

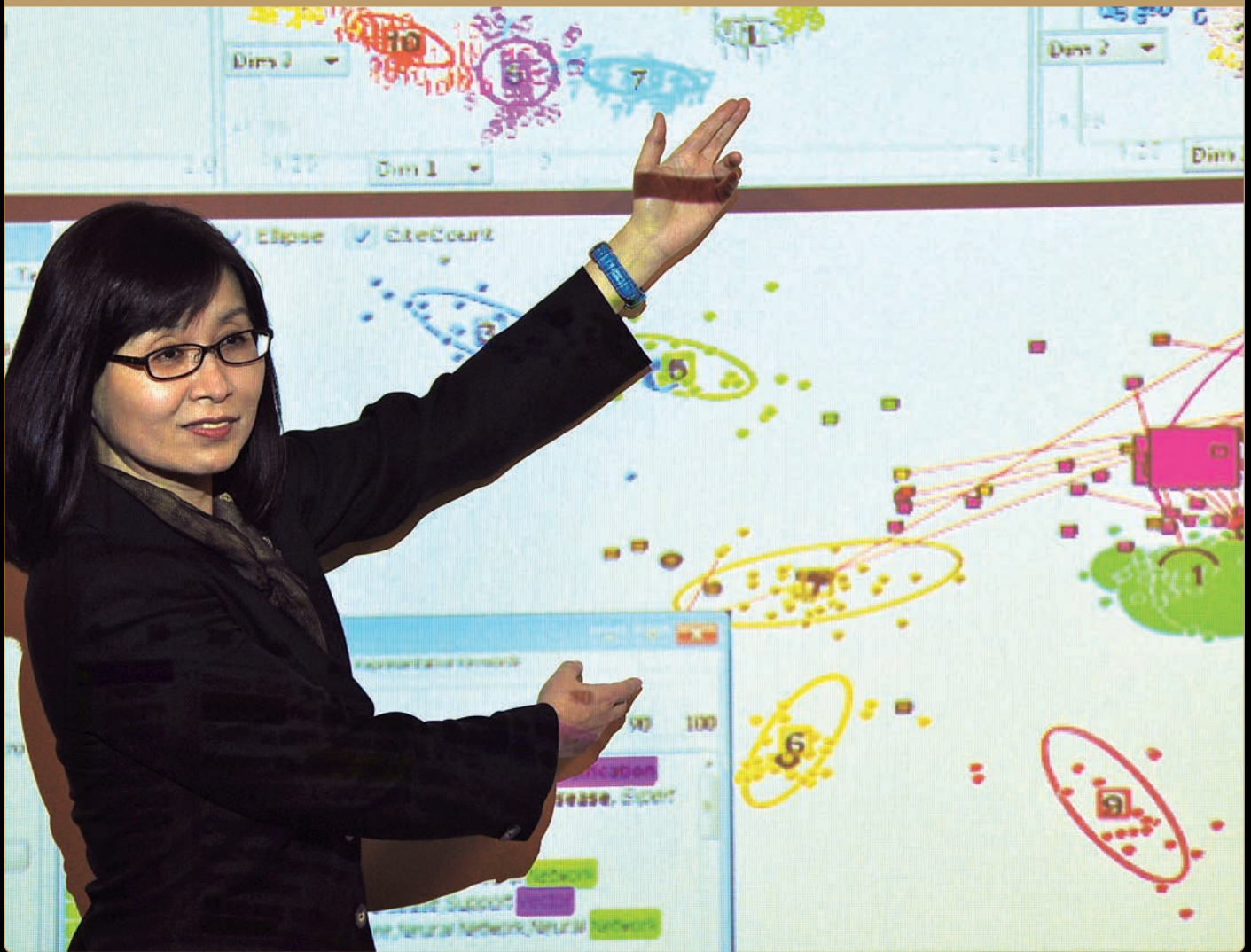
Horizons

Research

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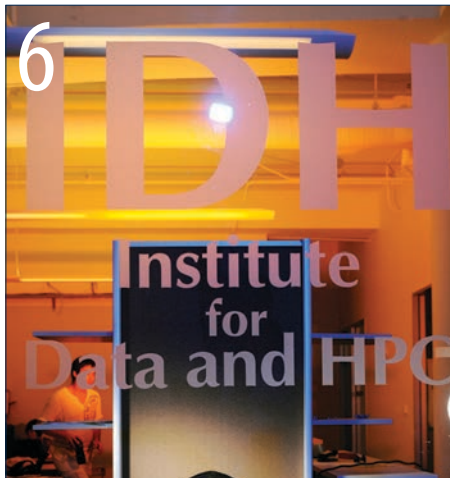
Fall 2012 – Winter 2013

TACKLING THE CHALLENGES OF BIG DATA



 **Georgia Institute**
of Technology

- *Fossil Coral Records*
- *A Strategy for Research*
- *All-Star Scientists*
- *Cathepsin Cannibalism*
- *Hurricane Radiometer*



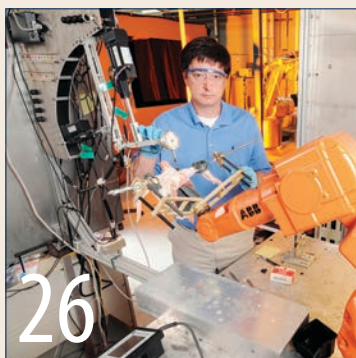
“These massive data sets are too large and complex for humans to effectively extract useful information without the aid of computational tools. The good news is that sophisticated computing approaches – such as machine learning algorithms and data visualization – now allow us to examine large, interrelated data sets with increasing speed and accuracy.”

– Richard Fujimoto, Regents’ Professor in the School of Computational Science and Engineering

COVER STORY

“Our data will provide a reference for the magnitude of ENSO-related changes that may have occurred, and allow researchers to probe the causes of past climate changes evident in other paleoclimate records and in model simulations of past climates.”

– Kim Cobb, associate professor in the School of Earth and Atmospheric Sciences

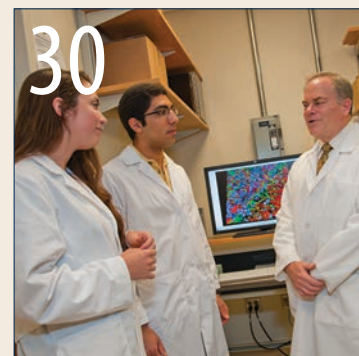


“...We have developed the sensing and actuation needed to allow an automated deboning system to adapt to the individual bird, as opposed to forcing the bird to conform to the machine.”

– Gary McMurray, chief of the Georgia Tech Research Institute’s (GTRI) Food Processing Technology Division

“Technology transition is too often a slow and painful process. It does not follow a linear, unidirectional and sequential path; though that is the way support processes have been designed and implemented. We are working hard to change this.”

– Stephen Cross, executive vice president for research



“The study results suggest that individuals who may have fewer individual achievements but are a major source of support and feedback for the people around them can have a major impact on their colleagues’ careers and help improve the aggregate output of their academic departments.”

— Alexander Oettl, assistant professor in the Scheller College of Business

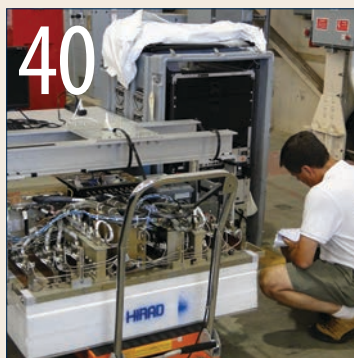


“These findings provide a new way of thinking about how these proteases are working with and against each other to remodel tissue.”

— Manu Platt, assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University

“This project is an example of the kinds of work we have been doing for the Department of Defense, and we’re pleased that this technology can be transitioned to assist with weather prediction and research.”

— Glenn Hopkins, research engineer in the Georgia Tech Research Institute (GTRI)



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Georgia Institute of Technology
75 Fifth St., N.W., Suite 100
Atlanta, GA 30308-1021 USA

STAFF

Editor: John Toon
Writers: Abby Robinson,
Rick Robinson, Sarah Goodwin
Photography: Gary Meek, Rob Felt
Design: Inward Solutions

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Cover: School of Computational Science and Engineering professor Haesun Park presents Visual Information Retrieval and Recommendation (VisIRR), a visual analytic system for large-scale document discovery, developed with the support of the NSF/DHS Foundations of Data and Visual Analytics (FODAVA) grant. (Photo: Barry Drake)

Georgia Tech Research Horizons Magazine

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By examining a set of fossil corals, scientists have tripled the amount of historic information available on the El Niño-Southern Oscillation, a Pacific Ocean climate cycle that affects climate worldwide. The new information will help assess the accuracy of climate model projections for 21st century climate change in the tropical Pacific.

Photo: Gary Meek



Researchers use cores like these taken from fossil coral to provide information about the strength of the El Niño Southern Oscillation (ENSO) during periods of time as long as 7,000 years ago.

Coral Records:

Fossils Suggest Recent El Niño Activity Rises Above Noisy Background

By John Toon

By examining a set of fossil corals that are as much as 7,000 years old, scientists have dramatically expanded the amount of information available on the El Niño-Southern Oscillation, a Pacific Ocean climate cycle that affects climate worldwide. The new information will help assess the accuracy of climate model projections for 21st century climate change in the tropical Pacific.

The new coral data show that 20th century El Niño-Southern Oscillation (ENSO) climate cycles are significantly stronger than ENSO variations captured in the fossil corals. But the data also reveal large natural variations in past ENSO strength, making it difficult to attribute the 20th century intensification of ENSO to rising carbon dioxide levels. Such large natural fluctuations in ENSO activity are also apparent in multi-century climate model simulations.

"We looked at the long-term variability of ENSO in the climate models and asked how it compares to the long-term variability of ENSO in the real world," said Kim Cobb, an associate professor in the Georgia Tech School of Earth and Atmospheric Sciences. "We show that they actually match fairly well. This project sets the stage for conducting more detailed data-model comparisons from specific time intervals to test the accuracy of ENSO characteristics in the various models."

The research, sponsored by the National Science Foundation (NSF), was reported Jan. 4, 2013, in the journal *Science*.

ENSO extremes drive changes in global temperature and precipitation patterns every two to seven

years. The variations are particularly pronounced in the central tropical Pacific, where Cobb and her team collected the fossil coral cores used in this study. By analyzing the ratio of specific oxygen isotopes in the coral skeletons, the scientists obtained information about ENSO-related temperature and rainfall variations during the periods of time in which the corals grew.

The researchers collected the coral samples by drilling cores from massive coral "rocks" rolled onto Pacific island beaches by the action of strong storms or tsunamis. Cobb and her team studied 17 such cores of varying lengths and ages recovered from Christmas and Fanning Islands, which are part of the Line Island chain located in the mid-Pacific.

The study of each core began with careful dating, done by analyzing the ratio of uranium to thorium. That work was performed by co-authors Larry Edwards and Hai Cheng at the University of Minnesota. Once the age of each core was determined, Cobb and her team chose a subset of the collection to be studied in detail.

They sawed each core in half and X-rayed the cross-sections to reveal the growth direction of each coral. The researchers then drilled out small samples of coral powder every millimeter down the core and analyzed them with mass spectrometers at Georgia Tech and the Scripps Institution of Oceanography to determine the ratio of oxygen isotopes.

The isotope ratio in the coral skeleton changes with the temperature and amount of rainfall, providing detailed information about environmental

conditions during each period of the coral's growth. As many as 20 samples were analyzed for each year of the coral's lifetime.


In all, Cobb's team added 650 years of monthly-resolved information about ENSO variations across nearly 7,000 years. That required analyzing approximately 15,000 samples over the course of the study, which began in 2005.

Using the new sequences to quantify the range of natural variability in El Niño-Southern Oscillation strength, the researchers have detected a modest, but statistically-significant increase in 20th century ENSO strength that may be related to anthropogenic climate change. However, the coral reconstruction shows an even higher level of ENSO strength 400 years ago, though its duration was shorter.

"The level of ENSO variability we see in the 20th century is not unprecedented," Cobb said. "But the 20th century does stand out, statistically, as being higher than the fossil coral baseline."

Information about the El Niño-Southern Oscillation is important for climate scientists because the cycle helps drive other aspects of global climate change.

"El Niño is something that people want to know about when they reconstruct past climate changes at a specific site," Cobb said. "Our data will provide a reference for the magnitude of ENSO-related changes that may have occurred, and allow researchers to probe the causes of past climate changes evident in other paleoclimate records and in model simulations of past climates."

Beyond the researchers already mentioned, the paper's co-authors include Hussein Sayani and Emanuele Di Lorenzo from Georgia Tech, and Christopher Charles, Niko Westphal and Jordan Watson from the Scripps Institution of Oceanography. In addition to the National Science Foundation, the project received assistance from Norwegian Cruise Lines, the National Geographic WAITT program and the Palmyra Atoll Research Consortium. 

The bulk of the research reported here was supported by the National Science Foundation (NSF) under Grant OCE-0752091. The content of this article is solely the responsibility of the authors and does not necessarily represent the official views of the NSF.



Watch a video about this research at
<http://bit.ly/XiByZR>

CONTACT

Kim Cobb
kim.cobb@eas.gatech.edu

“Our data will provide a reference for the magnitude of ENSO-related changes that may have occurred, and allow researchers to probe the causes of past climate changes evident in other paleoclimate records and in model simulations of past climates.”

— Kim Cobb, associate professor in the School of Earth and Atmospheric Sciences



Associate professor Kim Cobb holds slabs of fossil coral taken from cores drilled in the Line Islands in the mid-Pacific Ocean. Powder from the slabs is examined in the mass spectrometer, which measures the ratio of oxygen isotopes to assess the strength of ENSO during the time the corals were growing.

Dozens of Georgia Tech research teams are working on the challenges involved in extracting vital knowledge from massive quantities of digital information – a discipline known as big data. The research is addressing challenges across many areas of science and technology.

Elizabeth Whitaker, a principal research scientist in the Georgia Tech Research Institute (GTRI), uses case-based reasoning to help tackle big-data problems in a variety of applications.



Photo: Gary Meek

Taming Big Data:

Georgia Tech Researchers Tackle the Challenges of Massive Information Sets

By Rick Robinson

In a sprawling Georgia Tech research center, materials scientists and mechanical engineers analyze petabytes of molecular-level data on metal alloys. Their goal is to minimize the time it takes to move innovative metal alloys from the laboratory to industry.

Across campus, biologists and computer scientists work to develop a diagnostic tool that would spot ovarian cancer by using machine learning to find key patterns in thousands of blood samples. Nearby, physicists use a new visualization facility to better understand terabytes of data on galaxy formation, while other researchers analyze multiple large data sets to improve war-zone surveillance and defend the nation's computing infrastructure.

"Today's technologies – including advanced research instruments, the digitizing of records, sensor and surveillance systems, and the Internet itself – are producing unprecedented amounts of digital information," said Richard Fujimoto, a Regents' Professor in the School of Computational Science and Engineering and interim director of the Georgia Tech Institute for Data and High Performance Computing (IDH). "These massive data sets are too large and complex for humans to effectively extract useful information without the aid of computational tools. The good news is that sophisticated computing approaches – such as machine learning algorithms and data visualization – now allow

us to examine large, interrelated data sets with increasing speed and accuracy."

Dozens of Georgia Tech teams are working on the challenges involved in extracting vital knowledge from massive quantities of digital information. These teams are supported by a growing number of resources, including the IDH; the Center for Data Analytics, the Center for High Performance Computing, and numerous high-performance computing installations at Georgia Tech, U.S. government laboratories and other universities.

In March 2012, the Obama Administration announced the Big Data Research and Development Initiative. This effort involves \$200 million in new programs, underscoring the national importance of overcoming the obstacles posed as data sets balloon past mere terabyte size – which require a trillion (10^{12}) bytes of storage – to petabytes, equivalent to a quadrillion (10^{15}) bytes.

"Handling a daily tsunami of new data in diverse fields from bioinformatics to finance, approximating the volume of all data created from the beginning of time through the 20th century, requires research breakthroughs in computer processing, algorithms and analytics," said Stephen E. Cross, executive vice president for research at Georgia Tech. "Big data is one of 12 core research areas at Georgia Tech, and we actively support a broad range of methodologies that address it."

CORE TECHNOLOGIES FOR UTILIZING BIG DATA

Many strategies are being employed to take advantage of massive data sets. These include cutting-edge software approaches, advanced hardware systems and visualization strategies, as well as sampling techniques that reduce data size and complexity without losing accuracy and usefulness.

Advancing Machine Learning Software

A point often made about big data in all its forms is that it's too big for humans to grasp; instead, it must be approached digitally, via computers. Thus, it's become critical for researchers to devise software routines, known as machine learning algorithms, that derive and exploit subtle patterns within massive data sets.

"The excitement about big data is everywhere today, in both industry and in academia,"

said Alexander Gray, an associate professor in the School of Computational Science and Engineering. "The amount of data captured and stored is doubling at an amazing rate – even faster than the 18 months of Moore's Law – and it's becoming relevant to every field there is."

Gray directs the Fundamental Algorithmic and Statistical Tools Laboratory (FASTlab) and is co-founder of Skytree Inc., a provider of industrial-level machine learning software and a member of Georgia Tech's Advanced Technology Development Center (ATDC) startup company accelerator.

Data sets occur in either structured or unstructured forms, Gray explained. Structured data, the familiar database approach involving columns and rows, is now a mature technology. It is well understood and can be readily exploited by simple data queries.

"Actually, in a way we've always had big data – of the structured variety," he said. "But now we've got data that's both big and unstructured, and that's a very different world."

Unstructured data consists of vast numbers of data points – individual data elements

CONTACTS

David Bader
bader@cc.gatech.edu

John Bartholdi
john.bartholdi@isye.gatech.edu

Dan Campbell
dan.campbell@gtri.gatech.edu

John Crittenden
john.crittenden@ce.gatech.edu

Stephen Cross
cross@gatech.edu

Judith Curry
judith.curry@eas.gatech.edu

Richard Fujimoto
richard.fujimoto@cc.gatech.edu

Hamid Garmestani
hamid.garmestani@mse.gatech.edu

Eric Gilbert
gilbert@cc.gatech.edu

Alexander Gray
agray@cc.gatech.edu

Subhro Guhathakurta
subhro.guha@coa.gatech.edu

Xiaoming Huo
xiaoming@isye.gatech.edu

Eva Lee
eva.lee@isye.gatech.edu

Tim Lieuwen
tim.lieuwen@aerospace.gatech.edu

Dimitri Mavris
dimitri.mavris@aerospace.gatech.edu

John McDonald
john.mcdonald@biology.gatech.edu

David McDowell
david.mcdowell@me.gatech.edu

Suresh Menon
suresh.menon@aerospace.gatech.edu

Haesun Park
hpark@cc.gatech.edu

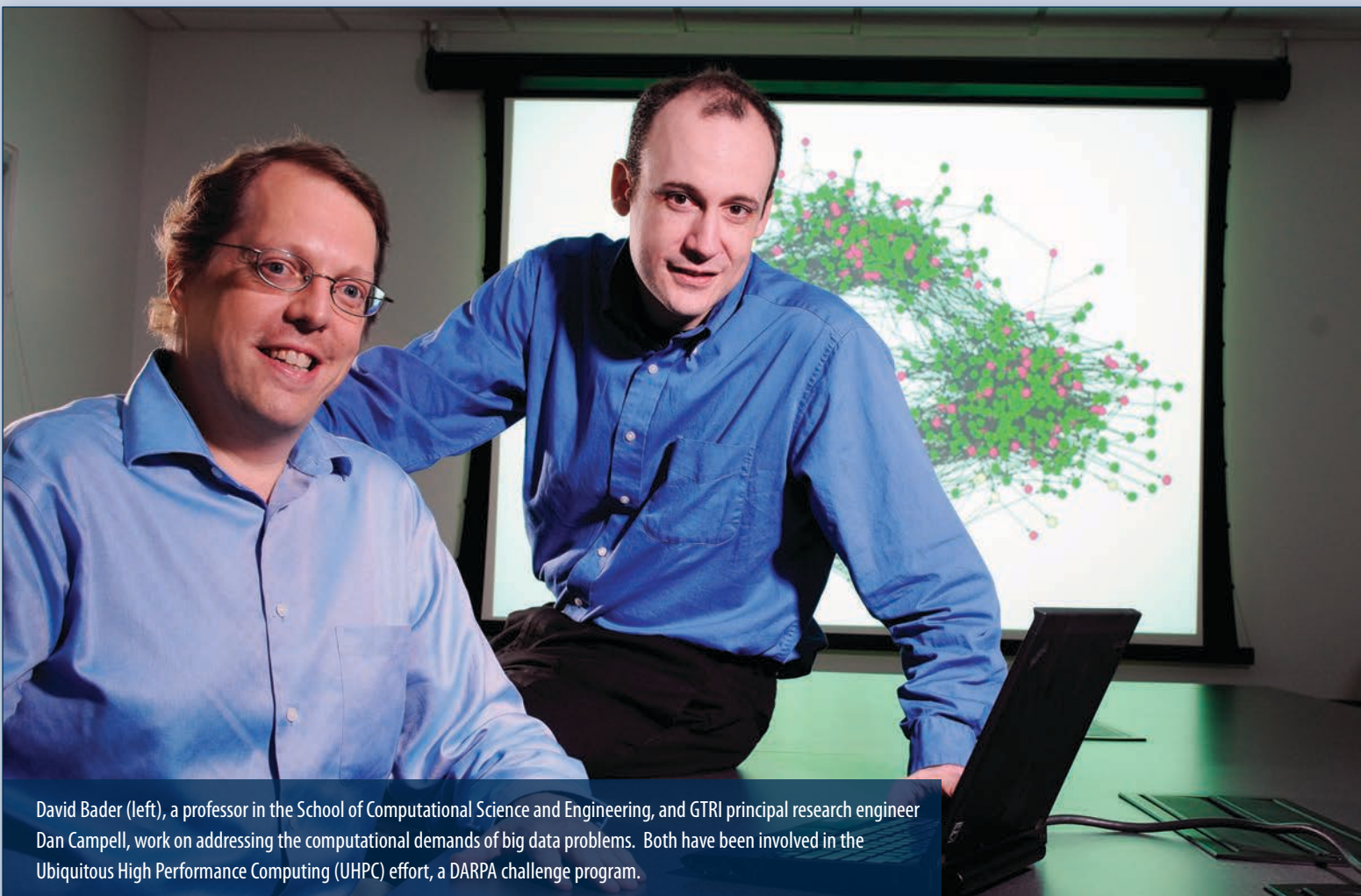
Mark Richards
mrichards@gatech.edu

Justin Romberg
jrom@ece.gatech.edu

Karsten Schwan
karsten.schwan@cc.gatech.edu



Richard Fujimoto, a Regents' Professor in the School of Computational Science and Engineering, is interim director of the Georgia Tech Institute for Data and High Performance Computing (IDH).



David Bader (left), a professor in the School of Computational Science and Engineering, and GTRI principal research engineer Dan Campell, work on addressing the computational demands of big data problems. Both have been involved in the Ubiquitous High Performance Computing (UHPC) effort, a DARPA challenge program.

– that don't occur in a neat database format and may or may not be interrelated.

Examples of relatively structured data are the weather information produced by modern radar, or cosmic data provided by optical and electromagnetic detectors. In these cases, users know basically where their desired data are; the challenge generally lies in separating those data from unwanted signals, referred to as background noise.

Other data types – often very important to business – are even less structured. A key example is the information generated by the Internet, where natural groupings can be hidden anywhere in reams of data.

In this arena, machine learning can uncover information that is instantly valuable, such as the searching and buying habits of millions of people. Or it can explore potentially valuable opinion and trend information contained in social media messages.

A key challenge in processing unstructured data is the fact that pertinent information consists mainly of plain text. Individual data elements have no fixed length and can't be easily captured and mined as in a conventional database.

Gray explained that Google Inc. made major strides in dealing with unstructured Internet data years ago, when it devised the MapReduce programming model that's at the heart of the efficient

Google search engine capability. Subsequently, a cadre of programmers developed Hadoop, an open source software platform that offers similar functionality.

"The Google formula showed the business world that big data can translate to big dollars – billions of them," he said.

However, there's a drawback to today's software platforms based on MapReduce, Gray believes. These platforms work reasonably well for the storage and management of unstructured data, and for simple analytics like queries and text searches.

But they don't work as well for advanced analytics, in which machine learning is needed to infer complex patterns and predictions, he said.

Gray and his colleagues are developing machine learning algorithms that address these issues. The goal is advanced analytics technology that can solve complex problems while offering streamlined performance that lowers computational costs.

"Advanced machine learning and big data are creating a marketing revolution that is making possible the personalization of everything," he said.

Developing Hardware Strategies

As information production escalates, faster and more sophisticated computer systems are vital to addressing the data challenges. At

Georgia Tech, researchers are investigating which hardware architectures are most effective for specific information-related problems.

The familiar parallel supercomputing technique – in which a computational task is divided among multiple processors – is well suited to numerous computer-intensive problems, explained David Bader, a professor in the School of Computational Science and Engineering and executive director of the new Center for High Performance Computing.

"If I'm performing a weather simulation or designing a vehicle or simulating molecular dynamics, the problem typically exhibits what we call locality," said Bader, who is also a researcher with the Georgia Tech Research Institute (GTRI). "I can divide the task up into equal-sized sections and assign them to processors that typically only need to communicate with their nearest neighbors."

But many big-data problems can be quite different, he explained. These are highly unstructured problems that involve vast data sets containing bits of related information that could be anywhere – the proverbial needle in the haystack. These problems require specialized hardware approaches.

Bader first began working on this issue years ago, by addressing the big-data challenges presented by social media. In social media, he explained, information relating to specific friendship networks or communities of followers is scattered in irregular patterns throughout vast quantities of unrelated data. What's needed is a new kind of data analytics – special algorithms that perform in-depth analyses.

To develop these new analytics, Bader and his colleagues have developed algorithms that analyze social networks. In this arena, he is working with Eric Gilbert, an assistant professor in the School of Interactive Computing, who is principal investigator for the Social Media in Strategic Communication (SMISC) Program sponsored by the Defense Advanced Research Projects Agency (DARPA).

Bader noted that algorithms able to parse social networks can be very useful for understanding other domains where critical bits of information are also highly scattered. Such do-

main involve many fields, from biology to the resilience of electric power grids.

This new kind of algorithm calls for a computer different from the familiar multi-processor parallel configuration. Bader and his colleagues are currently utilizing an unusual massively multithreaded supercomputer, the Cray XMT, one of which is located at the Pacific Northwest National Laboratory of the Department of Energy.

The Cray XMT includes a custom processor and a massively multi-threaded architecture. Moreover, it addresses a single main memory area that can be as large as 64 terabytes.

"This design allows me to place an entire massive data set into that main memory, which helps exploit the natural concurrency in exploring the vertices of a graph," Bader said. "It's like a workstation on steroids. I can just take my unstructured problem, without worrying about reorganizing it into regular-sized pieces, and run it orders of magnitude faster than if I used cloud computing or a conventional supercomputer."

In the future, less rarified hardware platforms may be able to tackle such data-intensive problems. Relief could come from initiatives like the Ubiquitous High Performance Computing (UHPC) program.

This DARPA challenge seeks to pack an ultra high-performance computer – powerful but with reduced power requirements – into a cabinet about the size of a refrigerator. Among the device requirements is the ability to analyze vast streams of unrelated data to find nuggets of useful information.

Bader is currently involved in two UHPC projects. In one, he is collaborating with Nvidia Corp. to help develop a UHPC system. This initiative's eight-year goal is to achieve at least a petaflop of computing speed – a trillion operations per second – using only 57 kilowatts of power.

In another effort, Bader is collaborating with Mark Richards, a principal research engineer in the School of Electrical and Computer Engineering, and Dan Campbell, a GTRI principal research engineer, to develop novel benchmarking approaches.

Bader is on the board of Emcien Corp., a big data analytics company that graduated from Georgia Tech's ATDC startup company accelerator.

CONTACTS (cont.)

Jianjun (Jan) Shi
jianjun.shi@isye.gatech.edu

Deirdre Shoemaker
deirdre.shoemaker@physics.gatech.edu

Chris Smoak
christopher.smoak@gtri.gatech.edu

John Stasko
john.stasko@cc.gatech.edu

John Stewart
john.stewart@gtri.gatech.edu

Joshua Weitz
jsweitz@gatech.edu

Elizabeth Whitaker
elizabeth.whitaker@gtri.gatech.edu

John Wise
jwise@physics.gatech.edu

Matthew Wolf
mwolf@cc.gatech.edu

Vigor Yang
vigor.yang@aerospace.gatech.edu

Ming Yuan
ming.yuan@isye.gatech.edu

Hongyuan Zha
zha@cc.gatech.edu

Advancing Data Techniques

Professor Karsten Schwan and his team in the School of Computer Science have expertise in “middleware” – software that negotiates between applications and operating systems and enables the management and manipulation of data in distributed applications.

For them, there are two different worlds of big data.

One area is typified by the familiar world of the Internet, where massive quantities of data are generated each day by millions of users. These data sets consist largely of billions of relatively small individual messages, most of them in the form of plain text.

Search engines, retailers, banks and others track these exchanges to gauge consumer behavior, help detect fraud and protect against online attacks. When Schwan and his team address the “data center applications” that provide these kinds of services, they must deal with the enormous scale of the data involved, which makes it imperative to explicitly manage the systems and the applications being run.

Working in this arena, Schwan collaborated with Hewlett-Packard Co. and IBM Corp. to initiate the area called autonomic computing. This approach involves observing such things as application “health” and maintaining the desired quality of service for data center applications.

These days, a different big data realm also concerns Schwan and his team in the Center for Experimental Research in Computer Systems (CERCS). They’re currently working with Department of Energy (DOE) researchers who study large chunks of very “dense” scientific data, meaning there are many connections between the data elements.

“So instead of having 100 million messages to consider, maybe I only have 100,000,” said Schwan, a Regents’ Professor. “But they’re really big pieces – a thousand times larger perhaps – and that changes a lot of things.”

The need to deal with large data pieces alters hardware approaches to capturing and storing data, he explained. Just moving and storing data is a challenge.

Moreover, the size of these data pieces also affects the software used to examine them. The code developed by Schwan’s team must enable DOE scientists to manage, analyze and visualize the many terabytes of modeling and simulation data produced by government supercomputers.

“Take the case of climate, where I want to understand what’s going on within one individual data run of half a petabyte,” said Matthew Wolf, a research scientist who is working on these problems with Schwan and with fellow research scientist Greg Eisenhauer. “But I also want to see how this current data set relates to a huge catalog of data runs going back 10 years. That’s a very dense problem.”

Georgia Tech is participating in the DOE’s Scalable Data Management, Analysis and Visualization (SDAV) Institute, announced in March 2012, which brings together the expertise of six national

laboratories and seven universities to help DOE scientists address big data issues. Schwan and his team are leading Georgia Tech’s involvement in the program, initially funded at \$5 million.

In addition, Schwan and his CERCS team are taking part in the Center for Exascale Simulation of Combustion in Turbulence (ExaCT), a DOE co-design center aimed at solving problems inherent in combustion and paving the way for new approaches to automotive engine designs.

Exascale computing represents a new dimension in data-processing capability, Wolf explained. Currently, the DOE’s goal is to build a computer that’s a thousand times more powerful than anything available today. This new technology will likely generate not 20 terabytes of data every 10 minutes – an output produced by some of today’s supercomputers – but a petabyte of data every 10 minutes.

“There’s a roadmap to get to exascale levels in terms of hardware, but in terms of software it turns out that you cross a critical threshold and fundamental changes will be required,” Wolf said. “Big data problems are bad today, and they’re going to get really bad tomorrow – unless we do something radically different.”

Visualizing Data Effectively

Like the proverbial picture worth a thousand words, a computer visualization can be more valuable than a mass of numbers. That’s because presenting data in a visual form – in graphs or other kinds of simulated images – can give researchers the ability to detect patterns that aren’t otherwise apparent.

“Visualization, many would argue, is most useful when you don’t know what you’re looking for,” said John Stasko, a professor in the School of Interactive Computing and director of the Information Interfaces Research Group. “Someone can drop a pile of data into visualization software and ask, ‘Anything here we should care about?’”

Today’s big data, he explained, presents real challenges to meaningful visualization. A monitor – even a whole cluster of monitors or a huge screen – has only so many pixels available. If the information to be represented dwarfs the available screen terrain, portraying the data in visual form is daunting.

To tackle data visualization issues, Stasko said, today’s visual analytics technology uses three components.

- *Computational data analysis* is the number crunching, modeling and transformation process that prepares purely numerical data for the visualization process. “Invariably when data is really big, you’re going to have to work with it first,” Stasko said. “We have to filter, manipulate and transform the information in a variety of ways.”
- *Interactive visual interfaces* make possible exploratory approaches that let analysts delve into data areas that interest them. Stasko has developed a system called Jigsaw, funded by the National Science Foundation (NSF) – and also by the Department of Homeland Security (DHS) through the

Regents' Professor Karsten Schwan (left) and research scientist Matthew Wolf of the School of Computer Science focus on middleware – software that negotiates between applications and operating systems and enables the management and manipulation of data in distributed applications.



VACCINE Center of Excellence. This knowledge-acquisition program can examine unstructured text – even plain narratives – to find key information hidden within.

- *Analytical reasoning* focuses on how people think – how they generate hypotheses and reach decisions. Stasko is working to build capabilities that facilitate human reason into his computer tools.

Partnering on Visual Analytics

Georgia Tech leads the Foundations of Data and Visual Analytics (FODAVA), a five-year program aimed at establishing visual analytics as a distinct research field by creating and advancing its computational foundations. The program is jointly sponsored by a \$3.4 million grant from the NSF and the DHS and includes collaborations with 17 other U.S. universities.

“Data and visual analytics is defined as the science of analytical reasoning, facilitated by integration of interactive visual interfaces and automated algorithms,” said Haesun Park, a professor in the School of Computational Science and Engineering, director of FODAVA, and executive director of the newly established Center for Data Analytics at Georgia Tech. “This project focuses on the mathematical, statistical and algorithmic foundations of visual analytics for massive and high dimensional data.”

FODAVA, now in its fourth year and involving 13 Georgia Tech faculty investigators, has been developing two principal types of software. The FODAVA team will make these foundational discoveries available to the data and visual analytics research communities.

Visual Information Retrieval and Recommendation Systems (VisIRR) – Researchers seeking specialized information on the Internet are generally confronted by ample results – too ample. The VisIRR platform hones automated search results by injecting human perception and visual interaction into the process.

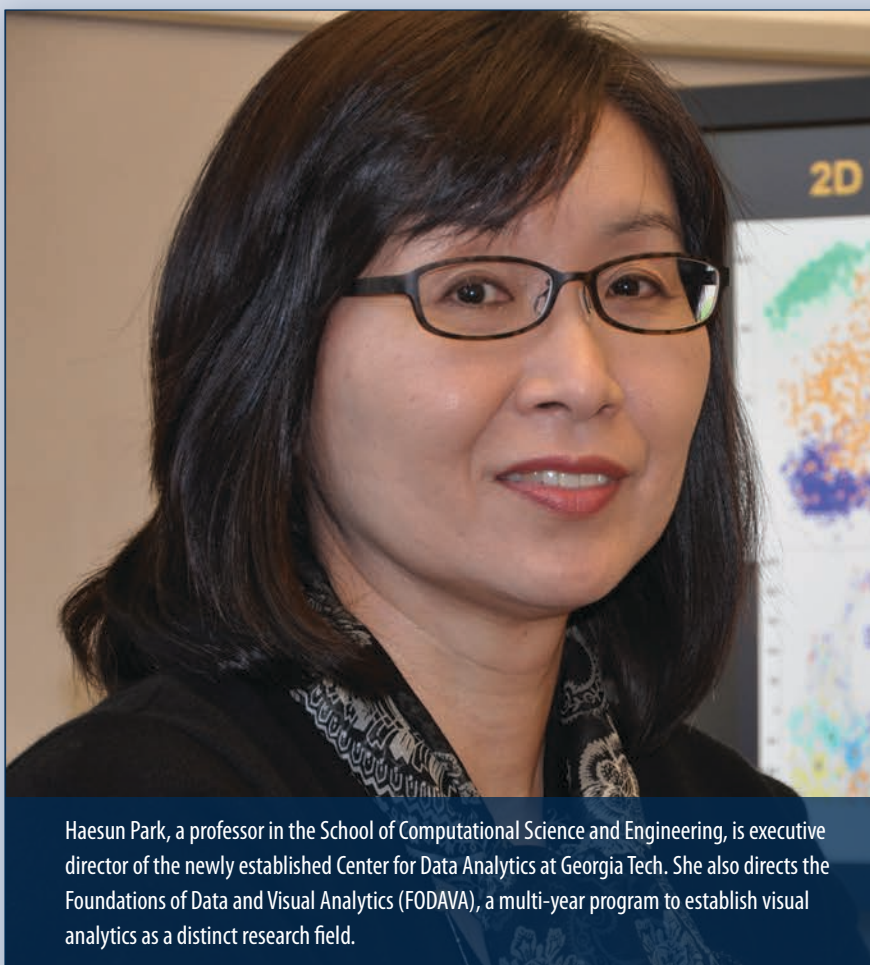
“Suppose out of millions of papers you want to find documents related to the document or topics of interest to you,” Park said. “Through automated algorithms we choose more relevant papers, thereby reducing the search space. Then we allow you to interact with the data throughout the retrieval process via visual interfaces. In addition, the retrieved documents are combined with the system-recommended documents, and their relationships are visually represented.”

VisIRR visualizations use spatial proximity to represent unstructured high dimensional data such as document collections. Two-dimensional and three-dimensional graphics represent the apparent relevance of various choices.

FODAVA research test bed – This software is aimed at researchers who want to find the most appropriate machine learning algorithm suite from the many available. It supports selection of the optimal tools to address such issues as dimension reduction, clustering and classification.

Park explained that this test bed provides an extensive library of routines that goes beyond automatic algorithms because it also offers visual interaction. It enables users to visualize the intermediate and final results that can be expected from choosing a specific suite.

“We’ve gotten a lot of requests for this kind of tool, especially from the bioinformatics community,” Park said. “This system allows you to try



Haesun Park, a professor in the School of Computational Science and Engineering, is executive director of the newly established Center for Data Analytics at Georgia Tech. She also directs the Foundations of Data and Visual Analytics (FODAVA), a multi-year program to establish visual analytics as a distinct research field.

many different possible combinations of algorithms and actually see the potential results – facilitating better understanding of data and better algorithm choices for specific applications.”

APPLYING BIG DATA TO REAL WORLD PROBLEMS

Researchers today don’t really have big data “problems,” suggests Vigor Yang, who is the William R. T. Oakes Professor and Chair of the Daniel Guggenheim School of Aerospace Engineering. He views them more as opportunities.

“After all, it’s the researchers themselves who painstakingly pursue and create these massive data sets as an integral part of their work,” Yang said.

Yet producing this volume of data is the only first step, he explained. Researchers must then mine it for the insights hidden within, and present the results in a form that can be utilized to improve the knowledge base.

Throughout Georgia Tech, researchers are utilizing big data to tackle a wide variety of problems. What follows is a sampling of some of that work.

APPLYING BIG DATA TO INDUSTRY

Accelerating Materials Development

In June 2011 President Barack Obama announced the Materials Genome Initiative for Global Competitiveness. Its stated aim is to reduce development time and cost by providing the infrastructure and training that American innovators need to discover, develop, manufacture and deploy advanced materials.

The initiative offers materials scientists the opportunity to better integrate the development of new materials with advanced manufacturing, said David McDowell, who is the Carter N. Paden Jr. Distinguished Chair in Metals Processing and Regents’ Professor in the Woodruff School of Mechanical Engineering. He also has a joint appointment in the School of Materials Science and Engineering.

“We need to link materials design and development together with new product development,” said McDowell, who is co-director of the Center for Computational Materials Design, a joint Penn State-Georgia Tech Industry/University Cooperative Research Center sponsored by the NSF. “It takes about 15 years to get new materials into advanced products today, yet it takes only 18 to 36 months to design these new products on the computer. There’s a big disconnect there.”

Novel materials research techniques such as atom probe tomography, serial sectioning and neutron scattering have given



Hamid Garmestani (left), a professor in the School of Materials Science and Engineering, and David McDowell, a Regents' Professor in the Woodruff School of Mechanical Engineering, are working on materials design methods that can foster more rapid new product development.

scientists new capabilities for characterizing the 3-D structure of materials from the atomic scale up, he explained. But these improved characterization capabilities also lead to huge data sets that are challenging to manipulate and interpret.

McDowell advocates a systems engineering approach that will use advances in both scientific tools and computation to design new materials that possess advanced internal architectures. The ability of computing technologies to exploit massive data sets is vital to the effort.

"The biggest challenge is how to store and mine large data sets, so we can get the information we're going to need for future materials development efforts," he said. "We're getting to the point where our understanding is sophisticated enough to start considering how to combine these tools."

Understanding Materials Microstructures

The drive to create new materials rapidly for industry requires a thorough analysis of the constituent parts, morphology and interconnections. Scientists are using novel research techniques to better understand the microstructure of target materials.

Hamid Garmestani, a professor in the School of Materials Science and Engineering, is investigating tiny segments of microstructures called grains, which are about 5 to 50 microns in

size. His aim is to fine-tune various material properties – such as strength, ductility and electronic/thermal conductivity – not by altering the basic chemical makeup of the material but by rearranging its grain distribution and morphology.

But directly observing the microstructure of a material hasn't produced the realism he's looking for. The problem is, when working at close to the atomic scale, direct observation of even a few grains of a material produces huge and unwieldy data sets.

"My team has been working with direct observations of the microstructure of a nickel 200 superalloy, focusing on a section that is perhaps eight grains by eight grains in size," Garmestani said. "We have to run the resulting data on a supercomputer for many weeks to get a useable model of that eight by eight grain microstructure."

So Garmestani and his team are also utilizing a simulation technique that allows them to view microstructures better while producing smaller data sets. By using statistical correlation functions to simulate the microstructures of nickel 200 and other materials, they have developed a statistical probability model – rather than a direct model – of grain-level structure.

The benefit of this simulation technique is that it allows researchers to view a given material at a much larger scale – thousands by thousands of grains. Sampling techniques based



Professor Dimitri Mavris and his team - Olivia Pinon Fischer, John Salmon, Kelly Griendling and Simon Briceno (left-to-right) - are pictured here with the Collaborative Visualization Environment (CoVE). The CoVE offers an 18-by-10-foot, high-resolution multimedia wall that supports visualization of data.

on statistical methods can form a more complete, and therefore more representative, model of the material.

"Especially with respect to the Materials Genome Initiative, I think people are increasingly seeing the advantages of going to statistical techniques rather than direct techniques," Garmestani said. "Statistical methods and the use of correlation functions can reduce computational demands and decrease the time needed to design new materials for industry."

Unraveling Logistics Problems

High volume distribution centers – whether they serve Wal-Mart, Home Depot or the Department of Defense – ship hundreds of thousands of items to many destinations daily. If these facilities can systematically save a few seconds of labor here or a centimeter of space there, the total efficiency gain can be significant.

Yet achieving big savings requires finding patterns in huge data sets. Engineers must analyze thousands or millions of customer orders and then use that information to optimize warehouse layouts and processes.

John Bartholdi is the Manhattan Associates Chair of Supply Chain Management in the H. Milton Stewart School of Industrial and Systems Engineering. He's working on warehousing optimization for the Defense Logistics Agency, and has also performed similar research for numerous corporations.

"We build tools to automate the search for exploitable patterns, which can hide in vast data sets," said Bartholdi, who is also research director of the Supply Chain and Logistics Institute. "We analyze

huge histories of customer orders, just like Amazon does. But instead of doing it to tune advertising and drive sales, we do it to tune the warehouse and the entire supply chain, to drive efficiencies."

Understanding the Manufacturing Process

Jianjun (Jan) Shi, the Carolyn J. Stewart Chair and professor in the School of Industrial and Systems Engineering, employs a multi-disciplinary data fusion approach to improving manufacturing processes that involve massive information sets. Shi combines data, statistical methods, signal processing, control theory and domain knowledge to solve manufacturing problems.

"We frequently analyze data from a factory's information system to monitor system status and performance via system informatics and control techniques," Shi said. "We then develop automated algorithms that can be implemented directly into production systems for performance improvement."

Among his projects:

- Working with major automobile manufacturers, Shi has introduced "Stream of Variation" technology that monitors multistage assembly stations to reduce variations in manufacturing processes. The resulting information is used to pinpoint the cause of any variation problems in the final product.
- In research for a large number of U.S. and international steel companies, Shi and his team have developed data fusion algorithms for inline sensing and defect detection for product quality and production efficiency improve-

ments. That software has been implemented in a dozen real-world production systems.

Building Predictive Models

Xiaoming Huo focuses on statistical modeling of large, diverse data sets. Huo, a School of Industrial and Systems Engineering professor, uses existing data to build predictive models – tools that forecast probable outcomes.

That's a distinct challenge, Huo said, because each data set is large and complex, and its useful features are unknown. He works in areas that include geophysics, automatic control, engineering signal modeling, financial data analysis and smart environment design.

Often, the data appear in the form of images, and Huo must develop feature-extraction methods customized for each problem.

"Given the size of the data and limitations on the number of features that can be utilized, the task of searching for useful data points is truly like searching for needles in a haystack," said Huo, who teaches both computational statistics and financial data. "Defining the predictors – the variables that you are going to utilize to build the statistical model – is the hardest question."

Among the approaches he uses are signal and image processing methods, along with inputs of "domain knowledge" – expert knowledge of the domain in question.

In one recent geophysical project, Huo's goal was to separate desired features from many similar ones. His data source was a large one – a 3-D image produced by some 8,000 sensors detecting man-made sonic vibrations in the earth over a 10-kilometer area.

Huo used automated image processing techniques, including Fourier domain techniques that analyze signals with respect to frequency rather than time. He extracted desired high frequency image components and removed unwanted low frequency data, resulting in a ground structure image that offered important information to petroleum geologists.

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IDH: Advancing Georgia Tech's Capabilities in Supercomputing and Big Data

The Institute for Data and High Performance Computing (IDH) provides a framework for developing and executing Georgia Tech's strategy in areas such as big data and high-performance computing. The institute supports a broad range of interdisciplinary research initiatives – on applications, algorithms, hardware and software systems, and the underlying foundational mathematics.

"IDH is at the Georgia Tech intellectual crossroads in leading interdisciplinary research to advance our abilities to process, understand and use the ever-increasing size and complexity of data," said Stephen E. Cross, executive vice president for research at Georgia Tech.

Richard Fujimoto, Regents' Professor and chair of the School of Computational Science and Engineering, is IDH interim director. He contends that computation has now gained widespread acceptance, alongside theory and experimentation, as a key paradigm for discovery and innovation in today's scientific and engineering disciplines.

"Georgia Tech has long emphasized interdisciplinary collaboration, and IDH supports the use of computing in ways that

impact many fields," Fujimoto said. "For example, one IDH initiative focuses on developing next-generation high-performance computing software for emerging applications and computing platforms; these projects require collaborations among faculty with different expertise."

Two centers have been established under IDH to date: the Center for High-Performance Computing, led by David Bader, and the Center for Data Analytics, led by Haesun Park. Both are professors in the School of Computational Science and Engineering.

In another effort, IDH is fostering cooperation among Georgia Tech researchers and Emory University's Center for Comprehensive Informatics, which is led by Joel H. Saltz, M.D., Ph.D., chair and professor of Emory's Department of Biomedical Informatics and adjunct professor of computational science and engineering at Georgia Tech. This research involves digital pathology, which focuses on automating detection and diagnosis of cancer and other diseases through advanced processing of large sets of image data.

– Rick Robinson

Predicting Future Environment

Climate research is especially dependent on large data sets. The meteorological and environmental investigations on which climate research depends rely on many data sources, current and historical.

The task of interpreting this data is at the heart of today's advanced climate research. And the models of future climate that result from this work are in high demand by both business and government.

"The biggest challenge in environmental science is not only that we have huge amounts of data, but that the data are inherently messy," said Judith Curry, professor and chair of the School of Earth and Atmospheric Sciences. "We're not talking about controlled laboratory situations – we're talking about lots of different data sets, from satellite measurements of the atmosphere to tree rings, and all of it measured by many different people."

Curry and her research team use advanced algorithms and parallel-processing techniques to get a handle on the data. That in turn allows them to produce complex future climate models that are used for ongoing research.

APPLYING BIG DATA FOR GOVERNMENT

Manipulating Data Visually

When researchers utilize big data sets to develop applications for government and industry, in-depth manipulation of that data can provide key insights.

The Collaborative Visualization Environment (CoVE), located in the School of Aerospace Engineering, offers an 18-by-10-foot, high-resolution multimedia wall that can simultaneously display and manage more than 60 data variables.

The Collaborative Design Environment (CoDE), located immediately next to the CoVE, is a reconfigurable facility that allows users to share resources across desktop sources and display devices in real time. The room has four screens, including the main 29-by-10-foot curved 3-D screen, making it suitable for collaborative design and analysis.

The CoVE and CoDE are utilized by numerous researchers, including Dimitri Mavris, who is the Boeing Professor of Advanced Aerospace Systems Analysis and director of the Aerospace Systems Design Laboratory (ASDL). Mavris helped establish these unique facilities, which were funded by the U.S. Office of Naval Research.

"My team has some 45 active projects underway for the Federal Aviation Administration, NASA, Navy, Air Force, Joint Forces Command and others, involving many different problems – and the CoVE and CoDE are probably our most valuable data-fusion tools, allowing us to bring together information from a wide variety of sources," Mavris said. "This type of visual analytics lets researchers explore causality –

meaning, if one parameter is changed, we can ask what will happen to the others."

Mavris – assisted by researchers Simon Briceno, Kelly Griendling, Olivia Pinon Fischer, John Salmon and others – is using the CoVE and CoDE to analyze massive data sets for a variety of projects, including:

- *Multimodal Operations for Vehicles During Emergency/First Response Scenarios (MOVERS)*: This form of operations research helps identify fleet size and mix to deliver cargo to many locations within a variety of humanitarian and military scenarios.
- *Tool to Reduce Error in Estimates from Satellites (TREES)*: The goal of this project is to quantify and trace the uncertainty of biomass estimation for the U.S. government. It uses existing optical data, data merging and regression techniques, along with expected advances in satellite sensing technology.
- *Micro Autonomous Systems & Technology (MAST)*: ASDL is supporting this broad-based program, in which multiple universities and companies are collaborating to develop cooperative teams of tiny autonomous robots. The CoDE environment enables investigators to create simulations of flying robots, which have already been used to develop actual flying prototypes.
- *Systems Platform, Integration and Design (SPID)*: CoVE uses a 3-D parametric environment, directly embedded within a conceptual design tool, to investigate such data-intensive problems as turbofan engine design.

Compressing the Sensing Process

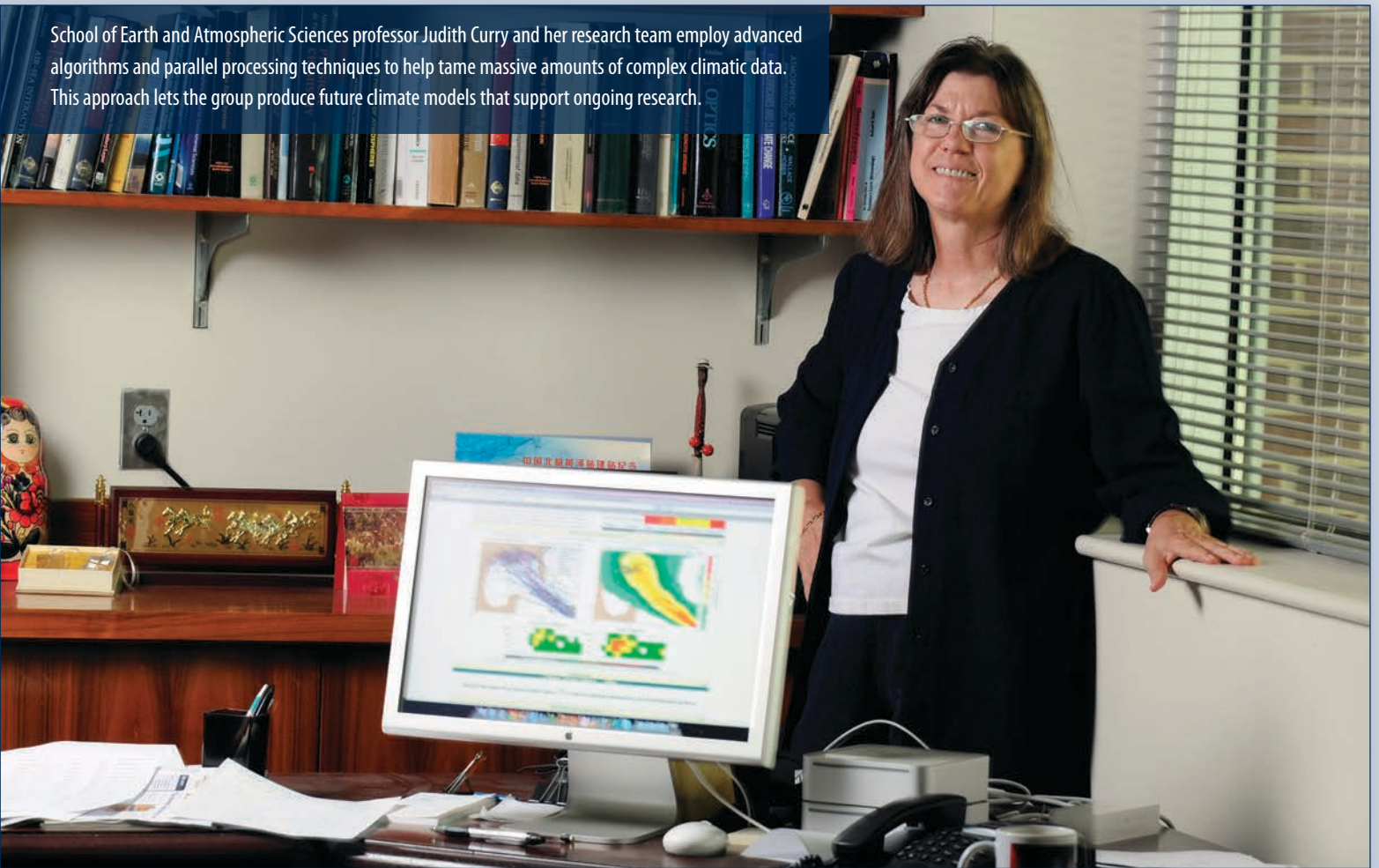
One approach to making data sets manageable involves acquiring them more efficiently. If you can capture only the data you want, there's less to manage, store and analyze.

Justin Romberg, an associate professor in the School of Electrical and Computer Engineering, is working on compressed sensing – theories of data sampling that promote more efficient ways to acquire data. With support from the Office of Naval Research and DARPA, he's focusing on the best ways to capture data at the sensor, which facilitates information processing down the line.

In the classical data-compression paradigm, he explained, users acquire a signal at very high resolution and produce large amounts of data. At some subsequent point they run a compression algorithm to reduce data size – as when raw image data is converted to a JPEG image either in the camera or on a computer.

"By contrast, our compressed sensing work integrates some of that compression directly into the acquisition process at the front end," he said. "Rather than have to sample a big array of pixels, I can sample a smaller number of pixels and acquire the data directly in compressed form."

School of Earth and Atmospheric Sciences professor Judith Curry and her research team employ advanced algorithms and parallel processing techniques to help tame massive amounts of complex climatic data. This approach lets the group produce future climate models that support ongoing research.



Georgia Tech: Developing Leaders & Solutions For Global Supply Chains



In the School of Industrial and Systems Engineering, professor John Bartholdi is working on warehousing optimization by automating the search for patterns that can be exploited to optimize the operations.

Mining Patient Data to Improve Clinical Practices

Professor Hongyuan Zha of the School of Computational Science and Engineering is using machine learning to pinpoint valuable information contained in large data sets on young heart patients. He is collaborating with Patrick Frias, M.D., an Atlanta area pediatric cardiologist, to find ways to make diagnostic approaches more consistent and less costly.

Zha is analyzing a year of patient records from the Children's Healthcare of Atlanta Sibley Heart Center, a statewide cardiac practice that sees thousands of children annually. Looking only at chest pain complaints, he is examining the relationships among the patient and family history questionnaire, the subsequent physician interview and examination, the diagnostic tests ordered, and the eventual diagnoses.

"One year of these records contains close to 20,000 cases, which is a very extensive data set," Zha said. "The goal here is to determine whether, by going through the historical data, we can come up with some rules or best practices that are more efficient than the existing ones."

The project was initiated by Mark Braunstein, M.D., a professor in the Georgia Tech School of Interactive Computing, who brought the collaborators together. Braunstein is associate director of the Health Systems Institute, an interdisciplinary initiative based at Georgia Tech and Emory University.

Zha, working with graduate student Thomas Perry, is using a technique known as cost-sensitive classification to analyze the

patient information. This approach seeks to identify which kinds of patient data are associated with the ordering of more elaborate and expensive diagnostic procedures, such as echocardiograms and stress tests.

Heart attacks are very rare in children, explained Frias, who is director of outpatient operations for the Sibley center. Of the 3,000 children that the center's physicians saw for chest pain complaints in 2012, perhaps 20 will have serious disease.

"The dilemma is, how do we figure out which child is the one that requires the extensive and expensive resources – always keeping in mind that you certainly don't want to miss a child with a serious disorder," he said.

The project's aim is development of a diagnostic tool that would enable primary-care physicians – the doctors most people see first – to determine reliably whether a child with chest pain really needs to see a pediatric cardiologist. The ultimate goal is to reduce variability in the tests ordered for these young patients.

"Physicians are of course arriving at quality decisions under current guidelines, but some of them may arrive there with less or more tests than the others," Frias said. "The accuracy of the diagnosis is the overriding goal; however, it can get very expensive if somebody out there is doing a lot of potentially unnecessary testing."

– Rick Robinson



Patrick Frias, M.D., (left) an Atlanta-area pediatric cardiologist, is working with professor Hongyuan Zha of the School of Computational Science and Engineering at Georgia Tech to pinpoint valuable information contained in large data sets on young heart patients.

Photo: Gary Meek

Romberg's projects include:

- *Improved dynamic MRI techniques* – By means of a recovery algorithm called motion-adaptive spatio-temporal regularization (MASTeR), Romberg and his team are investigating ways to increase the rate at which magnetic resonance imaging machines acquire high-resolution images. The aim is to produce dynamic video rather than static images.
- *Enhanced radar receivers* – Large bandwidth radar scanning can require the processing of billions of digital samples per second. Working with Northrop Grumman and the California Institute of Technology, Romberg and his team are studying hardware and software approaches that would let analog sensors gather a lower number of samples at the front end while still providing effective results.

Applying Case-Based Reasoning

Case-based learning and reasoning is a powerful tool for utilizing big data. It captures knowledge about known entities and situations, and then adapts that information to address the unknown.

The case-based approach helps deal with big-data problems in numerous applications, explained Elizabeth Whitaker, a GTRI principal research scientist.

Case-based reasoning uses a library of past experiences called cases. Each case consists of a problem and its associated solution, along with any problem context information.

When the system is given a new problem, it searches the case library for the past cases that solve problems similar to the new problem. One of the most similar cases is chosen, and its solution is adapted and reused to solve the current problem.

Case-based learning techniques capture the reasoning process of human experts, then store that data in a form that can be reused in an automated system. New knowledge is structured rapidly, as it becomes available, and indexed for rapid retrieval and reuse.

"In a big-data problem, several techniques can accelerate case retrieval," she said. "It can be computed on parallel processors to increase the speed of searching a very large case library. And off-line clustering techniques can structure the case library into a tree, so that only a small number of cases have to be compared with the target case before the relevant ones are identified."

GTRI recently participated in a research program called Behavioral Learning for Advanced Electronic Warfare (BLADE), sponsored by DARPA. BLADE's goal was to effectively counter adaptive wireless communication threats in tactical environments.

To explore novel approaches to jamming, GTRI-supplied case-based techniques were integrated with algorithms from other team members.

Driving Defense-Relevant Computing

GTRI researchers are working to ensure that future high-perfor-

mance computing can successfully support military requirements.

The Challenge Applications and Scalable Metrics (CHASM) project, led by GTRI principal research engineer Dan Campbell, is part of the Ubiquitous High Performance Computing (UHPC) program sponsored by DARPA. The UHPC effort at Georgia Tech also involves professor David Bader of the School of Computational Science and Engineering, who leads an applications team that is collaborating with Nvidia Corp. on development of a UHPC system.

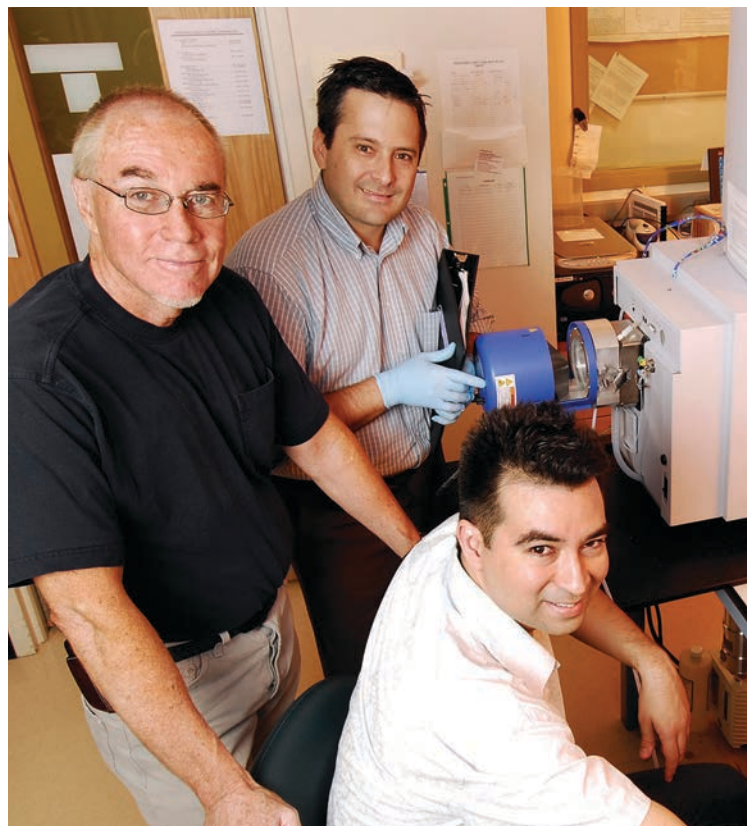
CHASM has focused on measuring the usefulness of UHPC designs in deployed platforms.

"The task under CHASM has been to find and document common execution models that maintain programmability of defense software on future architectures," Campbell said. "This is an important area because those future computers are likely to be far more parallel, heterogeneous and dynamic than current systems."

CHASM developed five challenge problems that span a broad area of both computing requirements and defense mission requirements. Campbell and his team created benchmarks, applications and metrics to measure the ability of both current and proposed computing systems to meet defense applications needs.

Pinpointing Incoming Malware

The Titan project is developing a system to share definitive intelligence on malicious software among a wide community. Corporate,



Researchers John McDonald, Facundo Fernández (left to right standing) and Alexander Gray work with a mass spectrometry system used to determine which metabolites in the blood indicate the presence of ovarian cancer.



Tim Lieuwen, a professor in the School of Aerospace Engineering, studies combustion technologies, including those used for power generation. Here Lieuwen (left), research engineer David Noble and professor Jerry Seitzman discuss a low emissions combustor component in the Zinn Aerospace Combustion lab.

government and other users could employ the system to identify financial threats, botnet schemes – even attacks by foreign states.

GTRI security specialists are investigating the best methods for identifying and neutralizing any malware intrusion. At the heart of the issue is a big-data challenge requiring novel strategies in both software and hardware, said Chris Smoak, a GTRI research scientist who leads the project.

“We’re receiving about 100,000 different malware samples a day,” Smoak said. “And I want to compare each of these 100,000 samples to each other – and to 20 million samples we’ve seen in the past. That’s about two trillion comparisons daily – and it requires a hybrid approach of new algorithms and high-performance computing.”

The GTRI team is applying machine learning software models to this vast data set to spot related threats while also reducing processing times.

For example, a single malware sample that was recently run on a GTRI computer produced 250 gigabytes of text data in 180 seconds – a huge file size that creates major investigative problems. However, 225 gigabytes of that malware-generated code turned out to be repetitive, and the Titan system was able to filter it out.

High-performance computing is also critical to the project. Hardware systems that exploit graphics processing units (GPUs) – specialized integrated circuits that are extremely fast and relatively inexpensive – will perform the extensive parallel processing required by the large-scale data.

Optimizing Flight Simulation

GTRI researchers have developed a technique that drastically reduces data retrieval time, allowing a flight simulator to achieve more realistic performance.

Officials from the Naval Air Warfare Center Aircraft Division wanted a particular flight simulator to give pilots a more accurate experience with electronic warfare (EW) systems, which enable aircraft to detect and avoid a variety of ground-based threats. In addition to improving the pilot experience, the Navy also wanted to collect realistic data on interactions between pilots and simulated threats – data that could add to aircraft defense knowledge.

A threat warning system was directly integrated into the flight simulator. It worked in tandem with scene projectors that could optically stimulate threat warning sensors.

The problem centered on the ability to generate scene data with the required level of detail, and then deliver that data to the scene-generating device in real time. Using highly detailed scene data translated to simulator response times that were too slow to be useful.

“It took 20 or 30 minutes to run a full engagement – and we wanted it to happen in less than five seconds,” said John Stewart, a GTRI senior research engineer who led the project. “If the computer has to search through gigabytes of data, it’s hard to get real-time performance.”

To address the issue, the GTRI team optimized the system in several ways. Using adaptive sampling techniques, they reduced the amount of initial threat data coming from the sensors.

Then they created a look-up table – essentially a condensed, optimized database – from reams of existing threat information by selecting only the most relevant, must-have information. To help do this, they minimized the number of parameters involved in each threat description.

As a result of this work, Stewart said, the testing of algorithms for detecting incoming threats has become more effective.

“Users can now get information on actual system performance – whether sensors are reliably detecting a variety of threats under a large number of rapidly changing conditions,” he said.

BIG DATA FOR COMBUSTION RESEARCH

Simulating Unstable Combustion

Suresh Menon, a professor in the School of Aerospace Engineering, studies problems associated with unstable combustion. Among numerous projects, he and his students are working on two combustion-related challenge projects from the Department of Defense, involving combustion instability in rocket engines and detonation of heterogeneous explosives.

In the rocket engine investigation, the team is developing complex simulation-based tools to predict performance of a laboratory-scale multi-injector liquid fuel rocket engine. The ultimate goal is to reliably predict whether next generation full-scale rocket engine designs will operate in a stable manner.

“Combustion instabilities in rocket engines are very complicated and not very well understood, and predicting these phenomena using computational tools – as we are doing in the challenge project – has never been attempted,” Menon said. “The computational resource requirements for this work are huge. It will take millions of processor hours to accomplish one simulation of a sub-scale engine. The data generated in the three-dimensional space and across time will also be enormous – tens of petabytes – making data storage and analysis major big-data challenges as well.”

Working with Department of Defense sponsors, Menon and his team are performing large-scale parallel computing on Department of Defense supercomputers. The simulations and the insight from them should help engine companies develop the next generation of rockets for the U.S. Air Force.

Eventually, the simulation code and models used within it could be used to study combustion dynamics in full-scale engines.

However, this is still a future goal, Menon explained, because no existing computers are powerful enough to model a full-scale rocket engine. Even future exascale computers can be expected to fall short.

“Our goal is to build an adaptive simulation code that not only can predict lab-scale events but can also be used eventually to

study real application problems,” he said. “Today, no one can afford to keep building rocket engines until they find a design that doesn’t explode. You want to identify the unstable designs in the computer simulation, not during ground or flight testing.”

Controlling Experimental Data

The increasing efficiency of research equipment can contribute significantly to investigative results – and to big-data challenges.

Tim Lieuwen, a professor in the School of Aerospace Engineering, studies combustion technologies, including those used for power generation. Working with sponsors that include the U.S. Air Force, Department of Energy and a range of energy and aerospace companies, he uses a mix of experimental tools to investigate low emission combustion technologies. He also examines other phenomena including combustion instabilities.

Over the last five years, he observed, his field has experienced the advent of powerful tools such as high-speed lasers and high-speed cameras. The results include some very large data sets.

“We can have multiple laser heads firing and multiple cameras taking pictures here in the Zinn Aerospace Combustion lab, and that will easily produce gigabytes of data per second and result in terabytes of data,” said Lieuwen, who is also executive director of Georgia Tech’s Strategic Energy Institute. “Just accessing and processing those data sets has become a primary challenge.”

To support their research, Lieuwen and his team manipulate their data using detailed mathematical techniques. In this effort, they’re supported by aerospace engineering professors including Suresh Menon and Vigor Yang, who specialize in developing simulations from data sets gathered by experimentation.

Increasingly, Lieuwen said, scientists will have to learn to reduce the amount of data gathered during experiments. The application of more sophisticated signal processing can help weed out unwanted data, while retaining the desirable information.

“We’re coming to the point where there isn’t enough storage to save everything,” he said.

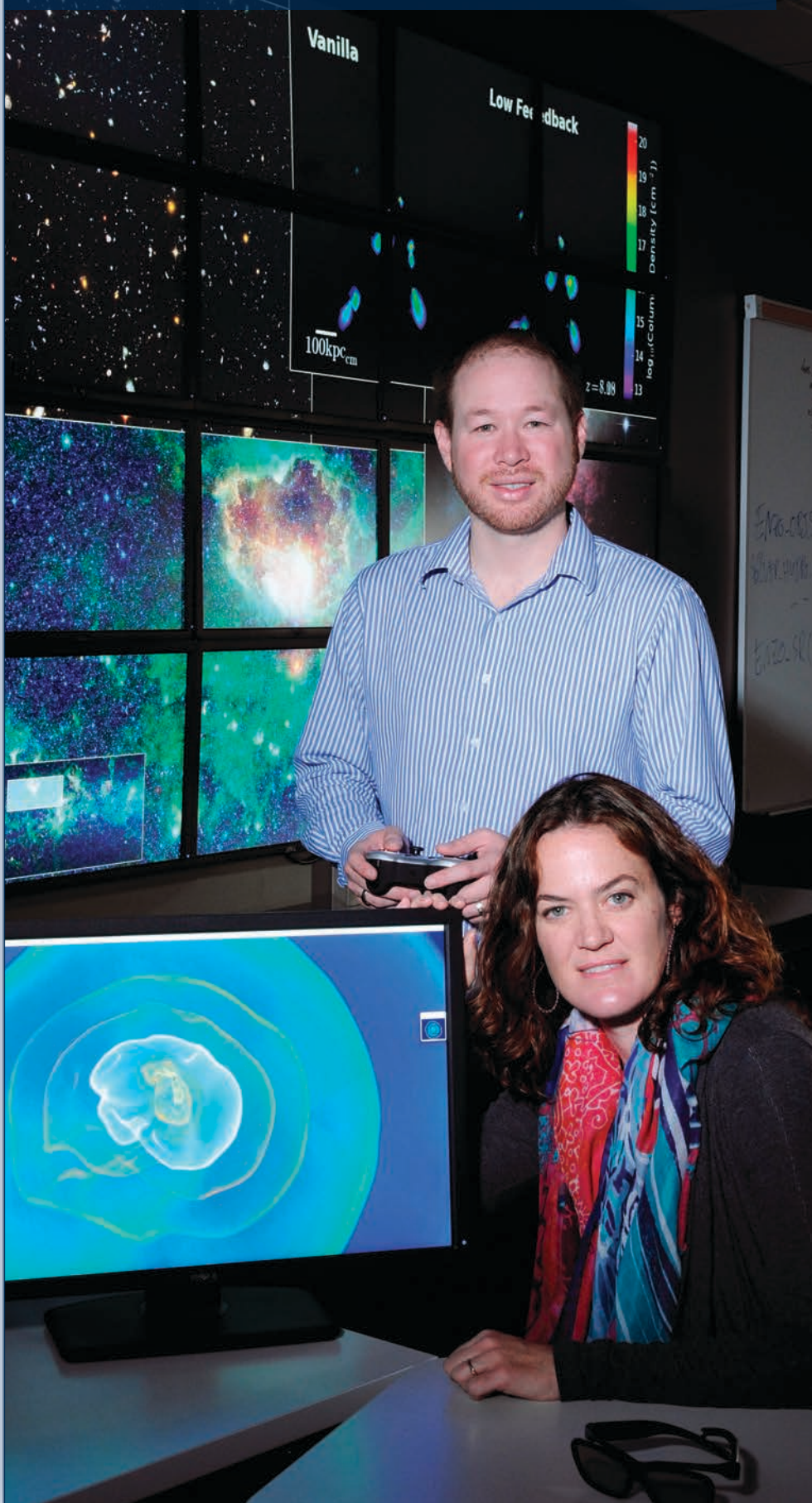
UTILIZING BIG DATA FOR HEALTH INFORMATICS

Supporting Cancer Detection

Health informatics is an area yielding important results from the mining of massive, medically related data sets. Information contained in genomics data, physical samples and even patient data digitized from paper records is providing insights on important health issues.

Georgia Tech scientists have utilized machine learning to identify telltale metabolite patterns in thousands of patient serum

Assistant professor John Wise and associate professor Deirdre Shoemaker — members of the Center for Relativistic Astrophysics in the School of Physics — use the center's new visualization laboratory to help tackle cosmological problems that involve massive data sets.



samples. The goal is to develop a reliable tool to detect ovarian cancer.

"Ovarian cancer is the fourth leading cause of death in women," said John McDonald, chief scientist of the Ovarian Cancer Institute and associate dean for biology program development in the School of Biology. "But it is a relatively rare cancer, so a functionally useful diagnostic test has to be 99 percent accurate or you are going to get too many false positives."

McDonald teamed with mass spectrometry expert Facundo Fernández, an associate professor in the School of Chemistry and Biochemistry, to sort molecules in the serum based on their weight and electrical charge.

With the help of Alexander Gray, an associate professor in the School of Computational Science and Engineering, the research team was able to detect patterns of key metabolites in the blood.

Using advanced machine learning techniques, the team distinguished patterns of small metabolites found in the blood of cancer patients from those of control subjects. The software was able to differentiate among women with and without ovarian cancer. Further investigation showed that the samples were recognized with 99 percent accuracy.

The diagnostic tool is currently undergoing further development. It is being extended to other types of cancer, McDonald said, and the number of metabolic features that can be used for diagnosis are being optimized.

The work is supported by the Ovarian Cancer Institute, the Deborah Nash Harris Endowment Fund, the Ovarian Cycle Foundation, the Ovarian Cancer Research Fund and the Georgia Research Alliance VentureLab program.

Predicting Drug Response

Ming Yuan, an associate professor in the School of Industrial and Systems Engineering, is using computational and mathematical approaches to analyze how

gene expression evolves over time in individuals with breast cancer – and whether these patterns can predict treatment outcomes.

Yuan is studying how gene expression evolves during the menstrual cycle and whether there is any association between these patterns and cancer relapse. Gene expression determines how much biochemical material results from a gene, and can be used to judge how active a gene is.

“Our goal is to weed out the genes that just change expression level due to a woman’s menstrual cycle and not because of tumor progression or treatment,” explained Yuan, who is also a Georgia Cancer Coalition Distinguished Cancer Scholar. “We want to know which genes are abnormally expressed over time and behave differently from the majority of genes, because that would make them likely drug targets.”

Improved predictors of relapse risk could help cancer patients make better treatment decisions in consultation with their physicians, he added. Yuan’s research is supported by the National Science Foundation and the Georgia Cancer Coalition.

Advancing Health-related Readiness

Eva K. Lee, a professor in the School of Industrial and Systems Engineering, specializes in large-scale computational algorithms and systems modeling, with an emphasis on medical/health-care risk and decision analysis, and logistics management. She is bringing complex modeling, machine learning, and optimization techniques to bear on a number of health informatics projects that involve very large data sets.

“Problems in health systems and biomedicine can often be addressed through systems modeling, algorithm and software design, and decision theory analysis,” said Lee, who is director of the Center for Operations Research in Medicine and HealthCare. “By advancing these tools, we can model very large scale evolving and heterogeneous data sets to pursue and uncover effective solutions.”

Among her projects:

- *Software suite for disaster medicine and emergency response* – Lee is collaborating with the Centers for Disease Control and Prevention and state and local authorities on a project that uses large-scale informatics techniques to support preparedness for epidemics and other emergencies. The work addresses biological, radiological and chemical emergency incidents as well as natural disasters. It brought Lee to Fukushima, Japan, to study the response to the radiological disaster there.
- *Strategies for predicting the immunity of vaccines* – This project uses novel predictive analytics to mine clinical and biological data, with the aim of predicting the effectiveness of vaccines on different groups of individuals. Under the leadership of Professor Bali Pulendran at Emory University, and in collaboration with researchers at the Dana-Farber

Cancer Institute, Duke University, the Institute for Systems Biology and the National Institutes of Health, Lee is developing a machine learning framework to predict vaccine outcomes based on massive genomic-temporal data.

- *Personalized target delivery for optimal treatment of cervical cancer* – Working with Rush University Medical Center, Lee and her team have been the first to incorporate sophisticated escalated dose delivery technology for cervical cancer patients. These personalized treatment plans incorporate biological information obtained from positron emission tomography that relates cancer cell proliferation with spatial distribution. The treatment objective is to optimize tumor control.

HARNESSING BIG DATA FOR SCIENTIFIC DISCOVERY

Visualizing Cosmic Processes

When it comes to big data, the field of astrophysics has been on the front lines for years.

John Wise, an assistant professor in the School of Physics, studies dwarf galaxies that are a thousand times smaller than the Milky Way. These small galaxies are building blocks of larger ones.

Wise, a member of the Center for Relativistic Astrophysics (CRA) at Georgia Tech, focuses on computational cosmology. He tackles large data sets with a variety of processing technologies, including simulations that utilize the center’s new visualization laboratory.

“When you observe a galaxy directly, you can’t see it evolving in time,” Wise said while demonstrating a video simulation derived from two terabytes of data. “But with simulations like this one you can turn the clock back, and see the important physics that goes into forming a galaxy and all of its stars.”

The new CRA visualization lab includes a 16-monitor wall to enable viewing of large images at high resolution.

“It’s always good to be able to output your data and view it in simulations like this, because it allows you to look for things that you have no idea about yet,” he said.

Studying Cosmic Forces

The complex and often elusive nature of the phenomena that astrophysicists investigate often means they must sort through huge amounts of information.

Deirdre Shoemaker, an associate professor in the School of Physics and a member of the Center for Relativistic Astrophysics (CRA), studies the mysterious cosmic entities called black holes. Collaborating with fellow CRA member Pablo Laguna, a physics professor, Shoemaker is using simulations of black holes to investigate something even more mysterious – gravitational waves,

which are predicted by Einstein's General Theory of Relativity but have never been directly observed.

"The collision of black holes is a central problem in general relativity, but Einstein's equations are extremely complex – only a computer can solve them," said Shoemaker, who is also an adjunct associate professor in the School of Computational Science and Engineering. "Solving Einstein's equations is extremely complicated, and it can take weeks for a supercomputer to chug through the equations, ultimately producing large 4-D data sets."

The resulting data could improve scientists' understanding of how to observe gravitational waves. That ultimately could reveal more information about the black hole systems that produced them.

Investigating Biological Systems

Joshua Weitz, an associate professor in the School of Biology, utilizes large-scale data sets in his studies of the structure and dynamics of complex biological systems. His research group includes ecologists, mathematicians, physicists and bioinformatics specialists who work on major research themes that include:

- Viral dynamics at the molecular, population and evolutionary scales;
- Systems biology and bioinformatics;
- Theoretical ecology and epidemiology;
- The structure and function of vascular networks.

"The work of our group is primarily theoretical in nature, and it includes the challenge of interpreting big data in a way that is both intuitive and retains key information," Weitz said. "This challenge is particularly acute in the study of environmental sequence and interaction data. We utilize the tools of nonlinear dynamics, network theory and large-scale data analysis to collaborate with experimentalists."

In a recent project, Weitz, together with Jonathan Dushoff of McMaster University, co-led a consortium of researchers who developed a dimension-reduction approach. They analyzed millions of short sequences of DNA taken from the environment and identified biogeographic patterns in the function of ocean microbes.

USING BIG DATA TO SUPPORT SUSTAINABILITY

Modeling Future Cities

The Brook Byers Institute for Sustainable Systems (BISS) focuses on sustainable urban infrastructure. Its goals include working with researchers from multiple disciplines to build a model that predicts how the Atlanta metro area will evolve in coming decades.

The project requires developing and utilizing large and heterogeneous data sets, said John Crittenden, a professor in the School of Civil and Environmental Engineering and director of BISS. Some

25 Georgia Tech professors and other researchers are cooperating on this goal.

"Our task is to visualize, using a broad spectrum of data inputs, what the future might look like for different development scenarios in Atlanta – and to potentially help other great cities as well," said Crittenden, who holds the Hightower Chair and is a Georgia Research Alliance Eminent Scholar in Environmental Technologies. "Basically, we're trying to predict the urban future."

Crittenden cites three key elements in this challenge:

- Predict decision-making by using complexity models to anticipate how demand for urban infrastructure will change over time and space.
- Employ concepts in community design, material choices and transportation networks to build a virtual city of the future.
- Produce metrics to measure the benefits resulting from different possible infrastructure investments.

"Most of what's out there now has been designed and built on the assumption that cheap, abundant fossil fuels would always be available," Crittenden said. "And obviously that's not the case."

Applying Geospatial Technologies

The Center for Geographic Information Systems in the College of Architecture develops and applies geospatial technologies, which involve retrieving, classifying, analyzing and visualizing geographic information. The center has a long track record of interdisciplinary research collaborations at Georgia Tech and has helped governments, nonprofits and private enterprise evaluate critical infrastructure for sustainable urban growth.

"We support the development of the next generation of geospatial technologies through high-performance and cloud computing and through expanding our international reach to address especially difficult global problems," said Subhro Guha-thakurta, a professor in the School of City & Regional Planning and director of the center. "By applying our technological resources, we can help communities, both locally and abroad, confront economic, social and climate uncertainties."

The center focuses on researching and developing the next generation of geospatial technologies, and applying geographic information system (GIS) tools and technologies to a variety of social and environmental problems. It also provides GIS education to students, researchers and professionals from several disciplines.

Big Data Among Core Research Areas

Research on big-data topics is among the 12 core research areas being pursued at Georgia Tech because analyzing enormous amounts of data is essential to progress in all research areas. To achieve advances in critical areas of science and technology, Georgia Tech is leveraging its unique expertise in big data to provide solutions that will transform the ability of individuals and organiza-

A Big Data Glossary

algorithm – a step-by-step procedure for performing a calculation, generally associated with data processing and automated reasoning.

analytics (advanced) – discovery of meaningful patterns in data using advanced techniques such as machine learning, data visualization and statistical analysis.

analytics (simple) – everyday tools for exploring data sets such as queries and text searches.

big data – data sets that are both massive and complex.

cloud computing – computing resources that are delivered as a service via a network, typically the Internet.

data mining – use of computational methods to find desired information in data sets.

data point – an individual data element, also known as a data feature.

data scientist – a computer scientist who focuses on multiple issues related to data sets, including statistical analysis, system architecture and storage.

exabyte – in data storage, a thousand petabytes, or 10^{18} bytes.

exascale computing – a future technology in which computers will reach speeds of at least one exaflop, which is a thousand times faster than a petaflop (top current supercomputers can reach several petaflops).

feature extraction – similar to data mining.

locality – in unstructured data, a term that indicates whether desired data elements occur in predictable groupings; non-local data elements can occur anywhere in a data set.

machine learning – alternatively known as advanced analytics, data analytics or predictive analytics; the use of automated algorithms to find and evaluate patterns in data, enabling predictions that are increasingly accurate.

parallel computing – a computational approach in which a large problem is divided into a number of smaller ones, which are then solved concurrently on multiple processors.

petabyte – in data storage, a thousand terabytes, or a quadrillion (10^{15}) bytes.

statistics – involves a number of approaches, largely based on advanced mathematics, that are used to collect, analyze and extract information from data sets.

structured data – familiar database technology in which data elements are characterized in a specific format and are contained in columns and rows, similar to an electronic spreadsheet.

terabyte – in data storage, a thousand gigabytes, or a trillion (10^{12}) bytes.

unstructured data – data that consists of a vast number of data points – individual data elements – that often take the form of plain text and may or may not be interrelated.


visual analytics – data analysis using visualization techniques, which enable researchers to look for novel patterns in data.

tions to analyze large and complex sets of data.

Georgia Tech supports multidisciplinary research teams that are both developing innovations in computational methods to advance big data analysis, and applying these techniques to industry, business and the public sector. Enabling technologies under development include data visualization, advanced analytics, machine learning, and high-performance computing.

Application areas for Georgia Tech's big data research agenda include astrophysics, biomedicine, combustion, energy, finance, health care, manufacturing, materials, information and cybersecurity, social networks, sustainability and transportation. Both undergraduate and graduate students contribute to research in

these critical areas.

For more information on big data research at Georgia Tech, please visit: (www.gatech.edu/research/areas/big-data). 

Abby Robinson also contributed to this article.

Research projects mentioned in this article are supported by sponsors that include the National Science Foundation (NSF), Office of Naval Research (ONR), National Institutes of Health (NIH), Department of Energy (DOE), Department of Homeland Security (DHS), U.S. Air Force (USAF) and the Defense Advanced Research Projects Agency (DARPA). Any opinions, findings, conclusions or recommendations expressed in this publication are those of the principal investigators and do not necessarily reflect the views of the NSF, ONR, NIH, DOE, DHS, USAF or DARPA.

Researchers have developed a prototype system that uses advanced imaging technology and a robotic cutting arm to automatically debone chicken and other poultry products. The Intelligent Cutting and Deboning System employs a 3-D vision system that determines where to cut a particular bird.

Photo: Gary Meek



A robotic system used in the Intelligent Cutting and Deboning project prepares to slice through the shoulder joint of a chicken. The system was developed by the GTRI Food Processing Technology Division.

A Cut Above:

Robot Uses 3-D Imaging and Sensor-based Cutting Technology to Debone Poultry

By Rick Robinson

Researchers at the Georgia Tech Research Institute (GTRI) have developed a prototype system that uses advanced imaging technology and a robotic cutting arm to automatically debone chicken and other poultry products.

The Intelligent Cutting and Deboning System employs a 3-D vision system that determines where to cut a particular bird. The device automatically performs precision cuts that optimize yield, while also greatly reducing the risk of bone fragments in the finished product.

"Each bird is unique in its size and shape," said Gary McMurray, chief of GTRI's Food Processing Technology Division. "So we have developed the sensing and actuation needed to allow an automated deboning system to adapt to the individual bird, as opposed to forcing the bird to conform to the machine."

Poultry is Georgia's top agricultural product, with an estimated annual economic impact of nearly \$20 billion statewide. Helping the poultry industry maximize its return on every flock can translate to important dividends. The research is funded by the state of Georgia through the Agricultural Technology Research Program at GTRI.

In the Intelligent Cutting and Deboning System, a bird is positioned in front of the vision system prior

to making a cut, explained GTRI research engineer Michael Matthews. The vision system works by making 3-D measurements of various location points on the outside of the bird. Then, using these points as inputs, custom algorithms define a proper cut by estimating the positions of internal structures such as bones and ligaments.

"Our statistics research shows that our external measurements correlate very well to the internal structure of the birds, and therefore will transition to ideal cutting paths," Matthews said. "In our prototype device, everything is registered to calibrated reference frames, allowing us to handle all cut geometries and to precisely align the bird and the cutting robot. Being able to test all possible cut geometries should enable us to design a smaller and more simplified final system."

The prototype uses a fixed two-degree-of-freedom cutting robot for making simple planar cuts. The bird is mounted on a six-degree-of-freedom robot arm that allows alignment of the bird and cutting robot to any desired position. The robot arm places the bird under the vision system, and then it moves the bird with respect to the cutting robot.

The system employs a force-feedback algorithm that can detect the transition from meat to bone,

said research engineer Ai-Ping Hu. That detection capability allows the cutting knife to move along the surface of the bone while maintaining a constant force.

Because ligaments are attached to bone, maintaining contact with the bone allows the knife to cut all the ligaments around the shoulder joint without cutting into the bone itself. A similar approach can be used for other parts of the bird where meat must be separated from bone.

Hu explained that the force-feedback algorithm uses a force sensor affixed to the knife handle. During a cutting operation, the sensor enables the robot to detect imminent contact with a bone. Then, instead of cutting straight through the bone, the system directs the cutting tool to take an appropriate detour around the bone.

"Fine tuning is needed to adjust the force thresholds, to be able to tell the difference

between meat, tendon, ligaments and bone, each of which has different material properties," Hu said.

McMurray said he expects the Intelligent Cutting and Deboning System to match or exceed the efficiency of the manual process. Testing of the deboning prototype system, including cutting experiments, has confirmed the system's ability to recognize bone during a cut and to avoid bone chips – thus demonstrating the validity of GTRI's approach.

"There are some very major factors in play in this project," McMurray said. "Our automated deboning technology can promote food safety, because bone chips are a hazard in boneless breast fillets. But it can also increase yield, which is significant because every 1 percent loss of breast meat represents about \$2.5 million to each of Georgia's 20 poultry processing plants."

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CONTACT

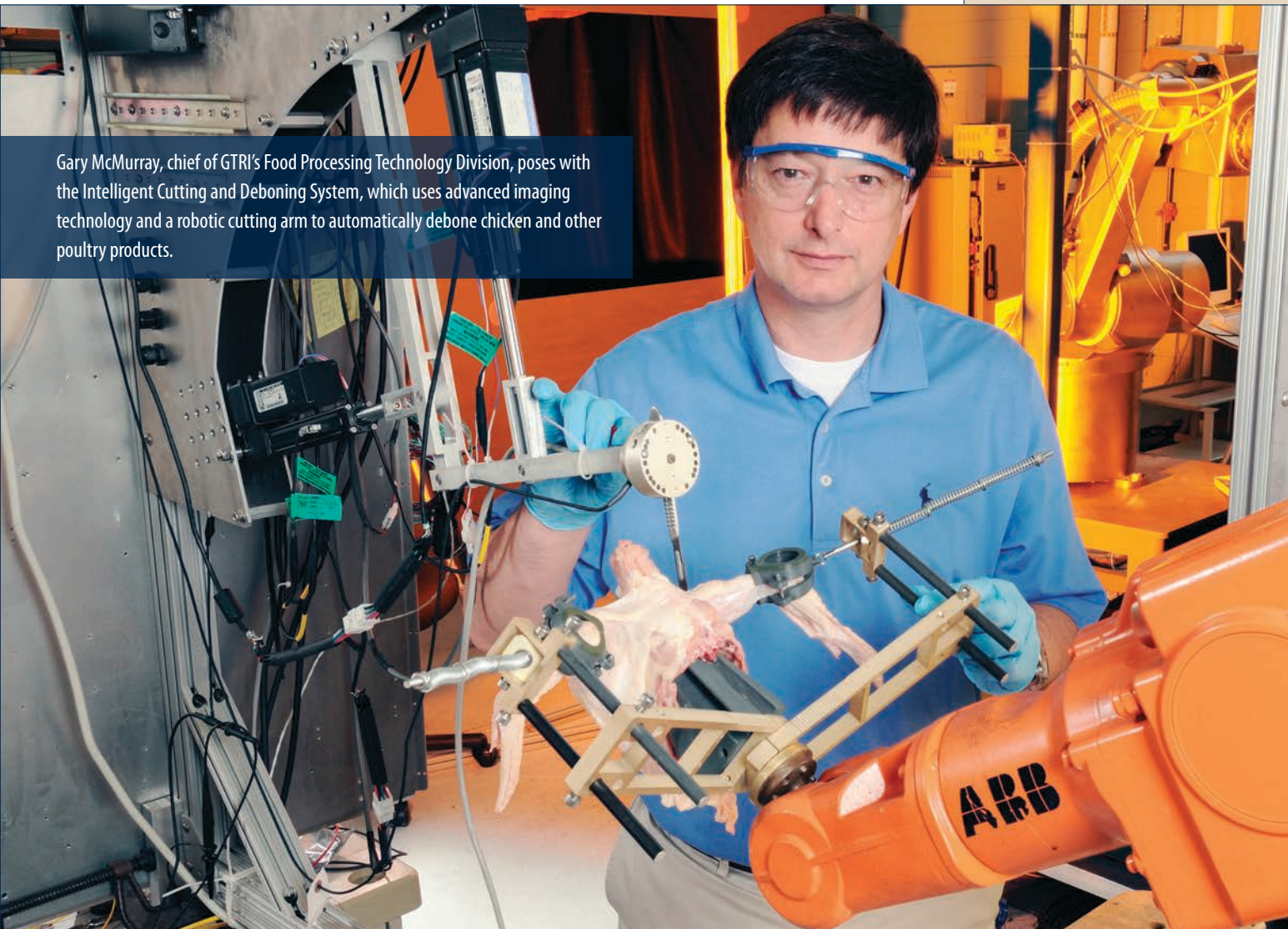
Gary McMurray

gary.mcmurray@gtri.gatech.edu

"...We have developed the sensing and actuation needed to allow an automated deboning system to adapt to the individual bird, as opposed to forcing the bird to conform to the machine."

— Gary McMurray, chief of the Georgia Tech Research Institute's (GTRI) Food Processing Technology Division

Gary McMurray, chief of GTRI's Food Processing Technology Division, poses with the Intelligent Cutting and Deboning System, which uses advanced imaging technology and a robotic cutting arm to automatically debone chicken and other poultry products.



Georgia Tech Faculty and Staff Receive Recognition

Seven faculty members were named Fellows of the American Association for the Advancement of Science: biomedical engineering professors **Shuming Nie** and **Eberhard Voit**, physics professor **Paul Goldbart**, biology professor **Julia Kubanek**, chemistry and biochemistry professor **Arthur Ragauskas**, materials science and engineering professor **Mohan Srinivasarao**, and mechanical engineering professor **Andrés García**.

The following 12 faculty members were named American Mathematical Society Fellows: math professors **Matt Baker**, **Jean Bellissard**, **John Etnyre**, **Wilfrid Gangbo**, **Michael Lacey**, **Michael Loss**, **Doron Lubinsky**, **Prasad Tetali**, and **Robin Thomas**; math associate professor **Brett Wick**; industrial and systems engineering professor **Bill Cook**; and computer science professor **Dana Randall**.

Mechanical engineering professor **Steven Liang** was named a Fellow of the Society of Manufacturing Engineers.

David Gottfried, senior research scientist in the Institute for Electronics and Nanotechnology, was named a Fellow of the American Chemical Society.

Mechanical engineering professor **Richard Neu** received the ASTM International Award of Merit and the accompanying title of Fellow from Committee on Fatigue and Fracture.

Industrial and systems engineering professor **David Goldsman** was named a Fellow of the Institute of Industrial Engineers.

Minami Yoda, mechanical engineering professor, became a Fellow of the American Physical Society.

Mechanical engineering professor

Andrés García was named Fellow, Biomaterials Science and Engineering, by the International Union of Societies of Biomaterials Science and Engineering.

GTRI laboratory director **Bill Melvin** was selected as a Military Sensing Symposia Fellow.

Alan Thomas, GTRI senior research scientist, was named a Senior Member of IEEE.

GTRI senior research scientist **Jack Wood** and principal research scientists **Mike Cathcart** and **Grady Tuell** were named Senior Members of SPIE, the International Society for Optics and Photonics.

Mechanical engineering assistant professor **Baratunde Cola** received the Presidential Early Career Award for Scientists and Engineers.

David Green, professor of the practice of architecture, received the 2012 Out of the Box Award and the President's Award from the Florida Redevelopment Association. He also received the 2012 Emerging Research/Science Park Award from the Association of University Research.

Biomedical engineering professor **Ajit Yoganathan** received the Robert A. Pritzker Award from the Biomedical Engineering Society.

Robert Rosson, GTRI principal research scientist, received the Founder's Award at the 58th Radiobiology and Radiochemical Measurements Conference.

Thomas Lux, Bourne Professor of Poetry, received the first Governor's Award for the Arts and Humanities.

Popular Science named **Andrea Thomaz**, assistant professor in the School of

Interactive Computing, one of its 2012 "Brilliant 10."

Dennis Hess, chemical & biomolecular engineering professor, received the 2012 Edward Goodrich Acheson Award from The Electrochemical Society.

Civil and environmental engineering professor **Kimberly Kurtis** received the American Concrete Institute's Delmar L. Bloem Distinguished Service Award.

Julia Kubanek, biology professor, received the Silverstein-Simeone Lecture Award from the International Society of Chemical Ecology.

Electrical and computer engineering professor **Thomas Habetler** received the IEEE Power Electronics Society Harry A. Owen Distinguished Service Award and the IEEE Industry Applications Society Gerald B. Kliman Innovator Award.

Lucien Dhooge, professor of business law and ethics, received the Best International Case Study Award from the Academy of Legal Studies in Business.

Civil and environmental engineering associate professor **Dominic Assimaki** received the 2012 Shamsher Prakash Foundation's Research Award.

Javier Irizarry, assistant professor of building construction, received the 2012 Outstanding Researcher Award for Region 2 of the Associated Schools of Construction.

GTRI principal research scientists **Gary Gimmestad** and **Leanne West**, senior research scientists **David Roberts** and **Jack Wood**, and senior research engineer **John Stewart** received The Optical Society's 2012 Paul F. Forman Engineering Excellence Award.

Electrical and computer engineering

associate professor **Muhannad Bakir** received a Young Faculty Award from the Defense Advanced Research Projects Agency.

Rebecca Burnett, director of the writing and communication program, received the Association for Business Communication's Meada Gibbs Outstanding Teacher Award.

Physics professor **Walt de Heer** received the 2012 Jesse W. Beams Research Award from the Southeastern Section of the American Physical Society.

Nancy Nersessian, professor of cognitive science in the School of Public Policy and the College of Computing, and her co-authors, received the 2012 William James Book Award sponsored by the Society for General Psychology Division I of the American Psychological Association.

Electrical and computer engineering associate professor **Moinuddin Qureshi** was selected for a 2012 Intel Early Career Faculty Honor Program Award and a NetApp Faculty Fellowship for System Architectures for Storage Class Memories.

Lora Weiss, GTRI principal research engineer, received the Academic Champion Award from the Association for Unmanned Vehicle Systems International. She was also selected as Woman of the Year in Technology by Georgia's Women in Technology.

Computing Dean **Zvi Galil** was awarded an honorary degree by the University of Waterloo at the mathematics portion of its 104th Convocation ceremony.

Wade Chumney, assistant professor of business law and ethics, received the Young Scholar Award of Excellence from

Georgia Tech Faculty and Staff Receive Recognition

the Southeastern Academy of Legal Studies in Business.

Mechanical engineering chair **William Wepfer** received the 2012 Fellow of ABET Award.

Ton Dieker, assistant professor in industrial and systems engineering, won the Erlang Prize from the Applied Probability Society of The Institute for Operations Research and the Management Sciences.

Mechanical engineering professor **David Rosen** received the Excellence in Research award from the ASME Computers & Information in Engineering Division.

Eric Overby, assistant professor of information technology management, received the Best Reviewer Award for 2012 from the journal *Information Systems Research*.

Earth and atmospheric sciences assistant professor **Josef Dufek** received the 2012 Macelwane Medal and professor **Athanasios Nenes** received the Ascent Award from the American Geophysical Union.

Robert Braun, aerospace engineering professor, received the 2012 Al Seiff Award at the 9th International Planetary Probe Workshop.

Electrical and computer engineering professor **Manos Tentzeris** and his Ph.D. student **Rushi Vyas** received the

Architecture Award of Excellence from the Architecture World Summit.

Steve Hackman and **Joel Sokol**, associate professors in industrial and systems engineering, took first place in the Institute of Industrial Engineers' Innovations in Curriculum Competition.

GTRI researchers **Tracy Wallace**, **Vic Tripp**, **Rob Hemphill**, **Tyrone Roach** and **Juan Santamaria** received the Northrop Grumman Information Systems' Annual Supplier Excellence Award 2012 for GTRI.

Paul Baker, senior research scientist in the College of Computing and adjunct professor at the School of Public Policy, was part of a team that won the Excellence in Research Award from the InfoSci-Journals group.

Industrial and systems engineering professor **George Nemhauser** received the John von Neumann Theory Prize from The Institute for Operations Research and the Management Sciences.

Vinod Singhal, professor of operations management, received the *Journal of Operations Management's* Best Associate Editor Award.

The Institute of International Education selected **Nico Declercq**, mechanical engineering associate professor, as one of 25 ambassadors for the European Commission-funded PromoDoc initiative.

Peter Webster, earth and atmospheric sciences professor, received the Mason Gold Medal from the Royal Meteorological Society.

SAE International presented **Caroline Genzale**, mechanical engineering assistant professor, with the John Johnson Award for Outstanding Research in Diesel Engines.

Atalay Atas, assistant professor of operations management, received the Wickham Skinner Early-Career Research Accomplishments Award from the Production & Operations Management Society.

School of Economics assistant professor **Shatakshiee Dhongde** received the Nancy and Richard Ruggles Memorial Fund Prize at the International Association for Research in Income and Wealth General Conference.

Laura Bier, assistant professor in the School of History, Technology and Society, was selected as a Fulbright Scholar for 2012-2013.

Biology professor **Mark Hay** received the 2012 Robert L. and Bettie P. Cody Award in Ocean Sciences from Scripps Institution of Oceanography at the University of California San Diego.

Margaret Kosal, assistant professor in The Sam Nunn School of International Affairs, was selected as a fellow of the Chief of Staff of the Army's inaugural Strategic Studies Group.

Arun Gokhale, materials science and engineering professor, received the 2013 Henry Clifton Sorby Award from the International Metallographic Society.

Biomedical engineering professor **Younan Xia** received the American Chemical Society's Award in the Chemistry of Materials sponsored by E. I. du Pont de Nemours and Co.

Manpreet Hora, assistant professor of operations management, received the *Academy of Management Journal's* Outstanding Reviewer Award.

Applied physiology professor **Mindy Millard-Stafford** received the 2012 Citation Award from the American College of Sports Medicine.

Sandra Slaughter, professor of information technology management, was elected to the Council for the Association for Information Systems, serving as the representative for the Americas Region.

Professor of architecture **Ellen Dunham-Jones** was the George Pearl Fellow at the University of New Mexico School of Architecture + Planning in 2012.

Bill Cook, industrial and systems engineering professor, was elected the new chair of the Mathematical Optimization Society.

— Compiled by Abby Robinson



Paul Goldbart



David Gottfried



Margaret Kosal



Bill Melvin



Vinod Singhal



Andrea Thomasz



Leanne West

FACULTY & STAFF AWARDS & HONORS

Georgia Tech's research strategy has three objectives: (1) pursuing transformative research, (2) strengthening collaborative partnerships with industry, government and nonprofits, and (3) maximizing the economic and societal impact of the research. In this interview, Stephen E. Cross, Georgia Tech's executive vice president for research, explains the strategy and how it was developed.

Photo: Tony Benner



Robert Guldberg, director of the Parker H. Petit Institute for Bioengineering and Bioscience (left) describes a program issue to Stephen Cross, Georgia Tech's executive vice president for research.

Research Q&A:

Georgia Tech Focuses on its Research Strategy

Stephen E. Cross was named Georgia Tech's executive vice president for research in 2010. In this role, he is responsible for the Institute's \$655-million-per-year research program, which is ranked among the largest of U.S. colleges and universities without a medical school.

The research enterprise is being reconstructed to focus on 12 core research areas that will both support existing Georgia Tech research sponsors and facilitate the expansion of industrially supported research.

In this interview, Cross discusses Georgia Tech's research strategy and what the development of a Georgia Tech-driven innovation ecosystem could mean for sponsors, industry partners, faculty and students – as well as the state, nation and global economy.

What is Georgia Tech's research strategy?

The research strategy has three objectives. The first is pursuing transformative research. We want to make it even easier to pursue research that is game-changing and leading edge, and have people asking, "What does Georgia Tech think?" To do this, we need to find new ways for faculty, students and post-docs to explore and solve exciting problems by working together across traditional academic disciplines.

The second objective is strengthening collaborative partnerships with industry, government and nonprofits. If we better understand the problems and needs of our partners, we will do an even better job of developing solutions that will have a meaningful impact. We need to be viewed as leaders who define

grand challenges and engage communities in collaborative problem solving.

The third objective is maximizing the economic and societal impact of our research. Accelerating the maturation and transition of our research results into real-world use is important and fundamentally related to the first two objectives.

This strategy involves the entire Georgia Tech research enterprise: the colleges and schools, the Georgia Tech Research Institute (GTRI), the Enterprise Innovation Institute (EI²), our contracting and licensing operations, our development and support functions and our interdisciplinary research institutes. We strive to be a research environment that is powered by ideas, led by faculty, energized by students and supported by professionals as "one Georgia Tech."

We hear a lot of about the importance of interdisciplinary research. How do you define this and what are its benefits?

An interdisciplinary pursuit can be contrasted with a multidisciplinary one where two or more existing disciplines are involved in achieving some outcome. For instance, the practice of architecture is multidisciplinary. If you want to design a building, you need an architect, but you also need an interior designer, a mechanical engineer, an electrical engineer and a civil engineer.

Interdisciplinary research occurs when two or more fields come together and new knowledge is



Stephen Cross, Georgia Tech's executive vice president for research, talks with students Susan Hastings and Mohammed Ali Najia in the Institute for Bioengineering and Bioscience Building.

created, possibly defining a new field of study. It is the intersection of these fields at the boundaries of their knowledge that creates new ways of thinking about problems and new ways to solve them. Interdisciplinary research institutes (IRIs) like the Parker H. Petit Institute for Bioengineering and Bioscience (IBB) and the Georgia Tech Manufacturing Institute (formerly known as the Manufacturing Research Center) were created in the late 1980s and early 1990s to provide intellectual crossroads where different academic pursuits could merge to explore and solve problems. They provide an environment where interaction between traditional academic disciplines is natural – and expected.

We want to have an environment that supports and facilitates interdisciplinary research because of our quest to be global leaders and to pursue game-changing ideas. I might add that, today, we also stress the importance of translational research that is focused on moving promising research results from the laboratory into real-world use. Some of my colleagues in chemistry and biochemistry describe our overall strategic approach to research as use-inspired; that is, one that integrates fundamental and translational research in interdisciplinary ways. This is well articulated by Donald Stokes in a book entitled *Pasteur's Quadrant*.

How did you get to the 12 core research areas?

Shortly after I was selected for this position in the spring of 2010, I was looking at a website that listed many of the centers, labs and groups across Georgia Tech. There was not much rhyme or reason to how they were grouped, and many were not even listed. Unless you had intimate knowledge about Georgia Tech's internal structure, it did not make much sense. Given my role in communicating and marketing our research capabilities, I wanted a better way to describe our research to the outside world.

So, with help from the associate deans of research and school chairs, we constructed a master list of all the centers, labs, groups and institutes. A list of around 300 dictated that we group many into similar thematic areas. For instance, in bioengineering and bioscience alone, there are 50 centers, groups, and labs; 15 of those, by their own choice, are affiliated with and supported by the Institute for Bioengineering and Bioscience. Similarly, 22 groups, labs and centers are affiliated with the Georgia Tech Manufacturing Institute.

Out of this distillation process came the current listing of 12 core research areas – a faithful and easy-to-understand summary of our research strengths. It is not cast in concrete and can change when it makes sense to describe it differently. But this list makes it easier for the outside community to understand and to navigate our research enterprise. The areas map roughly to strategic markets and important areas for the state of Georgia and other sponsors. Since we have taken this approach, we have received very positive feedback from inside and outside of Georgia Tech.

Many areas are supported by an interdisciplinary research institute (IRI). What is an IRI supposed to be and how does it contribute?

An interdisciplinary research institute is a research organization that includes representation from across Georgia Tech and that administratively reports to the executive vice president for research. Each IRI is led by a research-active faculty member who is a thought leader in a core research area and is committed to supporting faculty and students doing research in that area. IRIs serve as intellectual crossroads for faculty and students, where interdisciplinary work is encouraged and supported. They blur the lines between traditional academic disciplines and contribute to the Georgia Tech culture of collaboration. This is important because when we collaborate, we come up with even better, and more creative, solutions to tough problems. Additionally, IRIs provide laboratory and shared administrative support, as well as new collaborative research opportunities, to faculty-led research centers and groups that elect to be affiliated with the IRI.

How does industry benefit from working with us?

We have strategic partnerships with many major corporations. These companies have many reasons for engaging with Georgia Tech. We must never forget that our main mission is education and that industry is very interested in hiring our students. Traditional education models are evolving. Expanding student opportunities beyond the classroom and into the lab is another way we can leverage our research enterprise to support education and increase our appeal to industry. An excellent example of this is the GE-sponsored Smart Grid Challenge in which Georgia Tech supports a venue where student teams compete to explore disruptive concepts. This model is increasingly popular with companies, and it provides a valuable team-based experiential learning opportunity for students. One way we can increase the volume of industry work while supporting the Institute's education mission is by providing more of these competitions and hands-on research and learning opportunities.

Industry also wants access to new technology and innovations, sometimes through direct support of research, sometimes through their investment in the companies we help create and nurture, and sometimes through the direct services provided to them. So we wish to increase the amount of research we do for industry and also the services we can provide to them.

Another important area is in growing the next generation of companies through our startup acceleration programs. Some of the early initiatives pursued under Georgia Tech's strategic plan have focused on innovation, including the Georgia Tech Integrated Program for Startups (GT:IPS) and Flashpoint, which both provide startup education for potential company formation. Through these initiatives, coupled with the recently established Innova-

tion Corps program, where Georgia Tech serves as one of three national sites to support commercialization of National Science Foundation-funded research, we have participated in programs that have created more than 100 new companies through the first three quarters of 2012. Georgia Tech is truly helping to nurture and grow new companies while providing existing companies easier access to the exciting research taking place here.

Could you talk about the concurrent processes for conducting research and translating it under this research strategy? How is that different from how things are traditionally done at universities?

Technology transition is too often a slow and painful process. It does not follow a linear, unidirectional and sequential path; though that is the way support processes have been designed and implemented. We are working hard to change this. The Georgia Tech Integrated Program for Startups (GT:IPS) and the new Industry@Tech website are good first steps.

Being the best at translational research and technology transition is consistent with our Georgia Tech strategic vision and our research strategy, in that we expect innovation and entrepreneurship to be embedded in everything we do. It is obvious that we all truly want our work to have more economic and societal impact. What is perhaps unique in our new approach is the intentional organization of professional support teams involving industry contracting, licensing, commercialization and communication from across the Institute to support research sponsorship opportunities in the core research areas.

Why is economic development so woven into the research strategy? Are we talking about that more than we used to?

Georgia Tech was created to support



Both graduate and undergraduate students are critical to Georgia Tech's research program. The research program provides these students with unique opportunities to learn about the real-world challenges facing industry and government.



Georgia Tech economic development and business assistance programs, including the Advanced Technology Development Center and Enterprise Innovation Institute, are located in the Centergy Building in Technology Square.

How does research fit into experiential learning—an important theme in the Georgia Tech strategic vision and plan?

If we take the Georgia Tech vision seriously – educating the technological leaders of the world – we need to ensure that our students have an opportunity to learn about leadership, teamwork and real-world problem solving. Our cooperative education program is a key part of this. The research enterprise is also used as part of our objective to increase the level of industry support to directly benefit experiential learning for our students. We are continuing to explore new ways in which we can provide unique learning opportunities, such as an undergraduate course in entrepreneurship and a possible co-op experience in startup company creation.

How does commercialization fit into what we are doing? Shouldn't we just be doing great scholarly research and publishing papers and not worrying about whether this work is ever used?

We should absolutely be doing great scholarly research – and we are! This scholarly work includes significant contributions to innovation literature. We find great value in having a balanced portfolio of basic and applied research, but we shouldn't forget that Georgia Tech was created with an economic development mission. We want to see that the research with clear market potential gets to companies that will commercialize it, and we want to continue fully supporting the creation of spinoff companies – many based on our research results. Some of the great research taking place at Georgia Tech can be quickly commercialized, while other research may spend many years in development before it is market-ready.

How can we provide companies with an advantage over their competition?

Companies gain a competitive advantage by hiring students who are really,

economic development in the state of Georgia, and, today, research universities are recognized as key elements in regional innovation ecosystems, which are vital to economic development. In this regard, we have several competitive advantages at Georgia Tech, including our state-sponsored economic development functions in the Enterprise Innovation Institute (EI²). Additionally, the Advanced Technology Development Center (ATDC) – incidentally the first and largest university-based incubator in the country – is consistently rated as one of the top ten facilitators of startup companies. We have focused recently on startup acceleration as part of our overall Georgia Tech strategic vision. We now seek to link each core research area to economic development opportunities, while increasing our industry sponsorship and opening

new facilities like the Carbon Neutral Energy Solutions Building to directly support industry work.

It is also significant that our students are seeking more opportunities to engage in entrepreneurial activities. The InVenture Prize, the Convergence Innovation Competition, and the Georgia Tech Research and Innovation Conference, in part, address this. Companies like GE Energy have sponsored competitions with cash awards for student teams exploring disruptive concepts.

Simply put, Georgia Tech has always had a focus on industry and economic development. We seek to grow our impact in ways that directly support the research enterprise and maximize the benefit Georgia Tech brings to our region, state, nation and the world.

really good. The Georgia Tech culture is one where students work very hard and are creative problem solvers. By hiring our students, companies have an immediate competitive advantage. Just take a look at the high percentage of Georgia Tech alumni that have executive positions in high-tech companies. Many of them credit their success to the real-world skills and work ethic learned at Georgia Tech. Industry also has access to some of the most creative minds in the world through our faculty. As we turn our attention more to meeting industry needs, companies can work with faculty and students to explore disruptive ideas – either through direct support for student projects, by licensing or investment in companies incubated through Georgia Tech.

Let's talk about basic research and the importance of federal funding. How are these elements important to our strategy, which places a lot of emphasis on industry?

Fundamental research is focused on discovery and understanding. Our culture is driven by use-inspired research where we blend science and engineering in very effective interdisciplinary ways. The federal government, through the National Science Foundation and many other federal agencies, is the leading funder of basic research. Increasingly, their programs are requiring a plan for how basic research will transition into commercial use. We have a distinct advantage because we do more than describe such transition; we live and breathe it!

So does this emphasis on commercialization of our technology and research also benefit the federal funding side?

Most of the new industries in the United States, for instance, the aerospace and Internet industries, had roots in federally funded research. Federal funding will continue to be the fuel that powers the fundamental research upon which the industries of the

future will be based. Georgia Tech will remain competitive, and we will win our fair share of federal funding.


What do you think sets Georgia Tech apart from our competitors?

I believe it is Georgia Tech's culture that combines a use-inspired approach with collegiality and hard work. We have exceptional facilities, faculty, students and staff. We innovate in everything we do—whether it is with educational approaches such as the Threads Program in the College of Computing or the Center for Music Technology in the College of Architecture. More recent examples are the Center for 21st Century Universities, our interdisciplinary research institutes such as the Institute for Electronics and Nanotechnology and the Institute for People and Technology, and startup acceleration programs such as Flashpoint.

We are also being bolder and more aggressive in encouraging all of Georgia Tech to work together as "one Georgia Tech" on our research strategy, and we are providing more thought leadership to our regional innovation ecosystem. We are executing these things in a systematic way, and our efforts are gaining national and international attention. We are

developing a unique ability to break down traditional academic barriers, which makes assembling interdisciplinary teams much easier. Industry partners have told us that our collaborative culture and willingness to work with them to solve tough problems is very different from what they see at other leading research universities.

Why do companies partner with Georgia Tech?

Georgia Tech is producing students who are future leaders and real-world thinkers, passionate about solving problems and mentored by faculty who are at the top of their game. We continue to build the best facilities, and we are increasingly using innovative contracts to provide streamlined access to intellectual property and the know-how behind it. 



Georgia Tech graduates are heavily recruited by industrial companies seeking future technological leaders.

A new study quantifies the impact of “helpful” scientists by measuring the impact on the publishing record of colleagues when the scientists died in mid-career. The deaths of highly helpful and productive scientists were associated with a 20 percent decrease in the subsequent quality of co-authors’ publications.

Image: Thinkstock



Scientists may help their colleagues in ways that have not, until now, been measured. A new study quantifies the impact of these scientists by examining the publication records of colleagues after these “helpful” scientists died in mid-career.

All-Star Scientists:

Study Examines the Role of “Helpful” Scientists in the Success of Others

By Abby Robinson

Researchers are typically judged by their ability to frequently publish papers in high-impact journals that are subsequently cited by other studies. This measure of productivity encapsulates an individual’s output that is personally beneficial.

But a new study highlights the role of “helpful” colleagues – those who, for instance, provide feedback on the papers of other scientists and are willing to serve as a sounding board for new ideas.

Conducted by a Georgia Tech researcher, the study reveals that individuals who co-authored papers with a highly helpful scientist experienced a decrease in the quality of papers they authored after the helpful scientist died. Conversely, the deaths of highly productive scientists who were not highly helpful did not influence the subsequent quality of their co-authors’ output.

“The study results suggest that individuals who may have fewer individual achievements but are a major source of support and feedback for the people around them can have a major impact on their colleagues’ careers and help improve the aggregate output of their academic departments,” said Alexander Oettl, an assistant professor in the Scheller College of Business at Georgia Tech. “In addition, the study implies that helpful scientists may be undervalued and overlooked by a scientific enterprise that rewards individual achievement above all else.”

The research was published in the June 2012 issue of the journal *Management Science* and was supported by the Social Sciences and Humanities Research Council of Canada and the Martin Prosperity Institute

Program on Innovation and Creative Industries. The findings were also the basis for a comment article in the Sept. 27, 2012, issue of the journal *Nature*.

Using a combination of academic paper publications and citations to capture scientist productivity and the receipt of academic paper acknowledgments to measure helpfulness, Oettl examined the change in the publishing output of co-authors of scientists who died.

Oettl examined more than 400,000 immunology articles and extracted the names of 149 immunologists who died mid-career. Then, he scoured more than 50,000 articles published in *The Journal of Immunology* between 1950 and 2007 for papers that thanked those scientists in their acknowledgements sections. He also examined papers published by those scientists to collect a list of their co-authors.

Of the 149 deceased scientists, Oettl classified 63 of them as very helpful because they emerged in the top 20 percent of people thanked in all acknowledgements for at least one year of their careers. He categorized 35 of the 63 helpful scientists as also being highly productive, which he defined as being in the top 5 percent for the number of annual citations and high impact factor immunology publications. Of the less helpful investigators, 17 were highly productive and 69 exhibited average productivity.

Oettl found that the deaths of the highly helpful and productive scientists were associated with a 20 percent decrease in the subsequent quality of their co-authors’ publications, whereas the deaths of individuals with high helpfulness but average pro-

ductivity were associated with a 10 percent decrease in co-author performance. The deaths of scientists with average helpfulness and high productivity had a positive impact on the performance of their co-authors, and the deaths of individuals with both average helpfulness and productivity did not have a statistically significant impact on the performance of their co-authors.

“The results show that the quality of a co-author’s output is most heavily influenced by ties to scientists with high helpfulness and not by ties to scientists who are merely prolific,” noted Oettl. “The study may also indicate that the death of an individual with high productivity but average helpfulness may free resources, such as time, for co-authors, which allows them to be more productive in that scientist’s absence.”

The research also showed that the deaths of immunologists who provided conceptual help – comments, criticism or advice about experiments and manuscripts – had a larger impact

on the performance of their co-authors than those who performed tests, provided technical help or shared materials.

This study has important implications for academic and research organizations, according to Oettl. Including helpfulness in the measure of what makes a “star” scientist may affect how organizations determine what types of individuals they should recruit and the ideal composition of personnel in the organization.

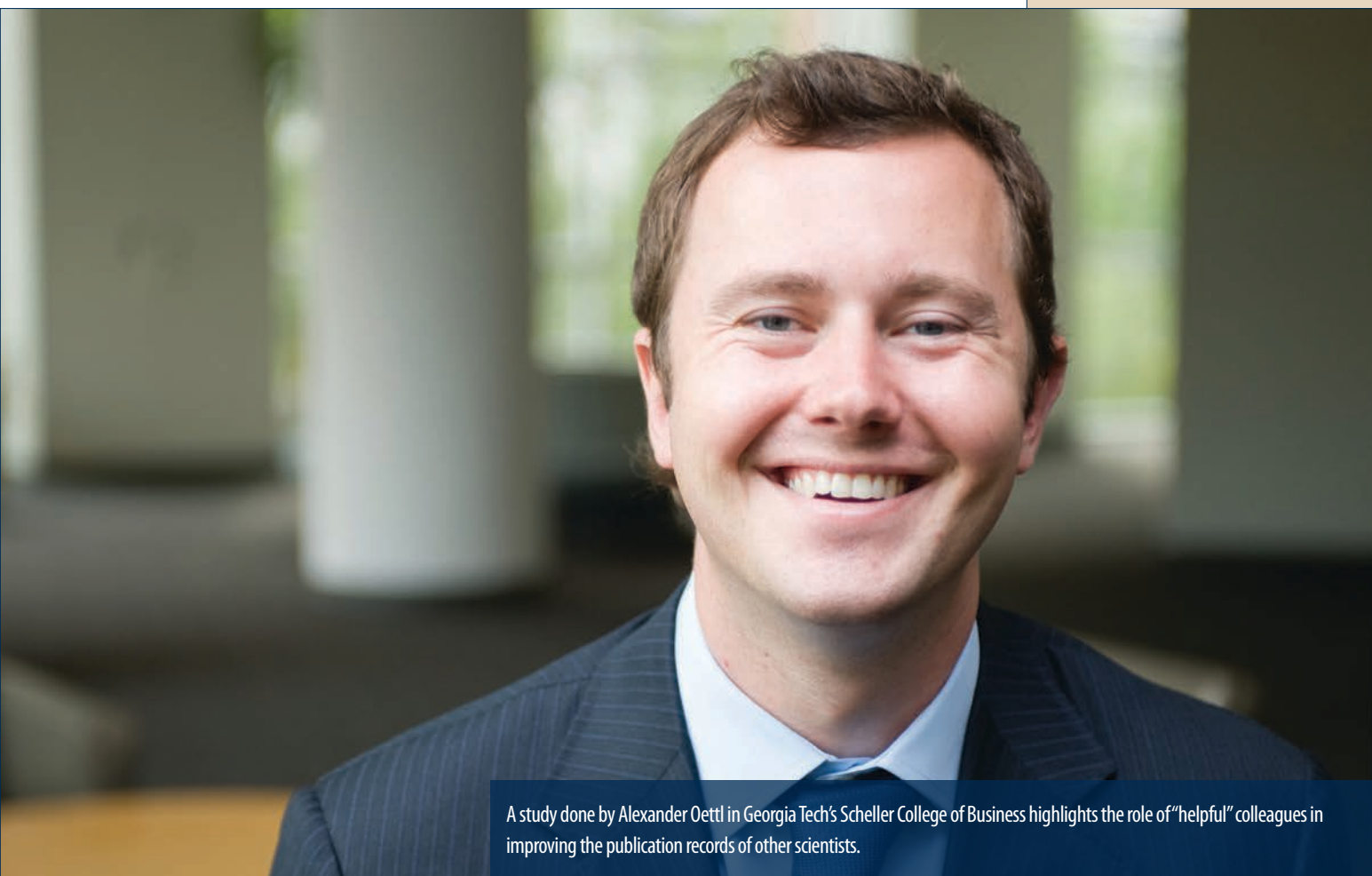
“Hiring committees should look beyond an applicant’s publication record and read the recommendations of peers and look for signs that the individual might influence departmental dynamics in a positive way,” added Oettl. rh

CONTACT

Alexander Oettl
alex.oettl@scheller.gatech.edu

“The study results suggest that individuals who may have fewer individual achievements but are a major source of support and feedback for the people around them can have a major impact on their colleagues’ careers and help improve the aggregate output of their academic departments.”

**— Alexander Oettl,
assistant professor in
the Scheller College of
Business**



A study done by Alexander Oettl in Georgia Tech’s Scheller College of Business highlights the role of “helpful” colleagues in improving the publication records of other scientists.

Members of a family of enzymes known as cathepsins, which are implicated in many disease processes, may attack one another instead of the bodily proteins they normally degrade. The phenomenon, known as “cathepsin cannibalism,” may help explain problems with drugs that have been developed to inhibit the effects of these powerful proteases.

Photo: Gary Meek



Using multiplex cathepsin zymography – a technique developed in the Platt laboratory – researchers studied the activity of two different cathepsins. The enzymes are implicated in many disease processes.

Cathepsin Cannibalism:

Enzymes Implicated in Disease Processes May Attack One Another

By John Toon

Researchers for the first time have shown that members of a family of enzymes known as cathepsins – which are implicated in many disease processes – may attack one another instead of the bodily proteins they normally degrade. Dubbed “cathepsin cannibalism,” the phenomenon may help explain problems with drugs that have been developed to inhibit the effects of these powerful proteases.

Cathepsins are involved in disease processes as varied as cancer metastasis, atherosclerosis, cardiovascular disease, osteoporosis and arthritis. Because cathepsins have harmful effects on critical proteins such as collagen and elastin, pharmaceutical companies have been developing drugs to inhibit activity of the enzymes. But so far these compounds have had too many side effects to be useful and have failed clinical trials.

Using a combination of modeling and experiments, researchers from Georgia Tech and Emory University have shown that one type of cathepsin preferentially attacks another, reducing the enzyme’s degradation of collagen. The work could affect not only the development of drugs to inhibit cathepsin activity, but could also lead to a better understanding of how the enzymes work together.

“These findings provide a new way of thinking about how these proteases are working with and against each other to remodel tissue,” said Manu Platt, an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering

at Georgia Tech and Emory University. “There has been an assumption that these cathepsins have been inert in relationship to one another, when in actuality they have been attacking one another. We think this may have broader implications for other classes of proteases.”

The research was supported by the National Institutes of Health, the National Science Foundation and the Georgia Cancer Coalition. Details of the study were reported Aug. 10, 2012, in the *Journal of Biological Chemistry*.

Platt and student Zachary Barry made their discovery accidentally while investigating the effects of cathepsin K and cathepsin S – two of the 11-member cathepsin family. Cathepsin K degrades both collagen and elastin, and is one of the most powerful proteases. Cathepsin S degrades elastin, and does not strongly attack collagen.

When the researchers combined the two cathepsins and allowed them to attack samples of elastin, they expected to see increased degradation of the protein. What they saw, however, was not much more damage than cathepsin K did by itself.

Platt at first believed the experiment was flawed, and asked Barry – then an undergraduate student in his lab who specialized in modeling – to examine what possible conditions could account for the experimental result. Barry’s modeling suggested the effects observed could occur if cathepsin S were degrading cathepsin K instead of attacking the elastin – a protein essential in the cardiovascular system.


That theoretical result led to additional experiments in which the researchers measured a direct correlation between an increase in the amount of cathepsin S added to the experiment and a reduction in the degradation of collagen. By increasing the amount of cathepsin S ten-fold over the amount used in the original experiment, Platt and Barry were able to completely block the activity of cathepsin K, preventing damage to the collagen sample.

"We saw that the cathepsin K was going away much faster when there was cathepsin S present than when it was by itself," said Platt, who is also a Georgia Cancer Coalition Distinguished Scholar. "We kept increasing the amount of cathepsin S until the collagen was not affected at all because all of the cathepsin K was eaten by the cathepsin S."

The researchers used a variety of tests to determine the amount of each enzyme, including fluorogenic substrate analysis, Western

blotting and multiplex cathepsin zymography – a sensitive technique developed in the Platt laboratory.

Beyond demonstrating for the first time that cathepsins can attack one another, the research also shows the complexity of the body's enzyme system – and may suggest why drugs designed to inhibit cathepsins haven't worked as intended.

"The effect of the cathepsins on one another complicates the system," said Platt. "If you are targeting this system pharmaceutically, you may not have the types or quantities of cathepsins that you expect, which could cause off-target binding and side effects that were not anticipated." 

The project described was supported by Award Number DP2OD007433 from the Office of the Director (OD) of the National Institutes of Health (NIH) and by the National Science Foundation (NSF) under the Science and Technology Center Emergent Behaviors of Integrated Cellular Systems (EBICS) Grant Number CBET-0939511. The content is solely the responsibility of the investigators and does not necessarily represent the official views of the OD, NIH or NSF.

CONTACT

Manu Platt
manu.platt@gatech.edu

"These findings provide a new way of thinking about how these proteases are working with and against each other to remodel tissue."

— Manu Platt, assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University



Research led by Manu Platt, an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, has shown for the first time that members of the cathepsin family of proteases can attack one another – instead of the protein substrates they normally degrade.

A device designed by Georgia Tech engineers is part of the Hurricane Imaging Radiometer (HIRAD), an experimental airborne system being developed by NASA and tested on a Global Hawk unmanned aerial vehicle. The radiometer could provide improved information on the wind and rain associated with hurricanes.

Photo: NASA



The Hurricane Imaging Radiometer (HIRAD), which contains a beam-former designed by Georgia Tech Research Institute (GTRI) engineers, is shown being installed on a NASA Global Hawk aircraft.

Monitoring Hurricanes:

Instrument for Remotely Measuring Storm Intensity Could Improve Forecasting

By John Toon

A device designed by engineers at the Georgia Tech Research Institute (GTRI) is part of the Hurricane Imaging Radiometer (HIRAD), an experimental airborne system developed by the Earth Science Office at the NASA Marshall Space Flight Center.

Known as an analog beam-former, the GTRI device is part of the radiometer, which is being tested by NASA on a Global Hawk unmanned aerial vehicle. The radiometer measures microwave radiation emitted by the sea foam that is produced when high winds blow across ocean waves. By measuring the electromagnetic radiation, scientists can remotely assess surface wind speeds at multiple locations within hurricanes.

The HIRAD could provide detailed information about the wind speeds and rain intensity inside hurricanes without the need to fly manned aircraft through the storms. In addition to the beam-former design, GTRI researchers also provided assistance to NASA with improvements aimed at a potential future, more advanced version of the radiometer.

"Improved knowledge of the wind speed field will enable the National Hurricane Center to better characterize the storm's intensity," explained Timothy Miller, Research and Analysis Team Lead for the Earth Science Office at the NASA Marshall Space Flight Center. "Better forecasts of storm intensity and structure will enable better warnings of such important factors as wind strength and storm surge. That would allow businesses and residents to prepare with more confidence in their knowledge of what is coming."

HIRAD was flown above two hurricanes in 2010 and a Pacific frontal system in 2012. Data it gathered on wind and rain will be provided to the scientific community for use in numerical modeling, and could also guide development of a next-generation system that would provide information on wind direction in addition to measuring wind speed and rain intensity.

GTRI researchers supported development of the radiometer with design of the beam-formers, which are part of the radiometer's array antenna. The array antenna gathers microwave signals from the ocean and the GTRI-designed devices – several of which are required – form "fan" beams of electromagnetic energy across the ground path of the aircraft's travel. The resulting signals are then fed into sensitive receivers developed by researchers at the University of Michigan and ProSensing, Inc., a Massachusetts company.

"There are different ways to build antennas to solve this problem, but array antennas provide multi-channel capability and greater sensitivity," said Glenn Hopkins, a research engineer who headed up the GTRI design work. "Because this system is passive – it doesn't send out radiation – we need to have maximum sensitivity and a focus on minimizing noise in the system."

The HIRAD system, known technically as a microwave synthetic aperture radiometer, is designed to operate in the microwave spectrum, from about 4 gigahertz to 7 gigahertz. Discrete parts of that range are used to enable discrimination between ocean surface emission and the rain located between the instrument and the surface.

"On the aircraft, the instrument would be flying a track over the storm, with a multitude of simultaneous beams," explained Hopkins. "We would be pixelating the surface and could determine what radiation is coming from each area to generate a map of the intensity of the wind speeds as we fly over the storm."

Beyond supporting the radiometer's need for high sensitivity and low noise, the beam-former also had to be as small and light as possible to be part of the Global Hawk payload.


"This project is an example of the kinds of work we have been doing for the Department of Defense, and we're pleased that this technology can be transitioned to assist with weather prediction and research," Hopkins said.

As part of a small business innovation research (SBIR) project with Spectral Research, Inc., GTRI researchers also participated in an effort to increase the capability of the HIRAD by designing a dual polarized array to replace the single polarized array that is part of the existing test system. The dual polarized array operates at the same 4 to 7 gigahertz range as the single polarized array, but provides

both polarization channels in the same area.

"One key challenge in the array study was to use the same footprint as the single polarization array," said Jim Maloney, a GTRI principal research engineer. "Prototype dual polarization arrays were built and measured to confirm the ability of GTRI's fragmented antenna technology to meet the bandwidth and form factor requirements."

The Global Hawk can fly at altitudes of more than 60,000 feet, and can stay in the air for as long as 31 hours, allowing it to remain in the hurricane area as much as four times longer than piloted aircraft now used for monitoring hurricanes. It provides data more detailed than what satellites could provide.

Development of HIRAD was supported by NASA and the National Oceanic and Atmospheric Administration (NOAA). The project involved partnerships among NASA's Marshall Space Flight Center, NOAA's Unmanned Aerial Systems Program, the University of Michigan, the University of Central Florida and NOAA's Hurricane Research Division. 

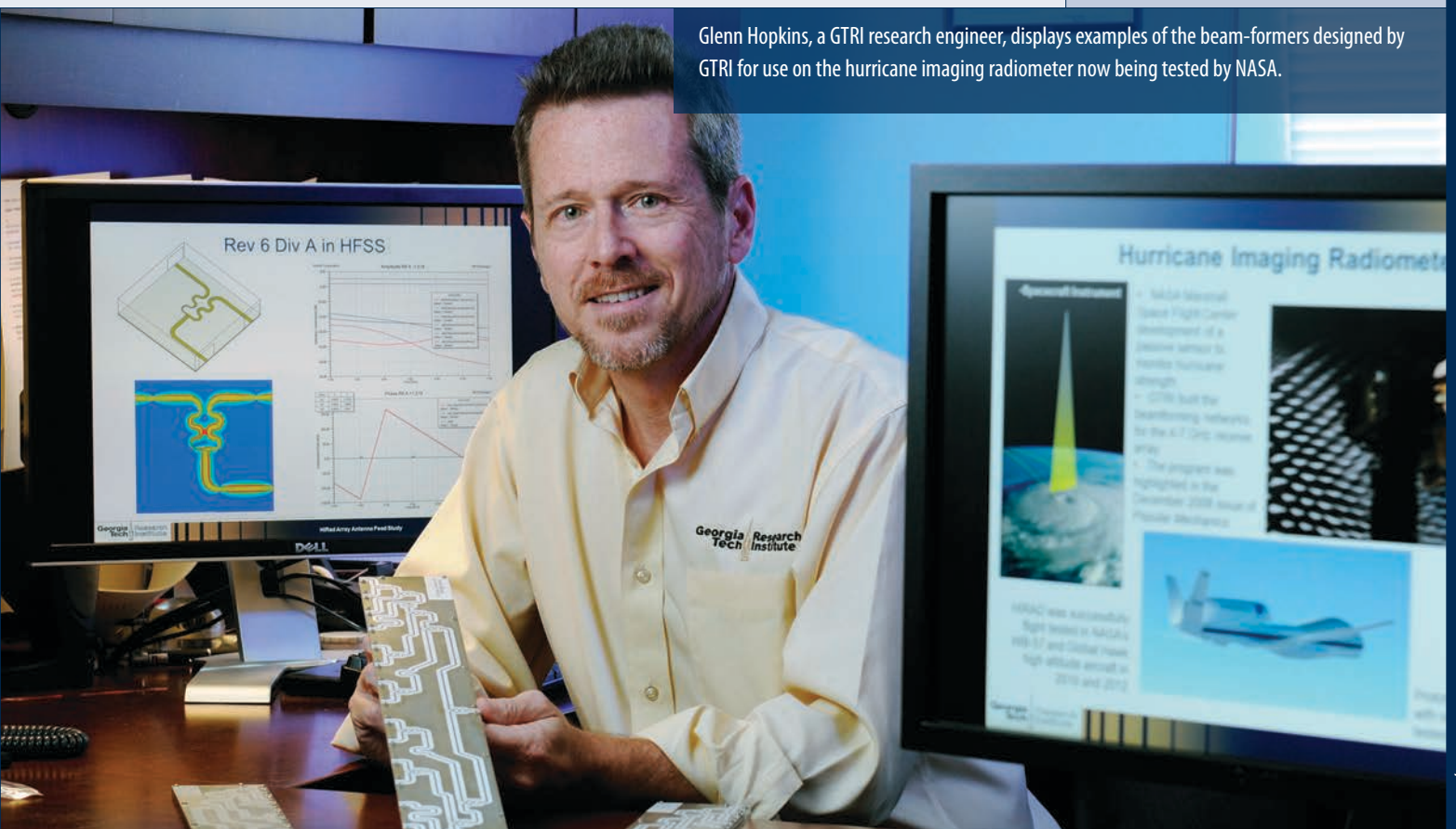
CONTACT

Glenn Hopkins
glenn.hopkins@gtri.gatech.edu

"This project is an example of the kinds of work we have been doing for the Department of Defense, and we're pleased that this technology can be transitioned to assist with weather prediction and research."

— Glenn Hopkins, research engineer in the Georgia Tech Research Institute (GTRI)

Glenn Hopkins, a GTRI research engineer, displays examples of the beam-formers designed by GTRI for use on the hurricane imaging radiometer now being tested by NASA.



Array Technology Could Improve Air Traffic Control System

Photo: Gary Meek

Problem:

- Aging radar network
 - Single mission, non-scalable, multi-agency system types (ASRs, TDWR, ARSR)
 - Up to 40-year-old technology (mechanical rotating, high O&M cost)
 - Multiple service life extension programs (SLEP) planned
 - Susceptible to mechanical failures and wind farm interference
- NextGen observation requirements might exceed current radar sensing capabilities

Possible Solution Alternatives:

- Conventional rotating replacement →
- Networked short range sensors →
- Rotating Phased Array Radar (PAR) →
- Fixed faced PAR →

GTRI researcher Tracy Wallace is helping the Federal Aviation Administration weigh the feasibility of replacing current U.S. air traffic control systems with more efficient and reliable multifunction phased-array radar (MPAR).

Aircraft operating in U.S. airspace rely on several different types of ground-based radars to help them fly safely. Yet these radars, based on older technologies that use many mechanical components, require frequent repairs as well as costly periodic maintenance programs.

A research team from the Georgia Tech Research Institute (GTRI) is working with the Federal Aviation Administration (FAA) and National Oceanic and Atmospheric Administration (NOAA) to investigate alternative approaches to the radars that currently support the nation's air traffic control and weather monitoring systems. The multi-year study is examining the feasibility of replacing that group of radars with a single system based on phased-array technology, an advanced design that uses solid-state electronics in place of many mechanical components.

As part of the NextGen Surveillance and Weather Radar capability program, one of the alternative approaches specifically being considered by the FAA is called multifunction phased-array radar (MPAR). MPAR has the capability to surpass current technologies in both reliability and ease of maintenance, said Tracy Wallace, a principal re-

search engineer who is leading GTRI's participation in the study.

A single MPAR installation at an airport could potentially replace all the conventional radars typically found in several locations around major airports today. Moreover, MPAR technology could enhance the capabilities of the nation's air traffic control and weather monitoring systems.

"The central question is whether converting to a phased-array system would be practical from a cost perspective," Wallace said. "Currently we're advising the government on the feasibility – including the expenditure, technical and scheduling issues – of developing an MPAR program. We're also preparing to support the investigation with modeling studies of prospective MPAR designs."

The FAA utilizes multiple platforms to maintain control of air traffic within the National Airspace System. There are several different radars in service to support the related tasks of tracking aircraft and monitoring weather conditions, including:

- Airport surveillance radar (ASR), which are moderate-range systems used to follow aircraft within 60 nautical miles of an airport;

- Air route surveillance radar (ARSR), which are long-range systems used to track aircraft as they fly between airports and as they approach U.S. borders;
- Terminal Doppler weather radar (TDWR), used near airports primarily to monitor wind-shear conditions.

Also important to air traffic control are NEXRAD radars, which are maintained and operated by NOAA, in conjunction with the National Weather Service (NWS). These long-range, pulse Doppler radars supply valuable weather information. They are used to monitor weather conditions faced by aircraft, and they are often seen on media reports, particularly during severe weather events such as tornadoes.

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.

— Rick Robinson

CONTACT:

Tracy Wallace
tracy.wallace@gtri.gatech.edu

Georgia Tech and Veterans Administration Collaborate on Health IT

Two major non-commercial health information technology organizations are working together in a new vendor-neutral health IT innovation network designed to stimulate development of new ideas and shorten the time required to bring new solutions into practice.

Researchers from the Department of Veterans Affairs (VA) Veterans Health Administration's (VHA) Innovation Sandbox Cloud and Georgia Tech's Interoperability and Integration Innovation Lab are working together to address interoperability issues, accelerate the development of integrated health IT solutions, provide an unbiased environment for testing new products and help train the IT workforce needed to move the industry forward. Georgia Tech is believed to be the first academic organization to connect directly to VHA's system.

Bringing together innovation facilities allows researchers from both organizations to collaborate on specific projects. The agreement also facilitates the use of the Veterans Health Information Systems and Technology Architecture (VistA), VHA's electronic health records system, to test new products and solutions. VistA is already used to help manage care for 7.6 million active U.S. veterans across VHA's nationwide health care system.

"We believe that together we can do something really unique and important," said Steve Rushing, direc-

tor of Health@E12, a health care innovation initiative at Georgia Tech. "By connecting our interoperability innovation lab to the VHA's Sandbox Cloud, we can create joint project teams to work on specific challenges, work together to address industry issues and develop best practices, and test applications designed to run with the VA's robust electronic health records system."

The VHA and Georgia Tech share many of the same goals and, by working together, the organizations can leverage investments made by the VA and other federal agencies, noted Robert Kolodner, M.D., who led development of VistA during his 28-year career at the VA. Kolodner serves as a strategic advisor to Georgia Tech on its health care IT initiatives.

"This collaboration enables decades of health IT advances by the VA to be combined with investments by other federal agencies and with resources from both the state and private sectors," Kolodner said. "Together, they create a robust, diverse education and simulation environment. We can train the health IT workforce necessary to succeed as our national health IT initiatives improve the health and well-being of individuals and communities across the nation."

Georgia Tech's Interoperability and Integration Innovation Lab (I3L) was established to stimulate new ideas

in health IT by creating a standards-based environment in which resources can be shared, barriers reduced, and new products more rapidly developed and introduced.

"The I3L will help us understand how to create conformance in interoperable systems and how in the future all of the health and medical devices and systems can be tied together to create a seamless view of what's happening to the patient," said Jeff Evans, deputy director of the Information and Communications Laboratory in the Georgia Tech Research Institute (GTRI). "It will take us into the future of what health care is going to be, while also supporting the requirements of today."

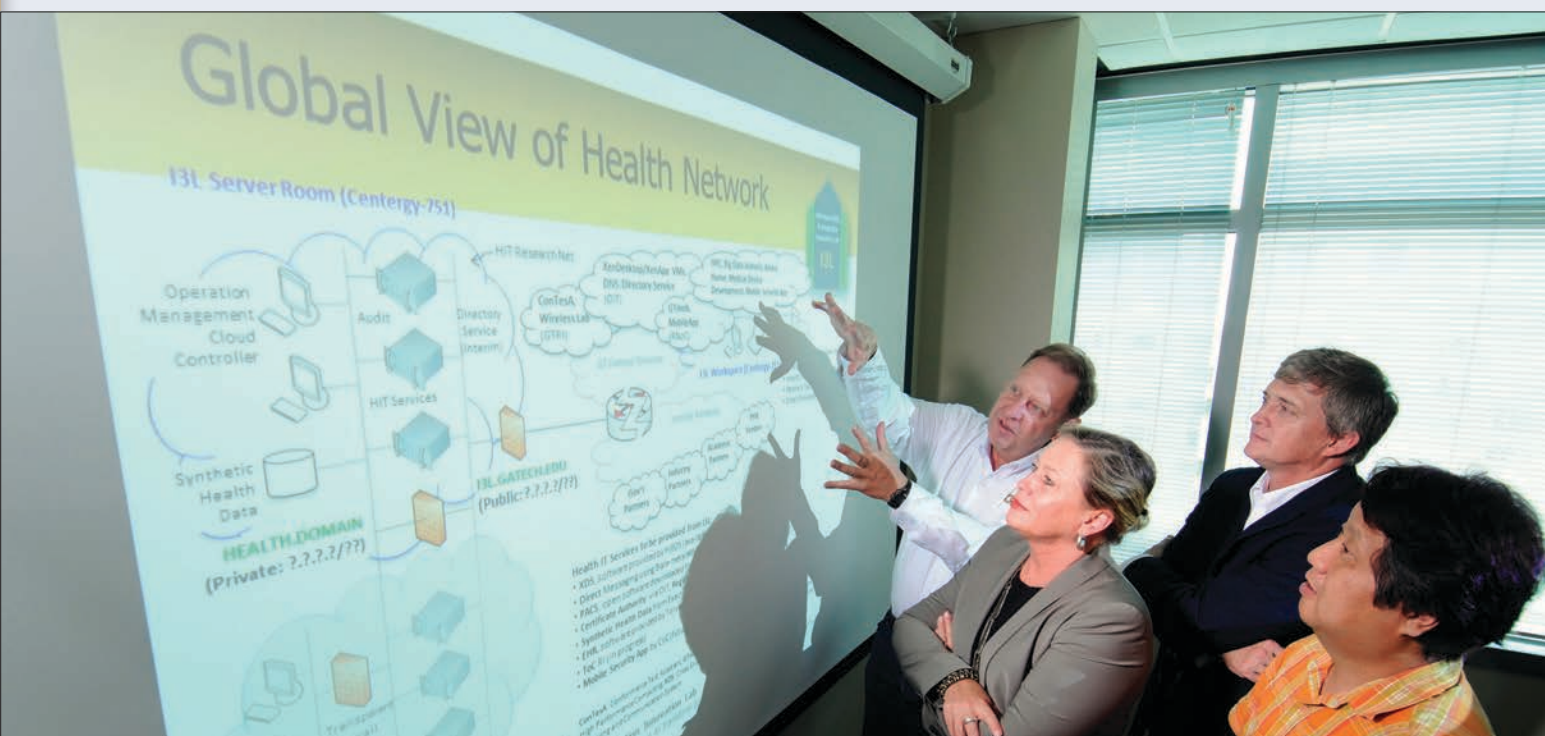
— John Toon

CONTACTS:

Steve Rushing
steve.rushing@innovate.gatech.edu

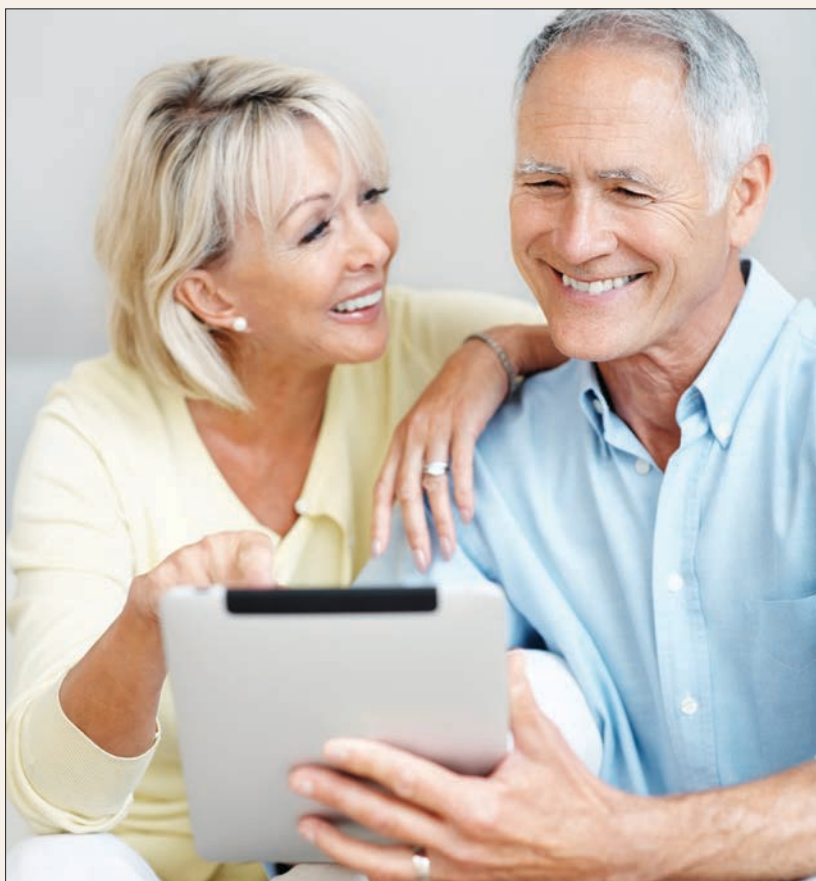
Jeff Evans
jeff.evans@gtri.gatech.edu

Georgia Tech researchers discuss interoperability issues in health information technology networks. Shown are (front row) Marla Gorges and Steve Rushing of the Enterprise Innovation Institute, and (back row, l-r) Jeff Evans and Myung Choi from the Georgia Tech Research Institute.



HomeLab Helps Companies Evaluate Health Technologies

Image: iStock



The Georgia Tech Research Institute (GTRI) launched HomeLab to help companies evaluate the in-home use of emerging health technologies designed for the aging adult population.

Baby boomers have witnessed many technological innovations, and they expect technology to provide them with solutions to help maintain their independence for as long as possible. They are outfitting their homes with products to help them live healthy lifestyles, manage chronic conditions, remember to take medications and remain connected with their caregivers.

To help companies evaluate baby boomers' perceptions, use and acceptance of home health and wellness technologies, Georgia Tech has launched HomeLab, a statewide network of adults 50 years of age and older recruited to evaluate the in-home usability and effectiveness of consumer products designed for the aging adult population.

HomeLab currently consists of 350 homes distributed throughout the state of Georgia; the network is expected to grow to 550 homes by 2014.

"My wife and I are in generally good health and are interested in assisting homebound citizens by evaluating new innovations for their independent living. We want to be part of the solution for this excellent challenge," said Ivan Cottrell. Cottrell signed up to be a HomeLab participant with his wife, Judy, who was a home health nurse in Florida and witnessed many seniors struggling to stay in their own homes.

The HomeLab infrastructure lessens the burden for companies that need to find participants 50 years of age and older for extended in-home product testing. Because Georgia Tech collects detailed information about each HomeLab participant's health and home up front, individuals can be rapidly recruited for targeted short- and long-term product testing.

"HomeLab provides an efficient means for companies to limit the cost of extensive user

testing that is required to bring a product to market," said Brad Fain, director of HomeLab and a principal research scientist in the Georgia Tech Research Institute (GTRI). "Evaluation of a pre-market or mature technology by Georgia Tech's HomeLab will provide a company with documented evidence for marketing, regulatory compliance and product design."

GTRI has a history of helping companies evaluate and improve the design of consumer products and currently serves as the independent product testing organization for the U.S. Arthritis Foundation, the Arthritis Society of Canada and Arthritis Australia. If a product passes GTRI's rigorous ease-of-use testing, the company that created the product can use the arthritis organization's logo in its advertisements and on its packaging.

For this work, GTRI recruits users to test a variety of consumer products – medicine bottles, beverage containers, office supplies, medical devices, vehicles and cell phones – in its Accessibility Evaluation Facility.

With the launch of HomeLab, GTRI will expand its product testing program to include extended in-home product evaluations, which will range from one month to one year in duration and involve 25 to 125 participants who are compensated for their time. HomeLab will provide companies with product design support, early product testing, and formal usability and effectiveness evaluations.

— Abby Robinson

CONTACT:

Brad Fain
brad.fain@gtri.gatech.edu

Georgia Tech Helps Expand NSF Innovation Corps Program

Photo: Gary Meek



Keith McGreggor, director of Georgia Tech's VentureLab program, presents to a group of 27 National Science Foundation I-Corps teams as part of a class held on the Georgia Tech campus in July 2012.

The National Science Foundation (NSF) has included Georgia Tech as a founding network node for its Innovation Corps (I-Corps) program, which aims to develop scientific and engineering discoveries into useful technologies, products and processes.

The I-Corps program connects NSF-funded scientific research with the technological, entrepreneurial and business communities to help create a stronger innovation ecosystem that couples scientific discovery with technology development and societal needs. Leveraging experience and guidance from established entrepreneurs and a targeted curriculum, I-Corps attendees learn to identify valuable product opportunities that can emerge from academic research.

Beyond Georgia Tech, the NSF has also established an I-Corps network node at the University of Michigan. By adding these two institutions to its I-Corps program – which began at Stanford University – the NSF will replicate the I-Corps curriculum across the country and begin creating a national network to identify emerging technology concepts that have potential to transition into economically viable products.

“One of Georgia Tech's strengths is its ability to provide the links needed to help move scientific research

quickly from the lab to products coming off the manufacturing floor,” said G. P. “Bud” Peterson, president of Georgia Tech. “We are honored to partner with NSF in expanding I-Corps’ ability to help the entrepreneurial and business communities and boost economic growth.”

With a three-year, \$1.5 million grant, Georgia Tech will research, analyze and leverage data from the I-Corps program to develop an understanding of how academic institutions can improve support for innovation ecosystems and how the I-Corps network can enable new collaborations in geographic regions to support commercialization opportunities. Georgia Tech will also teach the I-Corps curriculum to cohorts of NSF-designated teams from around the United States.

“Through our translation-friendly technology transfer policies and our 11-year-old VentureLab program, Georgia Tech has built a repeatable process for successfully generating new companies from research at the university,” said Stephen Fleming, the project’s principal investigator and executive director of the Enterprise Innovation Institute. “Now we will be able to share with participants of the NSF I-Corps program our experience and commitment to developing best practices in the science of vetting ideas for their suitability to be successful startups.”

Georgia Tech has so far taught two groups of teams, each of which included an NSF-sponsored researcher. Spanning a broad range of potential products and research areas, the teams enrolled in the program participate in a specially designed training curriculum, obtaining guidance and mentoring from private- and public-sector experts – including technology developers, business leaders and venture capitalists. They receive \$50,000 grants to begin assessing the commercial readiness of their technology concepts.

The Innovation Corps is supported by the National Science Foundation, the Ewing Marion Kauffman Foundation, and the Deshpande Foundation.

— Abby Robinson

CONTACTS:

Stephen Fleming
fleming@gatech.edu

Keith McGreggor
keith.mcgreggor@gatech.edu

Manufacturing Survey Shows In-Sourcing Exceeding Outsourcing

Graphic: Rhys Black

The 2012 Georgia Manufacturing Survey provides some good news for Georgia companies. For the first time since researchers began tracking the statistic, more Georgia manufacturers have been benefitting from in-sourcing — production work coming to them from outside the state — than have been losing work to other states and countries.

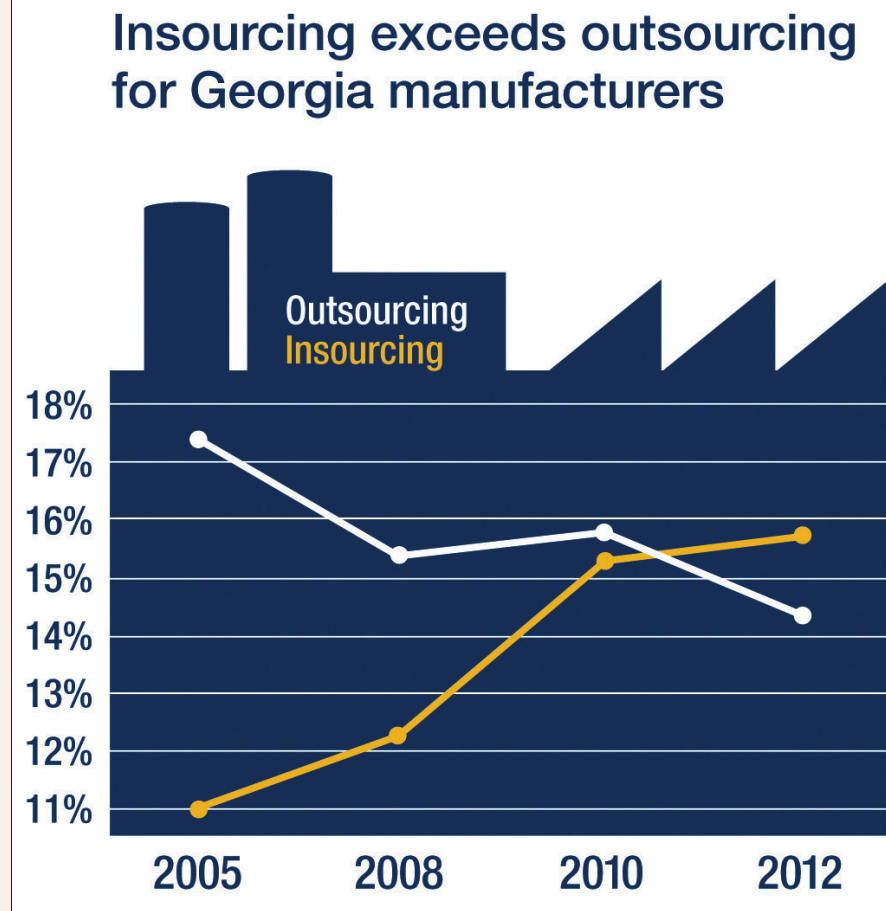
Nearly 16 percent of the companies responding to the survey said work had been transferred to them from outside Georgia, compared to slightly more than 14 percent that lost work to out-of-state facilities. The percentage of companies receiving work from facilities outside Georgia grew from just 11 percent the first year the question was asked in 2005, while the percentage of companies losing work fell from slightly more than 17 percent that year.

“We have finally seen a crossing of the lines so that more companies in Georgia are benefitting from in-sourcing than are losing to outsourcing,” said Jan Youtie, director of policy research services in Georgia Tech’s Enterprise Innovation Institute. “It’s not a huge difference at this point, but it is a positive and consistent trend for the manufacturing community.”

The in-sourced work most commonly came from other facilities in the United States, though a growing percentage of companies reported production transferred to them from outside the United States. The percentage of companies benefitting from this “on-shoring” trend grew to 4.3 percent from 2.6 percent in 2005.

“This may be about the total cost of manufacturing,” said Youtie, who also holds a faculty position in the Georgia Tech School of Public Policy. “Companies are taking a hard look at aspects of production they formerly assumed were cheaper overseas. There are costs involved in outsourcing that may not have been considered before, such as logistics and regulatory issues. Rising foreign labor costs may be another factor.”

The Georgia Manufacturing Survey is conducted every two or three years to assess the use of modern manufacturing technology, practices and techniques by Georgia industry. It was



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conducted by Georgia Tech researchers in collaboration with Kennesaw State University, the Georgia Department of Labor, and the Atlanta accounting firm Habif, Arogeti and Wynne, LLP. The 2012 survey was conducted from February to May of 2012, and received responses from 528 companies that had 10 or more employees.

As in past years, the study compared profitability of companies with different competitive strategies. The return on sales for companies competing on the basis of innovative products, processes or services was twice that of companies competing on the basis of low price. Innovative companies also pay higher wages than companies using other strategies.

“We see that science-based industries are more likely to prioritize innovation as a strategy,” explained Philip Shapira, co-director of the

survey, and a professor in Georgia Tech’s School of Public Policy and at the Manchester Business School in the United Kingdom. “Industries such as food and apparel are less likely to compete that way. However, no sector in Georgia has a large percentage of firms competing on innovation, though companies in any industry can use innovation.”

— John Toon

CONTACTS:

Philip Shapira
philip.shapira@pubpolicy.gatech.edu

Jan Youtie
jan.youtie@innovate.gatech.edu

Camera Uses Muscle Like Action to Mimic Human Eye Movement

Photo: Billy Gallagher

Using piezoelectric materials, researchers have replicated the muscle motion of the human eye to control camera systems in a way designed to improve the operation of robots. This new muscle like action could help make robotic tools safer and more effective for MRI-guided surgery and robotic rehabilitation.

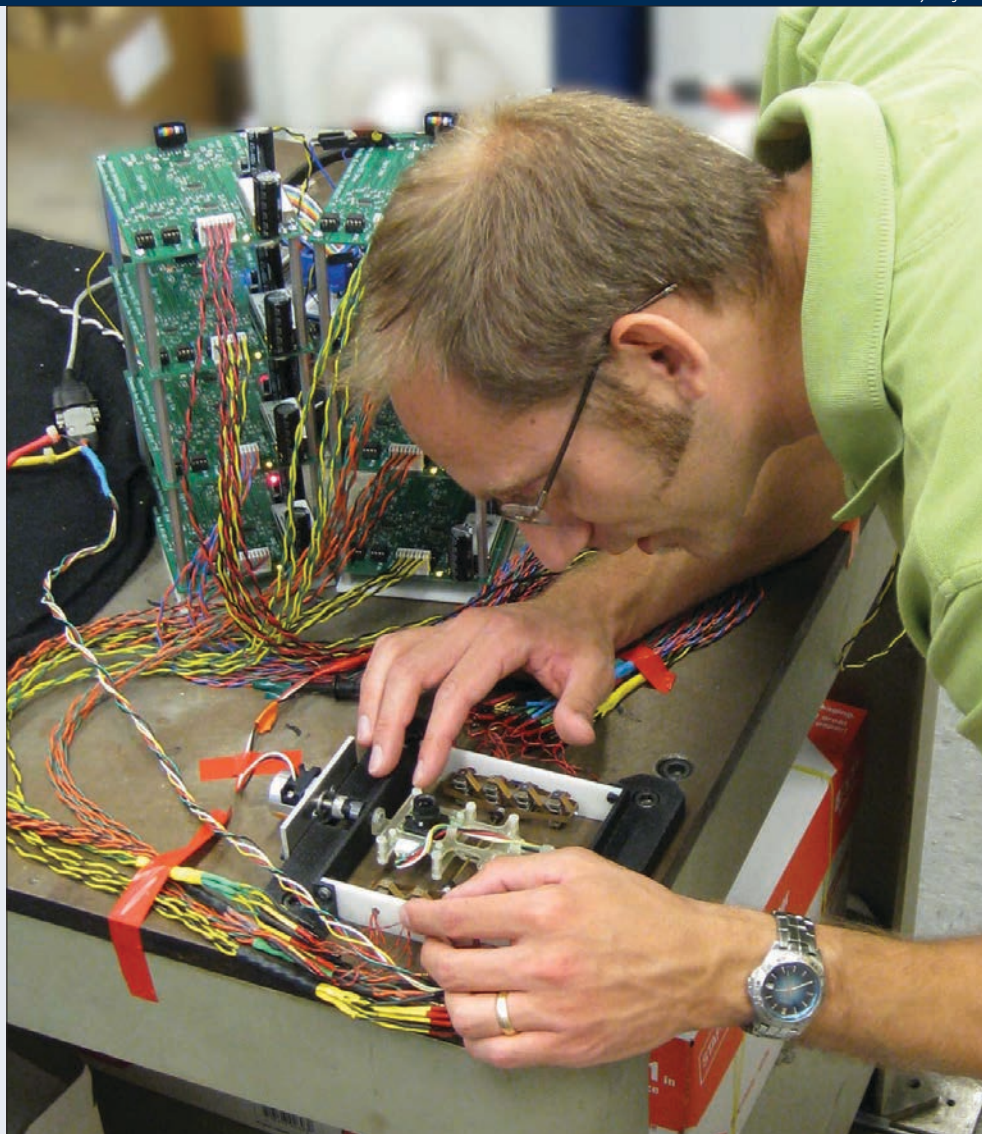
Key to the new control system is a piezoelectric cellular actuator that uses a novel biologically inspired technology that will allow a robot eye to move more like a real eye. This will be useful for research studies on human eye movement as well as making video feeds from robots more intuitive. The research was conducted by Ph.D. candidate Joshua Schultz under the direction of assistant professor Jun Ueda, both from Georgia Tech's George W. Woodruff School of Mechanical Engineering.

"For a robot to be truly bio-inspired, it should possess actuation, or motion generators, with properties in common with the musculature of biological organisms," said Schultz, who is now a post-doctoral fellow at the Italian Institute of Technology. "The actuators developed in our lab embody many properties in common with biological muscle, especially a cellular structure. Essentially, in the human eye muscles are controlled by neural impulses. Eventually, the actuators we are developing will be used to capture the kinematics and performance of the human eye."

Details of the research were presented June 25, 2012, at the IEEE International Conference on Biomedical Robotics and Biomechanics in Rome, Italy. The research is funded by National Science Foundation. Schultz also receives partial support from the Achievement Rewards for College Scientists (ARCS) Foundation.

Ueda, who leads the Georgia Tech Bio-Robotics and Human Modeling Laboratory in the School of Mechanical Engineering, said this novel technology will lay the groundwork for investigating research questions in systems that possess a large number of active units operating together. Possible applications include industrial, medical, rehabilitation and intelligent assistive robots.

"Robustness against uncertainty of model and environment is crucial for robots physically interacting with humans and environments," said Ueda. "Successful integration relies on the coordinated design of control, structure, actuators and sensors by considering the dy-



Joshua Schultz makes some final adjustments to the camera positioning mechanism used in the muscle like cellular actuators of the robot vision system.

namic interaction among them."

Piezoelectric materials expand or contract when electricity is applied to them, providing a way to transform input signals into motion. This principle is the basis for piezoelectric actuators that have been used in numerous applications, but use in robotics applications has been limited due to piezoelectric ceramic's minuscule displacement.

The cellular actuator concept developed by the research team was inspired by the biological muscle structure that connects many small actuator units in series or in parallel to increase the amount of motion.

— Sarah Goodwin

CONTACT:

Jun Ueda
jun.ueda@me.gatech.edu



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