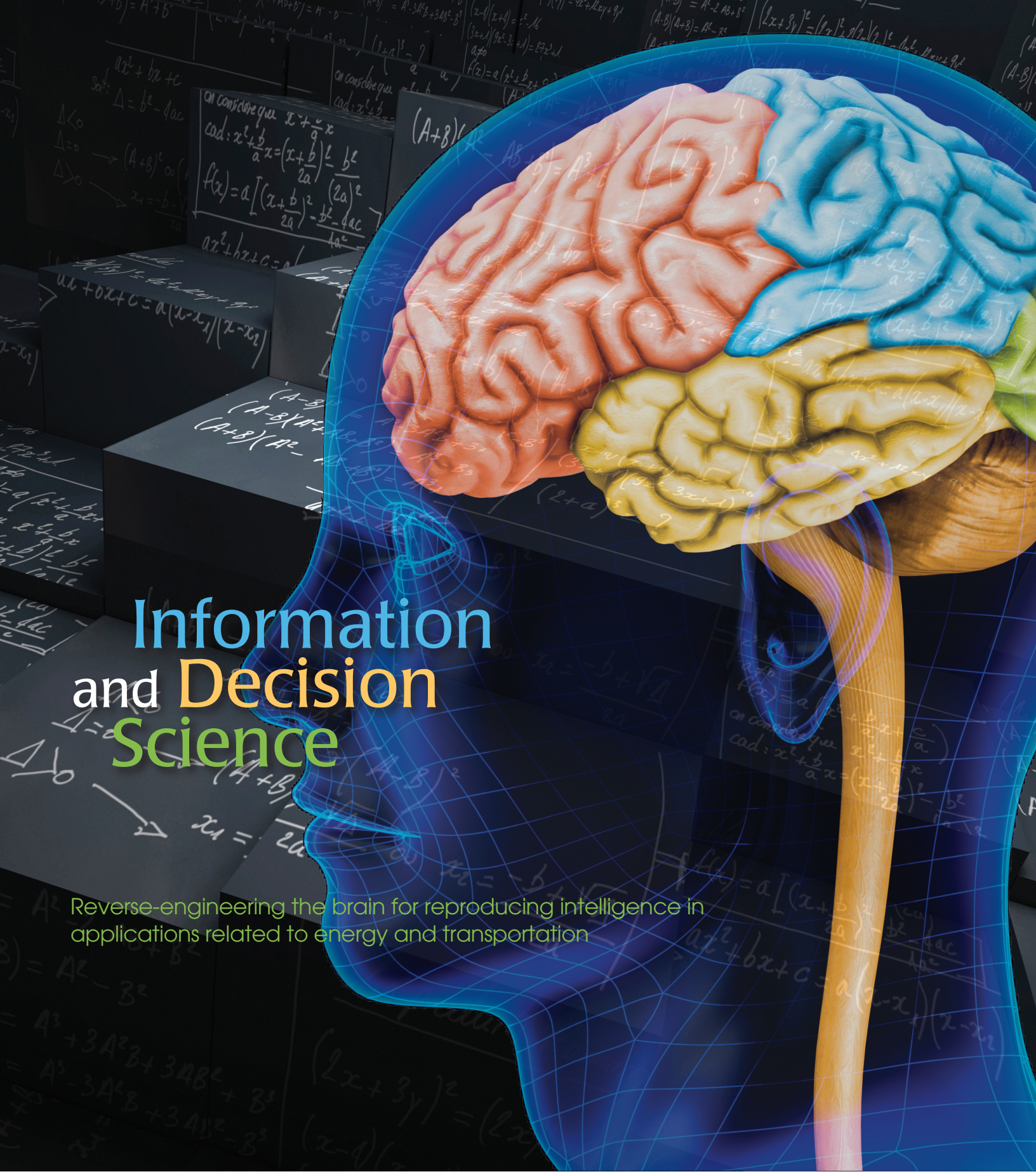


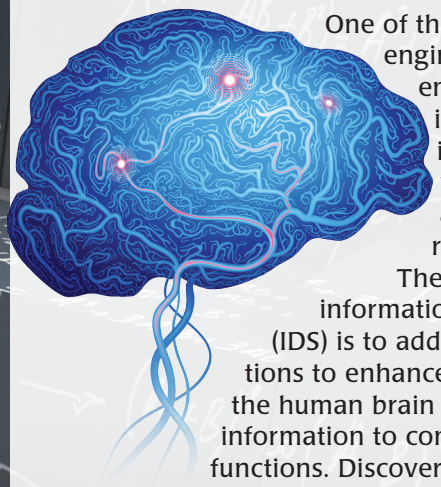
Information and Decision Science

Reverse-engineering the brain for reproducing intelligence in applications related to energy and transportation

OAK RIDGE NATIONAL LABORATORY

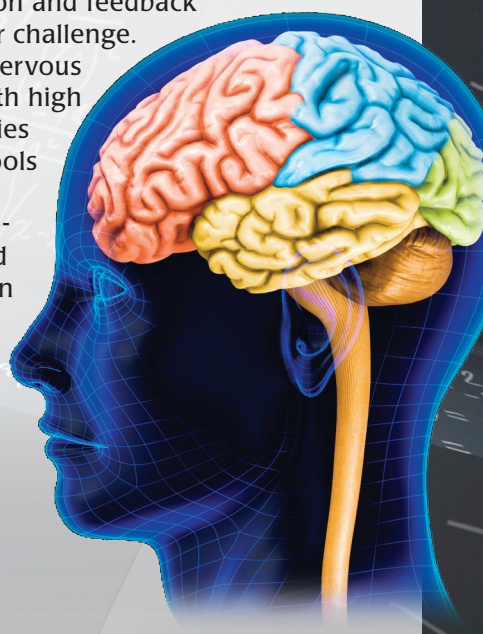
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Information and Decision Science (IDS)



One of the great challenges in engineering is to reverse engineer the brain. The intersection of engineering and neuroscience promises significant advances in a great range of applications. The research objective in information and decision science (IDS) is to address scientific questions to enhance understanding of how the human brain receives and processes information to control a wide range of functions. Discovering how the brain works by reverse engineering will enable creation of thinking machines capable of emulating human intelligence through sophisticated models. These models will compose an integrated information processing and control system that can represent an artificial central nervous system able to simulate the brain's operation. Advancing research in IDS can play a key role in developing these models.

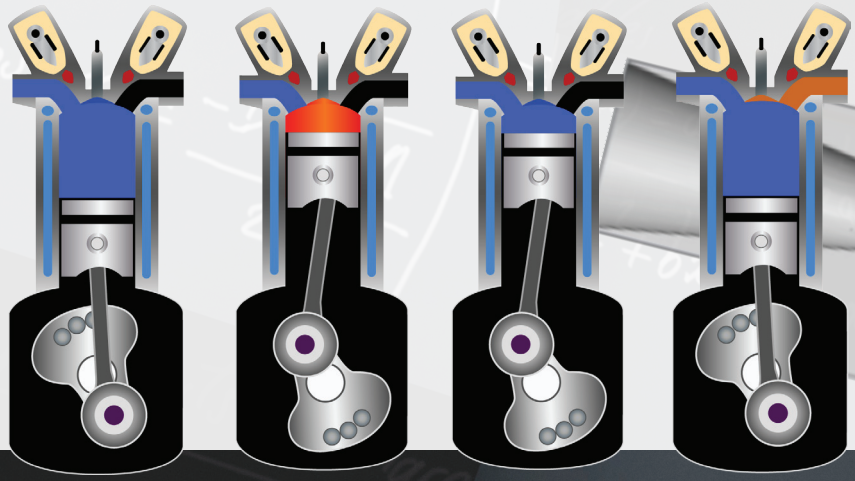
Substantial progress in this direction has been made through developing methods to simultaneously measure the activities of multiple brain cells. However, details of the brain's secret communication code remain to be investigated further. Nerve cells communicate by firing electrical pulses. Because each nerve cell receives messages from tens of thousands of others and circuits of nerve cells are linked in complex networks, it is extremely difficult to trace the signaling pathways. Analyzing the complexities associated with nerve cell signals and circuits, their evolution and feedback loops, constitutes a major challenge. Developing an artificial nervous system in conjunction with high level computing capabilities can yield sophisticated tools to simulate various functions of the brain, contributing substantially toward making machines that can learn and truly think and thus dramatically impact problems in energy, transportation, health care, manufacturing, and communication.

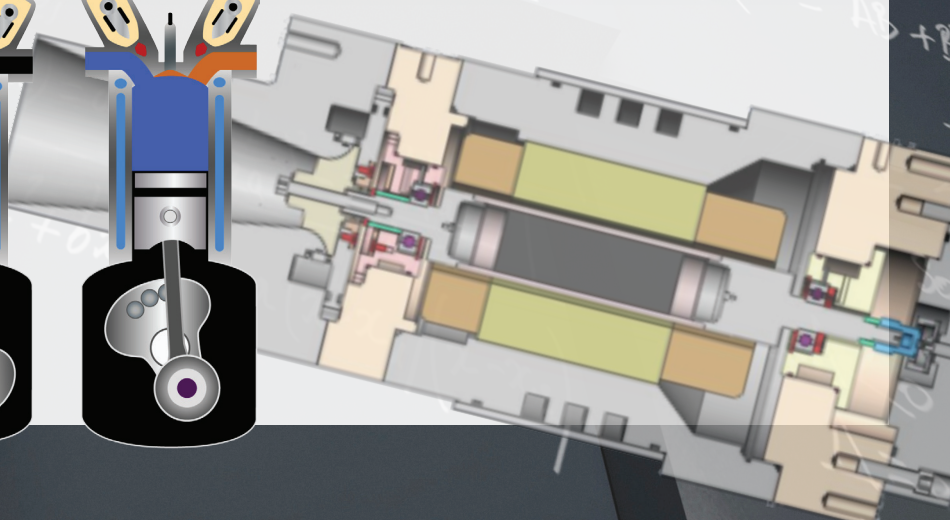


Artificial nervous systems for internal combustion engines

Modern vehicles have ingenious electronic control systems that can control engine operation with discretion to balance fuel economy, emissions, and power. These control units include algorithms for specific driving conditions (e.g., different speed profiles for highway and city driving). However, each individual driving style is different, and thus real-world situations rarely conform to the hypothetical driving conditions of current control algorithms.

Control theory is being advanced and algorithms are being developed to make the engine's control unit act more like an artificial nervous system capable of optimizing engine operations and settings based on the driving behavior of individual drivers. Through this new approach, the engine progressively tracks the driver's driving style and eventually learns to operate in a manner that optimizes specified performance criteria (e.g., fuel economy and emissions) for the particular driving style.

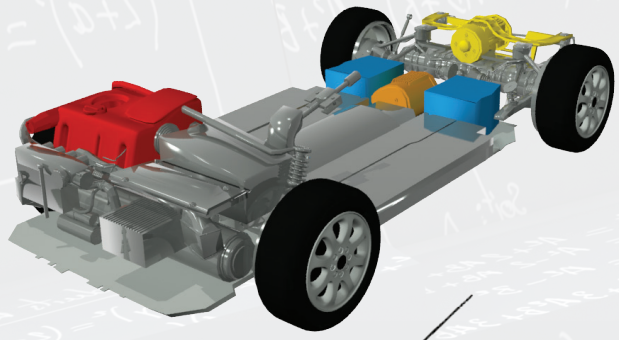


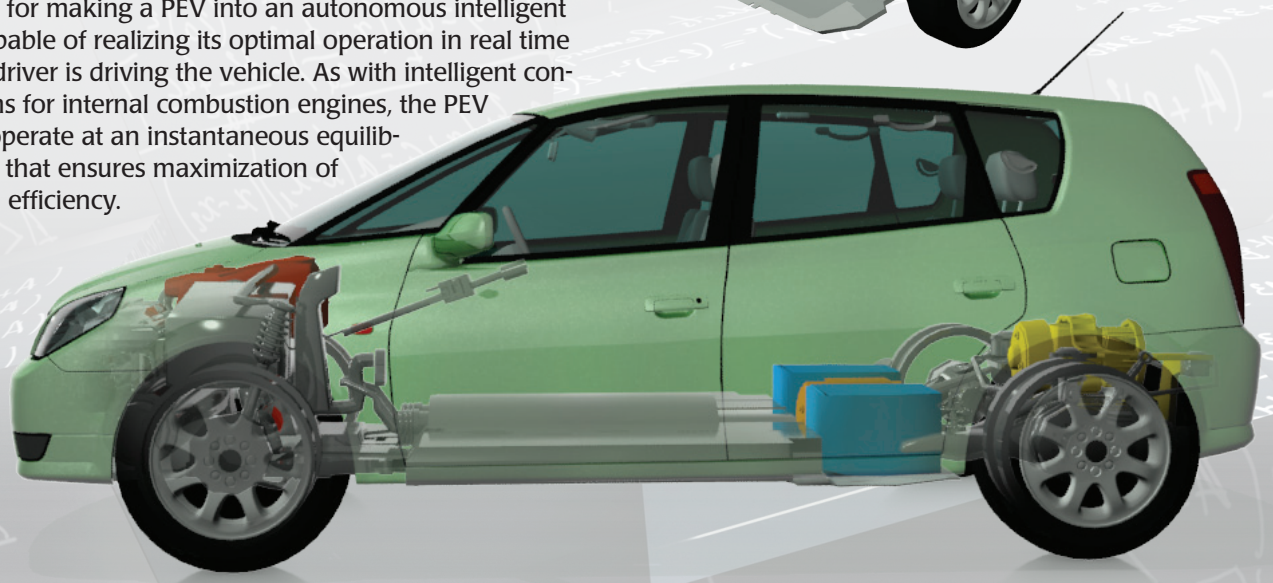


Autonomous intelligent plug-in electric vehicles

Plug-in electric vehicles (PEVs) have attracted considerable attention due to their potential to reduce petroleum consumption and greenhouse gas emissions in the transportation sector. PEVs are especially appealing for short daily commutes with excessive stop-and-go driving. However, the high costs associated with their components, and in particular with their energy storage systems, have been significant barriers to extensive market penetration of PEVs.

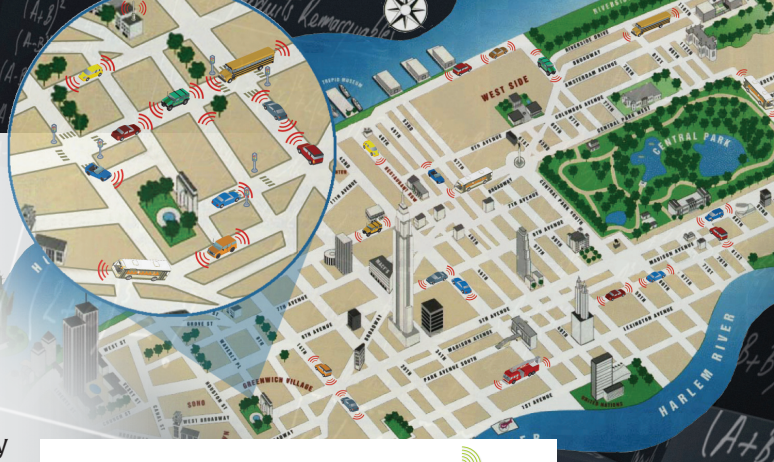
The theoretical framework and control algorithms are being developed for making a PEV into an autonomous intelligent system capable of realizing its optimal operation in real time while the driver is driving the vehicle. As with intelligent control systems for internal combustion engines, the PEV learns to operate at an instantaneous equilibrium point that ensures maximization of the overall efficiency.





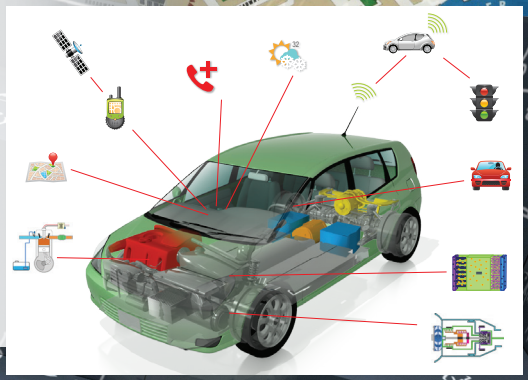
Driver information systems

The variation in fuel consumption for different driving styles is significant, so developing a means of improving driver behavior to maximize fuel economy is another way to reduce fuel consumption in existing fleets. Because of this, driving style factors that have a major impact on fuel economy are being investigated, and an optimization framework with a real-time feedback system, including visual instructions, is being developed to enable drivers to alter their driving styles in response to actual driving conditions to improve fuel efficiency. Realizing a more eco-driving style can contribute significantly to sustainable mobility.



iVEHICLE

iVEHICLE (intelligent VEhicle and HIghway Communication Leveraged for Efficiency) project represents an exciting new approach to improving PEV efficiency. In this area, a controller represents an artificial central nervous system for the PEV that integrates and processes information received through communication between vehicles and advanced information systems and optimizes overall PEV operation to improve battery capacity and lifetime. Through iVEHICLE, the supervisory controllers will be able to compute the most efficient PEV operating mode based on information received from preceding vehicles and infrastructure. iVEHICLE research is designed to provide an answer to the following question: "How much more efficiency can we achieve in a PEV if cybernetics technologies are integrated?"



Artificial digital organisms in cities

Our cities are rapidly transforming into artificial ecosystems of interconnected and interdependent intelligent digital organisms. There are substantial opportunities for reducing energy consumption in both new and existing buildings. Hybrid buildings with more than one available renewable resource (e.g., solar and wind) are receiving increasing attention as digital organisms. An artificial nervous system in these organisms can make them rational machines with the capacity to optimize overall efficiency. Creating digital brains in buildings can be a key pathway to addressing concerns regarding meeting the world's growing demand for energy and minimizing related impacts on the environment, improving sustainability, and facilitating cost-effective energy generation.

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U.S. DEPARTMENT OF ENERGY

IDS research directly supports the DOE office of Energy Efficiency and Renewable Energy, as well as the DOE office of Science. The research will also support other DOE offices and programs, other government agencies, research organizations in the private sector, and private industry.

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