TDAQ Subgroup White Paper Organization and Progress

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Paper Organization Meeting Nov.9

- Held our white paper kick-off and Snowmass reawakening meeting earlier this month: https://indico.fnal.gov/event/51566/
- Included a survey (still open!) for people to to express their interest in contributing to or leading a TDAQ white paper, and in what areas
- Meeting goals:
  - Get a sense of who will be submitting TDAQ white papers
  - Facilitate common white papers on topics of broad interest
    - Allow contributions from those who may not be able to commit to a full stand-alone white paper
    - Show community-driven input on pressing needs
    - Identify (co)-editors for these efforts
- Had about 18 participants, and one presentation on an already complete white paper (Fast ML)

Background: Overview of LOIs

- We had a great selection of LOIs showing interest in innovating TDAQ for the future

- Along with specific thrusts, some general trends clearly emerged, which form the basis for possible TDAQ white papers:

    - Artificial Intelligence and Machine Learning in TDAQ
    - General innovations in TDAQ for next generation detectors
    - Readout technologies for future detectors

Proposed Common White Papers, and Associated LOIs

"Artificial Intelligence and Machine Learning in Trigger and DAQ" **68, 189, 190, 191, 249, 251**

- Big and popular topic, so depending on community feedback consider split to two white papers? e.g. "AI/ML at the edge" and "AI/ML in High-level triggers, event-filtering, and detector control"
- Work closely with **IF07** (especially on the former) and **computing frontier** (especially on the latter)

"Innovating Trigger and DAQ for the next generation of detectors" **184, 185, 186, 187, 251**

- Include TDAQ architecture and infrastructure (e.g. streaming DAQ), fast computation on heterogeneous computing, fast timing, trigger-aware ASIC development (work with IF07)
- Natural place for ideas not specific to AI/ML (e.g. fast tracking triggers, fast spectral analysis), and a way to tie-in needs of future experiments

"Readout technologies for future detectors" **168, 183, 188,**

- Include wireless readout, rad-hard links, multiplexed high-speed readout (**with IF07**)

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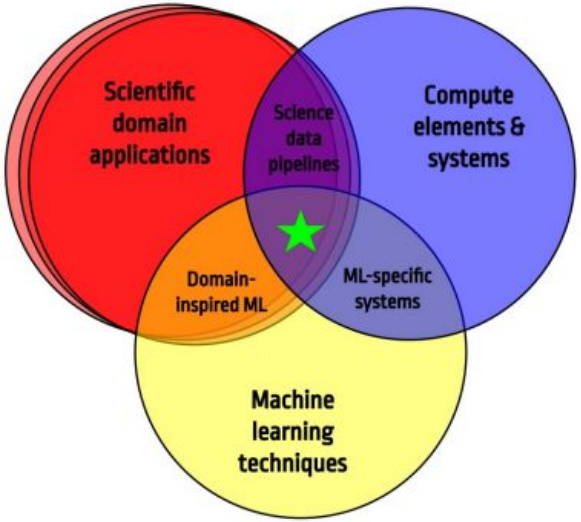
This area already has one white paper completed, as reported by Allison Deiana:

- **Applications and Techniques for Fast Machine Learning in Science**, arXiv:2110.13041

Content of White Paper



Contents

This report aims to summarize the progress in the community to understand how our scientific challenges overlap and where there are potential commonalities in data representations, ML approaches, and technology, including hardware and software platforms. Therefore, **the content of the report includes the following: descriptions of a number of different scientific domains including existing work and applications for embedded ML; potential overlaps across scientific domains in data representation or system constraints; and an overview of state-of-the-art techniques for efficient machine learning and compute platforms, both cutting-edge and speculative technologies**.

Other Proposed Common White Papers

“Innovating Trigger and DAQ for the next generation of detectors”

- Include TDAQ architecture and infrastructure (e.g. streaming DAQ), fast computation on heterogeneous computing, fast timing, trigger-aware ASIC development (work with IF07)
- “Self-driving” triggers
- Natural place for ideas not specific to AI/ML (e.g. fast tracking triggers, fast spectral analysis), and a way to tie-in needs of future experiments

General catch-all for innovative ideas. Interest by David Miller, Catrin Bernius, Rainer Bartoldus to coordinate and edit

“Readout technologies for future detectors”

- Include wireless readout, rad-hard links, multiplexed high-speed readout (**with IF07**)

Jinlong Zhang and Michael Begel kindly agree to help coordinate

Additional plans for contributed white papers

...that we know about!

- David Miller: “Self-driving data trigger, filtering, and acquisition systems for high-throughput physics facilities”
- Caterina Doglioni: “Real-time analysis (scouting/turbo stream/trigger level analysis) for the HL-LHC and beyond”
- Ashutosh Kotwal: “Track triggering using silicon detectors”

We are also contacting a few people who marked on our survey that they were interested in helping edit and organize white papers

Backup

Broad Timeline for white papers

- 19 Nov 2021: White paper kickoff for IF
  - Goal to share plans on white papers/advertise contributions
- 14-17 Feb 2022: White paper wrap-up
  - Part of CPAD workshop
  - Goal to get final push on white papers, particularly common efforts
- 15 March 2022: White paper final deadline

What happens after that

- Preliminary topical group reports: end of May 2022
- Preliminary frontier reports: end of June 2022
- Snowmass community summer study: 17-27 July 2022 @ UW-Seattle
    - This then leads into the final executive summaries and group/frontier reports, to be finished by ~Oct 2022

Experiment/detector-specific DAQ needs

- Project 8 DAQ (Oblath)
  - Real-time spectral analysis and tracking for trigger/data reduction (compute-intensive)
- Low-energy events in DUNE (Karagiorgi et al.)
  - Largely improved algorithms and data compression to extend low-energy sensitivity
- Belle-II upgrades (Vahsen et al)
  - DAQ upgrades underway for increased rates, timing upgrades envisioned for long-lived particle triggers(?)
- Optical instrumentation for EM calorimeters (Rutchi et al)
- Muon Scintillator R&D for Higgs factory/long-lived particle searches (Wang et al)
- Large Scintillator Arrays (Young et al)
  - Signal coincidence and >100 ps timing resolution (for position reco)

- TRACK-BASED TRIGGERS FOR EXOTIC SIGNATURES (Holmes et al., 8)

Real-time processing hardware

- System on chip/readout-integrated ASICs for triggering, feature extraction, self-calibration, etc. (Mostafanezhad et al., Miryala et al., Miller et al 132)
  - Miryala discusses some specific issues, like non-volatile memory and co-design
  - Miller highlights need for Multi-Processor SoC and FPGA for DL/AI needs

- FPGAs for ML inference (Miller et al 132, Herbst et al)

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TDAQ AI/ML

- Inference applications
  - Fast inference, heterogenous acceleration, ML as a service (Liu et al, Acosta Flechas et al.)
  - FPGA-based edge AI (R.Herbst et al.)
  - High speed instrumentation for front-end DAQ (Mostafanezhad et al)
- New techniques
  - Non Von-Neumann neuromorphic computing, non-volatile memory (Miryala et al.)
  - Self-driving trigger for automated/adaptive data selection (Miller et al)
  - Real-time adaptive deep-learning with embedded systems (Miller et al)
- And a number of experiment-focused needs...
  - (Sorry, too many to list!)

TDAQ techniques/algorithms

- Charged-particle track trigger algorithm in FPGA (Kotwal)
- Track-based triggers for exotic signatures (Holmes et al)
- Self-driving triggers for automated/adaptive data selection (Miller et al.)
- Real-time adaptive deep-learning with embedded systems (Miller et al.)
- Extending scalable readout systems (SRS) for better/more programmable triggering (Muller et al.)
- Asynchronous L1 triggers for Colliders (Acosta et al.)
- Non Von-Neumann neuromorphic computing (Miryala et al.)

- And again, a lot of items embedded in more experiment-specific LOIs (across EF, NF, RF, CF...)

Readout technologies

- Wireless data transfer for Colliders (Zhang et al.)
- Rad-hard photonics-based links (Zhang et al.)
- Wavelength division multiplexing (Garcia-Sciveres et al)

- And of course, also touches on a number of other LOIs (timing, electronics, etc.)