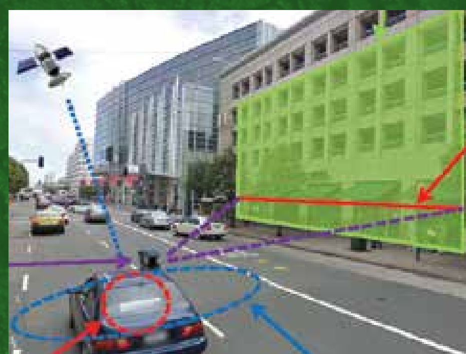
Exploratory Advanced Research Program

The Role of Artificial Intelligence and Machine Learning


in Federally Supported Surface Transportation Initiatives

EXPLORATORY ADVANCED RESEARCH

U.S. Department of Transportation
Federal Highway Administration

Notice

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Contents

Introduction

When people hear the phrase "artificial intelligence," they might think of robots and machines that perform efficiently and quickly some of the functions that humans do, such as translating signs in a foreign language, or of robotic dogs that comfort older adults. When defined within the context of the transportation sector, artificial intelligence conjures up futuristic images of cars that can drive by themselves, taking into account factors such as speed, the distances of nearby cars, and weather conditions.

Artificial intelligence within transportation does include highly automated vehicles. Further, the use of artificial intelligence through enabling computers to digest and analyze large amounts of data and form conclusions—a process known as machine learning—can provide broad public benefits to transportation in numerous ways. It can improve traffic flows at individual signalized intersections, along specific routes as part of integrated corridor management, or can support human decisionmaking processes in a Traffic Management Center for various tasks, including, for example, incident detection and management, traffic demand prediction, and detouring corridor signal control. Artificial intelligence can also facilitate traffic safety through monitoring real-time traffic and weather conditions and by sending those data to traffic signals and to platoons of partially or fully automated vehicles. It can discern and anticipate how drivers might react under certain traffic situations through reviewing naturalistic driving study video data or by processing data and providing information to travelers with disabilities to provide assistance in trip planning and increased situational awareness while traveling.

FHWA test vehicles simulate a "platoon" of vehicles using cooperative adaptive cruise control. Source: FHWA.

What Is Artificial Intelligence?

Artificial intelligence consists of the "thoughts" and conclusions that computers make after receiving data inputs. If human intelligence uses the brain to receive, store, and analyze information, artificial intelligence uses various technologies to also receive, store, and analyze information.

In transportation, artificial intelligence encompasses a wide area of technology, from Advanced Driver Assistance Systems to predictive traffic modeling and control systems.

What Is Machine Learning?

Machine learning is a branch within artificial intelligence in which computers use programming as a jumping-off point to create their own processes to analyze vast amounts of data. The machines themselves develop processes and algorithms to take these data and compute observations, trends, and conclusions about the data.

Within the transportation sector, machine learning technologies can be useful in finding data trends. For instance, machine learning can consist of ingesting great amounts of traffic data; analyzing those data with other data, such as weather conditions, traffic volume, and vehicular speeds; and then developing observations that might help traffic engineers make certain intersections safer.

The Exploratory Advanced Research (EAR) Program of the Federal Highway Administration (FHWA) is exploring the development of artificial intelligence and machine learning technology within the surface transportation sector. By working with universities, industry, and Government conducting cutting-edge research in these fields, FHWA ultimately seeks to make surface transportation safer and more efficient.

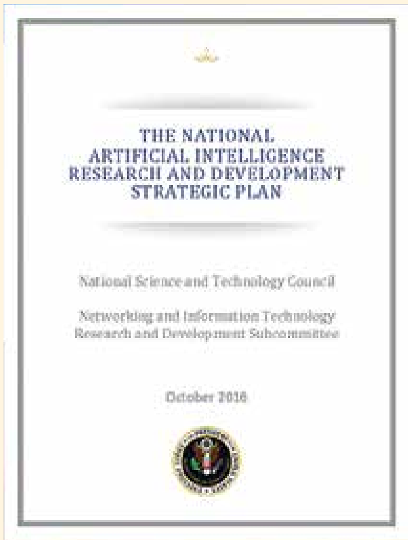
The U.S. Department of Transportation (DOT) has a keen interest in developing technologies that promote traffic safety and improve efficiency. Those technologies include helping the transport of people or cargo to run more smoothly.

"It is such an exciting time to be in the transportation space today. We're witnessing a growing torrent of technological advances and new concepts that could fundamentally alter the transportation landscape in the coming decades—maybe even sooner," said Derek Kan, Under Secretary of Transportation for Policy at DOT's John A. Volpe National Transportation Center, an agency that provides multidisciplinary and cross-modal expertise on emerging transportation issues. Kan's remarks were part of Volpe's 2018 speaker series on Transportation in the Age of Artificial Intelligence and Predictive Analytics.

For instance, new sensors create large amounts of multimodal surface transportation data, and technologies can be developed to find synergies among all these datasets so that traffic engineers and public planners can better understand what variables may bring about traffic crashes or injuries.

Efforts to increase the use of artificial intelligence and machine learning in federally supported surface transportation research are part of wider plans to develop and refine the Federal Government's role in developing technologies related to artificial intelligence and machine learning. There is a need to clarify how the Federal Government should invest in research and development (R&D) within the realm of artificial intelligence, since the R&D landscape includes not only the Federal Government but also nonprofits and private-sector industries.

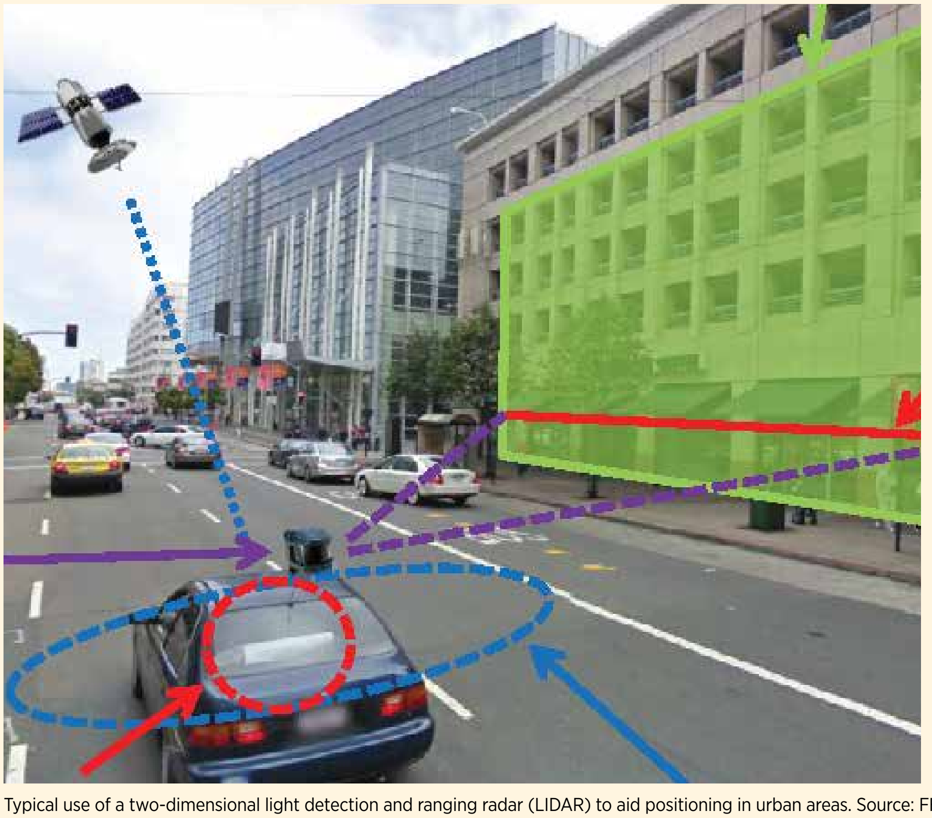
In October 2016, the National Science and Technology Council, which on behalf of the White House coordinates science and technology policy across the various Federal departments that support R&D, published *The National Artificial Intelligence Research and Development Strategic Plan*. The plan outlined how Federal Government agencies should prioritize federally funded R&D in artificial intelligence. It provided a framework for Federal agencies to decide how to proceed with R&D in such a way that addresses long-term technical and societal challenges while also honoring individual agencies' budgets, capabilities, and missions.



Source: National Science and Technology Council.

The plan laid out seven strategies in determining how to prioritize research in artificial intelligence. Some of these strategies resonate with the objectives of the EAR Program. One strategy was developing methods for human–artificial intelligence systems collaboration to optimize performance. Another strategy was ensuring the safety and security of artificial intelligence systems so that operations occur in a well-defined, reliable, and safe manner. Two other strategies were developing shared public datasets and environments for artificial intelligence training and testing, and measuring and evaluating artificial intelligence technologies through standards and benchmarks.

The Federal Government will continue to revise its plans on how to support R&D efforts for artificial intelligence and machine learning as discoveries in both the public and the private sectors advance what technologies are available.



Typical use of a two-dimensional light detection and ranging radar (LIDAR) to aid positioning in urban areas. Source: FHWA.

EAR Program's Involvement in R&D for Artificial Intelligence and Machine Learning

FHWA EAR Program investments help realize *The National Artificial Intelligence Research and Development Strategic Plan* through enabling longer term research that might not have immediate or clear return on investment so might not necessarily be compatible with private industry pursuits.

Artificial intelligence for use in transportation can benefit society in multiple ways. One way is to augment data from structural health monitoring of highway assets such as bridges, which can also lead to reduced repair and reconstruction costs, not to mention the general public's increased confidence in safe structures. Another way is to improve network mobility, which can lead to more efficient traffic flows and supply chain logistics flows, as well as potentially reducing transportation-related emissions.

FHWA's EAR Program has recently supported two research areas to develop technologies associated with artificial intelligence and machine learning. One area is the collection of large amounts of traffic data, including safety data, to spot trends and identify relationships between seemingly disparate data streams. The second area is the development of video analytics research to help determine driver behavior in various driving scenarios.

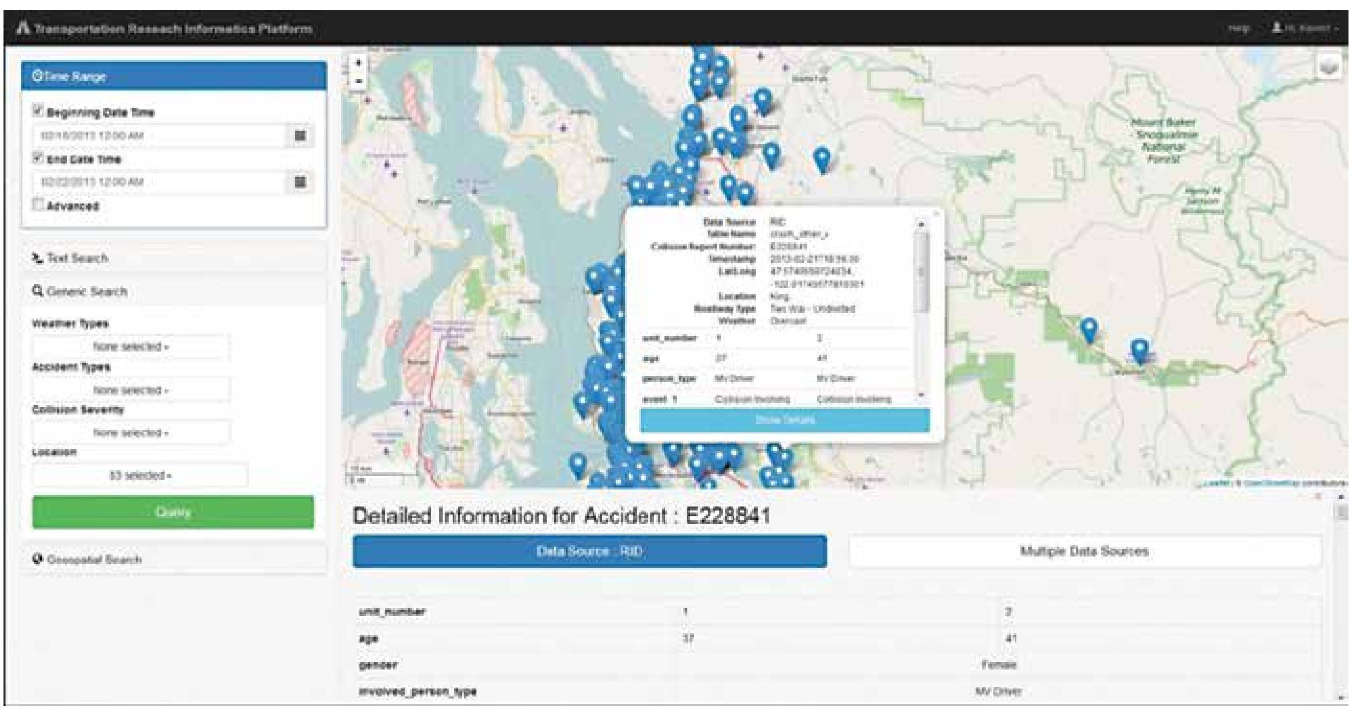
Making Sense of Big Data

In the area of data collection and analysis, FHWA's EAR Program recently supported research performed by two entities, Calspan-University of Buffalo Research Center (CUBRC), a systems integration research organization, and the Palo Alto Research Center (PARC), an R&D firm.

Both research projects sought to process massive amounts of transportation-related data—sometimes referred to as big data—from structured, semistructured, and unstructured datasets.

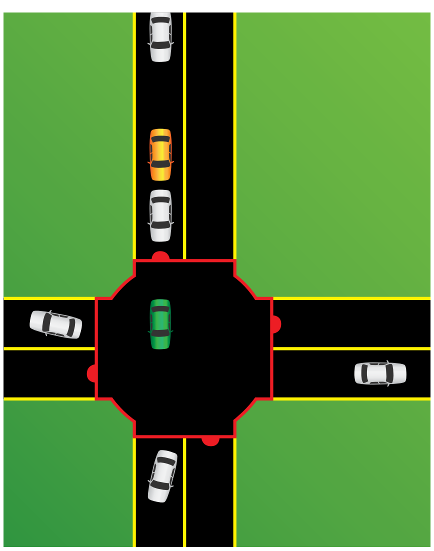
PARC's project researchers developed automated methods to integrate information from large unrelated datasets. For the project "**Merging Information from Disparate Sources to Enhance Traffic Safety**," the PARC researchers established machine learning tools to process data from several datasets, including the second Strategic Highway Research Program (SHRP 2), which included a naturalistic driving study (NDS) that provided trip summary records of more than 36,000 baseline driving events, and another dataset with information describing the physical characteristics of the most frequently traveled roadway sections. The firm also processed data from additional datasets, including Clarus roadway-weather data and video logs, and data revealing video, radar, and still photography information from Chicago intersections. The machine learning tools developed from processing and analyzing these datasets together enabled researchers to detect safety issues that might not have been so readily spotted otherwise.

CUBRC's project researchers developed a layered infrastructure to ingest, store, analyze, and display information. For the project "**Knowledge Discovery in Massive Transportation Datasets**," the researchers produced the Transportation Research Informatics Platform (TRIP), a dashboard that provides users with a way to see streaming data and historical data of traffic in Seattle, Washington. The data include information on crashes, traffic volumes, roadway characteristics, weather and roadway surface conditions, and work zones and traffic laws.



CUBRC developed the TRIP Interface to allow researchers to access accident information and overlay other search terms such as weather types, accident types, collision severity, and location. © 2017 CUBRC, Basemap © MapQuest.


Big Data
Next Exit



Using Video Analytics to Help Analyze Driver Behavior

Promoting traffic safety has also been the ultimate goal for the EAR Program's support of video analytics research and the pursuit to establish baselines for high-risk driving behavior. Researchers from multiple universities and organizations have been examining ways to develop machine learning tools to process the vast amount of video data available in the SHRP 2 NDS data.

These data consist of 1.2-million hours of video data collected from the vehicles of approximately 3,000 volunteers going about their regular activities. The vehicles of the volunteers were equipped with four cameras, a global positioning system popularly known as GPS, and other sensors. By analyzing the NDS data, researchers hope to understand the correlations among driver behavior, road design, traffic, and other factors.

There have been multiple video analytics approaches to these massive datasets. At Carnegie Mellon University, researchers developed machine learning tools to process and analyze the NDS data. They developed learning algorithms that could parse out important data from less important data as well as recognize and cull together desired factors. The tools address ways to automate the interpretation of ambiguous video data by building a sequence of context-dependent predictions. Additional video analytics projects at Carnegie Mellon included the development of an automated real-time system to analyze drivers' emotional states and determine driver distraction or fatigue, and the creation of an automated image distorting technique that could mask faces while still preserving facial behaviors.

SRI International developed a comprehensive coding system, known as DCode, that could assist researchers wanting to analyze SHRP 2 data. The coding system allows researchers to extract driver behavior features, such as head pose, facial expressions, and gestures of holding a mobile phone. Data on the surrounding environment are also available. The organization also produced an image distortion technique that could mask faces while also preserving characteristics such as facial expressions and head pose.

Researchers at the University of Wisconsin–Madison developed automated and semi-automated video coding as a way to develop an open software platform that could ultimately quantify driver distraction and engagement. The platform would enable feature extraction, behavior characterization, and visualization of SHRP 2 data. And at Oak Ridge National Laboratory, researchers developed calibration and measurement techniques to help the broader community of researchers wanting to work with NDS data.

Because the amount of data is so vast, there are still plenty of research opportunities to analyze the SHRP 2 data and NDS data. FHWA is planning further study on developing contextual data to aid in the behavior analysis of video data, creating reduced datasets that avoid privacy concerns, and refining data security methods.

Researchers at the University of Wisconsin–Madison developed an interface that allows the viewer to see cabin video and roadway video simultaneously.


Snohomish County
King County
Pierce County

Additional Opportunities and Challenges for Artificial Intelligence and Machine Learning Research

As FHWA's EAR Program delves further into supporting research efforts for artificial intelligence and machine learning, it seeks to advance research areas that have positive implications for surface transportation systems.

There are two general categories of research for artificial intelligence and machine learning.

The first general category is research that involves studying and analyzing collected datasets. This category encompasses the big data projects and the video analytics projects described previously. FHWA has access to video and sensor data from the SHRP 2 safety studies, and additional research can be made to sort and process the data to provide better insights not only into how and why crashes happen but also how and why drivers avoid crashes. Other research areas within this general category include development of forecasting and prediction tools, data validation to ensure quality control, and data discovery and integration for a variety of topics from freight movement to interpretation of signal data from non-destructive technologies measuring the conditions of structures and pavements.

The second general category is developing tools to provide real-time operational support, such as the timing of traffic signals. This research category includes the development of real-time artificial intelligence applications, which will require longer term exploration because of the advanced technologies these applications require.

Another topic that benefits from real-time operational support is supporting the population with disabilities by providing artificial intelligence and machine learning tools that can respond to travel and mobility needs, including those needs of passengers with disabilities who must travel across multiple transportation modes.

A chest-mounted stereo camera and inertial measurement unit form part of a pedestrian navigation system developed by Auburn University. © Auburn University.

Conclusion

FHWA's EAR Program stands ready to provide continued support to artificial intelligence and machine learning research, particularly as they can be applied to traffic safety. Given the ever-evolving nature of these disciplines, the opportunities to develop transportation-related tools that aid in the greater public good are almost as vast as the data available.

Getting Involved with the EAR Program

To take advantage of a broad variety of scientific and engineering discoveries, the EAR Program involves both traditional stakeholders (State department of transportation researchers, University Transportation Center researchers, and Transportation Research Board committee and panel members) and nontraditional stakeholders (investigators from private industry, related disciplines in academia, and research programs in other countries) throughout the research process.

Learn More

For more information, see the EAR Program website at https://highways.dot.gov/research/exploratory-advanced-research. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events.

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EAR Program Results

The EAR Program strives to develop partnerships with the public and private sectors because the very nature of the EAR Program is to apply ideas across traditional fields of research and stimulate new approaches to problemsolving. The program bridges basic research (e.g., academic work funded by National Science Foundation grants) and applied research (e.g., studies funded by State departments of transportation). In addition to sponsoring EAR Program projects that advance the development of highway infrastructure and operations, the EAR Program is committed to promoting cross-fertilization with other technical fields, furthering promising lines of research, and deepening vital research capacity.

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