TrackML: A tracking machine learning challenge

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CHEP 2018, Sofia, Bulgaria, 12.07.2018
The tracking problem

Combinatorial nature of current approach.
High-luminosity LHC

greater than 10k particles

greater than 100k hits
Are there better approaches?
How to find them?
Do we have to do it ourselves?

→ Use challenge format to look for new solutions
Are there better approaches?  
How to find them?  
Do we have to do it ourselves?

→ Use challenge format to look for new solutions
Defining the problem

Real experiment metrics

- Tracking efficiency
- Fake rate vs. purity
- Momentum resolution
- Impact resolution

Simplify and reduce

- No parameter estimation
- No hit merging/splitting/sharing
- Use single metric
Defining the problem

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Connect the dots
Defining the problem

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Dataset format

Space points as CSV file

```plaintext
hit_id, x, y, z, volume_id, layer_id, module_id
...
2, -812.8, -631.4, 411.5, ...
3, 649.4, -785.7, -309.1, ...
...
```

Submission as CSV file

```plaintext
event_id, hit_id, track_id
...
51, 2, 42
51, 3, 23
...
```
A two-phased challenge

**Accuracy phase**

Currently running until August, 13th
Submit **reconstruction result** only
Evaluate only **accuracy**
Leader prizes 12 k$, 8 k$, 5 k$
Special jury prizes (NVIDIA V100 GPU)

**Troughput phase**

Expected to start in September
Submit reconstruction **code**
Evaluate **accuracy** and **speed**
Expected prizes 7 k$, 5 k$, 3 k$
Special jury prizes
Accuracy phase score

\[ \text{track} = \{5, 23, 42, \ldots\} \]
\[ \text{majority particle} = \{5, 17, 23, 42, \ldots\} \]
\[ \text{good hits} = \text{track} \cap \text{majority particle} \]

\[ S \sim \sum_{\text{events}} \sum_{\text{tracks}} \begin{cases} 0 & \text{#good hits} < 50 \%, \#\text{hits} < 3 \\ \sum_{\text{good hits}} w_i & \text{else} \end{cases} \]

\[ S_{\text{perfect}} = 1 \]
\[ w_i = w_i \text{ (hit order, particle } p_\perp) \]
Accuracy phase score (cont’d)

Hit order

Particle $p_{\perp}$

[Diagram of detector layers showing hit order with particle origin and track labels: high weight, mid weight, low weight, highest weight.]

[Graph showing particle distribution vs. $p_{\perp}$ with two curves: orange for all tracks and blue for 3 < nhits.]

[p_{\perp} - dependent weight $p_{\perp} < 3$ GeV (current)]
Throughput phase score (proposal)

Nonlinear combination of accuracy score and processing time
Status accuracy phase challenge

Started in Mai
Ends on August 13th
>500 teams
Best scores are improving
Algorithms known only after finish
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Lessons learned

You need to simplify

A lot of questions on physics and detector details

This is an unusual dataset

Variable # inputs, # outputs, lots of discussions on possible algorithms

You need extensive crosschecks

A few minor dataset features: beam size, electron scattering, sensor thickness

Examples

What you provide might skew the discussion
Organizers

Paolo Calafiura, Steven Farrell, Heather Gray (LBNL Berkeley), Jean-Roch Vlimant (Caltech), Isabelle Guyon (ChaLearn, U Paris Saclay), Cécile Germain (LAL/LRI, U Paris Saclay), David Rousseau, Yetkin Yilnaz (LAL Orsay, U Paris Saclay), Vincenzo Innocente, Andreas Salzburger (CERN), Ilija Vukotic (U of Chicago), Tobias Golling, Moritz Kiehn, Sabrina Amrouche (U Genève), Edward Moyse (U of Massachusetts), Vava Gligorov (LPNHE Paris), Mikhail Hushchyn, Andrey Ustyuzhanin (Yandex)
Summary

A public machine learning challenge to find/evaluate novel tracking approaches.

Website
https://sites.google.com/site/trackmlparticle/

Phase I challenge
https://www.kaggle.com/c/trackml-particle-identification

Twitter
@trackmllh
A public machine learning challenge to find/evaluate novel tracking approaches.

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@trackmllhc

Join the challenge!
Appendix
The TrackML silicon tracker

Long strips

Short strips

Pixels
Simulation setup

Generator
- Pythia8 $t\bar{t}$ as signal
- Pythia8 minimum bias as pile up, $\mu = 200$
- Luminous region $\sigma_z = 5\text{ mm}$

ACTS fast simulation
- ATLAS-like field
- Parameterized interaction effects
- 15\% random hits
## Ground truth (only for training dataset)

### event...-particles.csv

<table>
<thead>
<tr>
<th>particle_id, vx, vy, vz, px, py, pz, q</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
</tr>
<tr>
<td>4503805785800704, −0.0083, 0.013, 0.30, 0.182, 0.064, 0.18, 1</td>
</tr>
<tr>
<td>4503943224754176, −0.0083, 0.013, 0.30, −0.051, 0.167, −0.12, −1</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

### event...-truth.csv

<table>
<thead>
<tr>
<th>hit_id, particle_id, tx, ty, tz, tpx, tpy, tpz</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
</tr>
<tr>
<td>2, 4513289073590272, −813., −630., 378., −0.74, −0.19, 0.27</td>
</tr>
<tr>
<td>3, 117094208786923520, 648., −786., −352., 0.12, −0.63, −0.21</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>
Scoring metric: example

Truth

particle 1 = \{2, 4, 8, 16, 32\}  weights 1 = \{25, 15, 10, 10, 15\}
particle 2 = \{3, 5, 9, 17, 33\}  weights 2 = \{7, 5, 5, 3, 5\}

Reconstruction

track a = \{3, 4, 8, 16, 32\}  good hits a = \{4, 8, 16, 32\}
track b = \{_, 5, 9, 17, 33\}  good hits b = \{5, 9, 17, 33\}

Score

score a = 50  score b = 18
score total = 68