New Solutions for an Increasingly Complicated World
The Broad Span of Engineering

At one extreme is the “nano” world, with a characteristic length of approximately 1/1000 the diameter of a human hair (~10^-7 meters) and below. Over the past few decades, progress on this scale has been enabled by continual improvement in our ability to fabricate, modify, and image on successively smaller scales. Among other things, this has led to new functional materials and ever more powerful integrated circuits for computers and other electronic devices. The nanoscale is also the characteristic size of components of living systems (e.g., a cell, and biological molecules like DNA). This has paved the way for increasing collaboration among engineering and health and life sciences, as we have presented in past issues of UNM Engineering.

At the other end of the size spectrum lies the large-scale complex systems issues that arguably present the greatest challenges to the entire world—things like energy, climate change, security, health care, transportation, high-bandwidth communications, and water, to name just a few. Complexity in these systems arises from many sources, such as their inherent interdisciplinary nature (e.g., they include economic, social, and political factors) and the integral involvement of people.

In this issue, we present a sampling of the work of School of Engineering faculty, staff, and students in the area of large-scale complex systems. Virtually all of the complex systems work going on in the School falls into the category that we have come to refer to as Information-Powered Systems. In general terms, IPSs are complex systems that embody the collection, storage, processing, and dissemination of information. Of particular interest are IPSs that can learn and adapt in sophisticated ways. IPSs take advantage of the ever increasing power of computing and high-bandwidth communications, two of the School’s overarching strategic research thrusts.

Many of the systems being studied involve physical networks (e.g., the World Wide Web, the electric grid), or can be usefully modeled as networks, as you will read in the first article, which discusses the work of Electrical and Computer Engineering Chair Professor Chaouki Abdallah.

Of course, not all important complex systems are man-made, the human brain being a notable example. A current graduate seminar combines neuroscience and engineering to focus on the link among behavior, cognition, and technology.

Many believe that advancing the field of large-scale complex systems will be among the most important achievements of engineering and computer science in this century. We hope you enjoy reading about the UNM School of Engineering’s exciting work in this area.

Joseph L. Cecchi
Dean of Engineering
Points of Pride

- Abhaya K. Datye, director of the UNM Center for Micro-Engineered Materials, was promoted to the rank of UNM Distinguished Professor, the highest faculty title that UNM bestows. Datye also received the National Science Foundation Industry/University Cooperative Research Center award for 2008, honoring his outstanding efforts as director of the UNM I/UCRC since 1994.

- Computer Science Assistant Professor Jed Crandall and a research team at UC Davis have been studying Internet censorship in China. Contrary to expectations, they discovered that the Chinese firewall does not always block censored traffic. The team developed an automated tool called ConceptDoppler, used it to test various censored phrases from the Chinese Wikipedia, and discovered that as much as 28% of the disallowed data passes through the firewall. Their work was reported on several on-line news sites, including Slashdot and BBC, and in a featured story in the March 2008 issue of *The Atlantic*.

- The Alliance for Transportation Research Institute in the Civil Engineering Department has received a Border Enforcement Grant of $1.8 million from the US Department of Transportation’s Federal Motor Carrier Safety Administration to support electronic screening at southern border crossing inspection facilities. In addition to ATRI, the UNM project team includes HELP, Inc., Parker Young, Transcore, and the New Mexico Border Authority.

- Two new research labs in the Electrical and Computer Engineering Department have students designing futuristic digital integrated circuits that can be remotely reprogrammed to change functions in the field. The labs are part of a consortium comprised of ECE, Sandia National Laboratories, Los Alamos National Laboratory, and the Air Force Research Laboratory that is developing new uses for field-programmable gate arrays in aerospace, defense, and industry.

- UNM Civil Engineering Professor Mahmoud R. Taha, Mechanical Engineering Professors Marwan Al-Haik and Claudia Luhrs, and Georgia Institute of Technology Professor Hamid Garmestani have been awarded $1.1 million from the Defense Threat Reduction Agency to investigate the fundamental processes for developing structural composites based on surface grown carbon nanotubes. This investigation will pave the road for creating the next generation composite materials with ultra high strength, fracture toughness, and deformability that is capable of mitigating blast events successfully.

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UNM Engineering  
Spring 2008  
Volume 5, Number 1

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UNM Engineering is published bimonthly by the University of New Mexico School of Engineering. Subscriptions are free; requests should be submitted to the address below. Material may not be reproduced without permission.

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FSC® Mixed Sources  
Product group identification:  
*Fully Managed Forests*  
www.fsc.org  
Cert No. 639502-0009  
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Researching the Mysteries of Complex Systems
12:15 lunch @ sandwich shop? You hit “send” and seconds later your email arrives in your colleague’s inbox. The reply is almost instantaneous: Sure.

With your email, you’ve connected in a most conventional 21st-century way. But consider that act more closely and you see how truly complex it is. With a click of a button, you communicated with your social circle using a computer to access the Internet, an information network that rides on a physical structure of lines and cables powered by the electrical grid that is fueled by the environmental system which, coming full circle, affects our social system. A simple function is actually extremely complicated. And the Internet is just one example of the many complex systems surrounding us.

A World of Challenges

Fueled by 50 years of dramatic technological advances, our world is now a series of complex systems, networks made up of hundreds, thousands, and even millions of dynamic parts or “nodes”—computers, people, cars, businesses, power plants, roads—linked together and intertwined with other networks. “We live in a networked world and the networks themselves are internetworked or interconnected,” says Chaouki Abdallah, chair of the Electrical and Computer Engineering Department. “When we meet a friend for lunch at a sandwich shop, we’re dependent on the food distribution network, which relies on the transportation network, which is affected by the financial system. What makes such man-made networks even more complex are networks of people and the decisions they make. People affect physical networks and are affected by them.”

These complex systems offer vast opportunities for economic development, information exchange, social networking, problem solving, and much more. They also present daunting challenges and immense liabilities in terms of management, security, and functionality. Complex systems have politicians, engineers, scientists, and business leaders asking: What is the best way to fix a critical network like our nation’s transportation system? How can you insulate the financial network from attack through the computer network? How do you protect our fragile environmental network from the impact of the transportation, energy, and social systems?

“The challenges faced by the world today are truly global in nature. They’re too complex to be solved by an individual, a university, or even one country,” explains Abdallah. Rising to these challenges demands a richer understanding of the complex interactions of technical, social, economic, and ecological factors. Finding solutions will require a revolutionary shift to a culture of innovation and the power of the most advanced technologies available. “The status quo and standard methods don’t suffice in the realm of complex systems,” says Joseph L. Cecchi, dean of the School of Engineering. “We’ll find answers using unconventional thinking, new technologies and by building partnerships among different disciplines.”

Around the world, and right here at UNM, multidisciplinary research teams led by engineers and computer scientists are using their expertise and technology to unravel some of the mysteries of complex systems. A recent study of network science commissioned by the National Academies shows that America is the world leader in complex systems research and New Mexico is eighth in the nation in the discipline.

Education is Key

Finding solutions to complex systems problems is happening in the laboratory and the classroom. “Educating future students to innovate in response to world challenges will require new approaches, including a broader curriculum, increased understanding of diverse cultures and global markets, and hands-on experience in technology transfer and commercialization,” says Cecchi.

SOE graduate students can already take courses in complex systems and reconfigurable systems as well as workshops and seminars that venture into new realms of complex systems research. A current graduate seminar links neuroscience and engineering to study the ultimate complex system: the brain. The class focuses on the development and organization of complex systems linking behavior, cognition, and technology. Speakers include a professor of neurology and psychology from The Mind Research Network, a non-profit neuroscience research center in Albuquerque where UNM is a member, senior researchers from Sandia National Laboratories, and world-renowned experts on neuroscience and complex systems.

“The challenges faced by the world today are truly global in nature. They’re too complex to be solved by an individual, a university, or even one country.”

Chaouki Abdallah
Chair of the Electrical and Computer Engineering Department

Undergraduate students get the solid foundation they need in engineering and their area of interest while they learn to think in a “systems” way through group projects. “We are moving away from traditional engineering where a person would focus on one component or structure,” says Charles Fleddermann, associate dean for academic affairs. “Now we look at things on a systems level and how disparate elements in a system work together.”

Complex Collaborations

Back in the labs, SOE faculty members from different departments are collaborating with other UNM researchers—mathematicians, sociologists, physicists, and more—to study complex systems. “We’re using our expertise which was focused on specific problems and we’re connecting with each other,” says Abdallah. In doing so, UNM research teams are making connections that will help solve some of the world’s biggest challenges.
Chaouki Abdallah
Testing Teleautonomy

When the researcher at the University of Illinois (U of I) moved the joystick handle, it triggered a command that sped across the Internet. A thousand miles away in the basement of the Electrical and Computer Engineering building on the UNM campus, Chaouki Abdallah and his team of students watched as one large robot and eight small slave robots began to move in formation. As the robots approached a wall, they relayed a signal to the U of I researcher who sensed pressure in the joystick and pulled back, maneuvering the robots out of harm’s way.

By using the Internet to control the robots, the two research teams successfully completed a teleautonomy research project funded by the National Science Foundation. The team received a $400,000 NSF grant for the project, which started in 2002 and was completed in 2005.

Researchers at the U of I handled the “tele,” or movement part of the project while Abdallah and his team managed the “autonomy” aspect, how the robots configured themselves and used resources based on commands sent from U of I. To do that, the robots used a physical control protocol that Abdallah adapted from an Internet protocol that manages how much information each user can send.

Because the teams were operating a network across a shared network, Abdallah and his team had to account for congestion on the Internet and factor it into the process. The team found that the delay between sending a command and receiving it averaged 15 milliseconds, but could spike to a minute or more. “It’s very important that the delays are accounted for or you’re going to crash,” says Abdallah. “The challenge is how to manage delays in systems that have changing dynamics.”

Abdallah says that this research illustrates how a complex network can be used to interact and control systems across large distances, with applications ranging from tele-surgery to using an earth-based mechanism to control robots constructing structures on other planets.

These mini robots, designed by Dr. Ray Byrne of Sandia National Laboratories, move blocks in formation to emulate a construction project.
Through his research on hybrid systems, Bert Tanner, professor of mechanical engineering, is studying how the whole can be greater than the sum of its parts. Hybrid systems are networks of dynamic, heterogeneous elements with both discreet and continuous behaviors. Tanner is researching ways to capitalize on the differences and cooperation between the elements in a hybrid system. “It’s all about bringing together resources from different, small, interconnected systems that are spread across networks and exploiting them,” he explains. An orchestra is an apt metaphor for his work. Each musician can play alone, but when all the musicians play the same score under the direction of a conductor, they produce a different, more elaborate musical performance. One of Tanner’s first challenges is to mathematically describe all of the elements in a hybrid system, bringing codes, programs, logic, mechanical devices, electronics, and more together in a single framework.

“As today’s engineering systems grow more complex, I see the need for a new framework that captures what we want to do with these systems,” says Tanner. He is using a variety of techniques from theoretical computer science, complex networks, modeling, simulation, and control theory to create these unifying mathematical models.

Tanner and one of his doctoral students, Wengi Zhang, are close to finishing a theoretical framework. Their first test of the framework will be on a sliding tile puzzle that would solve itself. Each tile in the puzzle will be an independent node or “agent,” and an enabling agent will push and pull the tiles around. Findings from the project will add another critical piece in the larger puzzle of complex systems.
Rafael Fierro
Dynamic Network Experiments

A team of small robots explores a dangerous area filled with noxious fumes. Several unmanned aerial vehicles scan the land below for a target. Both scenarios are examples of dynamic networks: decentralized systems of heterogeneous nodes that work together to achieve a specific mission. Rafael Fierro, professor of electrical and computer engineering, is interested in exactly how these networks coordinate to achieve their mission.

In particular, Fierro is trying to develop a systematic, computational approach for the analysis and design of these decentralized systems that can be repeated with a high degree of confidence. “Past research has been ad hoc,” he comments. “You do something but you can’t be guaranteed that it will work the same next time. The goal is to develop some kind of repeatable algorithm.”

What differentiates Fierro’s work goes beyond the theoretical. “My work is experimentally motivated,” he says. “I develop a solid theory and then validate it on actual hardware.” In one experiment, he created his own dynamic network of robots equipped with sensors and cameras that navigate in an environment while avoiding collisions, differentiating intruders, and hypothesizing a trajectory to intercept the intruders.

He has also applied his ideas to a robotic version of Marco Polo, the classic swimming pool search game, and other games that are being developed with the partial support of the NSF. The goal of this project is to explore various aspects of robot/human interaction and help encourage children’s interest in engineering.

“You do something but you can’t be guaranteed that it will work the same next time. The goal is to develop some kind of repeatable algorithm.”

Rafael Fierro
Professor of electrical and computer engineering

Fierro’s work is inspired by other disciplines including biology, computer science, and electrical engineering. “It’s quite challenging because you need to understand several disciplines in order to create a coherent framework,” he says. “That’s what makes this interesting.” His work could apply to many key areas of complex systems including homeland security, search and rescue, autonomous sampling networks for oceanographic applications, stability of the energy grid, and more.
In early February, four undersea Internet cables in the Middle East failed, one severed by a six-ton ship anchor. Outages across the region and to American military forces in the area were reported and Internet traffic was snarled for days. It isn’t uncommon for undersea Internet cables to break or go offline, but the fact that four major cables serving one region failed at the same time emphasized the vulnerability of this critical communication network.

The FIND Challenge
That scenario is a perfect example of why research teams from around the United States are working on the Future Internet Network Design, an initiative sponsored by the National Science Foundation. FIND challenges researchers to move beyond the Internet’s current constraints and redesign it to address questions about security, information dissemination, economics, and preserving a free and open network. “This project asks us to totally forget what we have now, and instead, see what we would want to do if we built the Internet from scratch,” explains Chaouki Abdallah, chair of the Electrical and Computer Engineering Department. “We also need to imagine how people will use the Internet fifteen years from now and build it to accommodate those new uses and expectations.” Abdallah is working on the FIND project with Wei Wennie Shu, associate professor of electrical and computer engineering; Greg Heileman, professor of electrical and computer engineering; and a number of UNM master’s and doctoral students.

Why does the Internet need to be reinvented now? When Robert Kahn and Vinton Cerf developed the data transmission standards that are the backbone of the current Internet, their goal was to keep a few computers connected in case of a nuclear attack. Today, it’s a very different story. Hundreds of millions of computers,
cell phones, and PDAs are connected through the Internet, and the network is used for everything from selling products to making friends and launching malicious attacks. “The Internet, as it exists today, is very clumsy and slow because it was designed for hundreds of things, not billions of things,” says Abdallah. “The problems of security, wireless access, hackers, and spam have grown exponentially. Our research addresses these issues and works to support what users will do with the Internet of the future.”

In 2006, UNM received a two-year $500,000 grant from NSF. UNM is splitting the grant with its research partner, the Corporation for National Research Initiatives (CNRI), a non-profit organization that fosters research on the national information structure. Internet pioneer Robert Kahn is president and CEO of the organization. “It has been very rewarding for our UNM team to work with Dr. Kahn. His insights into the original Internet design have been very valuable,” says Abdallah.

The team is thinking outside the box—indeed far beyond any known framework—to address all challenges related to developing tomorrow’s Internet. While most FIND research teams are looking at a single aspect of the Internet redesign such as security or mobility, the CNRI/UNM team is one of only two working on all aspects of the Internet’s new architecture. “The work we’re doing cuts across every level of the project from the physical infrastructure and how networks form, all the way to changing social attitudes and social networks,” explains Abdallah.

Network Architecture
Using a variety of mathematical tools including control theory, game theory, network science, simulation, and programming, the CNRI/UNM team is re-engineering the Internet as a logical network, not a physical one. They call their approach transient network architecture and it resolves two of the biggest Internet design challenges. “The transient network architecture emphasizes mobility and at the same time addresses security. From the very beginning of the design process, we’ve considered both factors,” says Shu. “Within such a logical framework, it is not only about communicating information, but also about managing it,” explains Heileman. “While the original Internet architecture was tailored for machine-to-machine applications, today’s Internet usage model is centered around information access and retrieval.”

Most of the functions currently dependent on hardware, like computers and PDAs, and physical infrastructure, like routers and undersea cables, would be transferred into software capable of migrating when resources are low, hardware fails, or cables are cut. Using control theory to evaluate its best resource options, the software would migrate to another working node—another computer or cell phone, for example—and the system would reallocate resources accordingly to keep content available and functions running smoothly. “We’ve designed this so if there is a problem with the network, the software moves because what you’re concerned with is not actually the hardware but rather the information and the ability to keep things moving forward,” explains Abdallah.

To appreciate how convenient transient network architecture would be, consider what happens when you lose your Blackberry. Right now, when you leave your PDA on a plane or drop it in the ocean, you’ve lost the hardware and all the valuable—and sometimes sensitive—information on it. With transient network architecture, you could simply call the Blackberry from another device, enter a few commands, and transfer your address book, emails, and other personal information to a new device. You’d have what’s most important to you—your information—and the Blackberry device itself would essentially become a useless shell.

Unique Identifiers and Associations
Part of what makes this transient Internet concept possible is the team’s use of persistent identifiers (PI), unique numbers attached to everything associated with the network. So regardless of where it is in the network, every person, computer, document, or software file would be assigned a unique PI, much like a social security number. Eventually, everything from people and equipment to appliances and clothes
with sensors in them would have a PI. "In the future, networks are going to consist of huge numbers of sensors and everything will have a PI and need to be networked," says Heileman, whose focus is digital rights management and content management. "Persistently and securely identifying network objects, whether users or content, enables a powerful notion of secure identity in the network. Our research builds upon this powerful notion to design an open, flexible information and digital rights management architecture that can better address the needs of a future Internet."

PIs would replace the current system of IP addresses, which are essentially ever-changing geographical locators associated with only a piece of hardware. Henry Jerez, a senior research scientist at CNRI and a UNM SOE graduate, studied how PIs are currently used by libraries to manage publications and digital objects. Then he adapted the idea for the UNM/CNRI FIND project so that PIs can be applied to computers, cell phones, people, and more. Joud Khoury, a PhD student at UNM, is one of the main contributors to the project. His dissertation work, in addition to investigating scalable naming architectures, is providing a taxonomy of most known networking architectures, and will, for the first time, allow for a fair comparison between proposed new architectures.

To manage the process of connecting so many PIs and the ad hoc way networks tend to form, the UNM/CNRI team created areas of influence (AOIs), distinct levels of connectivity between PIs within a specified region and among different AOIs. There are three AOI circles: local, intermediate, and global. When one PI tries to connect with another, the AOI system first searches for the two PIs at the local level. If they aren’t present at that level, the system expands the search to the intermediate level and then, if needed, to the global level (see diagram below).

Now in their second year of the FIND initiative, the UNM/CNRI team has already tested their new transient network architecture on the UNM campus using a robot, PDAs, and cell phones. The robot can move from one part of the campus to another, disconnect itself, and then connect at a remote location seamlessly. This test effectively demonstrates that devices and agents may connect to the Internet from anywhere in the world, be able to receive commands, and coordinate their actions with nearby or remote devices. Now the team is hoping to test the system on the City of Albuquerque’s Rapid Ride buses.

Twice a year, the team meets with other FIND teams to share results and ideas. Ultimately, the best research results from FIND will be tested through the Global Environment for Network Innovations (GENI). GENI is a NSF-sponsored research facility designed for realistic experiments on the radical network designs of today that could become the design standards of tomorrow.

The UNM/CNRI FIND team proposes a transient network architecture composed of nodes with unique persistent identifiers that group together into associations or Areas of Influence (AOIs). There are three AOI circles that correspond to different identity trust levels: a local or personal user authority, an intermediate or AOI-level authority, and a global trust authority.
Imagine a group of small, mobile robots methodically searching a warehouse for an explosive device or testing the air for a dangerous toxin. Each intrepid robot, or “agent,” has its own sensing capabilities, but it can cover only so much ground on its own. To complete the mission, the agents must move in a coordinated fashion, share information, and work together while reporting to the human in charge. Restrict power resources, limit sensing and processing capability, and add physical obstacles like walls, uneven terrain, and weather, and the agents’ job becomes much more challenging.

Yasamin Mostofi is researching ways to make their job easier. An assistant professor in the Electrical and Computer Engineering Department, Mostofi is studying cooperative networks and ways to make them more efficient and robust. She conducts her research with a team of masters and doctoral students including Alireza Ghaffarkhah, Mehrzad Chegini, and Yongxiang Ruan.

Improving Network Potential

A subcategory of complex systems, cooperative networks are groups of decentralized agents, sometimes called “nodes,” that work together to achieve a common goal without the direction of a leader. An agent can be anything from computer software to a sensor or power plant. The advent of cheap embedded units equipped with sensing, communication, and processing capabilities has created new and unimaginable possibilities for learning and interacting with our environment. The vision of such networks cooperatively learning and adapting to
achieve a common goal is closer than ever. However, to realize the full potential of cooperative networks, several challenges must be addressed. Understanding and optimization of information flow is one of the critical challenges of network science, which is a new field of investigation for studying complex networks.

Mostofi’s academic background gives her research a unique twist. She earned her Ph.D. in communications and conducted post-doctoral research in control and dynamical systems. Using her experience and understanding of communication links between agents, she applies a realistic view of how communication affects high-level decision-making and control in cooperative networks, something that has received little attention. “Due to the complex and multidisciplinary nature of the problem, it is common to assume ideal communication links or links that are perfect within a certain radius when it comes to motion planning,” explains Mostofi. “This, however, is too simplistic and does not allow for understanding and optimization of information flow in mobile cooperative networks.” She was one of the first researchers to propose communication aware decision-making strategies where issues such as multipath fading and shadowing, both random and time varying factors that affect link quality, are accounted for in high level decision-making and motion-planning.

Mostofi and her team are working on multiple research projects that focus on two main areas: developing mathematical foundations for understanding cooperative networks and creating smarter algorithms to improve the network’s performance and robustness, with an emphasis on information flow.

Planning the Next Step
To achieve the goal in a timely and efficient manner, each agent must make strategic decisions about movement based on information from other agents. Otherwise, all of the agents may search the same area.

Agents must also take into account how actions will affect their ability to communicate. “Motion planning cannot ignore communication,” says Mostofi. “As you move around, communication link qualities are going to change due to effects such as fading and shadowing so we need to take those into account.” A move in one direction may improve an agent’s ability to sense a target, but diminish its capacity to exchange information with other agents because of the extra power required to communicate, a process Mostofi refers to as “communication and sensing trade-offs.” This means that an agent may need to sacrifice some local sensing quality in order to have stronger communication links, and hence better overall networked sensing. On the other hand, an agent may need to rely on itself, from time to time, if the cost of communication is too high.

To get better insight into designing cooperative networks, Mostofi learned from networks in the natural world. Studies of social insect colonies have shown that in collective foraging, if the cost of communication among individuals in a large area is high, insects may decide to explore the area independently as opposed to relying on getting the information from others. Based on such studies, she proved that the optimum design in cooperative mobile networks involves similar strategies, which she characterized mathematically.
Reaching an Agreement

Once the agents have planned their next step, they must be able to reach a consensus about their findings. Mostofi and her team are researching that challenge with Majeed Hayat, professor of electrical and computer engineering, and Patrick Bridges, assistant professor of computer science. Their network science-related research project is funded by the Defense Threat Reduction Agency. In August 2007, the team received $400,000 from DTRA to design a network that can withstand a deliberate attack. However, findings from the research would be applicable to all types of networks facing a variety of threats or failures.

Mostofi and her team are responsible for robust and distributed estimation and detection of the attacks; or how to make agents smarter so they can share information and reach an agreement about the situation while lowering the probability of making false assessments.

“The main challenge is that the information for such estimation and detection is sparse and distributed over the network,” says Mostofi. “Network consensus problems have therefore received considerable importance and attention in recent years. Most of the work in this area, however, has focused on estimation type consensus.”

Using matrix analysis, probability, and communication theory, her team has mathematically characterized the relationship between the transient behavior of detection consensus and link qualities. This characterization shows that it is beneficial for the agents to communicate to reach a consensus over the occurrence of an event—but only up to a point. When links between agents have deteriorated, probabilistic measures of link quality must also be factored in to how the agents make decisions. To address this, Mostofi uses concepts such as soft information processing, a familiar approach in coding theory, to make smarter agents. In a sense, this allows an agent receiving information over a poor-quality link to weigh it less heavily than the information coming from an agent with a better connection.

The UNM research team has already developed intelligent algorithms for increasing robustness of cooperative networks to attacks and failures. Now, they’ve put in a proposal with DTRA to extend their research to more complex scenarios.

Sharing Tasks

Another focus of the team is on computation, communication, and control, a process that evaluates how best to allocate both computation and communication resources among agents that are in charge of real-time and cooperative decision-making and control. While problems at the intersection of communication and control have received considerable attention in recent years, the intersection of the three has mainly stayed unexplored.

Working in real time and managing tasks, agents in the network must distribute tasks among themselves and do so in an adaptive and decentralized manner that allows for the fact that agents fail and new agents join the network. Communication resources such as limited bandwidth must be allocated accordingly and cannot be optimized independently. “It results in very interesting trade-offs as to how agents should share computation and communication resources and allocate tasks,” says Mostofi.

So far, Mostofi has developed an optimization framework where the optimum allocation of computing resources is related to the characteristics of the jobs and link qualities. Through solving the dual problem, Mostofi was able to find a closed-form expression for the optimum solution.

“This, however, is just the beginning,” says Mostofi. Judging by their diverse projects and passion for research, Mostofi and her team will move beyond researching better agents to finding new solutions for an increasingly complicated world.
SYMPOTUM Focuses on
Education for Innovation

How can the United States overcome unprecedented economic global competition and escalating crises in technical education, energy, climate change, security, health, transportation, and resource access?

“Educatng for Innovation: Connecting UNM to the World’s Challenges,” a symposium at UNM held on October 2, 2007, sought answers to these questions. The premise of the symposium was that the key to facing these challenges is strengthening the culture of innovation.

New Mexico Senators Jeff Bingaman and Pete Domenici were honorary symposium co-chairs. Both have played key leadership roles in raising the awareness of threats to US competitiveness, the importance of innovation, the necessity of re-invigorating investment in research, and the imperative of transforming education.

Creativity, Innovation, and the New Sciences of Learning

Morning keynote speaker R. Keith Sawyer, professor of psychology and education at Washington University, asserted that innovation today is always collaborative. From developing the ATM to open source operating systems to the world’s best-selling guitar strings, the innovations that have changed our world are the result of people collaborating, not individuals working alone. Sawyer said the primary task of educators is to prepare students to participate creatively in today’s knowledge economy. Students must have a deep understanding of complex concepts, be able to work in teams, and know how to manipulate concepts creatively.

Three Major Challenges and Strategies to Solve Them

Afternoon keynote speaker Robert Galvin, founder of the Galvin Electricity Initiative and retired CEO and chairman of Motorola, said that Albuquerque could be the epitome of a leadership community if it strives to find answers to three basic challenges.

How do you make an electric power system that never fails? Roughly 500,000 Americans spend at least two hours a day without electricity in their homes and businesses, costing our economy $150 billion a year. The Galvin Energy Initiative offers a forum to exchange ideas about improving the nation’s electrical infrastructure on their web site, www.galvinpower.com.

How can we eliminate traffic congestion? Galvin said that public-private partnerships are needed to develop innovative, practical, cost-effective ways to increase road capacity and manage the transportation system.

How can we draw up scientific roadmaps to explore the fundamental challenges that must be solved? Galvin asserted that the culture of science must be more productive and that new science roadmaps, similar to those used in engineering, should be developed to explore society’s larger challenges.

The two nationally known keynote speakers were followed by panel discussions with local leaders from academia, the national labs, and the private sector. The symposium was one of six celebrating the installation of UNM President David Schmidly. The UNM School of Engineering partnered with the Anderson School of Management and STC.UNM to host the event, which was sponsored by the Albuquerque Chamber of Commerce, Mesa del Sol, and Albuquerque Economic Development.

Sawyer’s talk was followed by a panel discussion moderated by Suleiman Kassicieh, professor, Anderson School of Management. Left to right: Duane Dimos, Sandia National Labs; Francis Edwards, private investor, Anderson Foundation Board; Vera John-Steiner, professor emerita, College of Education; and Trevor Loy, managing partner, Flywheel Ventures.

Galvin’s talk was followed by a panel discussion with, left to right: Lisa Kuuttila, president and CEO, STC.UNM; Michael D. Daly, president, Mesa del Sol; Ned Godshall, CEO, Altelia Inc.; Jack McGowan, president, Energy Control, Inc.; Jeff Sterba, CEO, PNM; and Terri Cole, president, Greater Albuquerque Chamber of Commerce (not shown).
Harold R. Bosch  
**Bachelor of Science, Civil Engineering, 1971**

Bosch is an internationally recognized expert in wind engineering and serves as director of the Aerodynamics Laboratory at the Federal Highway Administration’s Turner Fairbank Highway Research Center. In his 35-year career with the FHWA, he has made significant contributions to the wind engineering of highway structures. In addition to his laboratory work, Bosch has helped pioneer long-term bridge monitoring technologies and has improved analytical wind models for long bridge spans.

Adrian B. Chernoff—Young Distinguished Engineer  
**Bachelor of Science, Mechanical Engineering, 1996; Master of Science, Mechanical Engineering, 1999**

Chernoff is a prolific inventor who holds 54 U.S. and foreign patents. He also has 50 patents pending and more than 800 documented ideas. He was the chief architect at General Motors and the principal inventor behind GM’s “Reinvention of the Automobile,” which has been claimed as the most significant advancement in transportation in the last 50 years. He also worked for Walt Disney Imagineering, Sandia National Laboratories, and NASA. Chernoff is currently working on several start-ups, including his consulting company, Ideation Genesis, and www.MUZZ.com, a web site dedicated to individuals who change the world.

Sajjad H. Durrani  
**Doctor of Science, Electrical Engineering, 1963**

Durrani is a world-renowned expert in satellite communications. He worked for the National Aeronautics and Space Administration (NASA) on the Tracking and Data Relay Satellite System (TDRSS) which is the primary relay for earth observation satellites, the Hubble Space Telescope, and the Space Shuttle. He managed NASA research on the subject, including program management for the Advanced Communication Technology Satellite (ACTS). In addition, Durrani taught engineering in Pakistan for 10 years and served as an adjunct professor at George Washington University and the University of Maryland.

Thomas J. Nesbitt  
**Bachelor of Science, Civil Engineering, 1948**

Nesbitt was a pioneer in utilizing recycled asphalt to save time, money and natural resources, and later used state-of-the-art technology to perform cold in-place recycling of asphalt pavement. He founded three successful companies and was an excellent businessman. Landmark projects include work on the Phoenix International Raceway, Scottsdale Airport, and Cardinal Stadium. Nesbitt was an active volunteer and continually found ways to contribute to the community and further education. He passed away in 2007, leaving a legacy of innovation, community involvement, and Lobo spirit as an inspiration for future generations of engineers.

Heinz W. Schmitt  
**Master of Science, Mechanical Engineering, 1962**

Schmitt worked at Sandia National Laboratories for 36 years, advancing from technical staff member to chief engineer and vice president of Weapons Systems, responsible for 1,600 employees and a $400 million budget. Schmitt’s leadership in nuclear weapons technology, policy development, and participation in several high-level federal government committees were judged to be so pivotal that he was awarded the Secretary of Defense Medal for Outstanding Public Service in 1993. He led Sandia’s initiative in advanced manufacturing, a major contributor to the national agile manufacturing effort, and the manufacturing engineering program at UNM. Schmitt is an avid volunteer and has served on several educational advisory boards at the local and national levels.
Nuclear power and energy expert Robert L. Long, PhD, and his wife Ann G. Long have been actively involved in helping students achieve their educational goals for decades. They recently gave a gift to the ChNE department to support chemical and nuclear engineering undergraduate educational activities, including scholarships, student organizations, and engineering competitions. They have also funded the Robert and Ann Long Endowed Presidential Scholarships for undergraduate students in chemical or nuclear engineering. Dr. Long’s association with the department began as a new faculty member in 1965. During his tenure he served as ChNE assistant chair from 1972-74 and chair from 1974-78.

Nuclear engineering seniors were given the opportunity to compete for the Gorham Family Scholarships. Decisions were made based on their essay, GPA, extracurricular activities, and financial need. Scholarships of $5000 each were awarded to Bryan Chapman, Allison Miller, Ben Maestas, Jesse Murray, Erica Ortega and Jessica Rodriguez.

ChNE Professor Abhaya K. Datye has been awarded a continuing grant of $2.5 million through the National Science Foundation Partnership for International Research and Education (PIRE). Datye’s program is investigating the critical steps required for chemical transformation of biomass-derived reactants into useful products. It provides new collaborative models for international research and education, with fellowship opportunities for graduate and undergraduate students to partner sites in Germany and Denmark.

Chair: Julia E. Fulghum
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Electrical and Computer Engineering

ECE Professor Sanjay Krishna received Early Career Achievement awards twice during February, one from IEEE's Nanotechnology Council and one from SPIE, the optical engineering society. The honors follow the September award of Krishna's second patent, co-authored with ECE Professor Majeed Hayat and Professor of Electronic and Electrical Engineering John David at the University of Sheffield, for a photodetector that provides an absorption region based on quantum wells and/or quantum dots with an avalanche gain region. IEEE’s Nanotechnology Council confers its award to recognize individuals who have made contributions with major impact on the field of nanotechnology. The SPIE award recognizes Krishna's work with self-assembled quantum dots. This is the first year SPIE has given an early career achievement award.

Chair: Chaouki Abdallah
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Computer Science

CS graduate student Sushmita Roy co-authored a paper titled, “Discovery of Functional Elements in 12 Drosophila Genomes Using Evolutionary Signatures,” which was published in the journal Nature, November 2007. Nature has also accepted a paper for publication authored by former student Aaron Clauset, Professor Cris Moore, and their collaborator Mark Newman. The paper is based on Clauset’s dissertation research and is titled, “Hierarchical structure and the prediction of missing links in networks.”

CS Professor Terran Lane received continuation funding from the National Science Foundation for his Research Experiences for Undergraduates program. In collaboration with the University of Oklahoma, Lane will be providing summer research opportunities for undergraduates in the field of Machine Learning.

Chair: Stephanie Forrest
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Mechanical Engineering

Under construction at the ME Department is a novel experimental apparatus funded by the US Defense Threat Reduction Agency and led by Professors Peter Vorobieff and Randy Truman. The tiltable Mach 2.5 shock tube is the first of its kind and will be used to study interactions of shock waves with density interfaces, particles, droplets, and bacterial spores. Earlier research shock tubes were stationary, with either horizontal or vertical orientation, making it possible to study only shock interaction with planar density interfaces stabilized by earth's gravity. The UNM shock tube will be tiltable, which makes it possible to use gravity-induced stratification to produce density interfaces oriented at an arbitrary angle to the direction of the shock—a feature sought after by numerical code developers who need experimental benchmarks to validate simulation results modeling a variety of physical processes, from supernova explosions to inertial confinement fusion.

Chair: Juan C. Heinrich
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Civil Engineering

CE Professor Mahmoud Taha was recently selected to be a Regent’s Lecturer, the most prestigious honor that UNM awards junior faculty. Taha’s research interests include structural health monitoring, nano-materials, artificial intelligence in structural engineering and biomechanics.

A new study co-authored by Associate Professor Julie Coonrod describes how climate change will result in decreased water availability in New Mexico’s Rio Grande Basin, cutting the state’s water supply and hurting its economy and agriculture. The study used a middle scenario of greenhouse gas emissions growth over the 21st century and examined a wide range of potential changes in temperature and precipitation. Projections suggest significantly less water in a warmer future, and at the same time, significantly more people. Major changes will be required in patterns of water use. The study was highlighted in the New York Times and numerous New Mexico media.

CE Professors Jerald Rounds and Susan Bogus were invited to participate in a NSF-sponsored workshop in China on a new multidisciplinary and multinational model to internationalize engineering education and research. They attended workshops, visited leading universities in Shanghai, Chongqing, and Beijing, and toured numerous construction and cultural sites.

Chair: Arup Maji
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