Transforming transportation with machine learning

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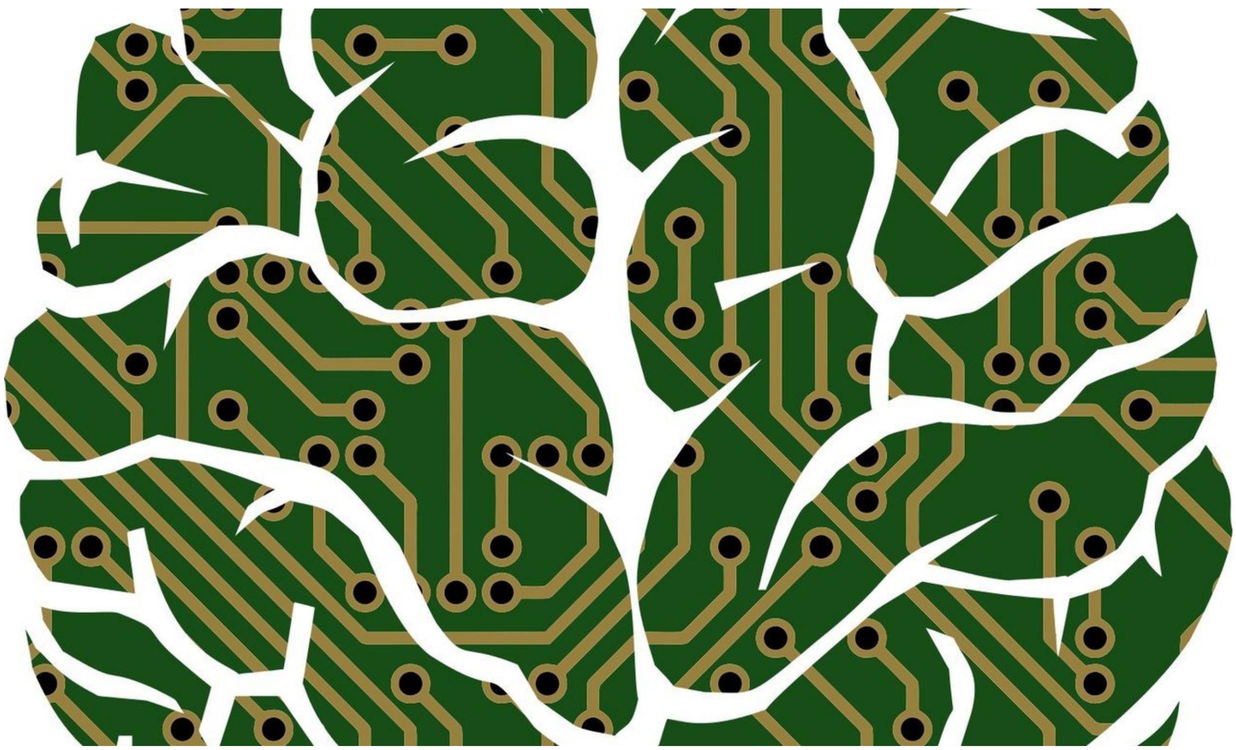

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You hear the buzzwords everywhere—machine learning, artificial intelligence—revolutionary new approaches to transform the way we interact with products, services, and information, from prescribing drugs to advertising messages.

Artificial intelligence, a branch of computer science dealing with the simulation of intelligent behavior in computers, is already behind many of the technologies we see today, including virtual online assistants and driverless cars. In transportation, the applications extend even further.

Argonne researchers actively leverage approaches for artificial intelligence to transform America's transportation and energy systems, by addressing complex problems like congestion, energy efficiency, emergency response planning, and safety. Their research provides a deeper understanding of transportation from the engine component level all the way up to large metropolitan areas, which helps decision makers find optimal solutions for making transportation systems and technologies more reliable and efficient.

In particular, researchers use machine learning techniques, which train computers to parse and discover hidden patterns within data and make novel predictions, without explicit programming. Engineers in the past would write code that tells a computer what to do. But in machine learning, engineers feed sample inputs and outputs to machine learning algorithms, then ask the machine to identify the relationship between the two. In doing so, the machine generates a model, which can then be used to make predictions.

The systematic need for machine learning in transportation

Argonne researchers are exploring ways machine learning techniques can help them understand the systematic design of transportation systems and pinpoint key bottlenecks that have propagating effects on entire systems. Research Engineer Eric Rask and Computer Scientist Prasanna Balaprakash are exploring opportunities in this area through a U.S. Department of Energy-funded high-performance computing project.

"We are engaged in this effort because understanding how transportation works as a system is critical to identifying and alleviating traffic issues and supporting future planning," Rask said. "Due to the diversity and complexity of the systems involved, achieving a comprehensive understanding can be a challenge, but machine learning can help us to better detect unseen trends and map out key relationships and their relative impact."

The resulting insights contribute to engineering better system controls that can make transportation more reliable, boost productivity, and save consumers on the millions of dollars wasted each year idling in traffic. More information also supports decision making; with more information on traffic incidents, for example, consumers and autonomous vehicles can make decisions about routing, planners can better coordinate emergency responses, and urban planners can implement controls to minimize disruption to other areas of the system.

Accelerating engine development and optimization

Argonne researchers apply machine learning to optimize advanced engine designs and processes. More recently, researchers have developed a powerful way to use deep learning (a category of machine learning methods) to create a new combustion model that reduces simulation time by half.

Deep learning uses a class of algorithms called deep neural networks that mimic the brain's simple signal processes in a hierarchical way; today, these networks, aided by high-performance computing, can be several layers deep. They enable researchers to model increasingly complex properties like multiple reaction pathways during fuel combustion.

"Traditionally, researchers will try to reduce the complexity of combustion reactions to save time when running simulations, but doing so can reduce the accuracy of their output," said Argonne's Computational Multi-Physics Section's Manager Sibendu Som. "With our new model, aided by machine learning, we can account for the entire fuel chemistry without sacrificing accuracy and save time. This capability is unique, not only in its application of neural networks but also in its ability to significantly reduce development time."

Argonne researchers have leveraged their machine learning knowledge to help a global petroleum and natural gas company optimize a diesel engine to run on a new fuel.

Prior to working with the lab, the company used high-fidelity modeling and development took several months. Argonne's expertise in combustion modeling, high-performance computing, and machine learning expertise helped them reduce development time to just days, while maintaining the same quality of result.

Optimizing routing

Argonne researchers are also exploring ways to use machine learning to optimize predictive routing for fleets or other travelers. Having a clear understanding of routing options available, and their associated energy, time, and environmental costs, and being able to predict changes can help fleet operators choose vehicles and routes that save of fuel costs while maximizing efficiency.

"To make routing decisions you need accurate energy information, and reliable predictions. You can get this with high-fidelity simulations, which take a lot of time and aren't readily accessible to most people," said Vehicle and Mobility Simulation Manager Aymeric Rousseau. "Another option is to use machine learning, through which you can get an acceptable answer right away, without requiring high-fidelity transportation system models."

Enabling fast and accurate decision making around fuel economy

Rousseau and his team also employ machine learning approaches to train vehicle models in support of CAFE (Corporate Average Fuel Economy) standards, which regulate the fuel economy of all cars and light trucks operating in the United States. Contracted by the U.S. Department of Transportation's National Highway Traffic Safety Administration, Argonne researchers support CAFE analyses by using machine learning to model the energy impacts of new vehicle technologies including engine, transmission, lightweighting, and electric drive technologies.

"Due to the large number of technologies available and the different vehicle classes and consumer requirements, car manufacturers are faced with millions of potential technology combinations," Rousseau said. "While Argonne has developed processes to individually model and simulate close to 1.5 million of those combinations using high-performance computing, many more options are still possible. Using machine learning models trained from the simulation results allows us to quickly answer policymakers' questions."

Making better transportation predictions

While simultaneously exploring engine and vehicle applications, Argonne researchers are also applying machine learning to large-scale system modeling, with an eye to energy and mobility impacts. Leading this effort, Rousseau and his team run high-fidelity models on thousands of simulations using high -erformance computing to train machine learning models.

To analyze city systems and predict how transportation will evolve in the future, researchers need to model all potential transportation technologies. But there are many vehicle options out there that use different fuel sources and have varying ranges of performance, not to mention buses, trains, biking, and other alternate modes of transport.

"A very large number of computational intensive model runs are required to quantify and understand the impact of the different technologies and their interdependence. Using machine learning allows us to quickly and efficiently identify critical parameters and technologies that one can then focus on to better leverage the high-fidelity models and scenario studies," Rousseau said.

Looking ahead, researchers strive to continue growing and maturing the lab's machine learning competencies, to enhance Argonne's ability to provide useful knowledge quickly.

"These competencies, plus Argonne's multidisciplinary team of experts and high-performance computing resources, are proving to be important tools for accelerating problem-solving in transportation, for challenges both large and small," Som said.

Provided by Argonne National Laboratory

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