NP Roundtable meeting

Application of AI and ML for the Operation of NP Accelerator Facilities

M. Farkhondeh
DOE Office of Nuclear Physics

January 30, 2020

Zoom meeting

Current SC Priority Research Initiatives

The Office of the Under Secretary for Science has identified six initiatives of special priority for the DOE Office of Science. These initiatives are activities or areas of research that are inherently multidisciplinary—cutting across several scientific fields—or especially promising, or both. They include Advanced and Sustainable Energy, **Artificial Intelligence and Machine Learning**, **Genomics**, High Performance Computing, Large-Scale Scientific Instrumentation, and Quantum Information Science. Source: Office of Science web page … More initiatives will be proposed in FY 2021 budget.

Artificial Intelligence and Machine Learning

AI: An ideal tool for deriving new insights from analysis of very large data sets. AI becomes more useful as the speed and computational power of today's supercomputers grows.

ML: Branch of AI

- Learn from data (training) to act in environments
- Ability to learn without being explicitly programmed

DL: Deep Learning Branch of ML

- Learning based on Deep Neural Networks

Recent and planned SC AI/ML Workshops

- **ASCR:** Advanced Scientific Computing Research **:** July – October 2019, ASCR along with ANL, LBNL, and ORNL hosted four "AI for Science" town hall meetings. …community input on scientific opportunities and challenges in the era of convergence of high performance computing and AI. https://www.ornl.gov/event/ai-science-town-hall and https://www.hpcwire.com/2019/08/02/ai-for-science-town-hall-series-kicks-off-at-argonne/
- **BES-** Basic Energy Science: 2019 AI/ML and Data Roundtable meeting: http://www.cvent.com/events/2019-ai-ml-and-data-roundtable/event-summary-187d00a5ce634be2b66852af45b08386.aspx?i=92964cc9-17d6-4a3c-9715-5a46f8bd2339
- **FES:** Fusion Energy Science- workshop on "Advancing Fusion with Machine Learning" on April 30 – May 2, 2019, … priority research opportunities in ML/AI…. https://www.orau.gov/advancingfusion2019/
- **NP**: Nuclear Physics
  - "AI for Nuclear Physics" Workshop at TJNAF on March 4-6, 2020. https://www.jlab.org/conference/AI2020/
  - "Application of AI and ML in operation of NP accelerator User facilities", January 30, 2020 Zoom meeting

SC Priority Research Initiative

TJNAF
AI and ML Workshop

- “AI for Nuclear Physics” Workshop at TJNAF on March 4-6, 2020.
  https://www.jlab.org/conference/AI2020/

SC Priority Research Initiative

- Purpose of this Roundtable:
  - Exchange of information, identify current areas of activity in the topic and identify opportunities for NP to play a role in this area in the future.
  - Inform our community of current and future opportunities relevant to application of AI/ML in improving efficiencies in operation of accelerator facilities.

- Topics to present and discuss in this Roundtable:
  - Current supported activities at your user facility in ML and AI specific to accelerator and operation of current and future user facility; and
  - Ideas on future opportunities or plans for ML/AI for improving accelerator operations at your institution.

Machine Learning / Artificial Intelligence

Executive Office of the President (EOP) Priority

- Major U.S. Government initiative is in planning stage

- **FY 2020 SC enacted budget - $71M** for AI/ML**,** NP did not receive specific AI/ML funding in the FY20 enacted but is part of the initiative. $71M in AI funding for ASCR, BES, BER, FES, and HEP.
  - AI/ML for accelerator operation will be part of the NP FOA for accelerator R&D
  - Possibility of either or both NP and SC FY 2020 FOA in AI/ML
- **ASCR FOA:** Advanced Scientific Computing: AI/ML FOA should publish soon and open to all.
- **FY 2021 Request-** NP is part of the FY 2021 AI/ML budget request. There may be AI/ML specific FOA for NP in FY 2021.

Future of Machine Learning in Science Discoveries

Draft AGENDA

2020 NP Roundtable Zoom Meeting on Machine Learning and Artificial Intelligence (ML/AI) for NP Accelerator Facilities

Thursday, January 30, 2020

2:00-5:30 pm ET

Time	Dur.* (min)	Presenter	Institution	Presentation Title	Comments
2:00 PM	15	M. Farkhondeh	DOE NP	Introduction	slides
2:15 PM	25	Chris Tennant	TJNAF	AI at Jefferson Lab	slides
2:40 PM	20	Lasitha Vidyaratne / Khan Iftekharuddin	ODU	Application of Machine Learning and Deep Learning for (Real-Time) SRF Cavity Fault Detection and Classification	slides
3:00 PM	25	Steve Lidia	MSU/FRIB	Towards AI enabled high-power heavy ion facility with confidence	slides
3:25 PM	20	Clay Dickerson	ANL-ATLAS	Opportunities for ML/AI at ATLAS	slides
3:45 PM	15	Brahim Mostapha	ANL	Potential ML/AI Applications for Accelerator Design Optimization	slides
4:00 PM	10	**Break**			
4:10 PM	20	Damon Todd	LBNL/88-inch	Superconducting ECR ion sources: an untapped application of artificial intelligence and its superhuman patience	slides
4:30 PM	20	Philip Dyer	BNL-RHIC	Machine Learning Efforts within BNL C-AD Controls Group	slides
4:50 PM	10	Robert Burch	TAMU	Utilizing ML/AI to optimize the day to day operations of the Cyclotron Institute's accelerator facilities	Verbal comments
5:00 PM	25	All		Discussion	
5:25 PM	5	Closing Remarks		**Talk durations include 5 minutes Q/A.**	
5:30 PM		**Adjourn**			
	*** : Talk duration includes 5 minutes Q/A.**				

Join from PC, Mac, Linux, iOS or Android: https://science.zoom.us/j/553737163
+1 646 876 9923 (US Toll) or +1 669 900 6833 (US Toll)
Meeting ID: 553 737 163

END

Future of Machine Learning in Science Discoveries

DOE research challenges touch all areas of AI

Data	Learning	Scalability	Assurance	Workflow
				
• Experimental design • Data curation and validation • Compressed sensing • Facilities operation and control	• Physics informed • Reinforcement learning • Adversarial networks • Representation learning and multi-modal data • "Foundational math" of learning	• Algorithms, complexity and convergence • Levels of parallelization • Mixed precision arithmetic • Communication • Implementations on accelerated-node hardware	• Uncertainty quantification • Explainability and interpretability • Validation and verification • Causal inference	• Edge computing • Compression • Online learning • Federated learning • Infrastructure • Augmented intelligence • Human-computer interface

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Source: DOE Office of Science.

Machine Learning for Particle Accelerators

Intersections between real-time machine learning, control and optimization of complex systems

ML-based solutions to challenges encountered in particle accelerators are now under development and yielding promising results.

https://conf.slac.stanford.edu/icfa-ml-2018

Anomaly detection and machine protection:

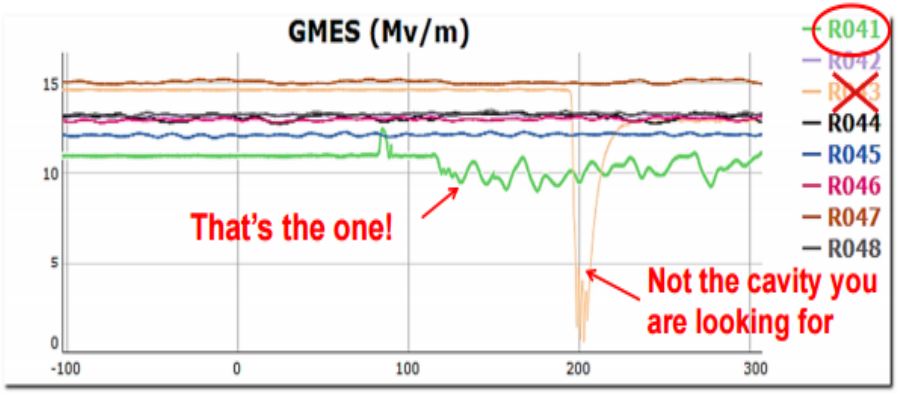
SRF Cavity Fault Classification Using Machine Learning at CEBAF at Jefferson Laboratory

- Apply Deep Learning to fault classification problem
- Recent collaboration with Old Dominion University provides expertise and resources to focus on more complex problems:
  - First unstable cavity identification
  - Trip prediction and avoidance
    1. Predict if a fault may occur
    2. Predict a type of a fault
- Create an application for the operators to suggest action based on fault classification and cavity identification
- New collaboration with SLAC will tie our trip prediction mechanism into a ML based modeling and control project for LCLS-II

Anna Solopova[1], A. Carpenter[1], T. Powers[1], Y. Roblin[1], C. Tennant[1], K. Iftekharuddin[2], L. Vidyaratne[2]

[1]Jefferson Lab [2]Old Dominion University

Cavity losing gradient first is not always the offending one!



Losing energy in the wrong cavities.

10th International Particle Accelerator Conference (IPAC19)
https://ipac19.org

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Slide Courtesy of Dr. Gulshan Rai

Future of Machine Learning in Science Discoveries

A computer Go program based on deep neural networks defeats a human professional player to achieve one of the grand challenges of artificial intelligence, a feat previously thought to be at least a decade away. (Nature Article 16961, Jan 27, 2016).

Like other machine learning algorithms, programs like Alpha Go have been trained on previous human and machine games, but the new player in the field – Alpha Zero – trains on no other input but the rules of the game, from which it then plays itself to train.

Could this type of algorithm help accelerate scientific discoveries based on just the rules of physics?

"… We expect unsupervised learning to become far more important in the longer term. Human and animal learning is largely unsupervised… Ultimately, major progress in artificial intelligence will come about through systems that combine representation learning with complex reasoning…"