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Science News

Probing Human Mind And Future Infrastructure Systems

ScienceDaily (Oct. 3, 2008) — The National Science Foundation (NSF) Office of Emerging Frontiers in Research and Innovation (EFRI) has announced 12 grants for fiscal year 2008, awarding a total of $23,779,056 over four years to 54 investigators representing 20 institutions.

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Interdisciplinary teams will pursue transformative, fundamental research in two areas of great promise: understanding the brain and how its abilities may be used through cognitive optimization and prediction; and developing ways to make complex, interdependent infrastructure systems more resilient and sustainable.

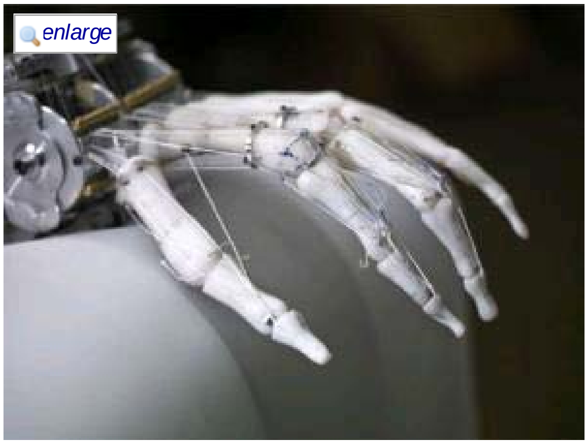
What researchers learn from the brain may open many new paths of discovery, in areas such as computing, robotics, medicine and education. Understanding how the brain moves the hand, for example, could illuminate entirely novel ways to help people who are paralyzed or use prosthetic limbs. Understanding how the brain visually recognizes objects will enable advances in artificial vision systems, robotic intelligence and more.

The second area of research will examine complex challenges in our nation's interwoven infrastructures as demands on these interdependent systems are changing. Researchers will investigate how to increase their resiliency and sustainability as, for example, numerous electric vehicles interact with the power grid. In addition to drawing electricity from the grid, electric vehicles may send stored energy to the grid. New research may find a role for these vehicles in stabilizing the electric power grid during a catastrophe and in managing fluctuations in electricity from renewable energy sources.

Learning from the brain

Four awards fall under the topic Cognitive Optimization and Prediction: From Neural Systems to Neurotechnology (COPN).

Creating a learning algorithm of the brain



The Anatomically Correct Testbed Hand has three fully actuated fingers that have the same biomechanical structure as the human hand. This hand is used to understand the human hand's biomechanical structure and neural control strategies, and will serve as a prosthetic and surgical tool one day. (Credit: Ellen Garvens, University of Washington)

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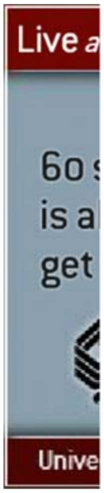

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The project "Deep learning in the mammalian visual cortex" (grant #0835878) will be led by Andrew Ng of Stanford, in collaboration with Ed Boyden of Massachusetts Institute of Technology (MIT), Yann LeCun of New York University, and Yang Dan of the University of California, Berkeley.

This project will employ high-performing artificial neural network systems, new models of deep learning from cognitive science, and new experiments on the visual cortex to begin integrating what is known about the challenging task of recognizing objects from visual inputs. The research will involve decisive experiments to test assumptions about local feedback in the learning system, the results of which may encourage new computational models of the brain.

Studying neural networks with an innovative patch-clamp array

The project "Dynamics of neural networks on a planar patch-clamp array: training, identification, and control" (0835947) will be led by Russell Tedrake of MIT, in collaboration with Alexandre Megretski and H. Sebastian Seung of MIT and Hongkun Park of Harvard University.

This research has the potential to revolutionize in vitro work on cells by solving technical problems with planar patch-clamp arrays. (Patch-clamp arrays are tiny electrodes placed within cells that can describe and control certain cell activities.) If successful, the new patch-clamp arrays will be able to monitor hundreds of cells effectively in parallel, a major step towards interfacing with hundreds of neurons in the brain itself.

A second goal is to develop new, simplified models of living neural circuits and to train these circuits to address benchmark challenges that represent the cutting edge of robotics research.

Determining how the brain controls the hand

The project "Reverse-engineering the human brain's ability to control the hand" (grant #0836042) will be led by Francisco Valero-Cuevas of the University of Southern California, in collaboration with Chang Liu of Northwestern University, Yoky Matsuoka of the University of Washington, and Emanuel Todorov of the University of California, San Diego.

The main goal of this project is to understand how to achieve dexterous, approximately optimal control of a hand by having humans and computers perform familiar but challenging tasks of manipulating objects. Researchers will use the same algorithms both to model human motor control and to go beyond the present state of the art in robotic manipulation. Dexterous robotic hands have a wide variety of possible applications in industry, space, and national security. Improved understanding of how humans learn to optimize hand performance will also have broader benefits, particularly for the disabled.

Modeling control of the electric power grid on the brain

The project "Neuroscience and neural networks for engineering the future intelligent electric power grid" (grant #0836017) will be led by Ganesh Venayagamoorthy of the Missouri University of Science and Technology (Missouri S&T, formerly University of Missouri-Rolla), in collaboration with Donald Wunsch of Missouri S&T, and Ronald Harley and

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Steve Potter of Georgia Institute of Technology.

While previous work on living neural networks (LLNs) has focused on challenges like managing a single control variable, electric power grids entail thousands of interconnected variables that must be managed in real-time. The new work in vitro will probe the ability of LNNs made up of thousands of cells to predict the behavior of a complicated power grid simulator, and it will test the ability of new biological learning models to explain their capabilities. New mathematical concepts for how to cope with such complexity will also be tested by addressing the same prediction challenge, and by attempting to apply adaptive, anticipatory control for the first time to large-scale power grid control in simulation.

Building resilient and sustainable interdependent infrastructures

Eight awards fall under the topic of Resilient and Sustainable Infrastructure (RESIN).

Considering air quality and water availability in electricity production

The project “The interface of infrastructures, markets, and natural cycles—Innovative modeling and control mechanisms for managing electricity, water, and air quality in Texas” (grant #0835414) will be led by David Allen of the University of Texas at Austin (UT), in collaboration with Michael Webber and Roberton Williams of UT, and A. Denny Ellerman and Ronald Prinn of MIT.

The project seeks to demonstrate that integrating data on air quality and water availability into decisions about electricity generation dispatch can make electricity generation and water supply infrastructures more sustainable and resilient. Using Texas as a test bed, the researchers will study, for example, how changes to air quality regulations and electricity markets affect resiliency and sustainability. This project’s use of such data provides an opportunity for a paradigm-shift in the management of water supply and electricity production.

Managing the risk of cascading failures

The project “Assessing and managing cascading failure vulnerabilities of complex interdependent, interactive, adaptive human-based infrastructure systems” (grant #0836047) will be led by Robert Bea of the University of California, Berkeley, in collaboration with Berkeley colleagues John Radke and Karlene Roberts.

The effects of Hurricane Katrina on the New Orleans area have demonstrated the need to consider many factors besides engineering in the reliability and performance of interdependent, complex infrastructure systems. This project aims to develop new, comprehensive risk assessment and management methods for such systems that will take organizational and societal factors into account, in addition to physical science and engineering.

The team will use the flood protection, water distribution, and power supply systems of the Sacramento–San Joaquin Delta area—aging systems that exist in a complex natural and human environment—to address the probability and consequences of failure. The ultimate goal is to improve their resiliency and sustainability while preserving their performance.

Designing infrastructure for biofuels

The project “Interdependence, resilience and sustainability of infrastructures for biofuel development” (grant #0835982) will be led by Ximing Cai of the University of Illinois at Urbana-Champaign (UIUC) in collaboration with four UIUC colleagues: Atul Jain, Madhu Khanna, Gregory McIsaac, and Uyang Yanfeng.

The project seeks to develop strategies to sustainably operate and expand the interdependent infrastructure systems of the emerging bio-economy. In particular, it will examine the systems used to develop biofuels from cellulosic feedstocks, including water supply, energy supply, and transportation, and their vulnerability to natural events and human factors. This research will answer timely and important questions as the nation counts on biofuel providing a greater share of its energy in the future.

Bringing energy and water to urban areas

The project “Sustainable infrastructures for energy and water supply (SINEWS)” (grant #0836046) will be led by John C. Crittenden of Arizona State University (ASU), in collaboration with four ASU colleagues: Samuel Ariaratnam, George Karady, Ke Li, and Charles Perrings.

How can growing cities ensure a reliable and long-term supply of water and energy? This project aims to increase understanding of how urban water and energy infrastructures depend on one another and will examine the life-cycle implications of different infrastructure options. Researchers will take into account risks connected to the infrastructure’s physical and socio-economic environments. Their overall goal is to maximize the resilience and sustainability of energy and water infrastructure systems.

Supplying water where it is scarce

The project “Optimization of conjunctive water supply and reuse systems with distributed treatment for high-growth, water-scarce regions” (grant #0835930) will be led by Kevin Lansey of the University of Arizona (UA), in collaboration with four UA colleagues: Robert Arnold, Guzin Bayraksan, Christopher Choi, and Christopher Scott.

Planners in Southern Arizona and beyond must make objective decisions about water systems, such as the use of dual water distribution systems, the degree of decentralization, and the size and timing of new facilities. This project will help planners make decisions that meet growing demands for water while using less energy and improving water quality. The researchers will develop a tool that integrates water and wastewater infrastructures and can evaluate various system configurations in the face of complex, competing objectives and uncertainty. The tool will optimize for aspects of sustainability (for example, maintenance costs, depletion of ecosystem water allocations, and institutional limits on water reuse)—a critical consideration where water is scarce.

Optimizing energy and transportation infrastructures

The project “21st Century national energy and transportation infrastructures: Balancing sustainability, costs, and resiliency (NETSCORE-21)” (grant #0835989) will be led by James

McCalley of Iowa State University (ISU) in collaboration with four colleagues from ISU: Dionysios Aliprantis, Konstantina Gkritza, Arun Somani, and Lizhi Wang.

The project aims to formulate optimal energy and transportation infrastructure designs in terms of future power generation technologies, energy transport and storage, and hybrid-electric transportation systems, while balancing sustainability, costs, and resiliency. The research will also identify and describe interdependencies between the energy/vehicular transportation systems and the energy resource portfolio. Outcomes of this research may contribute to a national blueprint that will drive energy policy, research, and investment for the next four decades.

Ensuring electricity and communications in a catastrophe

The project “Resilient and sustainable interdependent electric power and communications systems” (grant #0835879) will be led by Lamine Mili of Virginia Polytechnic Institute & State University (VT). He will collaborate with Sandeep Shukla and Michael von Spakovsky of VT, Benjamin Hobbs of Johns Hopkins University, and Arnold Urken of Stevens Institute of Technology.

When an electric power system fails, it can affect the system’s own communications networks. This project will develop complex systems theories to make these interdependent infrastructures more robust, agile, and sustainable through the use of sophisticated models and stabilization techniques and the involvement of microgrids, which may generate power from renewable resources.

Integrating electric vehicles into the grid

The project “A multi-scale design and control framework for dynamically coupled sustainable and resilient infrastructures, with application to vehicle-to-grid integration” (grant #0835995) will be led by Jeffrey Stein of the University of Michigan-Ann Arbor (U-M). He will collaborate with Zoran Filipi, Greg Keoleian, and Huei Peng at U-M and with Mariesa Crow of Missouri University of Science and Technology.

Plug-in hybrid electric vehicles (PHEVs) link transportation and electricity infrastructures by using grid electricity to power the engine and, potentially, by sending stored electricity to the grid (vehicle to grid, or V2G). How PHEVs are used may affect the sustainability and resiliency of these infrastructures. The project will quantify the infrastructure effects of PHEVs and design PHEV power trains to balance the needs of both infrastructures. Researchers will also develop power and energy management strategies that take into account the various roles and interactions of PHEVs and electrical grids. In particular, it will examine the distributed capacity provided by V2G integration and the resulting abilities to accommodate renewable resource intermittency and prevent and recover from catastrophic failures.

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