Award #: 1931561, 1931469

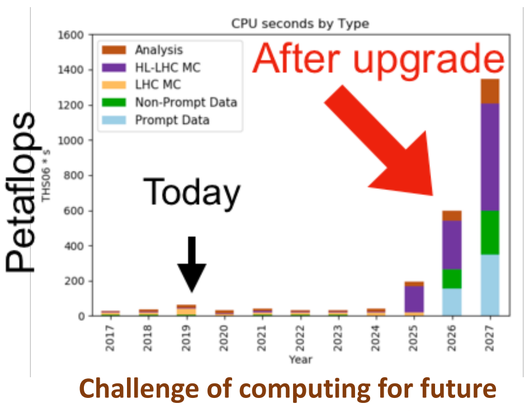
CSSI Collaborative Research: Frameworks: Machine Learning and FPGA computing for real-time applications in big-data physics experiments

PIs: Eliu Huerta[1] Erik Katsavounidis[2]; co-Pis: Philip Harris[2] Daniel S. Katz[1] Volodymyr Kindratenko[1]
[1]National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign
[2]Massachusetts Institute of Technology

Vision To promote artificial intelligence (AI) as the standard tool for computing and data analytics in big-data physics experiments

Mission Accelerate the convergence of AI and extreme-scale computing to design interpretable, trustworthy and reproduceable physics-inspired AI models and optimization schemes for big-data physics experiments; advance GPU-accelerated, neuromorphic chips and field programmable gate arrays computing for real-time AI learning and inference analyses

Summary



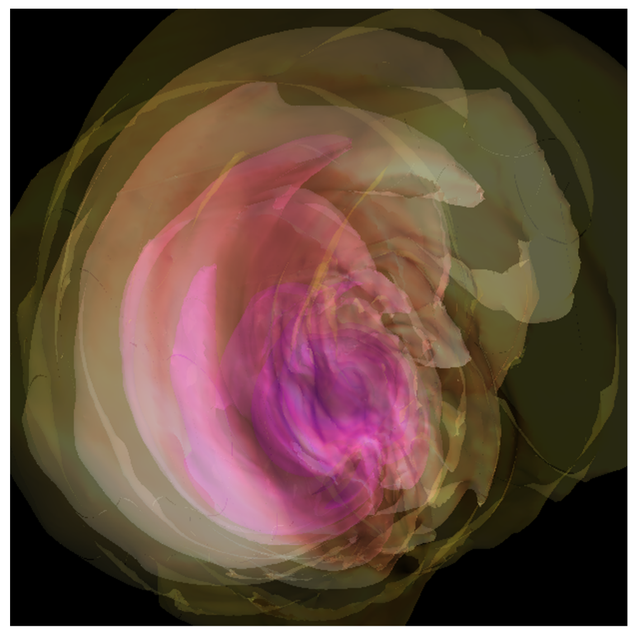
Challenge of computing for future LHC experiment in petaflops

High Energy Physics (HEP) and Gravitational Wave (GW) Astrophysics share a common thread of computational grand challenges

Investments in detector upgrades to existing facilities (LHC and LIGO) will enhance their science reach and potential for physics discovery

A commensurate investment in R&D to harness innovation in signal-processing algorithms and accelerated computing is critical to realize the science goals of these experiments in the big-data era

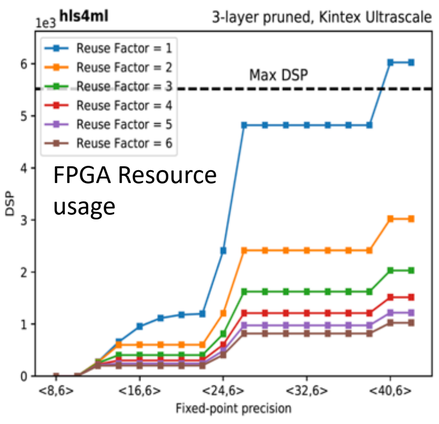
Multi-institutional and interdisciplinary program to accelerate the design and deployment of accelerated AI tools to process large-volume and high-speed data sets



Neutron star merger © NCSA/University of Illinois

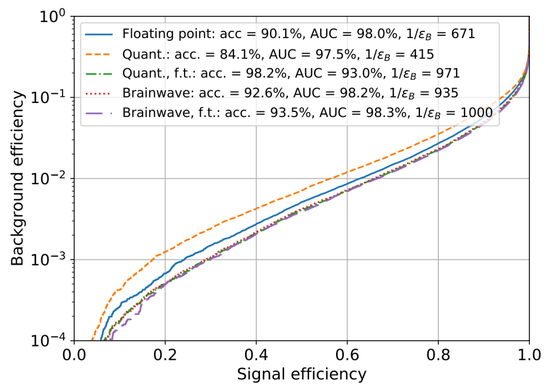
Examples

HLS4ML: An FPGA based compiler for deep neural network acceleration



P. Harris *et al* Neurips Physics '19 (74)

Fixed point Resnet50 FPGA-based implementation of Top quark Signal Selection using Microsoft Brainwave FPGA cluster

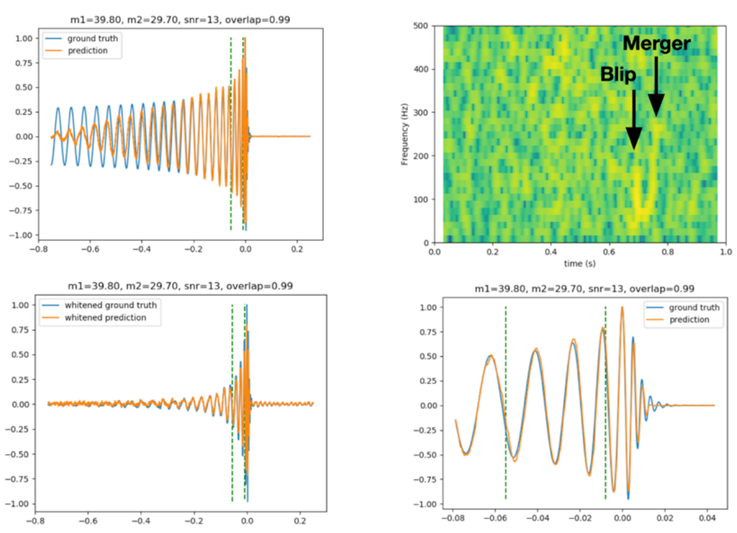


P. Harris *et* al Neurips Physics '19 (64)

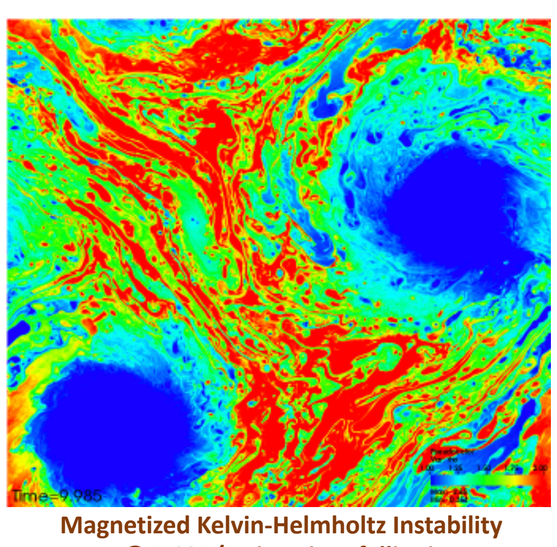
FPGA resource and latency optimization

Model	Initiation Interval	Accuracy	Latency	DSP	BRAM	FF	LUT
MNIST dense model	128	0.97	2.6 μs	21%	45%	12%	33%
MNIST binary dense model	128	0.93	2.6 μs	0%	33%	7%	39%
MNIST ternary dense model	128	0.95	2.6 μs	0%	33%	7%	40%
MNIST dense model, 95% pruned with zero suppression	128	0.96	2.8 μs	1%	34%	13%	164%
MNIST dense model	4096	0.97	68.1 μs	1%	66%	27%	83%
MNIST dense model, 95% pruned with zero suppression	4096	0.96	82.1 μs	0%	34%	9%	25%

Denoise and deglitch waveform signals embedded in advanced LIGO data that are contaminated by real noise anomalies
W Wei & EA Huerta, Physics Letters B 800, 135081 (2020)



Accelerate the modeling of multi-messenger sources using AI to learn and model magnetohydrodynamics turbulence
S Rosofsky & EA Huerta, Accepted to *Phys. Rev.* D



Magnetized Kelvin-Helmholtz Instability © NCSA/University of Illinois

Education, Outreach and Training AI Program

Workshops and Tutorials in Accelerated AI

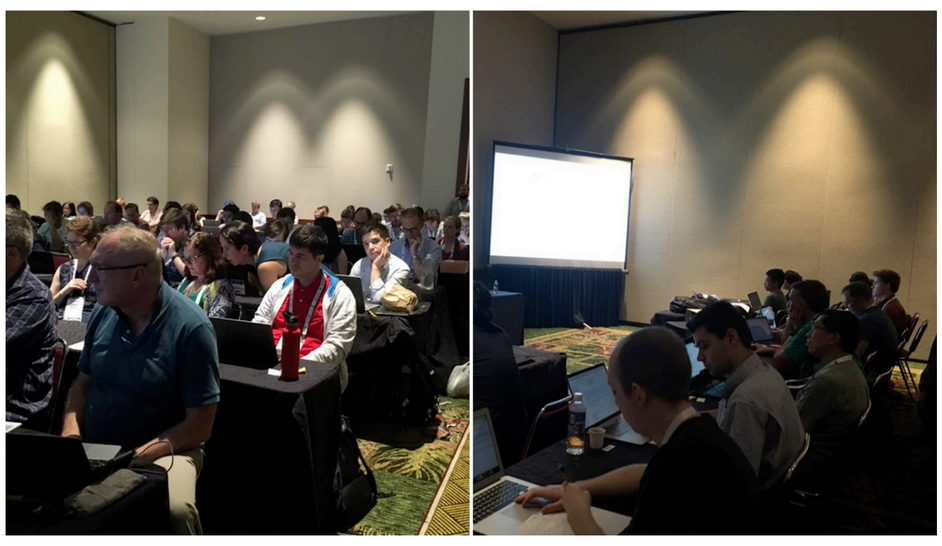
Hands-on Machine Learning for Astronomers: Artificial Intelligence for Big-Data Astronomy, 235th Meeting of the American Astronomical Society, Honolulu, Hawaii, 4-8 January 2020 (Workshop was oversubscribed. Open source code available at https://sites.google.com/view/aas235mlworkshop/home

The Center for Artificial Intelligence Innovation at the University of Illinois offers weekly hands-on tutorials and hackathons for students, postdocs and staff. NVIDIA and IBM are co-sponsors of this training and education program http://www.ncsa.illinois.edu/enabling/data/deep_learning/news/hal_spring20

Upcoming Workshop in Accelerated AI for Big-data Physics Experiments
Big Ten Center @ Chicago, 23-27 July 2020
http://www.ncsa.illinois.edu/Conferences/AcceleratedAINCSA/

Caltech IPAC @caltechipac · Jan 7

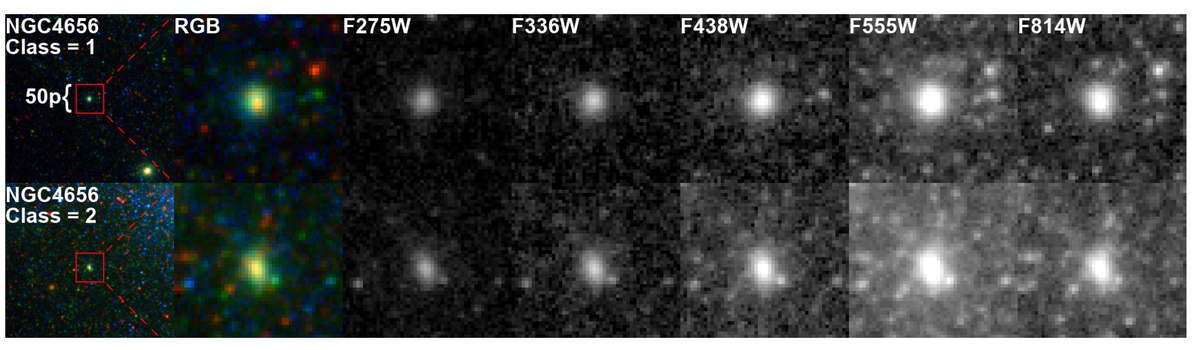
GREAT turnout for @astrofaisst's hands-on #MachineLearning for astronomers workshop! The overflow crowd is learning how to use #ArtificialIntelligence for #BigData #astronomy. #AAS235



Cross-pollinating efforts

The tools designed in this project have been seamlessly applied to tackle big-data challenges in astronomy

Astronomy: novel AI tools to classify compact star clusters detected in Hubble Space telescope UV-optical imaging of nearby spiral galaxies. These AI tools have outperformed human classification accuracy for the first time (W Wei, EA Huerta, et al.. Accepted to MNRAs)



Acknowledgements We acknowledge NSF awards OAC-1931561, OAC-1931469, and the NSF MRI OAC-1725729 Hardware Accelerated Learning (HAL) deep learning machine at NCSA. We obtained access to resources in the Extreme Science and Engineering Discovery Environment (XSEDE) and Argonne Leadership Computing Facility through peer-review awards TG-PHY160053 and DE-AC02-06CH11357.