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AI and High-Performance Computing: Accelerating the Future of Mobility

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Oak Ridge National Laboratory

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

About me

- Lead of Data and AI Section – 50 researchers and engineers
- Research in intelligent agents, machine learning, swarming technology, genetic algorithms, deep learning on high performance, quantum, and neuromorphic computers.
- 160+ research papers, 19 patents, 4 R&D 100 awards, 3 Gordon Bell Finalists
- Married 36 years, a son in the US Navy, and a daughter who works at ORNL
- Love/Hate relationship with my 1966 GTO (since 1980)

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Machine Learning and AI – It's a wild ride

- AI is everywhere, everyone is an expert
- Great opportunities with huge challenges
- A pivotal time for AI in mobility

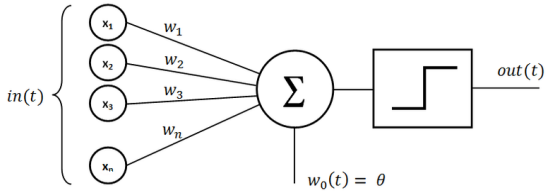
Brief History of AI – The Perceptron – Model the Brain

1943 - The Perceptron – a simple neuron and synapse system

1958 - Perceptron machine created

Start of the first AI revolution

Could not do XOR, the Perceptron is dead



Perceptron

McCulloch, W; Pitts, W (1943). "A Logical Calculus of Ideas Immanent in Nervous Activity". Bulletin of Mathematical Biophysics. 5: 115–133

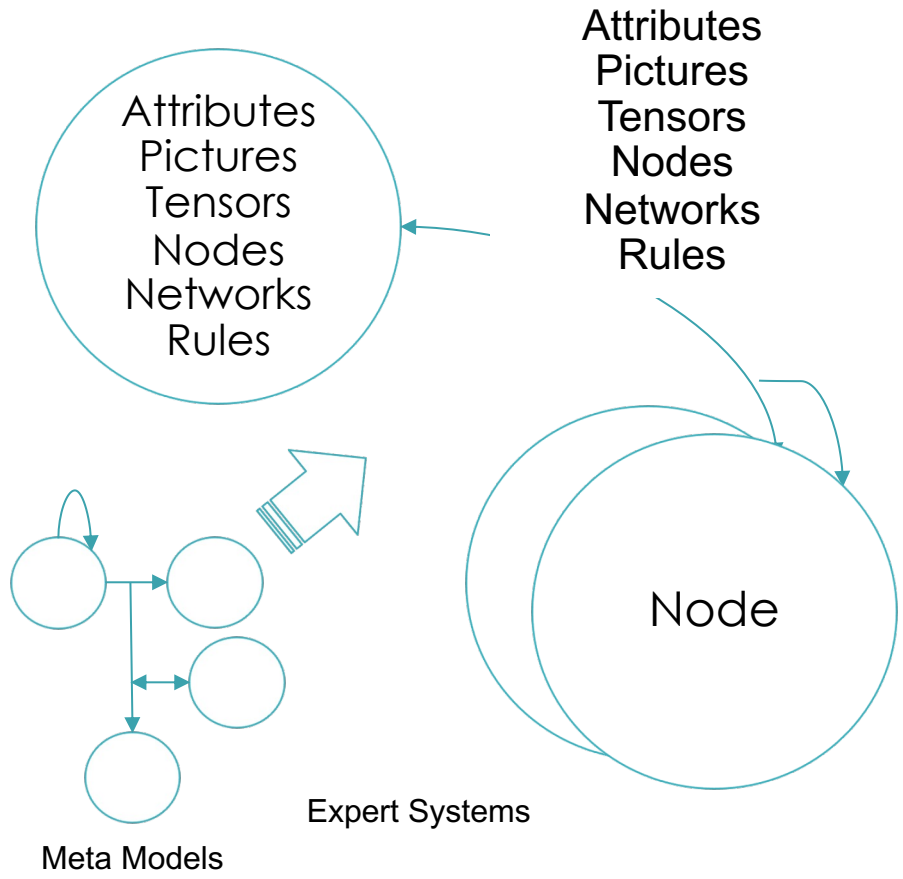
Rosenblatt, Frank (1957). "The Perceptron—a perceiving and recognizing automaton". Report 85-460-1. Cornell Aeronautical Laboratory.

Expert System – Follow the rules

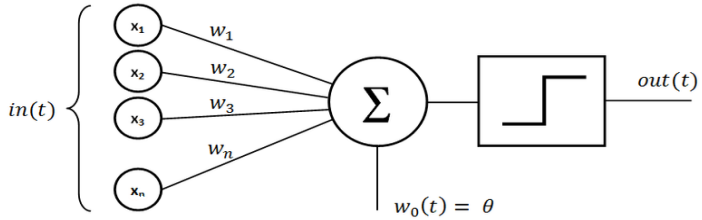
Represent knowledge in graphs and rules

With enough knowledge and rules a computer should be able to think?

Define a representation and rules for an employee?

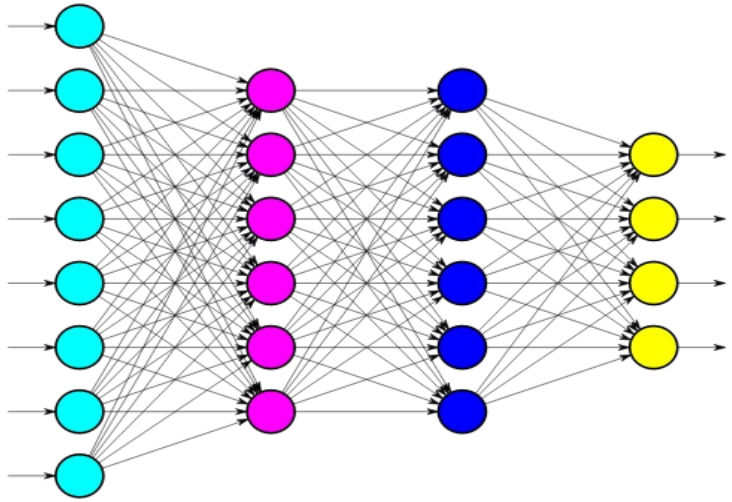


The Perceptron and GPUs

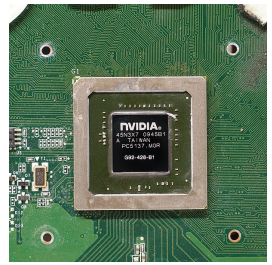


Perceptron

- Fast simulation of brain structure Neural Network
- Train on examples (people's faces)
- Predict based on new data
- Revolutionary results, new AI revolution



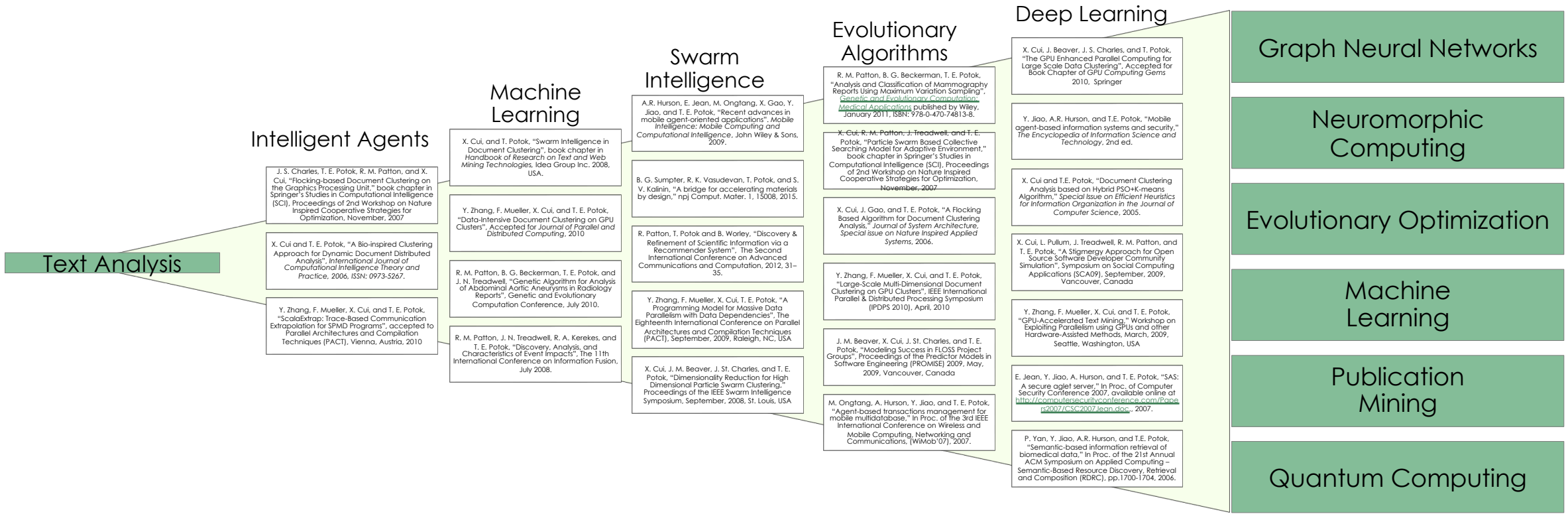
Deep Learning Network

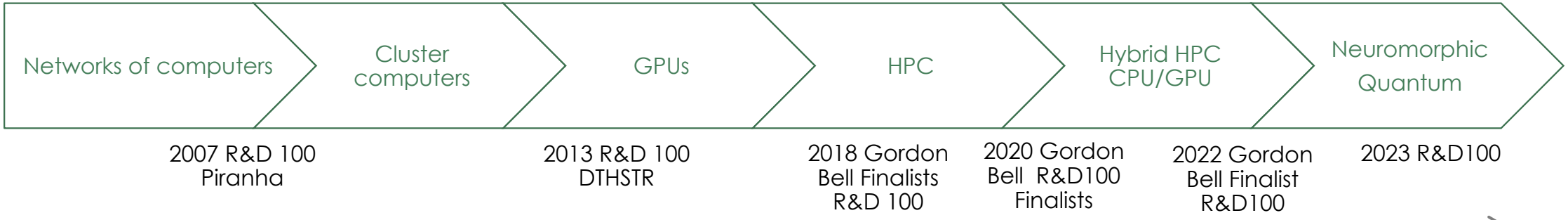


GPU

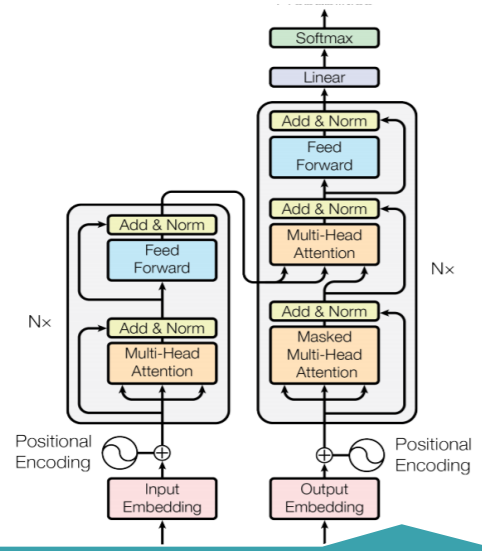
AI/ML Background

Army NSA SOCOM FBI NRO DIA Marines Navy CIA DHS DOE NCTC OSD MDA





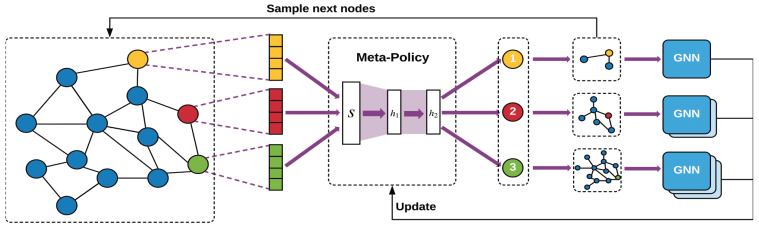
New AI Trends



Large Language Model

- What word comes next?

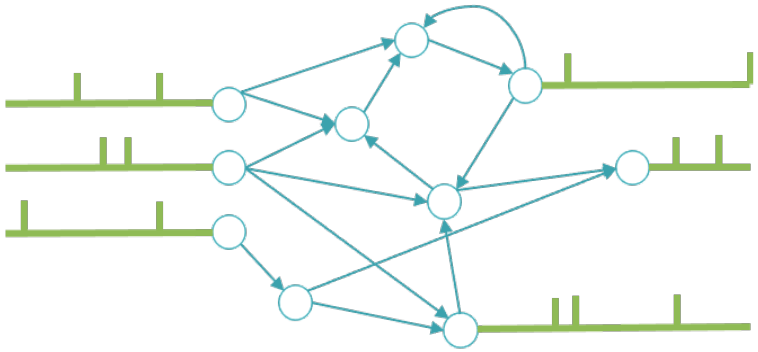
Vaswani, A., "Attention Is All You Need", arXiv e-prints, 2017.



Learning from graphs

- Does this person fit in my social network?

Kwei-Herng Lai, et al. 2020. Policy-GNN: Aggregation Optimization for Graph Neural Networks.(KDD '20).

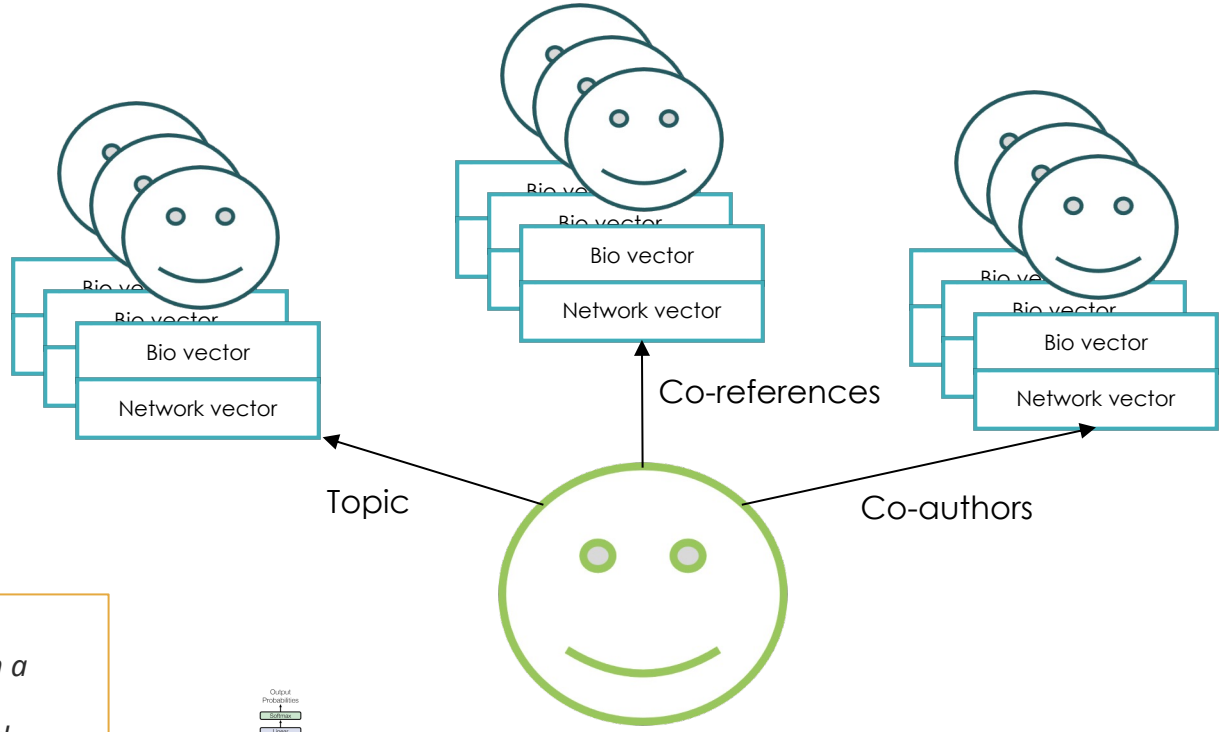


Brain Inspired Computing

- Native AI at very low power

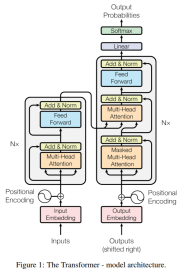
Catherine Schuman

Example: Representing an employee



Biography

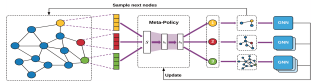
"My name is Alex Drysdale and I am a Junior Web Developer for Oswald Technologies. I am an accomplished coder and programmer, and I enjoy using my skills to contribute to the exciting technological advances that happen every day at Oswald Tech. I graduated from the California Institute of Technology in 2016 with a bachelor's degree in software development. While in school, I earned the 2015 Edmund Gains Award for my exemplary academic performance and leadership skills."



Large Language Model

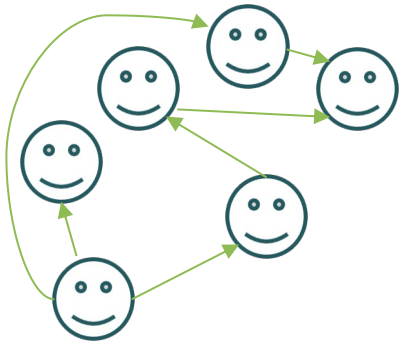
Bio vector

Network vector



Graph Neural Network

Professional Network

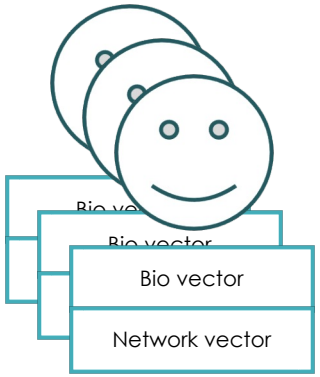


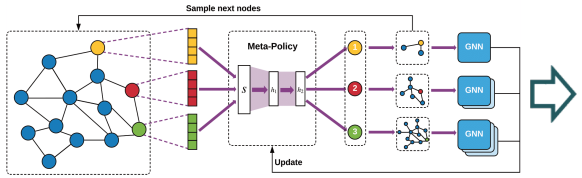
Example: Using the network

Bio vector

Network vector

Smoky Mountain Mobility





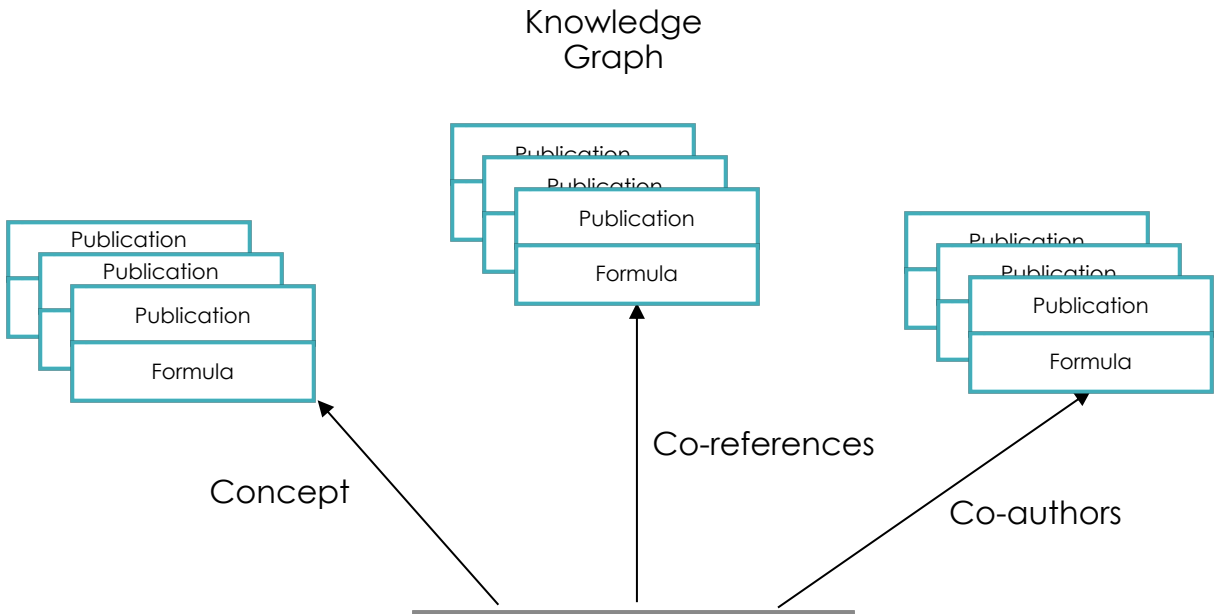
Graph Neural Network

Is this person a fit for SMMC?

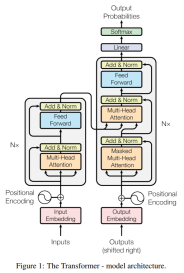
What sessions would be of interest?

Who should they meet?

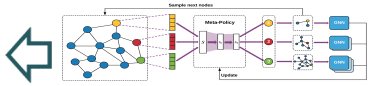
Nine Yards – Material Science



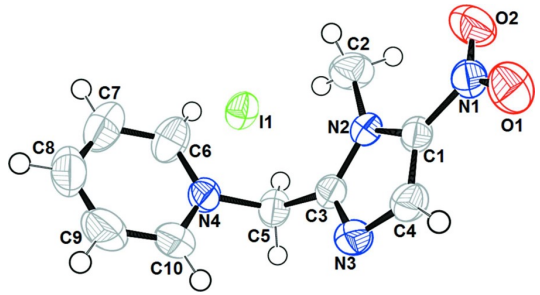
In the title salt, $C_{10}H_{11}N_4O_2^+\cdot I^-$, the asymmetric unit consists of a pyridinium cation bearning a (1-methyl-5-nitro-1*H*-imidazol-2-yl)methyl group at the N position and an iodide anion. The imidazole ring is quasiplanar, with a maxiumum deviation of 0.0032 (16) Å, and forms a dihedral angle of 67.39 (6)° with the plane of the pyridinium ring. The crystal packing can be described as alternating zigzag layers of cations parallel to the (001) plane, which are sandwiched by the iodide ions. The structure features two types of hydrogen bonds (C—H···O and C—H···I), *viz*. cation–anion and cation–cation, which lead to the form ation of a three-dimensional network.



Large Language Model



Graph Neural Network



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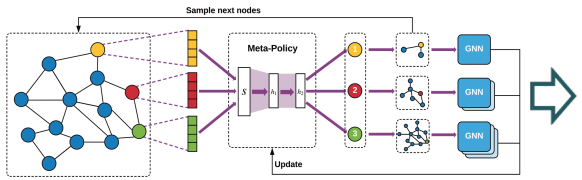
Generative AI and Knowledge Graph

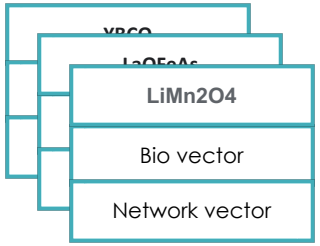
C10 H11 I N4 O2

Publication

Formula



Enhanced Storage Composites



Graph Neural Network

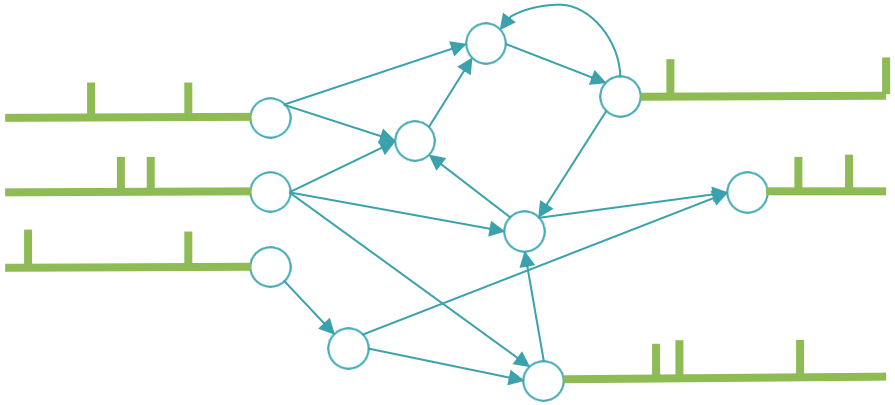
Will this material produce a better batteries?

Under what conditions can this battery operate?

Can it be used to power a vehicle?

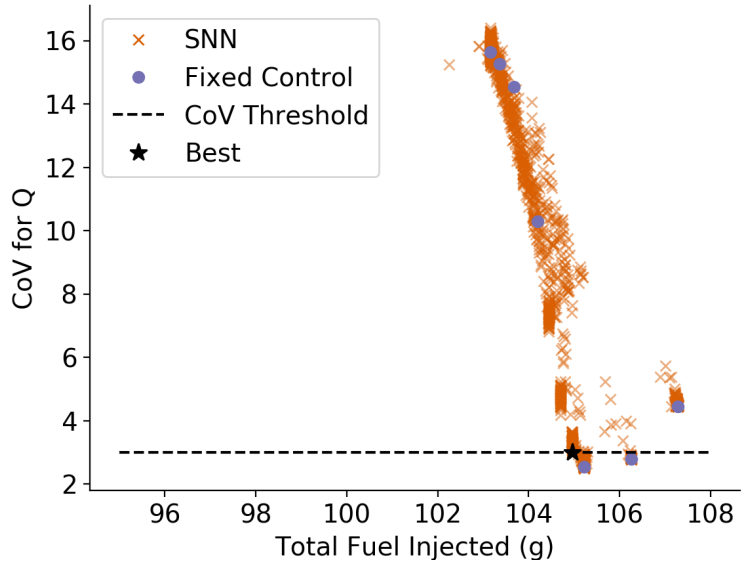
Neuromorphic Computing: Back to the perceptron in hardware - Engine Control for Fuel Efficiency

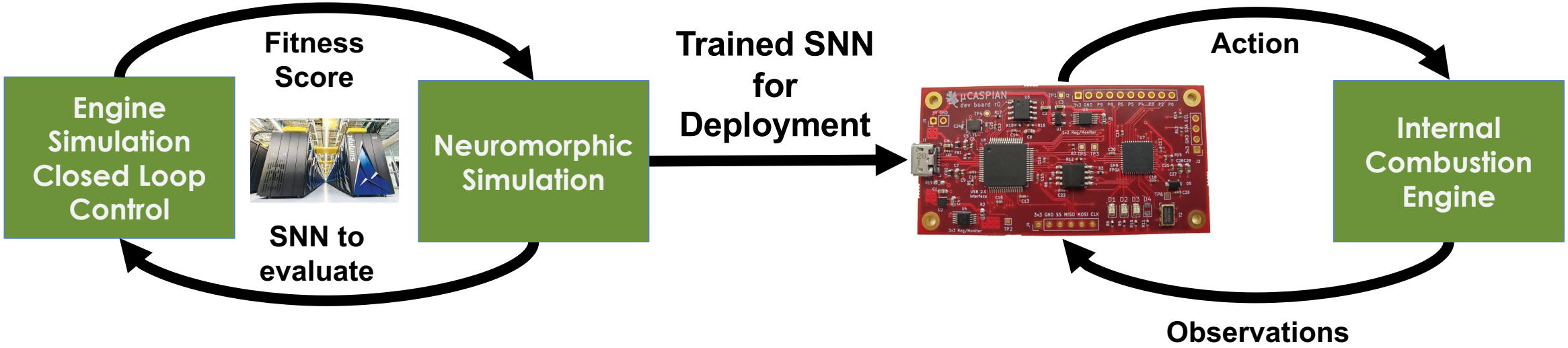
Engine Signal



Fuel Control

Spiking Neural Network (SNN)





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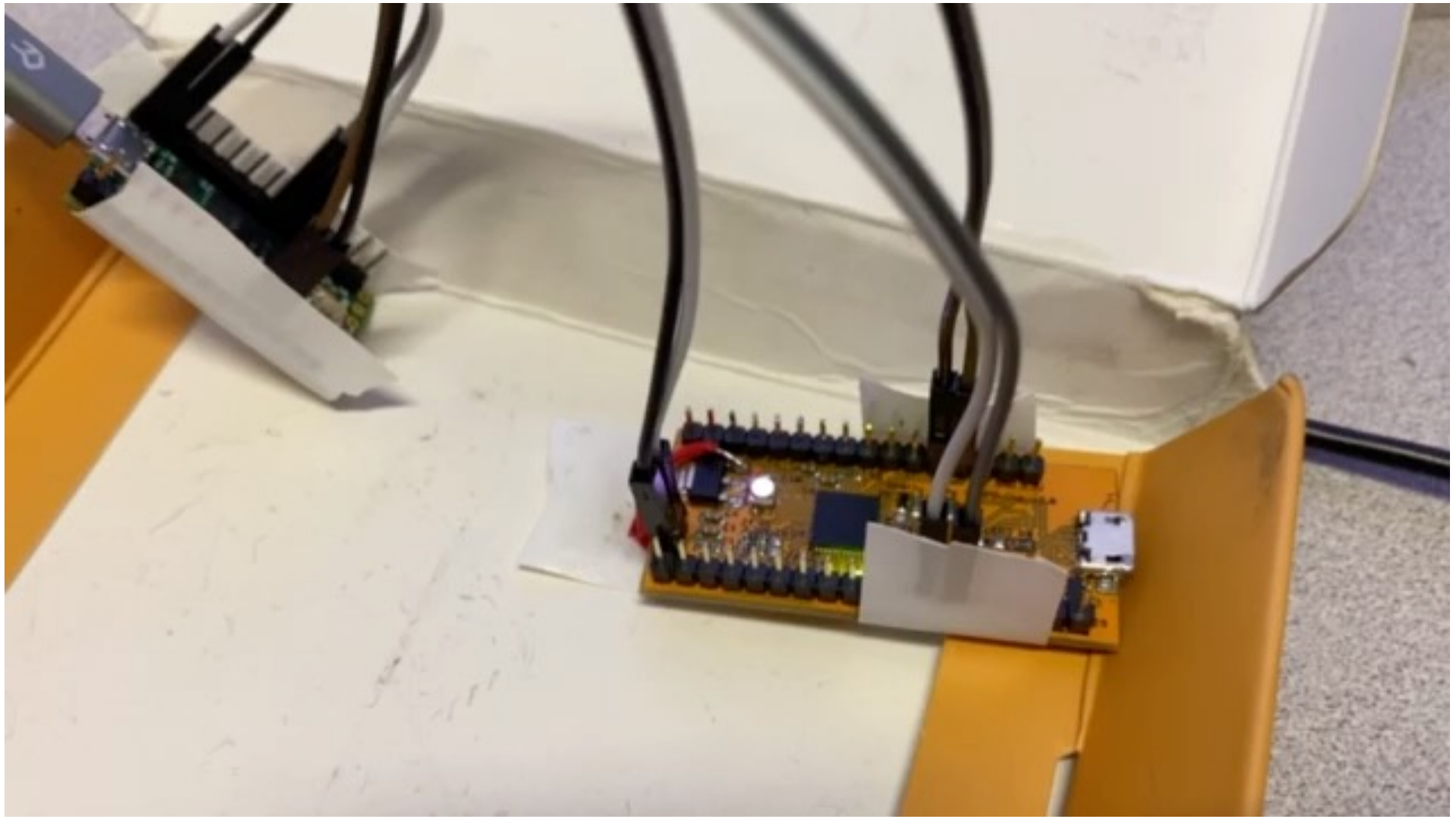
Catherine D. Schuman, Steven R. Young, J. Parker Mitchell, J. Travis Johnston, Derek Rose, Bryan P. Maldonado, Brian C. Kaul. "Low Size, Weight, and Power Neuromorphic Computing to Improve Combustion Engine Efficiency." International Conference on Green and Sustainable Computing 2020. Accepted.

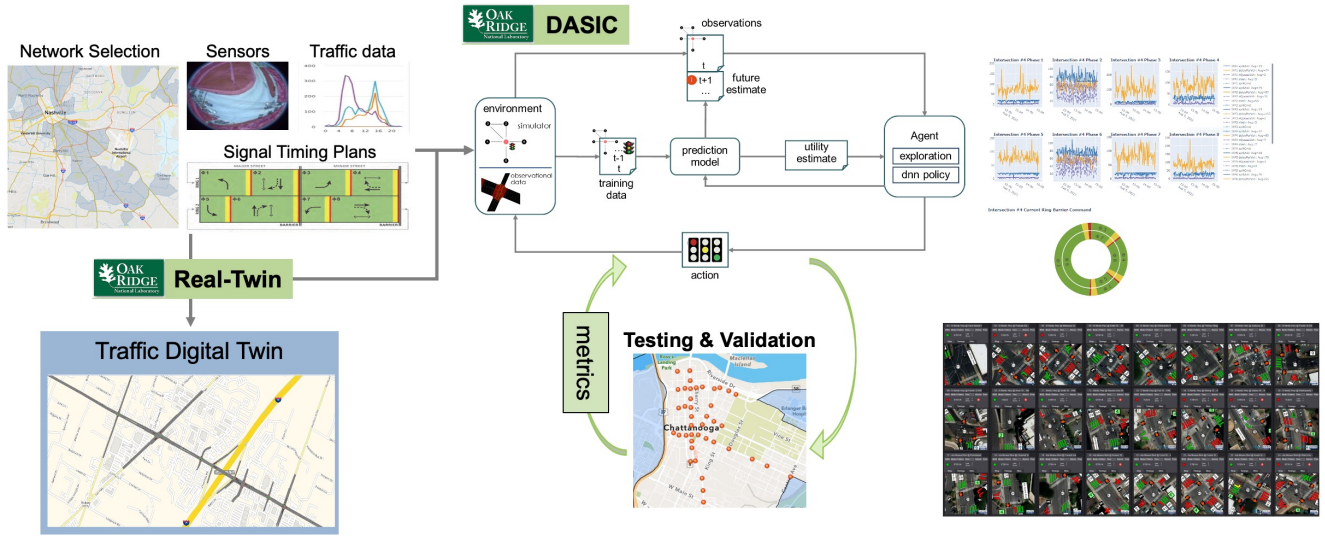
Neuromorphic Engine Control for Fuel Efficiency



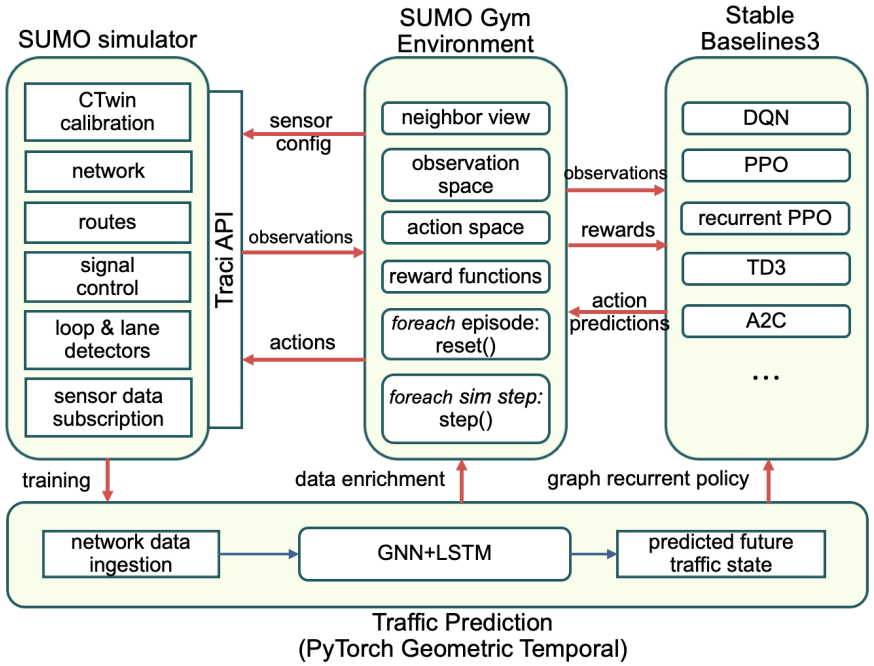
DASIC

- **Objective**
  - Develop a prediction model for estimation of future system state and utility → removes computation load from the RL engine and can be used as a low-cost, low fidelity model to improve RL efficiency.
  - Develop a reinforcement learning-based control system for traffic signal timing.
  - Partial Observability Issue: limited sensor coverage → use Graph Neural Network (GNN) to estimate.
  - Scalability: RL agent is trained in a decentralized way: all controllers to have an independently trained with neighbor data→ allow rapid real world deployment.

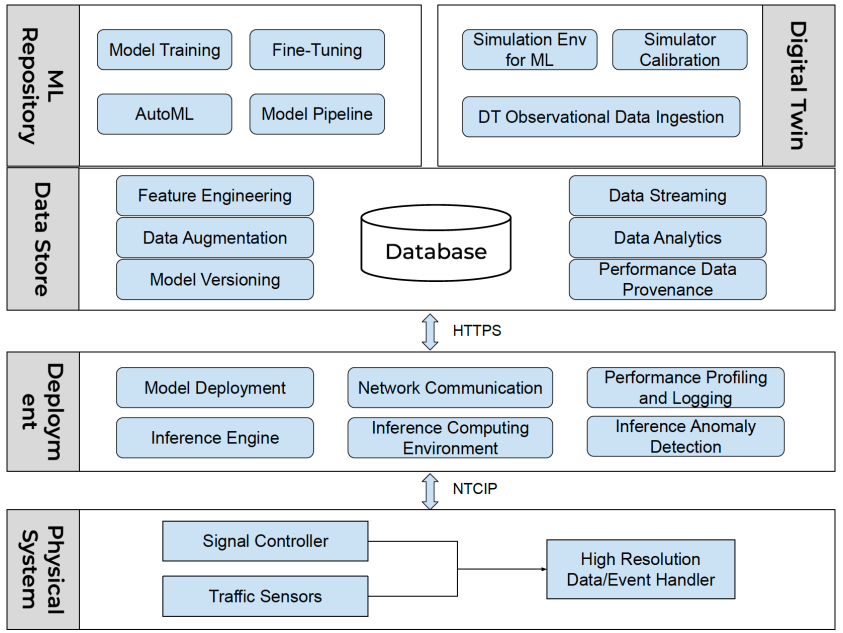
- **Coupled Transportation Digital Twins and AI-empowered Control**



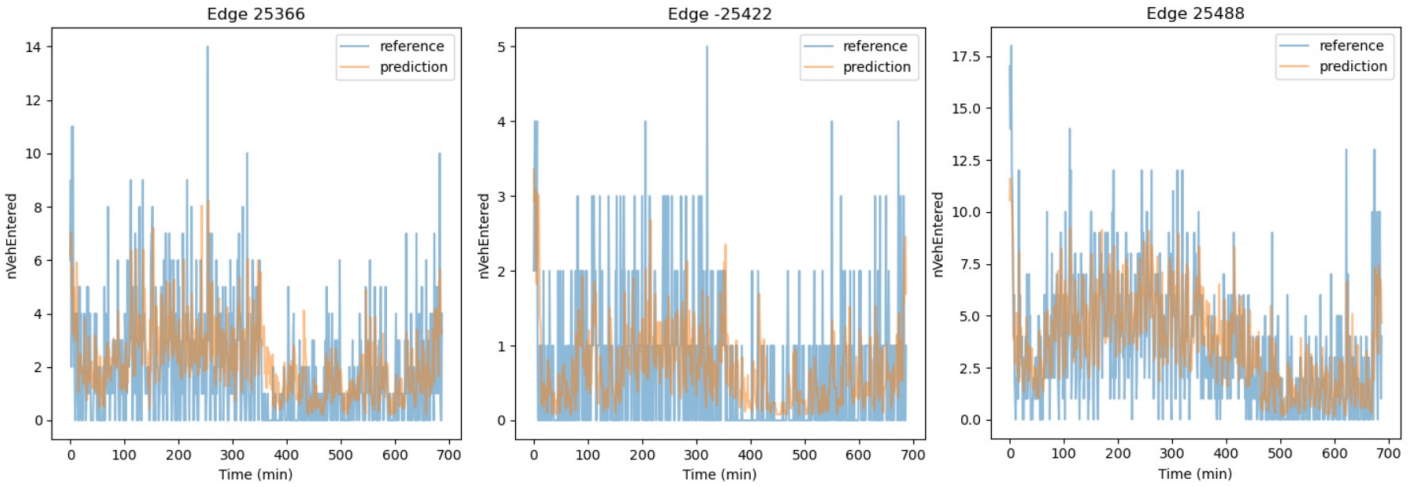
Results



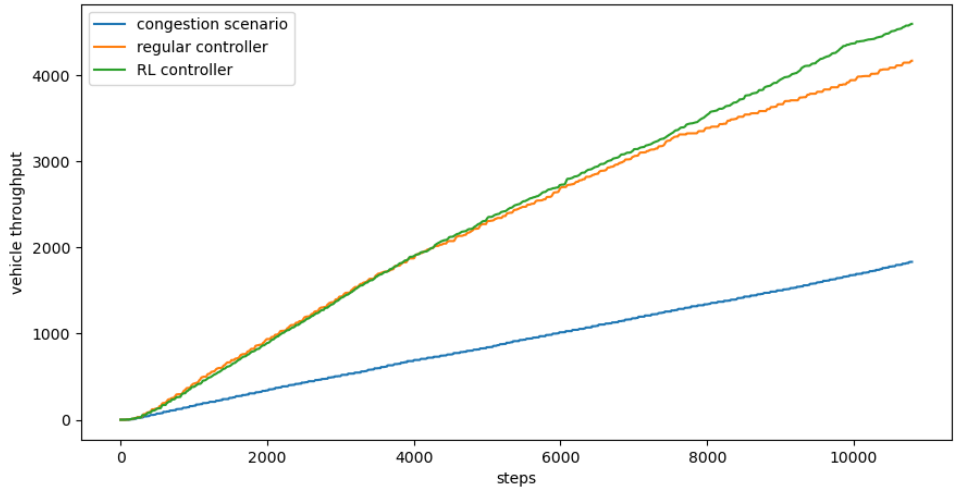
Implementation



Training and deployment pipeline



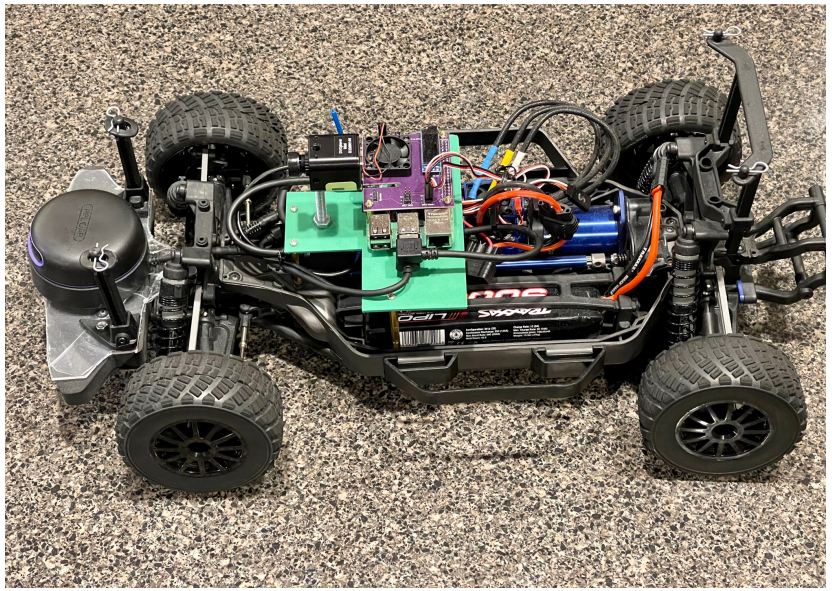
Performance of the prediction model (GNN + LSTM)



Performance of RL agent: traffic volume

Neuromorphic Computing: Energy Efficient AI for the Edge

- Open research questions:
  1. How do we design AI for edge computing?
  2. What are the technological barriers to development and deployment of AI to the edge?
  3. How effective can AI leverage multi-sensor data (e.g., camera, LIDAR, Radar, GPS, IMUs)?



From small scale Test & Development

To full scale Test & Development

Driving Innovation: The Strength of ORNL

Award-Winning AI Research:

Recognized Excellence: Our groundbreaking AI research has garnered prestigious awards, pushing the boundaries of artificial intelligence and its transformative potential.

National Transportation Research Center:

Pioneering Mobility Solutions: At the forefront of national transportation research, we are shaping the future of mobility through cutting-edge technologies and sustainable practices.

World's Fastest Computer:

Powering Possibilities: Unleashing unprecedented computational capabilities, our institution is home to the world's fastest computer, driving advancements across diverse fields and propelling us into the digital frontier.

Join us on this journey of innovation and discovery!"

Acknowledgements and Contact Info

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