Algorithms for Reconstruction and Analysis

Nhan Tran for ARA
Dec 2, 2019

ARA

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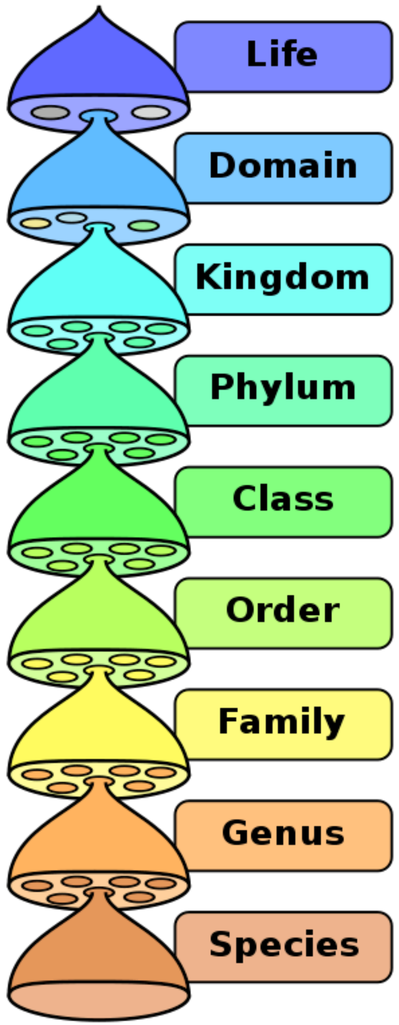
ARA



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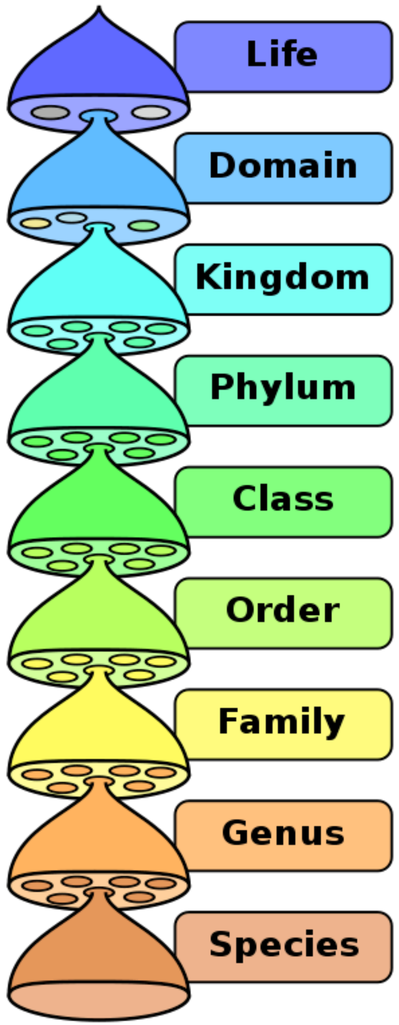

Executive Branch

DOE

Office of Science

Fermilab

CD

SCD

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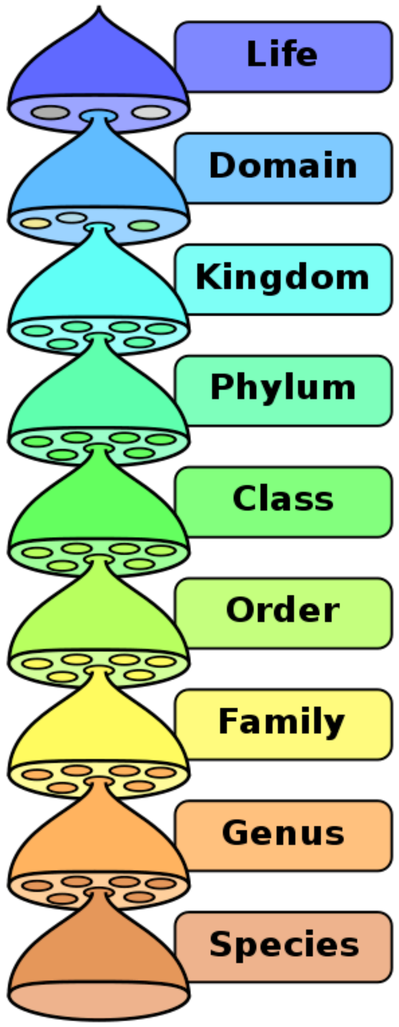

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ALGORITHMS RECONSTURCITON & ANALYSIS (ARA)

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S. Berkman
G. Cerati
J Goncalves Cadeira
L. Gray
A. Hall
R. Kutshcke
K. Lato (on-call)
B. Nord
K. Pedro
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M. Wospakrik
(E. Snider)
(G. Perdue)

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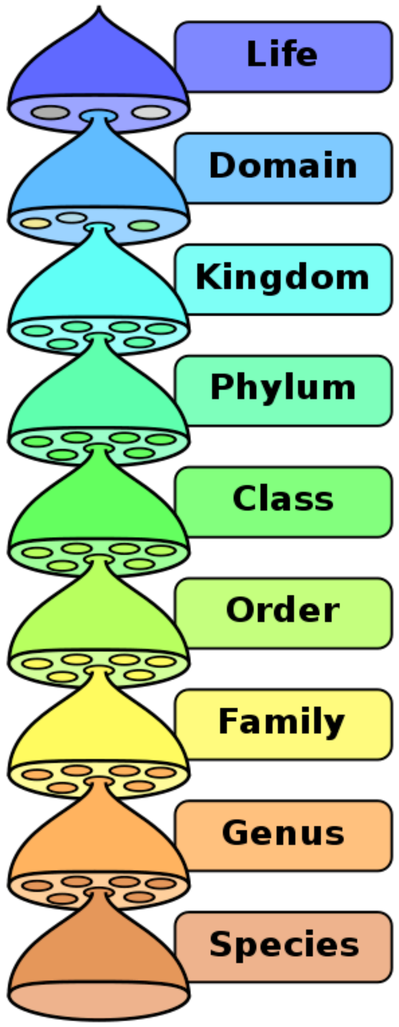

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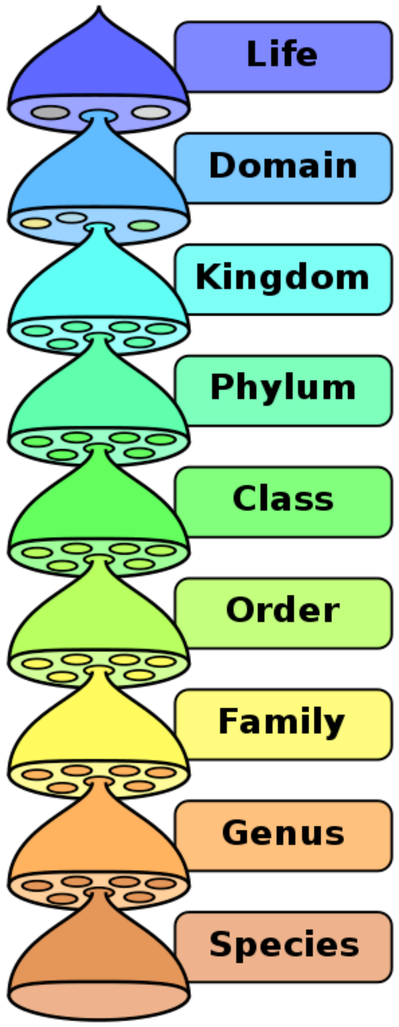

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ARA is a nearctic genus of scientists…

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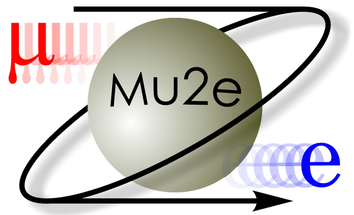
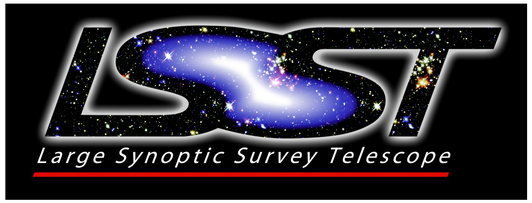
ARA - algorithms for reconstruction and analysis

- A wide variety of applications and techniques for reconstruction and analysis
  - Making new algorithms
  - Making current algorithms more (computationally) efficient
  - Connecting algorithms in software framework/pipeline





… and counting!

MIR (→ ARA) highlights

- neutrinos/mu2e (Berkman, Cerati, Kutschke, Perdue, Snider, Wospakrik, Wang)
  - LArSoft:
    - **Large-scale data production campaigns for ProtoDUNE, ICARUS, and MicroBooNE**
    - Making code thread-safe (large workflows and improved efficiency), migrate to GitHub
    - LArSoft workshop well-attended by SCD and neutrino community
  - SciDAC work: implemented improvements in hit finder with parallelization/vectorization; SBNFit fitting framework on HPC
  - General development, support, coordination of reconstruction across neutrinos
    - e.g. First data-driven energy calibration of μBooNE with $\pi^0 \rightarrow \gamma\gamma$ (joint with ND)

https://arxiv.org/abs/1910.02166

- cosmic (Nord, Caldiera)

https://arxiv.org/abs/1810.01483

  - New study in deploying AI for CMB de-noising
    Papers in review: galaxy mergers, strong lens regression, SZ signal cluster detection
  - LDRD for deep learning pipelines in HEP; JTFI grant for telescope scheduling/controls

MIR (→ ARA) highlights

- CMS/LHC (Cerati, Gray, Hall, Pedro, Tran)
  - mkFit parallelized track fitter – adapting Kalman Track fitter to SIMD architectures *https://arxiv.org/abs/1906.11744*
  - Graph Neural Networks for Calorimetery LDRD: new ML architectures to learn representations from higher dimensional non-Euclidean detector inputs
  - Accelerated machine learning as a Service using FPGAs with Microsoft *https://arxiv.org/abs/1904.08986*
  - COFFEA - an efficient columnar analysis framework

- High velocity AI grant (DOE) to accelerate inference and training for uncertainty quantification
- ExaTrkX project kicking off: advanced track finding and pattern recognition with ML, building off of successful HepTrkX

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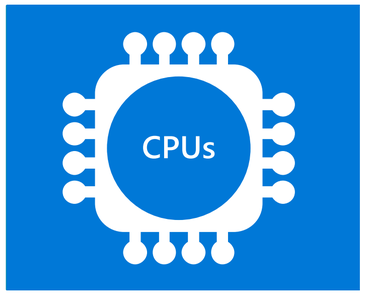
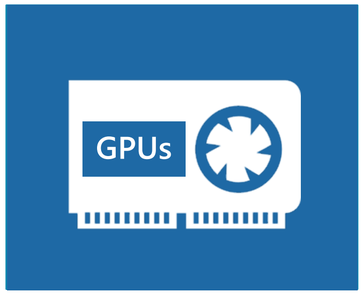
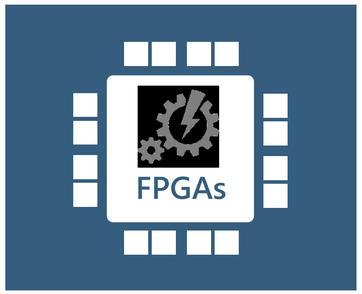
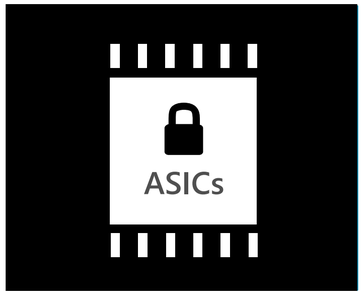
- Considerations:
  - Physics performance (and knowledge)
  - Efficient algorithms for modern computing architectures
    - Modern chip architectures, multi-core/thread, heterogeneity
  - Ease and accessibility

Computing architecture evolution

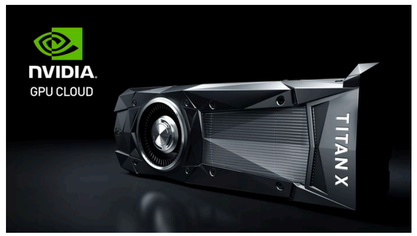


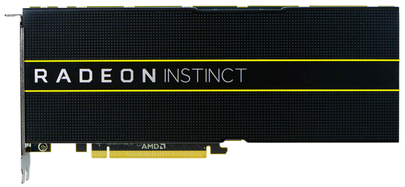


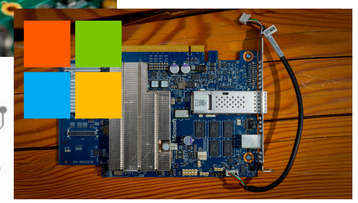


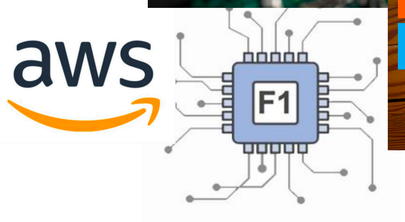


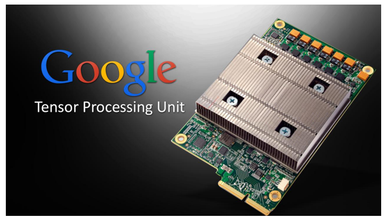
FLEXIBILITY → EFFICIENCY



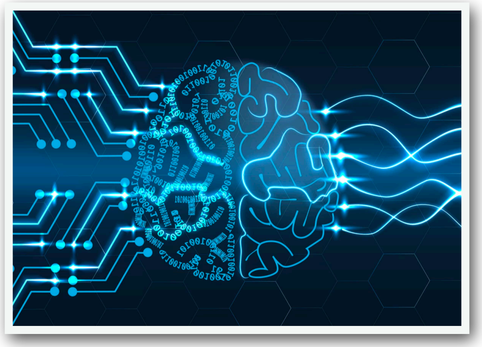




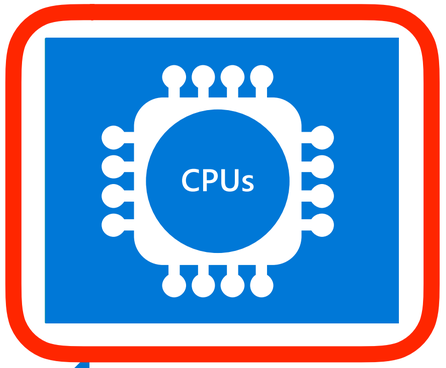




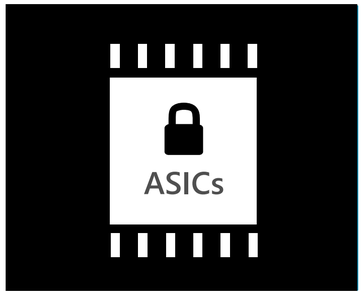
Advances in heterogeneous computing driven by **machine learning**



Computing architecture evolution



Still the workhorse…
Many active projects showing large gains optimizing "traditional" hardware



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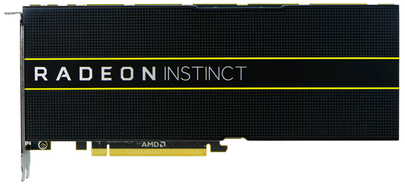

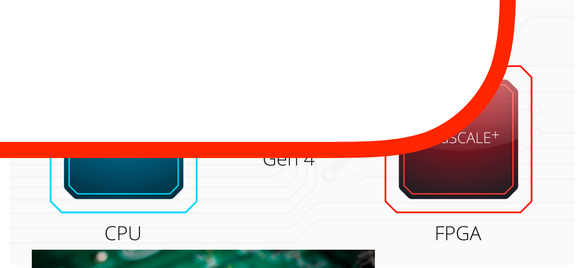

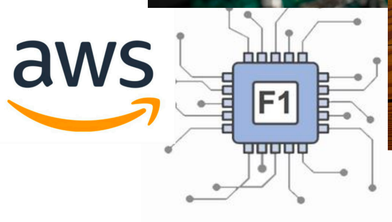

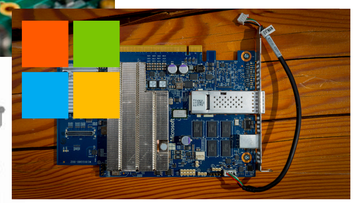

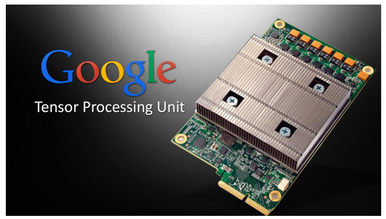

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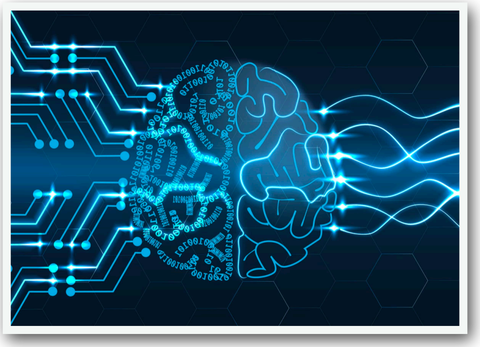


Computing architecture evolution

We should understand how to utilize HPC systems … but let's understand what our optimal solution is and if possible, how we can use HPC resources. (personal opinion)

Optimization approach

Re-engineer physics algorithms for new hardware

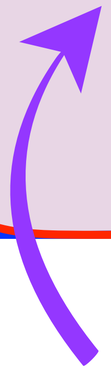
Language: OpenCL, OpenMP, HLS, …?

Hardware: CPU, FPGA, GPU

Re-cast physics problem as a machine learning problem

Language: C++, Python (TensorFlow, PyTorch,…)

Hardware: CPU, FPGA, GPU, ASIC



Is there a way to have the best of both worlds?

Opportunities and challenges ahead!