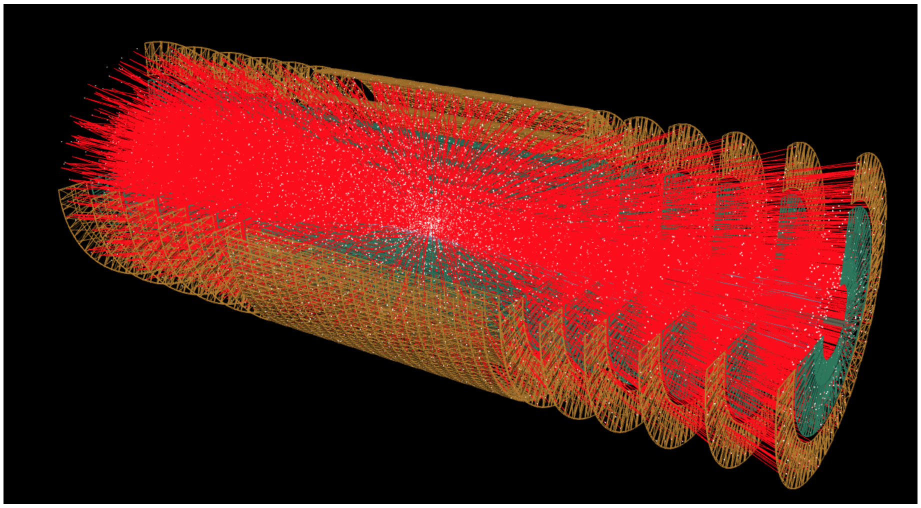

Figure 1: Etched-out collision image : measurement points are white, trajectories are red. The tracking volume is a cylinder of 1m radius and 5m length. The measurement points have precision of 10 μm to 3 mm. The goal of TrackML is to cluster points into trajectories.

that matters to most physics analysis has allowed to elect the algorithms. The metric is based on the overall fraction of points associated to a good track.

2. The second "Throughput" phase (which has run October 2018 to March 2019 on Codalab[7]) is focussed on optimising the inference speed on two CPU core (a number of software from top performers of the first phase have been released as possible starting point). The training speed remains unconstrained. The ranking score is combining the accuracy score with the inference speed.

The Accuracy phase has had 656 participants. It has revealed a variety of approaches, from deep learning to more traditional combinatorial approaches including mixed approaches. A thorough investigation of the submissions has shown that the single metric chosen has lead to algorithms which were also best w.r.t. the more complex and varied metrics in the domain [8]. The Throughput phase had less participants for a variety of reasons which will be exposed. Nevertheless the top participants' submissions are one order of magnitude faster than the state of the art. Analysis of the submissions are still on-going at the time of writing but it has been demonstrated that the speed vs accuracy optimisation done by participants on the challenge platform to be valid also for the very different environment of the domain.

How to run a challenge with a strong incentive on speed inference is an open problem (see for example the recent Airbus challenge on Kaggle [9]). The experience of the two steps TrackML should be a valuable contribution to the workshop.

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