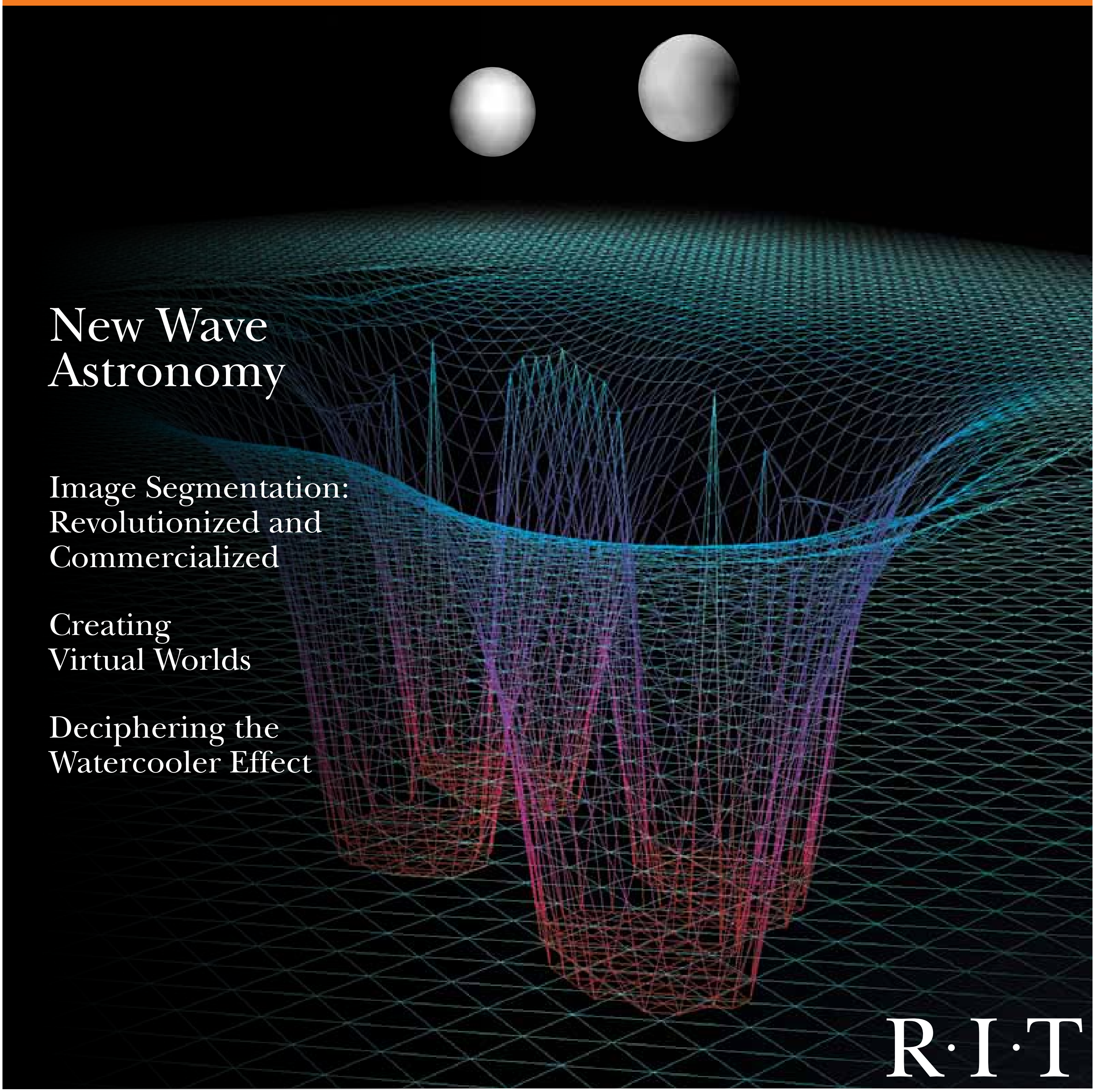
RESEARCH at RIT

The Rochester Institute of Technology Research Report

Spring/Summer 2010

SPOTLIGHT ON

MODELING



New Wave Astronomy

Image Segmentation: Revolutionized and Commercialized

Creating Virtual Worlds

Deciphering the Watercooler Effect

www.rit.edu/research

RESEARCH at RIT

The Rochester Institute of Technology
Spring/Summer 2010

Executive Editor
Donald Boyd,
Vice President for Research

Managing Editor
Mike Dwyer, Director,
Research Relations Office

Editor
Kara Teske,
Research Communication Specialist,
Research Relations Office

Design Director
Jeff Arbegast, Art Director,
University Publications

Head Writer
William Dube, Senior Communication
Specialist, University News Services

Contributing Writers
Susan Gawlowicz,
Senior Communication Specialist,
University News Services

Contributing Photographers
Elizabeth Lamark, Photographer,
Educational Technology Center

John Myers, Photographer

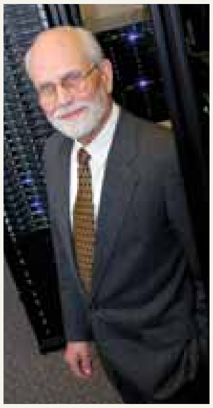
Office of Research Relations
74 Lomb Memorial Drive
Rochester, NY 14623
585-475-2167
E-mail: kmtpop@rit.edu

Rochester Institute of Technology publishes *Research at RIT*. RIT will admit and hire men and women; veterans; people with disabilities; individuals of any race, color, creed, religion, national or ethnic origin, sexual orientation, age, or marital status in compliance with all appropriate legislation.

Vol. 3, No. 2
11M-P0918-5/10-PAL-JSA

Modeling, Simulation, and Visualization

Through the creation of novel mathematical models and their application to simulation and visualization, RIT researchers are making new discoveries and advancing technology.



What happens when black holes merge 500 million light years away? What does an image tell us that we can't see with our own eyes? What is the experience like at war? At a Fortune 500 company? In another world? How does information spread and who decides what's true or not? These are just a few questions that are being answered by RIT researchers through advanced models, simulations, and visualizations.

In past issues we have featured some of RIT's core research areas: Imaging, Sustainability, Bio-X, and Energy. This issue explores modeling, an approach used by researchers across disciplines to bring new information into sight and advance our understanding and technology.

At the Center for Computational Relativity and Gravitation, a team of scientists has created a model that for the first time simulates the merger of two black holes using Einstein's theory of general relativity. The groundbreaking research in computational astrophysics and numerical relativity uses supercomputers in hopes of confirming Einstein's theory of general relativity.

RIT has a long history of partnering with industry to serve its education and research needs. Dr. Eli Saber, from electrical engineering, has been collaborating with many industry partners to advance their technology by applying image segmentation techniques. A program, entitled Corporate R&D and introduced by RIT President Destler, encourages such collaboration by allowing the company to own the intellectual property in defined situations. You'll learn about some of these collaborations in this issue.

Our interactive games and media department is gaining a national reputation as a leader in game design and development, with key partnerships with industry giants like Adobe, Microsoft, and Activision. RIT game designers, faculty, and students alike are creating virtual worlds that go beyond entertainment and provide engaging educational visualization experiences.

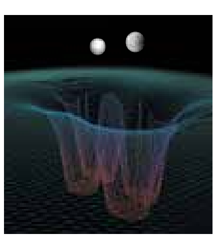
Finally, in this issue a multidisciplinary effort led by psychologist Dr. Nicholas DiFonzo is trying to bring truth to the rumor mill through the development of mathematical models. The research is analyzing how rumors spread and their effects on what society believes.

I encourage you to learn more about the exciting research happening at RIT through the following articles and by connecting online at www.rit.edu/research.

Best Regards,

Donald Boyd, Ph.D.
Vice President for Research

Inside this Issue



On the Cover
The model, created by researchers at the Center for Computational Relativity and Gravitation, shows two black holes on the verge of colliding and producing a single, larger black hole resulting in the release of gravitational waves. The simulations are used by scientists to aid in the discovery of gravitational waves that will confirm Einstein's theory of general relativity.

Computational Voyage to Prove Einstein's Theory: Dr. Bruno Mundim, Dr. Scott Noble, Dr. Yosef Zlochower, Dr. Carlos Lousto, Dr. Manuela Campanelli, Dr. John Whelan, Dr. Hans-Peter Bischof, Dr. Josh Faber, and Dr. Hiroyuki Nakano (counter-clockwise from top to bottom), all researchers at the Center for Computational Relativity and Gravitation, are producing a groundbreaking body of research in computational astrophysics and numerical relativity. The renowned center uses massive supercomputers to solve Einstein's general relativity equations connecting matter, space, and time.

New Wave Astronomy

by Susan Gawlowicz

A group of scientists at Rochester Institute of Technology are on a computational quest to simulate black holes and gravitational waves creating a new science of multimessenger astronomy.

Back to the Beginning

How can we see the universe without using light? A new generation of scientists is working to use gravitational waves—ripples propagating through space and time—to learn about the darkest objects in the cosmos—colliding black holes—and perhaps solve mysteries buried deep in the history of the universe.

Scientists at RIT's Center for Computational Relativity and Gravitation (CCRG) are busy smashing together black holes and neutron stars on supercomputers to see what gravitational waves might look like. Other scientists in the lab are adding electromagnetic fields and matter to the scenario to mimic nature. And while most of the researchers in the center are simulating gravitational waves, one scientist in particular is analyzing actual data collected by an international collaboration chasing gravitational waves. Together, the CCRG group is producing a body of groundbreaking research in computational astrophysics and numerical relativity, a specialized research field that uses supercomputers to solve the equations in Einstein's theory of general relativity.

The Center for Computational Relativity and Gravitation

Dr. Manuela Campanelli, director of the center and associate professor of mathematical sciences, arrived at RIT with noteworthy accomplishments to launch and lead the center. At a scientific meeting two years prior, Campanelli and her collaborators Dr. Carlos Lousto and Dr. Yosef Zlochower made an announcement that would put gravitational wave observation closer into reach. They had, for the first time, simulated the merger of two black holes on a supercomputer, solving the 10 interrelated equations for strong field gravity that comprise Einstein's famous theory of general relativity connecting matter, space, and time.

The simulation of gravitational waves from black hole collisions serves as a critical step toward verifying Einstein's theory. That essential breakthrough, sought for decades, hinged on a fresh approach to solving Einstein's equations and the development of sufficient computing power to handle the complex mathematics.

Campanelli's team, then at the University of Texas at Brownsville, was one of two independent groups of scientists to solve the decades-old problem. The moving-puncture approach, introduced by Campanelli's team, led to the discovery of enormous gravitational-radiation recoils or "kicks" from spinning supermassive black holes, close to 4,000 km/s, or nearly one percent the speed of light.

Detecting Gravitational Waves: The LIGO Hanford Observatory, located in the Washington desert, is part of a network of ground-based detectors working in unison to detect and measure the form of gravitational waves. Scientists are using simulations of gravitational waves provided by researchers at the Center for Computational Relativity and Gravitation as blueprints to sift through the "noise" in LIGO's data.

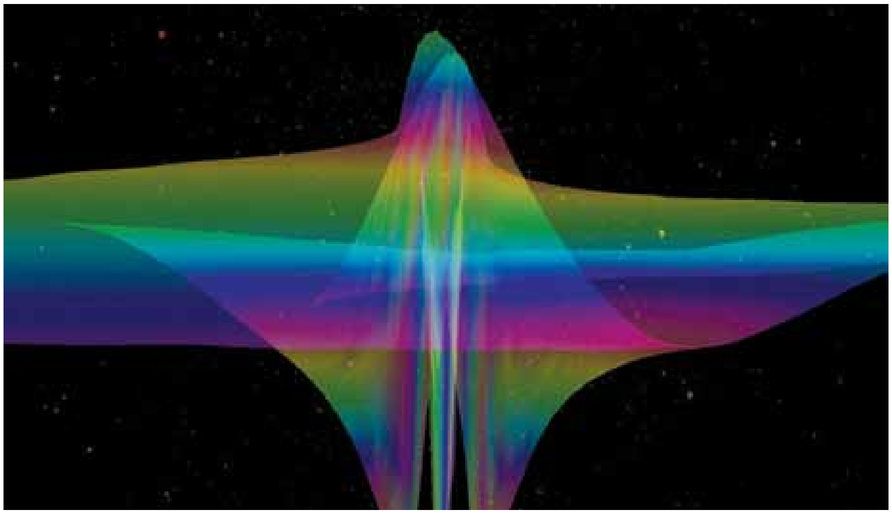
The CCRG was founded in the School of Mathematical Sciences in January 2007, then headed by Dr. Sophia Maggelakis, with five initial members: Campanelli, Lousto, and Zlochower of the School of Mathematical Sciences; Dr. David Merritt of the physics department; and Dr. Hans-Peter Bischof of the computer science department. In three years, the center has doubled in size and has brought in $3 million in research funding from NASA and the National Science Foundation. The center focuses on five well-defined research areas: gravitational wave detection, numerical relativity, galactic dynamics, high-performance computing, and scientific visualization.

Making Waves

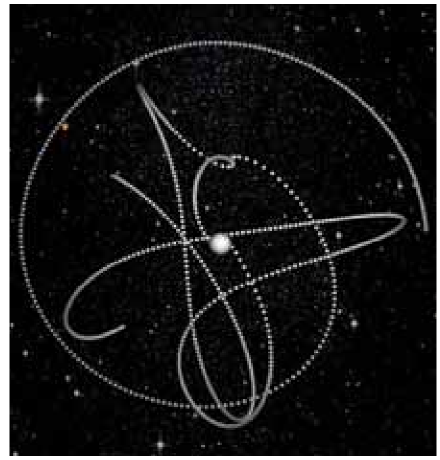
Scientists are intrigued by gravitational waves for their ability to pass through the same matter that blocks light, or electromagnetic radiation—the focus of conventional astronomy.

"We're trying to make the first detection of gravitational waves," says Dr. John Whelan, CCRG member and associate professor in the School of Mathematical Sciences (SMS).

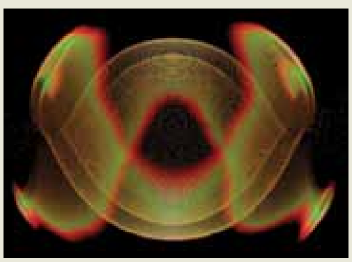
"That's not the end goal; it's the beginning of initiating the field of gravitational wave astronomy. Almost all of the informa-



When Black Holes Collide: The collision of two black holes generates gravitational waves—distortions in the curvature of space-time—that travel at the speed of light and hold clues to the origin of the universe. The simulated gravitational wave in this image was emitted by two colliding black holes. The height and color indicate the amplitude of the wave.



Three Black Holes Orbiting: An irresistible gravitational pull draws three black holes into increasingly tight orbits and two massive collisions. This visualization traces the interactions and curious trajectories of a trio of same-sized masses.



Scientific Visualization

Dr. Hans-Peter Bischof, an expert in framework design and associate professor of computer science, specializes in bringing black holes into view through computer graphics and animated movies illustrating the center's results.

"The science done at CCRG is very difficult to explain to the general public," Bischof says. "A movie is one way to capture the essential information and let it speak for itself."

In late 2007, the History Channel's *The Universe: Cosmic Holes* featured Bischof's visualizations of black holes based on Campanelli, Lousto, and Zlochower's research.

Visit http://ccrg.rit.edu/research/visualization to view some of the center's animated visualizations.

tion we get about the universe comes from collecting photons, collecting light in the form of visible light, radio waves, gamma rays, anything along the electromagnetic spectrum. The idea of gravitational waves is that we'd open up a whole new spectrum of waves propagating at the speed of light."

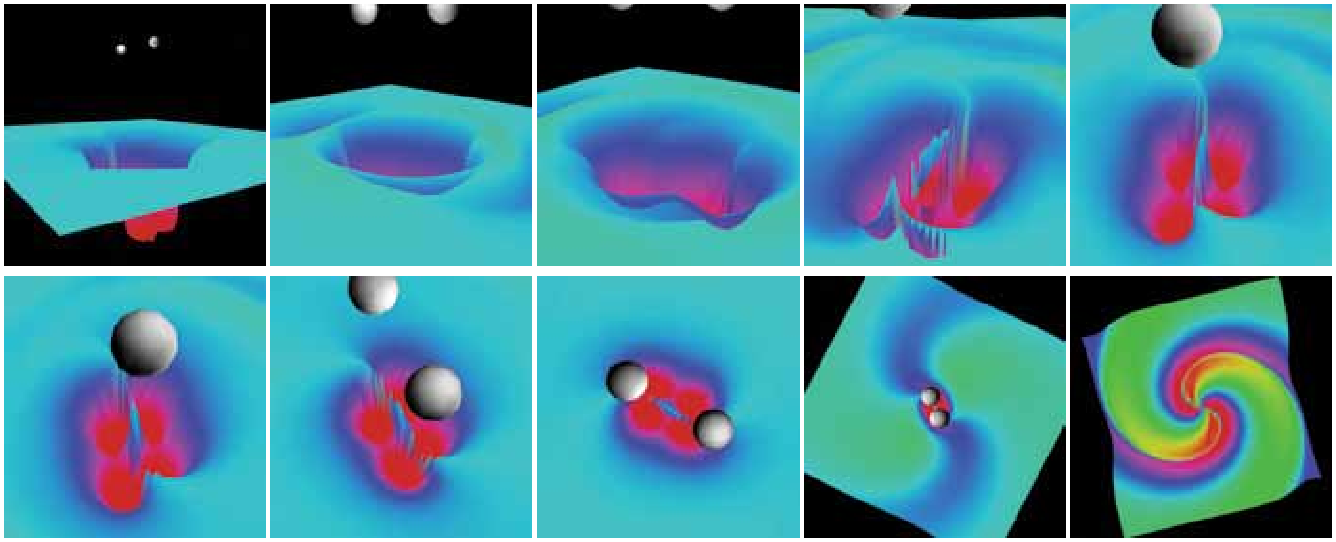
The scientific collaboration supporting the Laser Interferometer Gravitational Wave Observatory (LIGO) expects to measure actual gravitational waves for the first time within the decade. Scientists like Whelan will compare real waves coming from space with simulations generated by his colleagues at CCRG and other centers contributing to LIGO. RIT is among the nearly 60 institutions that comprise the LIGO Scientific Collaboration.

LIGO, operated by California Institute of Technology and Massachusetts Institute of Technology, uses ground-based laser interferometers with four-kilometer arms to measure the geometry of space-time and look for gravitational waves. The National Science Foundation-funded project consists of two separate observatories—one located in Livingston, La., and the other in Richland, Wash.—that work in unison to search for gravitational waves, such as those produced in binary black hole coalescences. Also participating in the worldwide network are the three-kilometer VIRGO interferometer near Pisa, Italy and the GEO-600 interferometer near Hannover, Germany.

The initial configuration of LIGO, which began scientific operation in 2002 and reached its design sensitivity in 2005, continues to collect data. Those data are being analyzed to search for gravitational-wave signals. The observatories are scheduled to go off-line later this year to begin a major upgrade. Advanced LIGO, a more powerful instrument, will be sensitive to black hole mergers occurring as far as 7 billion light years away, whereas initial LIGO has a range of *only* 500 million light years.

"Advanced LIGO will be able to detect distortions one-tenth as large as initial LIGO and the volume of space we'll be able to see is 1,000 times as large," says Whelan. "The significance of being able to see mergers occurring farther away is that we have a greater volume of space to observe, and the odds of an event occurring within that volume are a lot higher."

A complementary gravitational-wave seeking initiative is the future space-based telescope, the Laser Interferometer Space Antenna (LISA). The probe is a NASA/



Simulating Gravitational Waves to Aid Discovery: A destructive dance draws together two black holes into a collision producing a single, larger black hole and stirring space-time with the release of gravitational waves. Templates of simulated waves, such as this one, will help researchers in the LIGO Scientific Collaboration and their partners in the VIRGO Collaboration detect the first actual gravitational wave sometime within the next decade.

European Space Agency mission designed to fish the universe for gravitational waves with lower frequencies and longer wavelengths than LIGO. LISA is expected to launch at the end of the decade. NASA/ESA's Pathfinder space probe, a technology proof-of-principle mission, will confirm LISA's capabilities in the next few years.

World Leaders

In a November 2007 interview with *Discover* magazine, well-known theoretical physicist Kip Thorne—a driving force behind LIGO—points to Campanelli, Lousto, and Zlochower's black hole simulations as some of the most exciting research taking place.

About the same time *Discover* published its interview with Thorne, Campanelli's team simulated three black holes evolving, orbiting, and eventually colliding, another computational feat never before realized. The simulation of multiple black holes, processed using the center's supercomputer cluster—newHorizons—tested the method designed for two masses and confirmed a robust computer code free of limitations. The results revealed the distinct gravitational signature a trio of black holes might produce.

Nearly three years later, Thorne remains impressed by the quality of research coming out of the center. "Members of the center have displayed amazingly good judgment in choice of research problems and remarkable skills in solving those problems," says Thorne, the Feynman Professor of Theoretical Physics, Emeritus, at California Institute of Technology. "As a result, they are world leaders in extracting, from numerical simulations, major new insights into the dynamics of warped space-time, and they are laying key foundations for the worldwide search for gravitational waves."

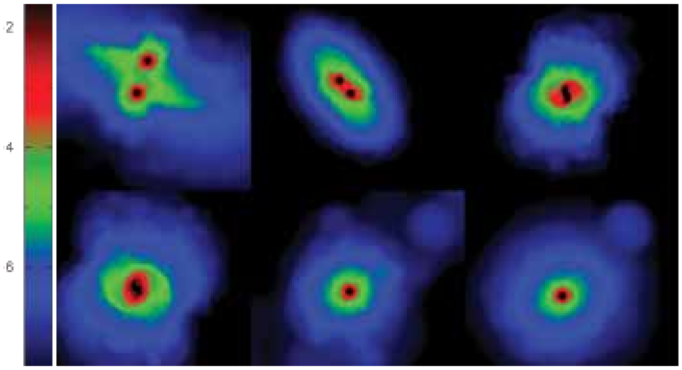
Numerical Relativity

"In order to confirm the detection of gravitational waves, scientists need models for the anticipated gravitational waves coming from space," says Campanelli, who was named a fellow of the American Physical Society in 2009.

Numerical relativists solve the equations comprising Einstein's theory of general relativity to model and simulate astrophysical events generating intense bursts of gravitational and electromagnetic radiation. Research at the center is expanding into the next level, building on Campanelli's breakthrough that solved Einstein's equations for binary black holes. Moving forward, scientists in the numerical relativity group are exploring ever more complicated scenarios, attempting realistic simulations of supermassive black holes in nature. Campanelli, Lousto, Zlochower, and Dr. Josh Faber, CCRG member and assistant professor in the School of Mathematical Sciences, are exploring extreme astrophysical conditions resulting from realistic simulations of colliding black holes and neutron stars.

A black hole or neutron star found in nature would be influenced by the gaseous environment in which it sits, the matter that surrounds it, and the unpredictable interplay of electromagnetic fields. To model these extreme astrophysical conditions, scientists at the center are taking Einstein to the next level, augmenting his field equations describing space-time with equations allowing for electromagnetic fields and hydrodynamics, and ratcheting up the complexity.

Faber adds: "Gravitational waves will tell you about the big picture of a neutron star, for instance. It will tell you about its mass, its size, and its composition. Electromagnetic radiation comes from the ripping apart of the star. That tends to give you a more fine-scale description of what's going on. It will tell you about



When Stars Collide Near Supermassive Black Holes: This sequence of images simulates a stellar collision occurring near a supermassive black hole. According to Dr. David Merritt, the resulting star's spectral properties mimic characteristics of a younger star, which may explain the population of young stars near the center of the Milky Way Galaxy.

Powering Science: Simulating the extreme regions of the orbital parameters requires the use of supercomputers, where simulations can still take months to finish while running 24/7. The CCRG team is helping to shape the next generation of supercomputer power by using available resources in novel ways and developing computational tools to enable new science.

the neutron star matter itself, particularly the matter that's being flung away."

Galactic Dynamics

Merritt, a pre-eminent astrophysicist at the center and professor of physics, studies the evolution of star clusters and galaxies with the gravitySimulator, a special-purpose computer for simulating galactic nuclei. In collaboration with Dr. Clifford Will at Washington University, Merritt is using gravitySimulator to test theories of gravity using stellar motions and has completed the first simulation of the entire cluster of stars at the center of the Milky Way.

"Stars close to the supermassive black hole should feel the effects of general relativity, which will cause their orbits to deviate from the predictions of classical gravitational theory," Merritt says. "The holy grail of such measurements is to test the so-called 'no-hair theorem,' which states that all properties of the space-time around a black hole are determined by just two numbers: its mass and its spin. The spin of the Milky Way supermassive black hole has not yet been measured, but stars moving in orbits with periods of one year or less should show the effects of the spin, which drags space-time around with it, causing orbits to gradually precess."

High-performance Computing

The CCRG team is helping to shape the next generation of supercomputer power by using available resources in novel ways and developing computational tools to enable new science.

Researchers at the center use supercomputers to simulate with mathematics and computer graphics what cannot be seen directly.

Simulating the extreme regions of the orbital parameters is computationally challenging because black holes have different masses and different spin or rotation parameters. Cyber infrastructure and computer code must be adapted to deal efficiently with extreme cases.

"Our research is competitive at the highest possible level," Lousto says. "To keep at the top you have to keep up your computational power. These simulations can take months to finish, running 24/7 on our supercomputer."

The team recently upgraded its supercomputer by 50 percent, adding 20 double nodes—each containing eight processors—to the original 85-node cluster. The additional power will help the team adapt its algorithms to model space parameters. The group was allocated 3.5 million computing processing units on the "Ranger" supercomputer housed at the Texas Advanced Computing Center in Austin. According to Lousto, this represents the equivalent of using 400 of the computer's processors around the clock for an entire year.

The relativity group is one of two already awarded time on the latest supercomputer still under construction. The team is helping to optimize the architecture of the machine known as Blue Waters, scheduled to begin operation in 2011 at the University of Illinois' National Center for Supercomputing Applications. It will consist of more than 200,000 processing cores and is expected to be the most powerful supercomputer in the world for open scientific research.

Into the Future

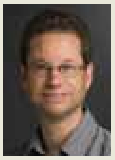
The detection of gravitational waves stand to confirm Einstein's theory of general relativity and introduce multimessenger astronomy—a coupling of data collected from the gravitational and the electromagnetic fields.

"Multimessenger astronomy is not only electromagnetic, it is gravitational wave and sometimes it is particle physics—high-energy particles like neutrinos released in supernova explosions," Campanelli says. "What we do is critical for this discovery to happen. We expect this area to keep expanding because the detection of gravitational waves will be the birth of gravitational wave astronomy, a new kind of astronomy."

On the Web

For more information about the Center for Computational Relativity and Gravitation, visit http://ccrg.rit.edu.

Nova, Supernova, or Stellar Collision?


Joel Kastner

Dr. Joel Kastner, professor of imaging science and astronomical sciences and technology, and a team of astronomers from around the world are exploring a new corner of the galaxy, staring at a star about 20,000 light years away in the constellation Monoceros that exploded in 2002. The event has created a peculiar and spectacular flare—not quite as bright as a supernova, but more explosive than a nova.

Kastner and his colleague Dr. Noam Soker at the Israel Institute for Technology believe the object is a coalescence of two stars, one that is about 10 times the mass of the sun and the other about the same mass as the sun. According to a theory developed in part by Soker, the more massive star consumed the smaller star, releasing a huge amount of energy and causing it to spin rapidly, which over time—years—will create a strong magnetic field and generate significant X-rays.

While immediately following the event X-rays were not visible, in 2008 a long exposure by the European Space Agency's orbiting XMM-Newton X-ray Observatory detected the presence of X-rays. However, by the end of the 28-hour exposure the X-ray brightness already appeared to be dropping off. And to Kastner's team's surprise, in a recent follow-up exposure with NASA's orbiting Chandra X-ray Observatory in January 2010, the object had completely disappeared from view.

"It may be that the remnant from the stellar merger is very unstable, closely resembling extremely young stars, which are known to show huge spikes of X-rays. We hope to continue tracking the X-rays coming from the remnant star with Chandra and XMM, since this may be one of the few cases where we can prove stellar cannibalism actually happens," explains Kastner.

A paper on Kastner's team's discovery of X-rays from the possible stellar merger in Monoceros, lead-authored by astronomical sciences and technology graduate students Fabio Antonini and Rudy Montez, has been submitted to the *Astrophysical Journal*.

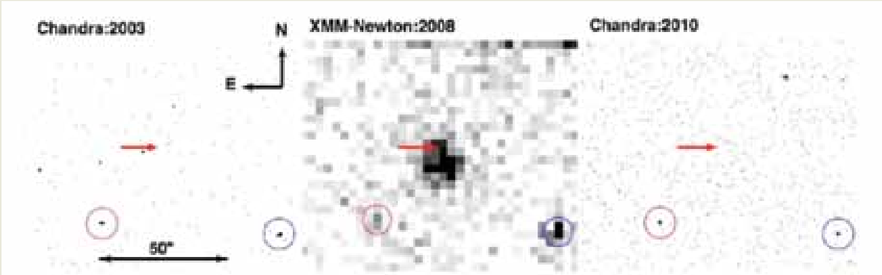


Image provided by astronomical sciences and technology graduate student Fabio Antonini.

Now You See It, Now You Don't: A sequence of images from two orbiting satellite X-ray observatories—NASA's Chandra (left and right panels) and ESA's XMM-Newton (center panel)—shows a bright X-ray source appearing at the position of the exploding star in Monoceros (red arrow) in 2008. However, no source was present one year after the explosion (left) or earlier this year (right). The red and blue circles highlight sources that appear in all three X-ray images, demonstrating the exploding star in 2008 was not an artifact of the XMM telescope or detector. Instead, it appears stellar cannibalism has produced a "born-again" star, one that produces X-rays in violent bursts.

Spectral Imaging Sheds Light on Ancient Mexico


David Messinger


Bill Middleton

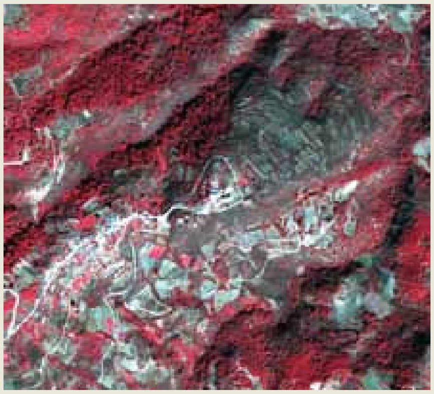
A multi-university, multidisciplinary research team is using sophisticated imaging technology to unlock the secrets of ancient Mexico. Through a partnership with NASA, the team is collecting hyperspectral and multispectral images of the landscape to map modern floral communities and agricultural land use in Oaxaca.

The state of Oaxaca in Southern Mexico has a 10,000-year history of human occupation. It was the center of ancient Mexico's prominent Zapotec state and has been a center for archeological and anthropological study and fieldwork for decades.

Led by Dr. Bill Middleton, professor and chair of the department of material culture sciences at RIT, the research team has uncovered new information about the kingdom's origin and ultimate decay. "Hyperspectral technology, which images simultaneously in over 240 colors (or spectral channels), is allowing us to record and collect high-quality data on a wide area, over 30 thousand square kilometers in total," says Dr. David Messinger, director of RIT's Digital Imaging and Remote Sensing Laboratory and a member of the research team. "This allows us to create the most comprehensive picture of current and past land use, environmental degradation, and landscape evolution ever developed for Southern Mexico."

Teams of field workers are using the imagery to more accurately assess local environments. The data collected is compared to sediment samples collected from ancient land surfaces, which are analyzed for plant microfossils such as opal phytoliths and pollen and used to reconstruct ancient environments and interpret how the region's landscape has evolved over time and the human impact on that evolution.

The team's preliminary findings indicate that periods of human stability actually enhanced landscape stability and prevented degradation, greatly contrasting modern views on human impacts on the environment. The team is continuing fieldwork at several excavation sites and hopes the research can further promote environmental preservation programs in Mexico.



Hyperspectral Imaging of Ancient Mexico: The technology captures up to 240 single wavelength bands, greatly enhancing the imaging accuracy. Scientists are using the imagery to map current land use and activity and accurately uncover possible archeological sites for excavation.

Image Segmentation Revolutionized and Commercialized

by Kara Teske

Image segmentation reveals information hidden to the human eye, enhancing the ability to extract and analyze meaningful information. RIT researchers are advancing the technology to support the business needs of industry partners, including Hewlett-Packard (HP), Ortho Clinical Diagnostics, a Johnson & Johnson company, and Lenel.

RIT and HP

For nearly a decade, RIT and HP have engaged in sponsored research activities that support HP's product development goals. Recently, Dr. Eli Saber, an associate professor in the department of electrical engineering, has been leading an effort in collaboration with HP that focuses on developing and advancing novel methodologies for image segmentation. "By leveraging Saber's experience and expertise, we are able to address the needs in our color and imaging work," says Dr. Ken Lindblom, distinguished technologist at HP. "RIT is able to provide a unique

Advancing Image Segmentation: Dr. Eli Saber, associate professor of electrical engineering, is developing novel image segmentation algorithms that have wide industry applications in areas such as printing, remote sensing, and biomedical imaging. Through partnerships with industry, Saber and his students are helping to address specific business challenges.

Segmentation at Lamberton Conservatory: Dr. Eli Saber, pictured in the desert setting at the Lamberton Conservatory, creates a particularly challenging environment for image segmentation due to the natural scenery and complex textures and shapes.

skill set that augments what exists in our business division."

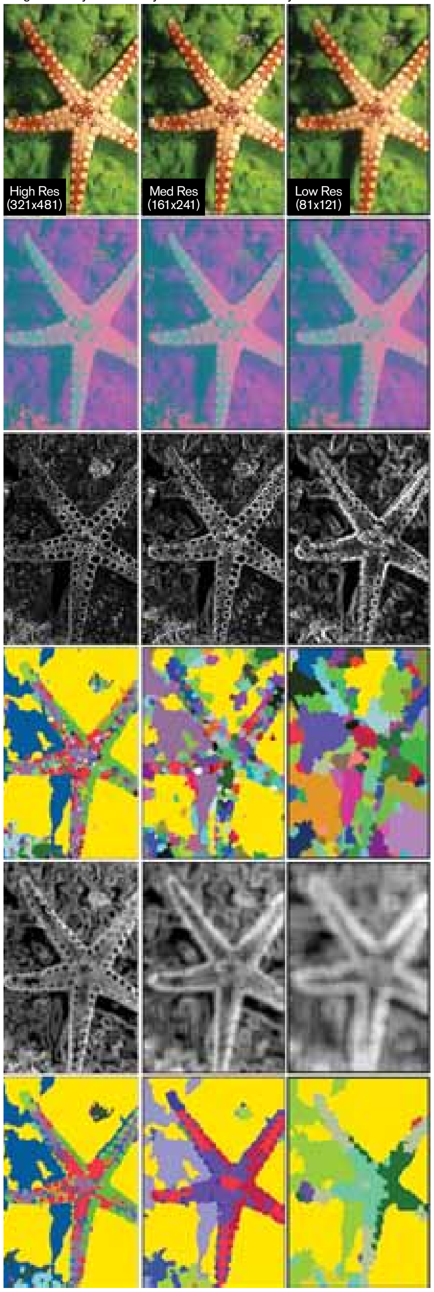
The interest in digital media has grown to new heights with the rapid technological advancements being made in the ability to capture and share digital images. This has necessitated the exploration of methods to interpret, organize, enhance, classify, and extract information from those images. Image segmentation is one approach that provides the foundation to make these functionalities more effective and expeditious.

Over the past two decades, many methodologies have been developed to tackle the complex problem of image segmentation, and the progression of these methodologies has resulted in the achievement of meaningful segmentations. However, the development of an effective simulated environment with real-time capabilities to perform this imaging task has proven to be extremely challenging. Saber, who is also an extended faculty member at the Chester F. Carlson Center for Imaging Science, along with Sreenath Rao Vantaram and Mustafa Jaber, imaging science doctoral students, and Mark Shaw and Ranjit Bhaskar, color and imaging R&D experts at HP, have developed a novel methodology that balances superior segmentation quality with speed. The patent-pending technique has been found extremely useful for diverse commercial and research initiatives related to the printing, medical, and remote sensing fields.

Novel Approach to Image Segmentation

The approach, Multiresolution Adaptive and Progressive Gradient-based color image SEGmentation (MAPGSEG), integrates color, texture, and gradient information in a multiresolution framework, and is based on the principle that the segmentation results of images at low resolution can be used to efficiently segment their corresponding high-resolution counterparts. The algorithm, which is implemented entirely in a

Image courtesy of University of California at Berkeley.



Multiresolution Adaptive and Progressive Gradient-based Color Image SEGmentation (MAPGSEG):

The novel approach is comprised of six modules processed at different image resolutions: (1) Input RGB image (2) convert image into CIE L*a*b* color space (3) compute gradient/edge information (4) initial estimate of various regions (5) texture characterization (6) final segmentation output where every region has a distinct color.

Handling Natural Environments: Sreenath Rao Vantaram, imaging science doctoral student, Dr. Eli Saber, associate professor of electrical engineering, and Mustafa Jaber, imaging science doctoral student, stand in the tropical dome at the Lamberton Conservatory (left). The novel MAPGSEG algorithm efficiently handles the complex image by integrating color, texture, and gradient information (right).

MATLAB—an interactive numerical computing environment—is comprised of six modules.

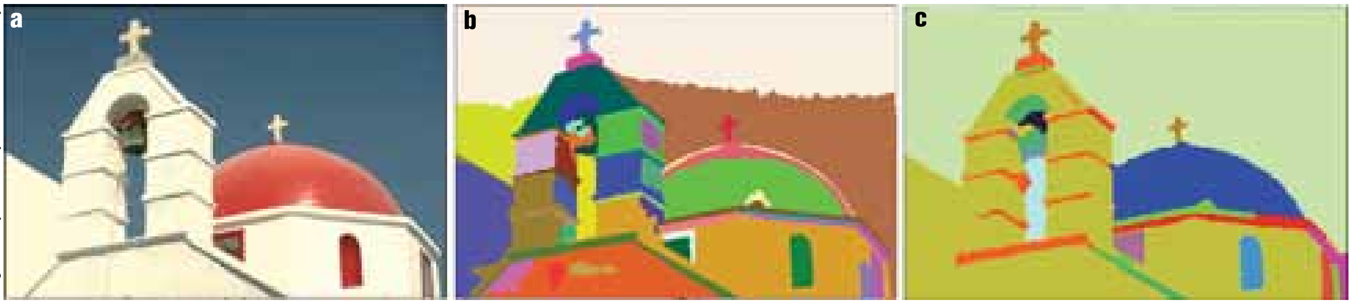
The first module performs dyadic wavelet decomposition to obtain high-quality approximations of the input RGB (red, green, blue color space) image at different resolution levels. The number of decomposition levels is automatically determined based on the smallest workable image dimension specified by a user or constrained by an application.

The second module converts the input image from RGB to the CIE L*a*b*, a device independent color space developed in 1976 by the Commission Internationale de l'Eclairage to achieve approximate perceptual consistency of colors. Consequently, the CIE L*a*b* color space facilitates improved color differentiation and separation of luminance-chrominance information, which enables the efficient handling of images with illumination variations. The color conversion scheme is followed by the computation of gradient information used to automatically and adaptively generate the thresholds required to process regions at different resolutions.

The third module performs a computationally efficient progressive and dynamic multiresolution region-growth procedure to create an initial estimate of regions in the image. In the fourth module, the MAPGSEG algorithm executes a texture characterization process, which differentiates textures at various resolutions. This module is an important aspect of the algorithm, as texture frequently manifests itself as multiple color shades or intensity variations due to material properties like density, gradient, and coarseness, impairing the process of image segmentation.

Next, the initially identified regions are integrated with the acquired texture model using a statistical region-merging procedure to obtain an interim segmentation. In the final phase, the acquired interim result is up-scaled and regions of high confidence are determined. These regions are passed on as a priori information to the next stage of the algorithm to process the remaining unsegmented areas with minimal computational costs. The algorithm progresses from one resolution level to another of the image pyramid until a segmentation result is achieved at the highest/original resolution and is semantically consistent with the input image.

Image courtesy of University of California at Berkeley.

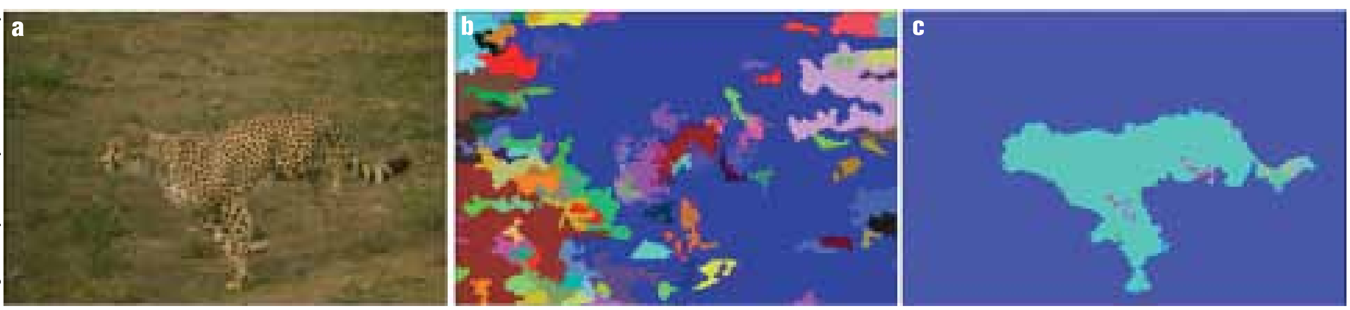


Handling Structural Variations: Gradient variations in natural scene images, as seen in the image of a church, often cause images to be over-segmented. A previous method (b) over-segments the sky and structural details of the church due to differences in illumination. The novel MAPGSEG algorithm (c) efficiently handles the illumination issues, resulting in an accurate segmentation.

Image courtesy of University of California at Berkeley.

Detecting Details: An image from a Formula 1 raceway (a) creates a complex scene where image content is likely to be occluded and contains fine details, such as text. A previous method (b) over-segments areas of the raceway occluded by the vehicles in the scene. MAPGSEG's region merging procedure separates occluded regions and extracts fine details with great competence, as shown in (c).

Image courtesy of University of California at Berkeley.



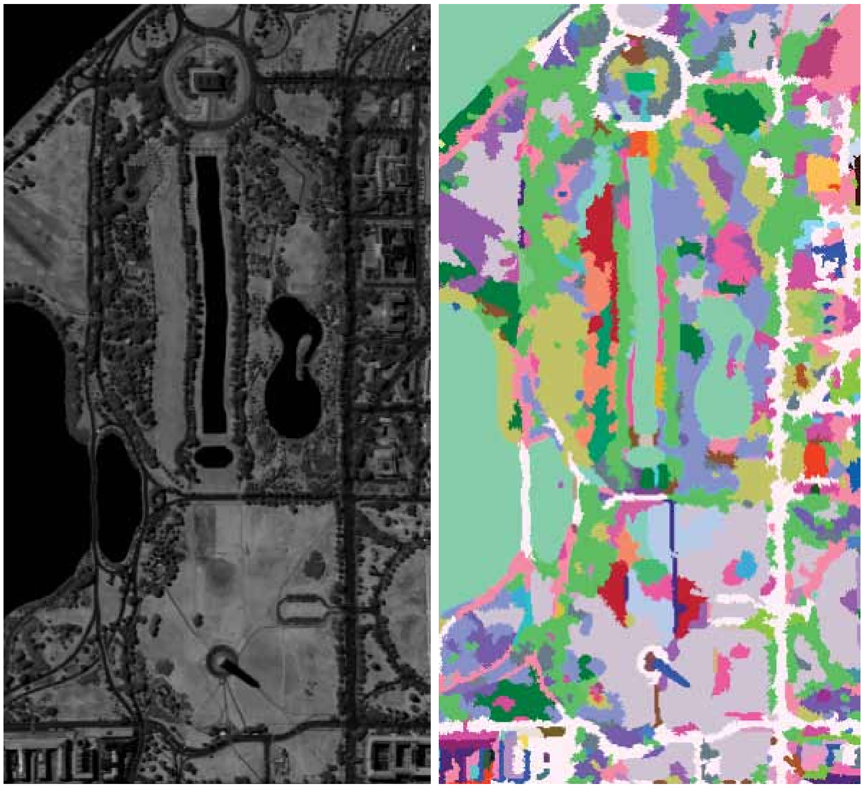
Distinguishing Textures: The image of a cheetah demonstrates the challenge of distinguishing textures when the dissimilar textures have great color similarity. Previous methods (b) were unable to distinguish the cheetah camouflaged by the sandy background; the results shown in (c) demonstrate the significance of MAPGSEG's texture characterization module.

Convincing Results

The team has evaluated the MAPGSEG technology using a prominent segmentation evaluation metric called the Normalized Probabilistic Rand (NPR) index on several hundred images made publicly available by the University of California at Berkeley. The results demonstrate their approach outperforms contemporary segmentation benchmarks with superior quality.

An example shown above illustrates a reasonably complex image of a church, which consists of stark illumination variations and a considerable number of structural details. By comparison, previous methods over-segment the image in the sky and dome regions due to illumination disparities. The structural details also cause these approaches to over-segment the facade of the church. The segmentation map that uses the novel MAPGSEG methodology illustrates the efficiency of the algorithm in handling issues of illumination. The images that proceed demonstrate the region growth strategy that merges similar color-texture regions independent of their spatial locations, resulting in an efficient and accurate image segmentation outcome.

The image of a Formula 1 racecourse presents a few challenges, such as the occlusion of image content by foreground objects as well as the presence of fine detail. Again, alternate methods over-segment the image, where MAPGSEG's region merging procedure successfully separates occluded regions and extracts fine details with great competence.



Segmentation for Remote Sensing: Image segmentation can be used as a pre-processing step for many remote sensing applications. A hyperspectral image of Washington, D.C., is segmented so that each color represents a region, distinguishing landmarks, roadways, buildings, waterways, and other characteristics.

Image courtesy of DataPhysics.

Segmentation for Medicine: Image segmentation of a computed tomographic (CT) image identifies each element within the body–be it an organ, tumor, or abnormality–as a different region.

The segmentation task becomes extremely challenging when regions with dissimilar textures have great color similarity, such as the image of the cheetah. In this scenario, the texture descriptor is able to segment the skin tone that complements the background. The results shown emphasize the significance of the texture characterization module in the MAPGSEG approach.

"This research has catapulted us forward in our understanding of image segmentation," says Shaw. "We have an algorithm that has progressively gone faster, which we will be able use as a building block in our business."

Fostering Innovation

The research team has expanded on this work through the RIT Corporate R&D program. In partnership with Ortho Clinical Diagnostics, a Johnson & Johnson company, and Lenel, a UTC Fire and Security company, master's degree students are developing imaging algorithms specific to the industry partner's business needs.

The Corporate R&D program was pioneered by RIT's President Bill Destler to foster research partnerships among industry and universities. The agreement allows companies to retain the rights to any intellectual property that may be generated during the research projects, while RIT retains the right to publish and conduct further research that builds off of the work.

"The benefits are mutual," says Saber. "We are able to conduct applied research that has a direct implication to their business needs; meanwhile, our students gain tremendous confidence and become more than adequately prepared for a career in industry."

"Going forward, we view university partnerships as complementary to our internal development processes. Sometimes we have an idea for the future, but are unable to focus on it right away. That's the beauty of working with a university; we can tune the research to our specific needs and it becomes very beneficial to the business," explains Lindblom.

"While the private sector should not dictate the intellectual directions of the university, if universities and colleges are to become the economic engines they aspire to be, then the research and development activities need to be focused, at least in part, on projects that have the potential to lead to new products and services," adds Destler.

On the Web

More information is available online.
http://people.rit.edu/esseee/
www.rit.edu/research/corporate

Partnerships to Improve Packaging Technology

Thomas Kausch

For over a decade, RIT's Packaging Dynamics Laboratory has partnered with industry to analyze the packaging designs and materials being used to encase, ship, and protect some of America's most popular products. Its efforts have helped to decrease product damage, reduce overall shipping costs, and lower material use in packaging. More recently the lab has also moved into material analysis, working with firms to increase recycled content and reduce the use of toxic materials, improving the overall sustainability of modern packaging technology.

"The science of packaging is an incredibly important component of product development and commercialization," notes Thomas Kausch, the lab's manager. "Just think of the myriad boxes, bottles, and Styrofoam used in consumer electronics, food and beverage, and shipping industries. An incredible amount of analysis, design, and engineering went into the development of these components, and often more time is spent on the package than on developing the product itself."

The lab has worked with a host of major companies over the years, including Corning, Constellation Brands, Sentry Safe, Cadbury Schweppes, and Johnson & Johnson. The team of engineers and students conduct environmental testing, vibration analysis, compression, and impact assessment to simulate how current packaging will hold up under different conditions. They work with firms to conduct redesigns based on the results and provide third-party analysis that can be used to illustrate packaging safety and security to potential clients.

"We purposely drop, shake, and 'kick' packages containing everything from glass bottles to high-definition TVs," says Kausch. "Most firms do not have the capability to conduct this kind of testing in-house, so our facility provides a valuable scientific resource that enhances the ultimate product we all see in the store."

Packaging Dynamics Laboratory: Environmental testing, vibration analysis, compression, and impact assessment is conducted at the Packaging Dynamics Lab to simulate how industry partners' packaging will hold up under different conditions.

RIT and Carestream Accelerate Medical Imaging Processing

Andreas Savakis

Due largely to the popularity of computer games, graphics processing units (GPUs) have become low cost, flexible in application, and able to run workloads well beyond 3-D graphics rendering. This has greatly enhanced various types of processing and visualization, including medical imaging. In the context of medical image segmentation, GPUs allow for the generation of models from volumetric scans, and greater localization of cancerous nodules during treatment, dramatically reducing radiation exposure to healthy tissue.

An RIT research team is working with Carestream Health and Roswell Park Cancer Institute on the improved use of GPUs in medical imaging for the advancement of image segmentation technology used in the process.

The team is currently exploring the GPU implementation of state-of-the-art medical imaging algorithms to speed up the execution of image segmentation. Initial analysis indicates that average segmentation time was reduced to less than one second, which corresponds to an increase in speed of over 50 times.

"Image segmentation is used to partition a digital image or volume into meaningful segments, making the representation easier to analyze and interpret," notes Andreas Savakis, professor and chair of the department of computer engineering at RIT. "When localizing cancerous nodes, the segmentation needs to be near instantaneous to accurately treat tumors during radiation therapy and differentiate between cancerous and healthy tissue."

The collaboration is facilitated by RIT's Corporate R&D program. Companies can receive applied research assistance that addresses specific design and development issues while retaining intellectual property rights for work developed through the project. This unique effort is designed to enhance university-industry collaboration and accelerate product development and commercialization.

"Our current collaboration with RIT will assist us in enhancing our medical imaging product line, while also advancing overall research in the field," says Dr. Jay Schildkraut, senior scientist at Carestream Health and a member of the research team.

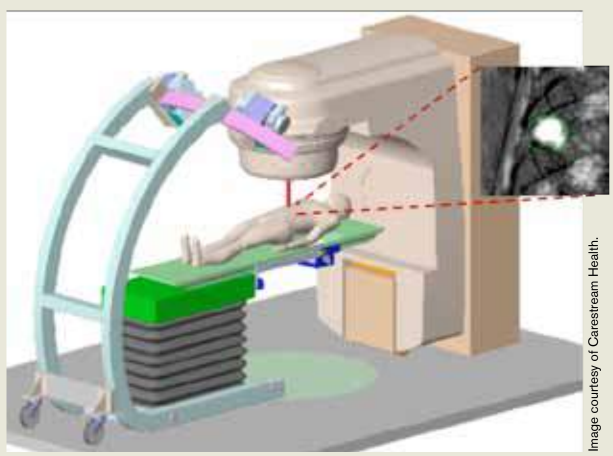


Image courtesy of Carestream Health.

Image Segmentation Provides Greater Localization: RIT and Carestream Health are collaborating to advance medical image segmentation. By accelerating the process and providing real-time analysis, doctors are able to better localize cancerous nodules during treatment.

Where the Left and Right Brain Collide: RIT's Interactive Games and Media (IGM) department brings together a wide variety of disciplines, from creative arts to software development. Led by Andy Phelps (right), IGM faculty and students are creating innovative media-rich experiences to define a new forum for entertainment, communication, and education.

Creating Virtual Worlds

by Kara Teske

Game developers at RIT are bringing to life real-world experiences through realistic interactive simulations, providing a new medium for entertainment, communication, and education.

More than Entertainment

For decades, games have provided a source of entertainment for people of all ages and have had a significant influence on our culture. Today, games are being used to address a wide range of challenges from academia, industry, government, and the military. “At the core is interactive graphics and real-time computing to create simulations that provide a media-rich, realistic, and social experience,” says Andy Phelps, associate professor and chair of the interactive games and media (IGM) department at the B. Thomas Golisano College of Computing and Information Sciences.

The research brings together a wide variety of disciplines, to combine visualization and communication in new contexts and platforms. “Other programs might be more heavy on programming or design, but at RIT it is a true blend of left brain-right brain,” explains Alex Lifschitz, an undergraduate student in game design and development. “It’s RIT’s innovation mindset that prevails,” adds Phelps. “Where some theorize about a new technology, we go out and build it.”

Future Game Technologies

RIT game developers are venturing into the emerging areas of augmented reality and multi-touch/multi-user interfaces. These technologies have the ability to engage people by merging real and virtual worlds. However, it is the interaction in the shared mixed media space that defines the experience. Developers are focused on both the technology and defining the experience in these environments.

“Augmented reality has interface potential similar to that which Nintendo recognized with the Wii,” explains Dr. Chris Egert, assistant professor of interactive games and media. “The innovation isn’t necessarily the technology, but how it facilitates collaboration. The mere fact my parents can play the Wii and be successful at it actually says something very powerful. Augmented reality has the ability to provide a similar intuitive venue with greater accessibility.”

A recently developed game entitled “Zeal” explored the unchartered territories of 3-D augmented reality. Developed by a team of six RIT graduate students—Nimesh Desai, Chip Hilseberg, Jon Lobaugh, Eric Moreau, Josh Wilson, and Jay Austin—the game creates an augmented boardgame where players use their hands to wage war on a shared tabletop.

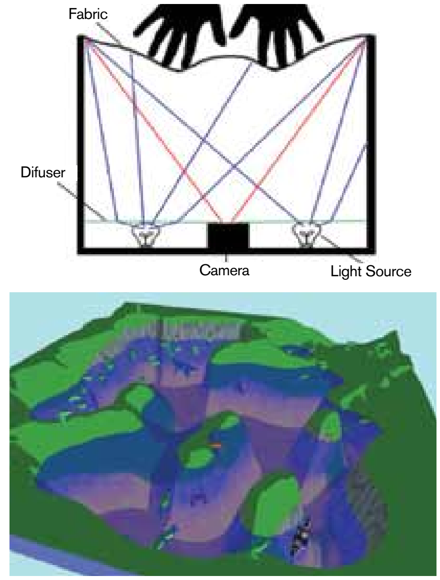
Emerging World of Augmented Reality: The 3-D augmented reality game Zeal, created by a team of graduate students, brings together real and virtual worlds. Players wage war in the boardgame and their real-world movements are tracked by fiduciary markers and translated into movements within the game world.

Fiduciary marker

Using a Web camera and a set of printed fiduciary markers, the Zeal system is able to translate real-world movements into game-world actions. Each fiduciary marker is assigned a value or action inside the game and as the players move the markers around the table, the camera picks up the effects of the movement inside the game world. “The game is a very simple test of concept, but it represents some of the future capabilities of games,” says Phelps.

The release of the Windows 7 operating system has spurred the development of other multi-touch interface applications.

The "Sociable" Surface Interface: Engineered and designed completely by students, the interface lets visitors interact on the multi-touch surface using a glass that tracks their connections, which are visualized next to their drink with an animated avatar.



3-D Alternative Interface: Alternative interfaces are transforming the way people interact with virtual worlds. This novel deformable surface controller allows players to interact at multiple points of contact in three dimensions. A camera inside the controller captures light variances as a result of the player's movements and controls the movements within the game.

RIT game developers are looking at how to integrate this technology into networks. Multi-touch interfaces operate the same way most surface computers do, but instead of detecting the motion of a mouse sensor, fingerprints are detected with tracking software and used as input into a computer.

Last year, students in the new media interactive development program (within IGM) partnered with new media design and imaging students from the College of Imaging Arts and Sciences to construct their own version of a surface interface, entitled "Sociable." The back-end development was made utilizing both ReacTIVision technology and Touchlib, and the software was programmed in Adobe Flash with Actionscript 3.0. This year, a game development team is also integrating the technology into a tiltable surface table, with similar functionality to the iPhone. A prototype is hoped to be unveiled at this year's Imagine RIT: Innovation and Creativity Festival.

Game developers are also looking at ways to improve the gaming experience through alternative interfaces. To date, multi-touch interfaces allow only a single point of two-dimensional, or in some cases three-dimensional, control. A team of students led by Dr. David Schwartz, assistant professor of interactive games and media, has designed a novel controller that allows multiple points of contact in all three dimensions. The deformable surface controller uses a flexible piece of cloth or rubber, a set of lights, and simple Web camera to capture three-dimensional input within a large area of motion. The user interacts with the controller by pushing down on the flexible surface. The current prototype is able to detect deformations ranging from 2 cm to approximately 30 cm.

These technologies are pushing the frontiers of game playing and interactivity. The future lies in the ability to make these technologies accessible and intuitive for a broad audience.

Games for Education

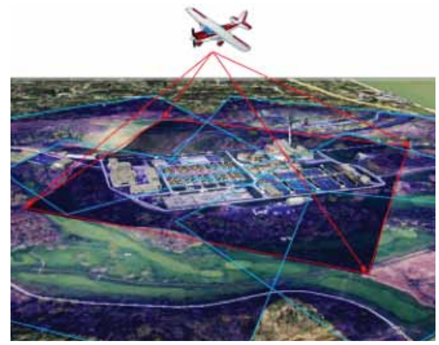
RIT game designers are exploring to what degree games can be used as a motivator for learning. Dr. Jessica Bayliss, associate professor of interactive games and media, has introduced a foundational course using games to teach introductory computing and programming.

The course was developed with support from Microsoft in an effort to raise retention among computer science students. "The course teaches critical computing skills, which is not always the most interesting topic for people," admits Bayliss. "By using games as a way to teach the curriculum, students become more engaged and attracted to the study of computing." Students take on the perspective of a game developer and software developer to understand how games are designed and programmed. "By putting the skills in the context of something students can relate to, they are able to learn better," adds Bayliss. While the course is taught through the interactive

Photograph Courtesy of One Laptop Per Child.

Enhancing Education in Third-World Countries: Stephen Jacobs, associate professor of interactive games and media, is teaching RIT students how to build educational games for the international humanitarian effort One Laptop Per Child.

"Fortune Hunter" Helps 4th Graders Learn Math: The educational game was developed by a team of undergraduate students. Pending Sugar Labs' approval, the game is expected to be distributed with Sugar software to over a million students around the world.



Game Technology Enables Realistic Scene Modeling: Recent advancements in game technology have enabled imaging scientists to develop a process called AeroSynth. The approach blends photogrammetry with computer vision techniques and applies it to geographic scenes imaged from an airborne platform, resulting in a realistic 3-D scene model.

games and media department, it teaches foundational computer science skills that can be applied across all computing disciplines.

In the first year alone, the IGM department saw a 90-percent retention rate among first-year students who took the course. The curriculum has also attracted a wider variety of people who may not normally be interested in the study of computing.

Bayliss and Schwartz are also exploring ways game design and instructional design can inform each other. "Much can be gained by understanding how learning occurs through games," says Bayliss.

Phelps explains, "At its root, games are the embodiment of what children learn as the scientific method: form a hypothesis, conduct the experiment, look at the results, refine your hypothesis, and repeat. Games provide a medium to do this virtually, through trial and error. Players learn the rules of the game and are thus exploring abstract concepts through in-world interactions—the exact process education aspires to."

"The power of games happens when the player experience is so enjoyable the learning becomes second nature," adds Schwartz.

Games for One Laptop Per Child

Stephen Jacobs, associate professor of interactive games and media and director of the Lab for Technological Literacy, is leading classes in which RIT students build educational math games for users of the One Laptop Per Child (OLPC) XO computer. The effort brings together Rochester educators, software developers, and RIT students with the international OLPC community. Class efforts support the Math4 project initiated by Sugar Labs, developers of the software platform used by the XO. RIT's participation is bolstered by a donation of 25 XO laptops from Fedora, six second-generation XO laptops from OLPC, and a grant from Red Hat.

The class project that has received the most outside interest is "Fortune Hunter," a dungeon-style computer game in which students solve math problems to conquer monsters and collect loot. The prototype was developed by RIT undergraduate students Mike DeVine, Kevin Hockey, Eric Kenvin, Preston Johnson, Justin Lewis, Jonathan Meschino, and David Silverman. If the final game meets with Sugar Labs' approval, it will be distributed with every copy of Sugar software, putting the game in the hands of over a million students around the world.

The class is being cited by The Humanitarian Foss Project as a model for open source education around the country. Both open source projects and humanitarian projects are being cited as drivers for computing education.

Games for Strategy and Decision Making

Games are also being explored to influence strategy and decision-making skills. Schwartz has worked in collaboration with the Air Force Research Laboratory

Game Design and Development Lab: The expansive lab is fully equipped with 66 Alienware gaming workstations, each with dual monitors and an Xbox 360 game console for XNA development. The collaborative environment provides students and faculty the resources they need to create virtual worlds and venture into emerging areas of augmented reality and alternative multi-touch interfaces.

on wargame design theory and software development. The military has used wargames since World War II for planning and training. Today's wargames create realistic simulations and allow players to model their own scenarios.

In partnership with the Chester F. Carlson Center for Imaging Science, RIT researchers have been able to automate synthetic scene generation by applying computer vision techniques. The process referred to as Airborne Synthetic Scene Generation, or AeroSynth, blends photogrammetry with computer vision techniques and applies it to geographic scenes imaged from an airborne platform. "By augmenting this technology, we can increase the fidelity of 3-D structure for realistic scene modeling," explains Dr. John Schott, Frederick and Anna B. Wiedman Chaired Professor and project leader.

The team is also looking at how to integrate the visualizations with external factors critical to the scene, such as newspaper clippings, employee records, and other data sets. Using game technology, they are attempting to simulate all of these processes to provide decision makers with a more complete perspective before making decisions.

Building on History

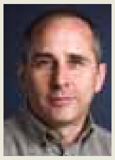
Critical to any game's success, whether educational or entertainment oriented, is the game's ability to capture fun. "You can build the most technologically brilliant game out there, but at the end of the day it has to be fun," says Egert. Important lessons can be learned from some of the classic games that define the industry. RIT is playing an integral role in preserving these virtual worlds through the Preserving Creative America initiative administered by the Library of Congress, in addition to a partnership with the International Center for the History of Electronic Games (ICHEG) at the Strong National Museum of Play.

As time goes on, it becomes increasingly challenging to preserve the technology and experience of historical games like Atari 2600 and Donkey Kong. Just as it's important to archive film and other historical documents, it's important for students to be able to understand the history of their major and the influence it has had on culture. "With games perhaps the need is even more significant, because unless you can actually play and experience the game, you will not completely understand the significance," explains Jacobs. "That's why we are so pleased to be aiding ICHEG in interpreting their collections and in the design of their emerging national exhibitions."

"Thirty years ago, game designers had to create a fun experience with extremely limited hardware, audio, and graphic choices. Yet despite those constraints, they were able to do so and to this day people still play them for hours and hours." These are the important lessons that will help enable future game designers to capture fun as technology continues to advance at warp speed.

On the Web
Information about the interactive games and media department is available online.
www.igm.rit.edu

Spotting Perceptual Learning

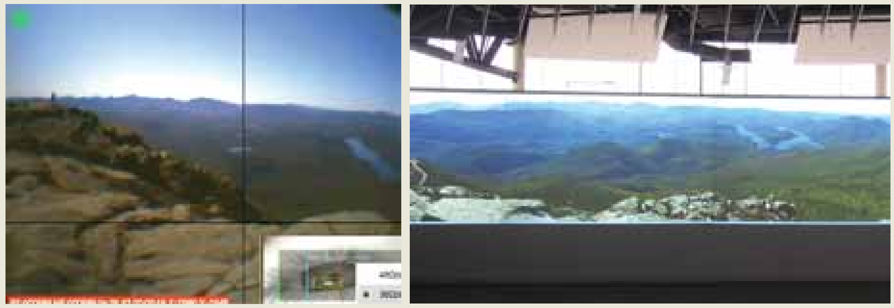

Jeff Pelz


Mitchell Rosen

From the sliding San Andreas Fault to the desert of Death Valley, the landscape provides geology lessons professors could only dream of bringing to the classroom. Dr. Jeff Pelz, professor at the Chester F. Carlson Center for Imaging Science and an expert in visual perception, is leading an RIT team in a multidisciplinary research project to explore how perceptual learning occurs in these complex environments. Co-PI Dr. Mitchell Rosen, research professor of RIT's Center for Student Innovation (CSI), and doctoral student Brandon May are capturing the experience in photographs, video, and audio to create a semi-immersive virtual field trip. The team will compare how people learn in actual versus virtual environments.

For over 10 years, Dr. John Tarduno, professor of geophysics at the University of Rochester, has led undergraduate students on a transformational 10-day journey from San Francisco, Calif., to Las Vegas, Nev., teaching fundamental geology lessons. The experience has led students to pursue advanced degrees and professions in geology.

A research team consisting of Dr. Robert Jacobs, professor of brain and cognitive sciences at the University of Rochester, Tarduno, Pelz, and Rosen won a five-year National Science Foundation grant to support the research. They seek to understand how students develop perceptual expertise in the field, what role perceptual learning plays in the understanding of geology, and to what extent those experiences transfer to the classroom through the use of imaging.



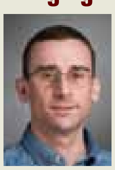
Capturing Perceptual Learning: A screen-capture from a student's eye-tracking device (left) depicts where the eye gazes while at a geological site in an effort to understand how perceptual learning occurs. Ultra-high-resolution imagery is used to replicate the experience in a virtual semi-immersive environment at the Center for Student Innovation (right).

Each student on the real and virtual trips will be equipped with a wearable eye-tracking device developed by Positive Science, a company formed by RIT graduate Jason Babcock. Each eyetracker has a camera that watches eye movements and another that captures the scene. Expert geologists will also be equipped with the device to help understand the differences in gaze behavior.

Rosen and May are producing ultra-high-resolution still imagery of the sites and a hemispherical video view with a 12-megapixel video camera. When projected on screens in the CSI, the final footage will allow viewers to walk up and examine some of the geological landmarks in life size.

"If we can understand how learning takes place in the natural environment, we may be able to replicate this experience for thousands of students across the country," adds Pelz.

Bringing Virtual Surfaces into the Real World


Ben Darling


James Ferwerda

Color scientists at the Munsell Color Science Laboratory are bringing a new dimension to computer graphics through a new immersive display system called the tangiBook. Developed by Dr. James Ferwerda, associate professor at the Chester F. Carlson Center for Imaging Science, and Benjamin Darling, color science doctoral student, the device allows users to interact with virtual surfaces as if they existed in the real world.

The first-generation tangiBook is based on an off-the-shelf laptop computer that incorporates a webcam and accelerometer, along with custom software that tracks the position of the viewer and the orientation of the laptop in real time. Using this information, realistic images of surfaces with complex textures and material properties illuminated by environment-mapped lighting are rendered to the screen at interactive rates. Tilting the laptop or moving in front of the screen produces realistic changes in the surface lighting and material appearance.

The tangiBook can provide enhanced access to collections in digital libraries and museums, allowing viewers to interact in a whole new way. When you visit a museum, you are able to observe the original artwork at a distance; with the tangiBook you can have a more intimate interaction, viewing the piece from different angles and under different lighting conditions. The technology also allows curators or artists to simulate how restorations or treatments may affect the artwork. Similarly, the technology can be used for soft proofing applications to simulate the effects of different papers and finishes on photographic prints.

A second-generation tangiDesk system is currently being engineered for high-performance applications. The research team is also developing a hand-held tangiPod device for the mass market that will provide consumers with interactive 3-D digital swatch books or catalogs of materials like cloth, carpet, and tile whose true appearance is difficult to capture in conventional photographs.

tangiBook in Action: Using an accelerometer, webcam, and custom software, the tangiBook tracks the orientation of the laptop screen and the position of the observer in real time. Tilting the laptop (as shown) or moving in front of the screen produces realistic changes in surface lighting and material appearance.

The Impact of a Rumor: Rumors can have a huge impact on politics, business, popular culture, and society as a whole. By analyzing how different social networks affect rumor spread and belief, Dr. Nicholas DiFonzo, professor of psychology, and his team of researchers hope to better understand rumor effects and how the negative consequences of this phenomenon can be reduced.

Deciphering the Watercooler Effect

by Will Dube

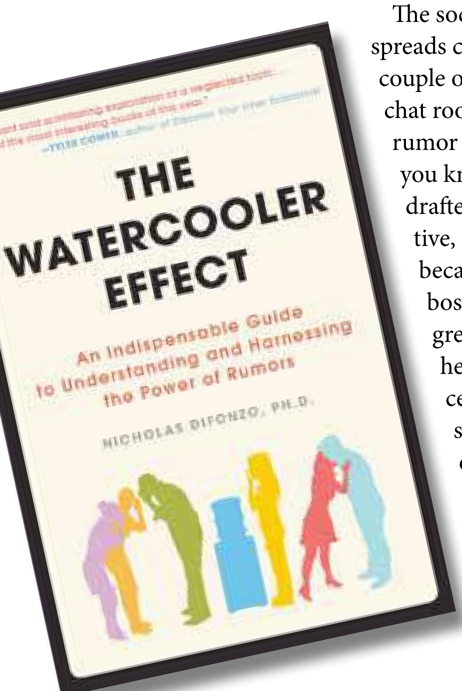
Rumors play a significant role in society, impacting what we believe as well as how we interact with our neighbors and colleagues. An RIT research team is enhancing our understanding of how rumors spread, why some are believed and others are not, and how they affect social interaction.

Dynamic Social Impact: The RIT team's research is based on Dynamic Social Impact Theory. As illustrated in the depiction of national voting patterns (Republicans denoted in red, Democrats in blue), DSIT states that individuals in a group influence each other over time, resulting in the self-organization of culture.

A Rumor is Born

Every day the morning starts either around the watercooler, grabbing coffee, or checking Facebook, sharing the latest "did you hear" stories. These casual exchanges of information are referred to as the Watercooler Effect. It's through these exchanges, where unverified information is spread through social networks, that rumors emerge.

"A rumor is what you do when you try to make sense of things with other people," notes Dr. Nicholas DiFonzo, professor of psychology at RIT and leader of the research team. "It's collective sense-making. The classic example is, 'I heard that the department is downsizing; what did you hear?'"



What We Hear at the Watercooler: Dr. Nicholas DiFonzo has spent nearly two decades studying how rumors affect society and how they spread through social networks. His book, *The Watercooler Effect: An Indispensable Guide to Understanding and Harnessing the Power of Rumors*, was released by Penguin Press in 2008.

The social networks in which a rumor spreads can be as small as a married couple or as large as a million-person chat room on the Internet, and the rumor can be either positive, "Did you know Hank in accounting got drafted by the Cowboys?" or negative, "I heard Sam got promoted because his dad is friends with the boss." While rumors make up a great deal of the information we hear on a daily basis and are a central component of how we socialize and relate to each other, very little is known about how rumors spread in society and how different types of social networks impact transmission.

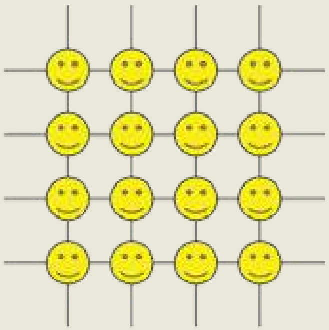
"Numerous rumors, such as those surrounding the death of Michael Jackson or the assassination of John F. Kennedy, linger for months—even years—and sometimes are considered more truthful than well-established facts," says DiFonzo, who is also the author of the scholarly book *Rumor Psychology* and the mass market book *The Watercooler Effect*. "Many rumors engender mistrust, suspicion, and conflict between people and groups, often causing societal chaos. Through better understanding of how rumors grow and spread, we hope to decrease their negative impact and often damaging consequences."

Developing Analytical Methods to Measure Rumors

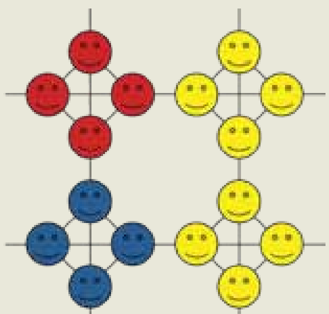
One of the most interesting and little-understood facets of rumors is how they propagate or spread from one person or group to another, and how different social networks affect that propagation. Through a grant from the National Science Foundation, DiFonzo's team has sought to mathematically model rumors in spatial networks and create a predictive equation to simulate how a rumor spreads.

"Social interactions are much more difficult to model than biological or chemical reactions, because many of the data points are incredibly fluid and many variables may not be known," adds Dr. Bernard Brooks, associate professor of mathematics at RIT who is collaborating with DiFonzo on the project.

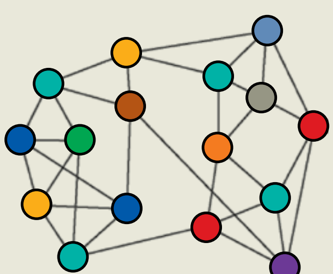
To create a proper model for rumor propagation, the team used several years' worth of empirical data, measuring how



Torus



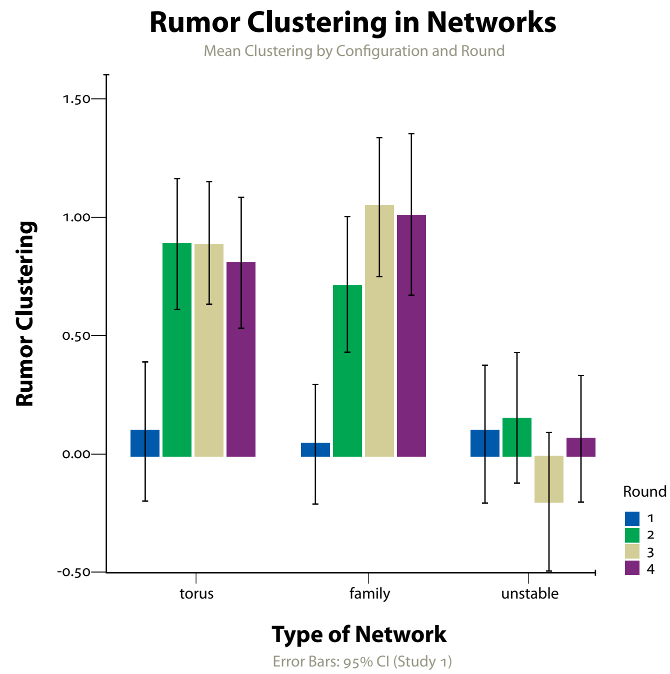
Family



Unstable

Defining Social Networks:

The RIT team is analyzing how rumors spread through different types of networks. The first panel above illustrates a lattice-like community with no cliques or clustered groups whatsoever. The middle shows a network where there are regularly-spaced close-knit groups or families within the community. The bottom shows a community with unstable connections between members, as typically occurs in neighbor-hoods or social settings.



Impact of Network Type on Rumor Clustering: Research results from a study where students discussed rumors over four rounds of communication indicate that rumors cluster (form homogenous pockets of rumors and emerge over time) more in more cliquish (family) networks than in non-cliquish (torus) networks, and not at all in unstable ones.

different rumors had spread, and applied Dynamic Social Impact Theory (DSIT) in developing the model parameters. DSIT states that beliefs and attitudes are based on:

- Strength of influential sources—You are more likely to believe a rumor told by a friend or family member.
- Immediacy of influence—Rumors often take hold in close-knit, homogeneous neighborhoods and communities.
- Number of sources—The more people in your network there are who believe a rumor, the more likely you will believe it.

Based on this, Brooks and DiFonzo developed the MBN-Dialogue Model of Rumor Transmission, where rumor spread is based on the motivations (M) for spreading the rumor, the strength of belief (B) in the rumor, and the novelty (N) or newness of the rumor. The model is one of the first to simulate how a rumor moves through a group based on empirical rumor research and can be used to model belief in derogatory rumors about an opposing goup, explore why some persist and some die out, and how different social networks impact propagation.

Testing Rumor Propagation

The team, which also includes David Ross and Deana Olles of the department of mathematics and Christopher Homan of the department of computer science at RIT, as well as faculty and students from the University of Wyoming and the University of South Australia, used the model to conduct a number of experiments in

Spreading Rumors: A multidisciplinary team, led by Dr. Nicholas DiFonzo, professor of psychology, conducts experiments with groups of students to test the MBN-Dialogue Model of Rumor Transmission. The analysis helps to explain which rumors gain credence and how the type of network affects group decision and belief over time.

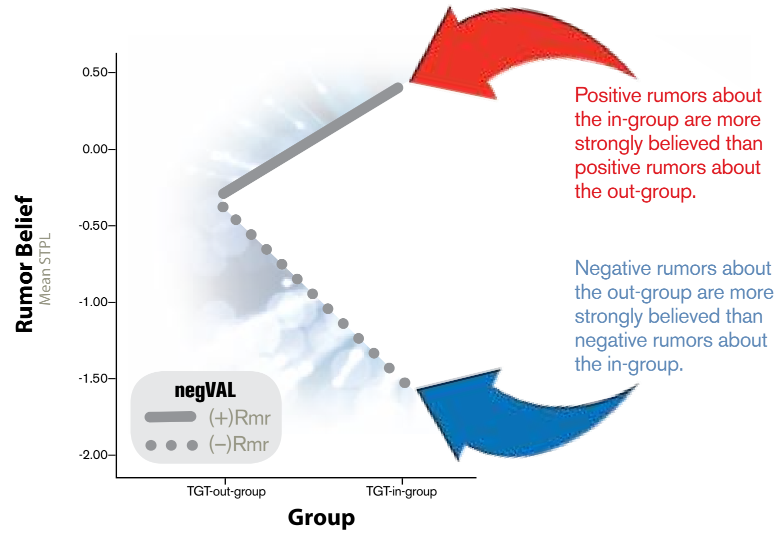
which groups of networked participants selected and discussed rumors via e-mail. Three 16-person groups each discussed eight ambiguous situations, such as "you hear that a professor you had was found dead from a gunshot wound." They then chose one of four alternate rumors provided to explain each situation, such as "he was robbed," and then discussed the different scenarios among themselves. The analysis investigated how the type of network that students were put into affected the degree to which homogenous pockets or clusters of rumors emerged, the extent to which rumors persisted or died out, and the level of confidence participants placed in rumors over time.

"Our data indicates that whether a rumor will be believed is less dependent on the rumor itself and more on the specific dynamics of the network it is introduced in," says DiFonzo. "For example, rumors introduced where groups of individuals are clustered together into clumps or cliques and have few connections to other groups in the network are more likely to take hold than in configurations that are less segmented."

Among the key findings: spatially proximate pockets of rumors emerged based on like-minded individuals adopting belief; over time rumor diversity decreased as certain rumors gained majority or plurality support; but minority rumors believed by a small number in a network did not typically die out even when a majority of individuals disbelieved the information.

"The results verify the use of the Dynamic Social Impact Theory to explain rumor spread and confidence and suggest that rumor propagation can be measured and predicted based on an analysis of the network in which it is introduced," says

DiFonzo. "This has clear implications not only for psychologists and social theorists but also for policy makers looking to analyze how information, particularly false information, spreads through communities and affects citizen reaction, especially during disasters and crisis events such as September 11, 2001."



Rumors Enhance Ingroup/Outgroup Distinctions: Initial data indicates that Democrats are more apt to believe negative rumors about Republicans and positive rumors about Democrats. With Republicans, just the reverse occurs.

Democrats Versus Republicans

The team is now exploring how rumor propagation is related to social categorization and in-group/out-group dynamics through an analysis of praising or derogatory rumors that circulate in situations of rivalry, conflict, or different group memberships. The research will better define how specific social networks influence rumor propagation and provide a deeper understanding of how rumors impact relationships between often-contentious groups such as Democrats and Republicans.

"There is a tendency to categorize people in us-versus-them terms, which can often lead to hostility toward the out-group," says Brooks. "Positive and negative rumors play an important role in this dynamic by enforcing in-group worthiness and out-group inferiority. Opposing political groups provide an excellent vehicle to test how rumors can enforce self-categorization."

An initial experiment used nine 16-person groups, each containing eight moderate to strongly identified Democrats and Republicans. Groups were presented with a series of nine controversial rumors, some positive and some negative, about the respective political parties, and asked to discuss the rumors.

The data shows that Democrats were more likely to believe negative rumors about Republicans and positive rumors about Democrats, while the Republican participants indicated the reverse. In addition, as the rumors propagated, confidence in out-group negative rumors increased more than in-group positive ones, illustrating the power of negative rumors, particularly when social categorization is a factor. Interestingly, when the networks were more integrated, with less homogeneity, rumor confidence decreased, especially with negative rumors.

Next, the team will conduct similar experiments using groups of men and women and hearing and deaf individuals to examine how other social groups with different in-group/out-group dynamics are impacted by positive and negative rumors. They will also look to modify the MBN-Dialogue Model to better assess out-group negative rumor propagation and examine how it differs from traditional rumor propagation. DiFonzo also hopes the work can ultimately assist in reducing rumor polarization to improve conflict reduction and cooperation efforts, particularly among conflicting social groups.

"Our findings suggest that integrating groups with individuals that have opposite viewpoints reduces the strength of belief and overall spread of negative information," notes DiFonzo. "This enhances the notion of increased social interaction as an antidote to out-group prejudice."

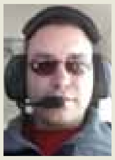
Rumors play an important role in everything from office politics to popular culture to whom we elect as president. By creating a broader scientific framework with which to analyze the impact of rumors and better educate individuals on how to deal with it, researchers at RIT hope to decrease the negative effects of this social phenomena. In addition, they want to enhance the general study of rumor psychology as a mechanism for creating better communication between citizens, communities, and governments.

"By better understanding rumors' impact on how we think and what we believe, individuals and groups can better communicate goals and reduce the possibility of misunderstanding and distortion at all levels of society," concludes DiFonzo.

On the Web

More information about this work and other related research is available online.
www.professornick.com

Advanced Imaging Aids Emergency Response



Jason Faurling

Don McKeown

Jan van Aardt

Last fall, RIT established the Information Products Laboratory for Emergency Response (IPLER) with the University at Buffalo (UB) and funded by a National Science Foundation grant.

Built on a foundation of state-of-the-art geospatial technology, IPLER's mission is to create a technology, policy, and business development incubator that will facilitate interaction among university researchers, private sector data, and product providers with public sector emergency response decision makers. The collaboration fosters innovative solutions for improved disaster mitigation planning, real-time response, and recovery efforts with direct societal benefit.

When the magnitude 7.0 earthquake shook Haiti on Tuesday, January 12, 2010, Don McKeown, distinguished researcher at the Chester F. Carlson Center for Imaging Science, realized an opportunity to engage the IPLER collaboration and RIT remote sensing technology to aid in the recovery. With support from the World Bank and ImageCat Inc., IPLER deployed RIT's Wildfire Airborne Sensor Program (WASP) system and a LIDAR sensor from Kucera International over Haiti, collecting high-quality aerial multispectral imagery and 3-D surface measurement LIDAR information.

WASP, initially developed for the U.S. Forest Service, consists of three infrared cameras and one visible camera, combining high-resolution color with infrared imaging. Jason Faulring, systems integration engineer, operated the system from the twin engine Piper Navajo as it flew over the devastation and fault line, while U.S. Air Force air traffic controllers, operating without radar and limited radio communications, struggled with dozens of flights into and out of the disaster area. Covering 250 square miles in seven days, Faulring and the Kucera pilots flew at 2,500 feet above the ground, capturing images at 0.15m spatial resolution and laser scanning the surface, all while maintaining vigilance for other air traffic and high terrain.

Partnering with the University of Puerto Rico at Mayaguez, the team transferred 960 GB of data via Internet2, peaking at 150 GB in 40 minutes. Back at RIT, a dedicated team of faculty, staff, and students led by McKeown and Dr. Jan van Aardt worked around the clock to process the data and distribute the information to relief agencies and emergency responders. Dr. David Messinger, assistant research professor and Dr. Bill Basener, associate professor, created a classifier to detect the blue relief tarps within the imagery associated with internally displaced persons (IDPs). By detecting the tarps, the exact geographic location of refugees could be determined to help direct distribution of relief materials to areas in greatest need.

Image Courtesy of RIT, World Bank, and ImageCat Inc.

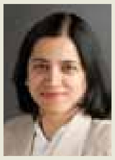
IPLER Responds to Haiti Disaster: RIT's WASP system captured high-resolution imagery of the Haiti earthquake aftermath with 0.15m spatial resolution. The images helped to pinpoint areas in need of rapid response.

The images can be accessed on UB's Virtual Disaster Viewer, and were also made available to Google, Yahoo!, Microsoft, the United Nations, U.S. Geological Survey, and ERDAS, a software developer of remote sensing applications.

"The Haiti response effort is a case in point, where RIT and its collaborators were able to collect, process, and disseminate data, while also developing value-added geospatial products," says van Aardt.

"It was so gratifying to see the application of our remote sensing technology to such a noble endeavor," adds McKeown. "Even more so when you see how the members of the RIT team—at home and in the field—pulled together and made it all work."

Models to Combat Global War on Terror



Shatakshee Dhongde

Through a grant from the Defense Threat Reduction Agency (DTRA), Dr. Shatakshee Dhongde, assistant professor of economics in the College of Liberal Arts, and researchers from Georgia Tech are developing models to better assess the social, political, and economic factors that motivate state and non-state actors, such as nations or terrorist organizations, to acquire and use chemical, biological, radiological, and nuclear weapons, also known as CBRN. The work will enhance the development of better predictive models designed to assess how and where CBRN weapons proliferate across the globe.

The three-year research effort is sponsored by the U.S. Department of Defense and will be incorporated into the department's efforts to better assess factors affecting CBRN activity around the world. The DOD will also use the research to better integrate socio-economic modeling into its overall defense analysis and terrorist prediction efforts.

"There are numerous socio-economic factors such as poverty, lack of education, and political and ethnic fractionalization that may impact non-state actors to seek out and ultimately acquire CBRN weapons," notes Dhongde. "However, there are currently few models that properly address these factors. By developing models that better address them we can learn more about how they are acquired and help prevent their proliferation."

Dhongde's team is currently consolidating data to test the relationships between variables that may impact the acquisition and proliferation of CBRN weapons. The information will be incorporated into a comprehensive database that will be used to develop test models for analyzing trends and overall proliferation over time.

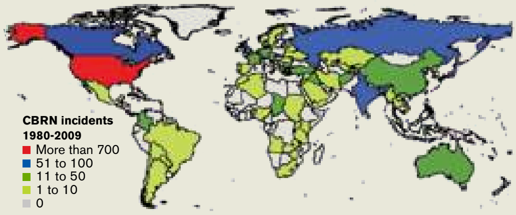


Image and data courtesy of WMD Terrorism Database.

Mapping of CBRN Incidents: A multidisciplinary research team is developing models to assess how and where CBRN weapons proliferate across the globe. The map identifies worldwide occurrences of CBRN incidents between 1980-2009.

The work builds on previous research conducted by Dhongde on the analysis of changes in poverty and income inequality due to globalization.

Research Awards and Honors

by William Dube

RIT values the contributions of its faculty, staff, and students across all colleges and centers. Below, we highlight members of the RIT community who have received significant internal, national, or international recognition this year.

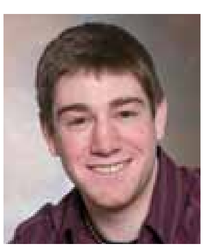
Distinguished Public Service Awards

The Four Presidents Distinguished Public Service Award was created by Alfred L. Davis, vice president emeritus, on the occasion of the 65th year of his association with RIT, to commemorate the dedication of the last four RIT presidents in their service to the Rochester community. The Bruce R. James '64 Distinguished Public Service Award is presented annually to an RIT student and commemorates the public service of Bruce James, former U.S. Public Printer and chairman emeritus of the RIT Board of Trustees.

Four Presidents Award

John Klofas, professor and chair of the department of criminal justice, was awarded the 2010 Four Presidents Award. Klofas has a long record of community service focusing on addressing crime, urbanization, and youth services. He has served as a member of numerous community, government, and not-for-profit boards, including the U.S. Assistant Attorney General's Advisory Board.

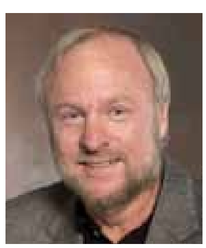
Bruce R. James Award



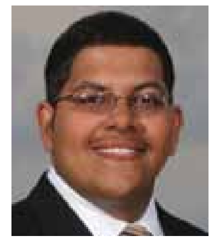
Ryan Buckley, a third-year biomedical sciences major, has been selected to receive the 2010 Bruce R. James Award. Buckley is being honored for his commitment to community development and service both in Rochester and around the world. He spent last summer in Kenya volunteering as a health-care worker for Kikuyu Hospital, in the city of Kikuyu, and the Imara Clinic, outside the city of Nairobi. He also spent time traveling to different villages throughout the country, providing health and educational support.

National and International Recognition

The National Press Photographers Association presented **Gunther Cartwright**, retired professor in the School of Photographic Arts and Sciences, with the Clifton C. Edom Award. The award recognizes someone who inspires members of the photojournalism community to reach new heights. Cartwright, who taught at RIT for nearly 35 years, was honored for his continued contributions to photojournalism education and professional development.

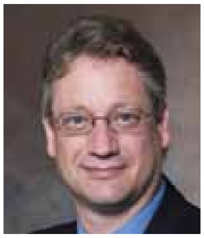


The biography *Edmund Booth: Deaf Pioneer*, written by **Harry Lang**, professor at the National Technical Institute for the Deaf, has been selected for inclusion in Deaf America Reads. The initiative, a project of the National Literary Society of the Deaf, promotes deaf culture and literacy in libraries across the U.S.



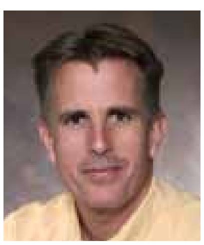
Seth Hubbard, assistant professor of physics and microsystems engineering, and **Reynold Bailey**, assistant professor of computer science, received Faculty Early Career Development Awards from the National Science Foundation. The honor goes to junior faculty doing research in areas of significant real-world impact. Hubbard was selected for his solar cell research with NASA's Glenn Research Center. Bailey was honored for his research in eye tracking, including the development of the analysis method the subtle gaze direction technique.

Manuela Campenelli, associate professor of mathematical sciences and director of the Center for Computational Relativity and Gravitation, was elected a fellow of the American Physical Society in 2009. Campenelli has earned international notice for her groundbreaking work on numerical simulations of binary black hole space-times and for explorations of astrophysical effects such as "super kicks" and spin-driven orbital dynamics.

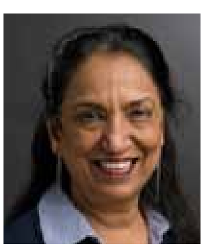


Samuel McQuade, graduate program coordinator in the Center for Multidisciplinary Studies, has been appointed to the National Telecommunications and Information Administration's Online Safety and Technology Working Group. The organization provides technical expertise and research support to the U.S. Department of Commerce related to online safety for children.

Jorge Díaz-Herrera, dean of the B. Thomas Golisano College of Computing and Information Sciences, has been appointed to the New York Broadband Development and Deployment Council. The newly created council will assist in ensuring affordable, high-speed, and high-capacity broadband access for all New Yorkers.

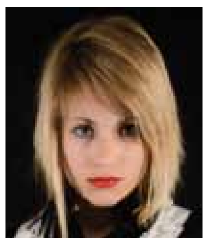


The Microsystems Engineering Program, headed by Professor **Bruce Smith**, has received a Graduate Assistance in Areas of National Need Award from the U.S. Dept. of Education. Funds provided through the award will support doctoral students in RIT's Ph.D. program in microsystems engineering.



Santosh Kurinec, professor of microelectronic engineering, has been named a Distinguished Lecturer by the Institute for Electrical and Electronics Engineers. The program honors engineering professionals who have advanced their fields through new technology developments.

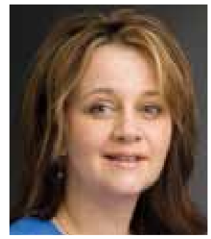
Katie Terezakis, assistant professor of philosophy, has been awarded a John William Miller Fellowship by Williams College. The award is presented to philosophers conducting research on the teachings of American philosopher John William Miller. Terezakis will use the fellowship to conduct an examination of Miller's published works.



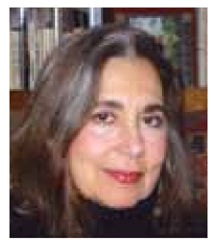
Lindsay Berkebile, a fourth-year film and animation student, is the winner of a 2009 Princess Grace Award. The Princess Grace Foundation-USA, named in honor of Princess Grace Kelly of Monaco, gives annual awards to aspiring artists in theater, dance, and film. Berkebile was one of only two undergraduate students to win a 2009 Princess Grace in the film category.

Ivan Kenneally, assistant professor of political science, has been appointed to the board of directors of the John Adams Center for the Study of Faith, Philosophy, and Public Affairs. Kenneally will assist in developing center initiatives, while also helping to create research symposia and conferences related to technology and society.

Stefan Preble, assistant professor of microsystems engineering, was awarded the Defense Advanced Research Projects Agency's Young Faculty Award and the Air Force Office of Scientific Research's Young Investigators Research Program Award. The awards are given to new tenure-track faculty working on next-generation technologies that will advance national defense.



Deborah Colton, assistant professor of marketing, received the 2009 S. Tamer Cavusgil Award from the American Marketing Association. The honor is presented annually for outstanding research in international marketing. Colton was selected for her work in marketing knowledge-transfer in multinational corporations.



Janet Zandy, professor of language and literature, received the 2010 Award of Excellence in Historical, Critical, and Theoretical Writing from the Society for Photographic Education. Zandy was selected for her research in working class photography and photojournalism.

Albert Paley, Charlotte Fredericks Mowris Endowed Chair in the School for American Crafts, was the subject of the career retrospective *Albert Paley: Dialogue with Steel*, presented by the New Jersey sculpture garden and museum Grounds for Sculpture. The exhibit ran from October 2009 to April 2010 and was the subject of an art review in the *New York Times*. Paley's artwork is featured in the Metropolitan Museum of Art, the Museum of Fine Arts, Boston, and the Smithsonian Institute.

About This Section

This listing is a sample of awards and honors that have been received by RIT faculty and staff over the past year. For more information, please visit www.rit.edu/news.

Innovation and Entrepreneurship

by Kara Teske

RIT provides an environment that inspires new ideas and propels them into tangible innovations with real-world benefits. Liban, Inc., a company formed out of technology developed at RIT, is a prime example of how the university can help to accelerate economic development.

Liban, Inc., Launched from RIT Research: Spun off in 2008 from research developed at the Center for Integrated Manufacturing Studies, Liban, Inc., is already providing economic development with 10 full-time employees and four commercial fleet customers.

Built on a Decade of Research

Smart product systems have been the focus of research at RIT's Center for Integrated Manufacturing Studies (CIMS) for over a decade. Through support from the Department of Defense, engineers and co-op students at CIMS have developed a system that monitors and assesses the performance of light armored vehicles. A computer installed on the vehicle monitors the vehicle's sensors and custom software developed at RIT monitors the driving behavior and maintenance condition of the vehicle.

In partnership with the U.S. Marine Corps Systems Command, the vehicle health management system was deployed on vehicles at Camp Pendleton, Calif. An unscheduled test of the system, where an equipped vehicle was sunk, tested the capability of the system. Following the accident, engineers were able to provide a play-by-play of the event, proving the robustness and maturity of the equipment.

In 2007, RIT partnered with Lockheed Martin to respond to a $150 million competitive contract with the U.S. Marines that would equip 10,000 military vehicles with the vehicle health system technology. To respond to the demands of the contract, Liban, Inc., was formed in January 2008.

Liban Emerges

RIT, through its Intellectual Property Management Office, transferred the technology to Liban to commercialize it into a product that can be sold to Lockheed Martin and, eventually, commercially. In October of 2008, David Chauncey, an experienced entrepreneur and electrical engineering alumnus, joined Liban as the chief executive officer, and the company quickly began to take shape.

While the military applications helped to accelerate the company, Chauncey conducted a market analysis and developed a business strategy that expands the technology into broader markets, such as the commercial freight industry. A team of students from RIT's Executive MBA program also conducted an in-depth marketing analysis for Liban as their capstone project. The report provided Liban with a wealth of information and insight of the industry, competitor landscape, and marketing strategy.

A talented board of directors was assembled to advise the young business endeavor, pulling expertise from the university and industry. Ron Zarrella, RIT trustee, former chairman of Bausch & Lomb, and past president at General Motors when OnStar was developed, provides unmatched industry experience. Other members include Dick Kaplan, CEO of Pictometry and serial entrepreneur, Dr. Jim Watters, senior vice president of Finance and Administration at RIT, Dr. Nabil Nasr, director of CIMS at RIT, and Geoffrey Rosenberger, co-founder of Clover Capital Management.

And in the fall of 2009, Ed McCarthy, senior program manager at CIMS and head engineer on the initial development of the technology, joined Liban as vice president of engineering.

Engineer Meet Entrepreneur: Ed McCarthy (left), vice president of engineering, and David Chauncey (right), chief executive officer of Liban, Inc., are taking advantage of the resources at RIT and the Clean Energy Incubator so they can focus on engineering and business development.

Based at RIT's Venture Creations in the Clean Energy Incubator, the company is leveraging the university's infrastructure, allowing Chauncey and McCarthy to focus on product and business development. "Being here at Venture Creations has been critical to us," says McCarthy. "The incubator gives us all the conditions we need to grow, from office space, to access to university resources and co-op students, to a networking infrastructure. These resources are invaluable to us."

New Markets and Products

The system now collects the data via Wi-Fi or cellular on a secure database that can be accessed via a Web-based interface. In almost real-time the customer can access the information about vehicle location, condition, and driver behavior.

Liban has proved its vehicle health management system can lead to an estimated $3,000 savings per truck annually. The savings comes across in three forms: fuel economy, maintenance, and driver safety. "A driver can have a huge impact on the fuel efficiency of a vehicle, by as much as 30 percent," says Chauncey. "By monitoring driver behavior and coaching drivers, we've been able to consistently show a 10-percent savings on fuel."

The system also allows operators to adjust the maintenance schedule to service the trucks when necessary rather than according to an arbitrary schedule. Additionally, when a vehicle does need service, diagnosing the problem earlier and ordering parts in advance can reduce offline times. Finally, by monitoring driver behavior, most companies will receive cost savings from their insurance companies.

To date, Liban employs 10 full-time employees, including an office manager, two salespeople, a marketing coordinator, and four engineers. Co-op students have also been brought on to assist with accounting and engineering.

Engineers at Liban continue to partner with RIT for technical support, software development, and troubleshooting. "RIT has been an integral role in this process and will continue to be as we go after advanced technologies and new capabilities," McCarthy says. For example, Bruce Hartpence at RIT's B. Thomas Golisano College for Computing and Information Sciences is helping to develop secure wireless communication networks for Liban's customer data through a Corporate R&D collaboration.

"RIT has shown itself as an institution that can transfer technology, take it from a research lab and actually have real customers using the technology," adds McCarthy.

"That has always been the vision at CIMS; we do cutting-edge research, but we always keep the customer in mind," says Dr. Nabil Nasr, director of CIMS. "It's this passion for engineering and the passion for economic growth that has helped to fuel the success of Liban."

Vehicle Health Management System: In almost real-time, customers can access the Web-based interface to view the location and condition of their vehicles, as well as driver behavior. The system saves an estimated $3,000 per truck annually.

R·I·T

Rochester Institute of Technology

125 Lomb Memorial Drive
Rochester, NY 14623-5608
www.rit.edu/research

Nonprofit Org.
U.S. Postage
PAID
Rochester, N.Y.
Permit 626

Rochester Institute of Technology

RIT is one of the largest private universities in the world. With a unique blend of rigor and imagination, of specialization and perspective, of intellect and practice, RIT is a vibrant community of ambitious and creative students from nearly 100 countries.

Aerial image courtesy of Stratus Imaging.

Rochester Institute of Technology is internationally recognized for academic leadership in computing, engineering, imaging technology, and fine and applied arts, in addition to unparalleled support services for students with hearing loss. Nearly 17,000 full- and part-time students are enrolled in more than 200 career-oriented and professional programs at RIT, and its cooperative education program is one of the oldest and largest in the nation.

For two decades, *U.S. News & World Report* has ranked RIT among the nation's leading comprehensive universities. RIT is featured in *The Princeton Review*'s 2009 edition of *The Best 368 Colleges* and in *Barron's Best Buys in Education. The Chronicle of Higher Education* recognizes RIT as a "Great College to Work For."

Contact Information

We conduct research to advance the body of knowledge, enhance student and faculty learning, and build our reputation in the scientific and technical communities while providing positive returns to our sponsoring partners. Please send your feedback directly or through the RIT research website at **www.rit.edu/research**.

Donald L. Boyd, Ph.D.

Vice President for Research
(585) 475-7844
donald.boyd@rit.edu

Michael E. Dwyer

Director, Research Relations Office
(585) 475-2698
mike.dwyer@rit.edu

10% postconsumer waste fiber