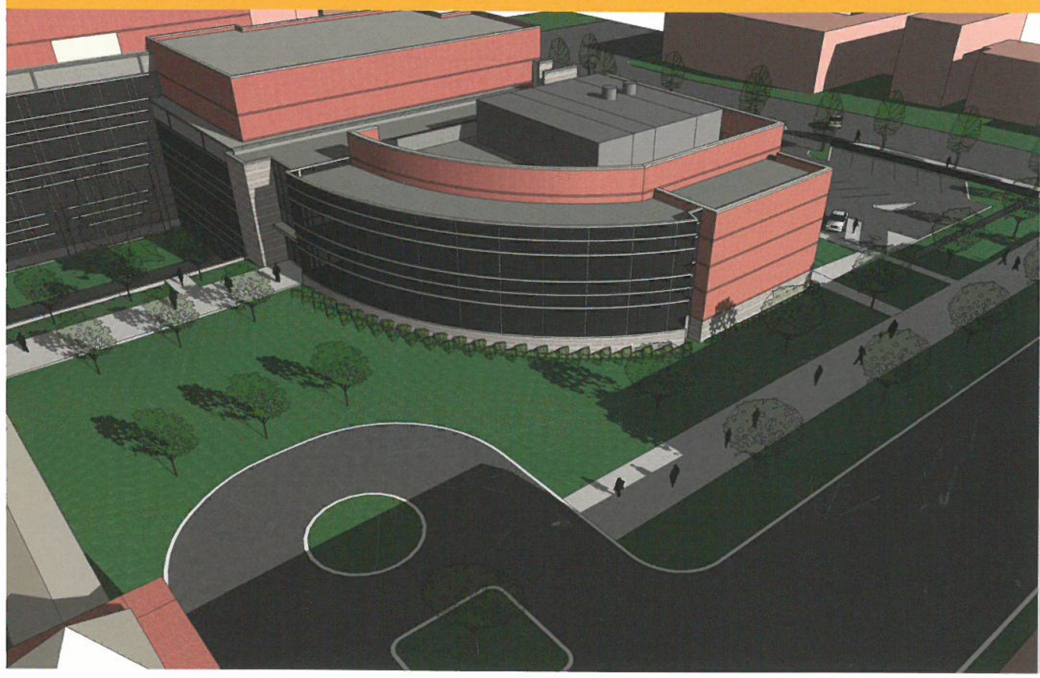

The new Health and Life Science Engineering building is scheduled to begin construction this fall and will adjoin the existing School of Engineering. The 25,000 square foot addition will provide a state of the art collaborative research environment connecting multiple University programs.

VCU School of Engineering

Virginia Commonwealth University

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VCU School of Engineering

Virginia Commonwealth University

Volume one Premiere Issue 2007

CONNECT **COLLABORATE** TRANSLATE

FROM THE DEAN

VCU School of Engineering

Dean Russ Jamison is pictured in the new da Vinci Center for Innovation in Product Design and Development. The Center will be part of the School of Engineering Phase II expansion, scheduled to open for classes in January 2008.

Welcome to this overview of ongoing research at the Virginia Commonwealth University School of Engineering. As one of the newest schools of engineering in the United States located on the campus of the largest university in the Commonwealth of Virginia, we have embraced translational and transformational research. The engagement of economies and cultures in a world of remarkable interconnectivity draws the research community closer in the search for global solutions to shared problems. Among our faculty are internationally recognized experts in genomics, energy, nanomaterials, tissue engineering, quantum computing, and semiconductors. These researchers and their students are intimately connected to colleagues here and elsewhere who share our vision.

We believe that the future of research is in interdisciplinary collaboration. As you read these research summaries, I invite you to contact the individual faculty members involved to get more information or to explore opportunities to work together. We welcome experts, and those who want to be, to join us in engaging the grand challenges of the 21st century.

Russell D. Jamison, PhD

CONTENTS

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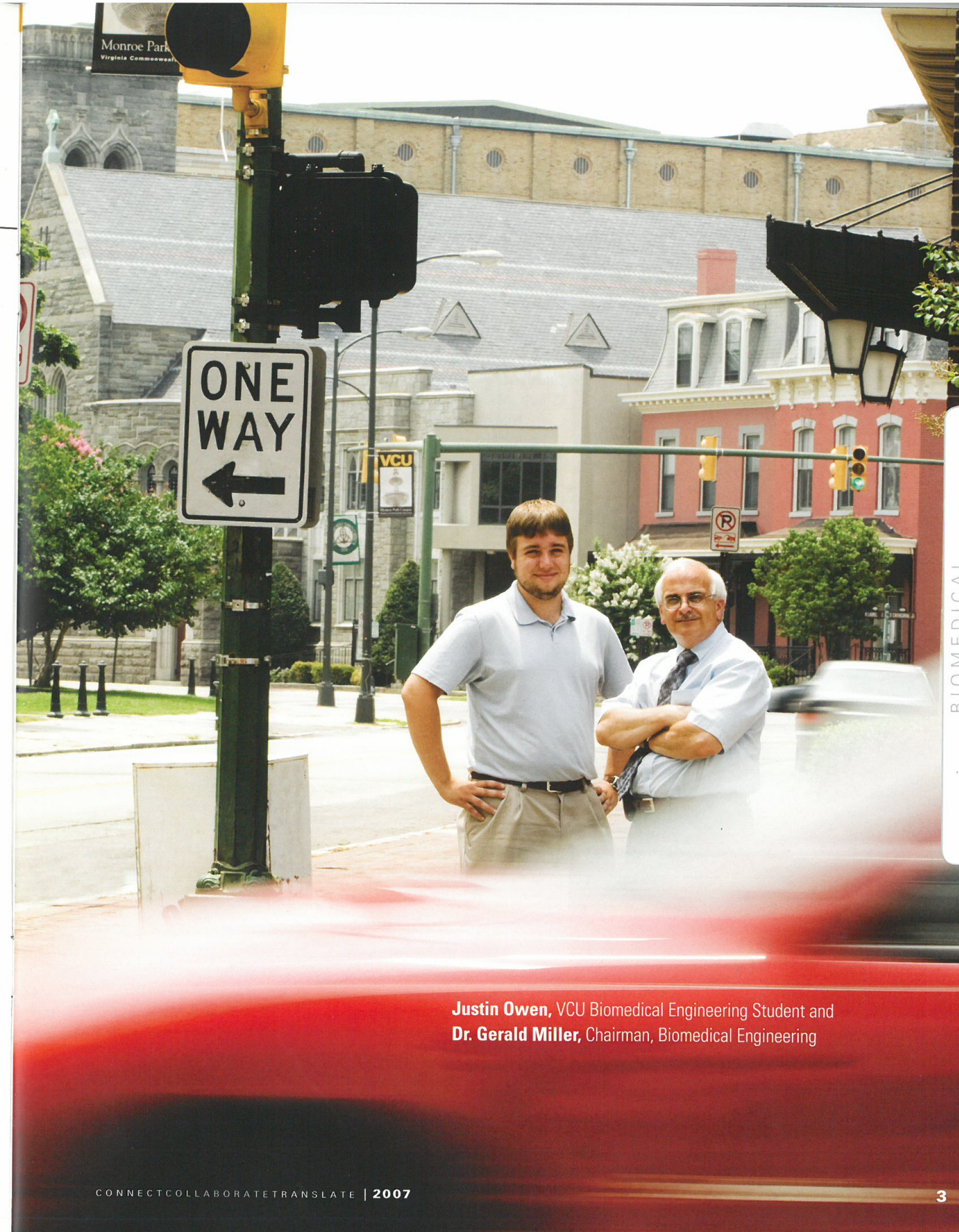
Bioengineering and Bioinformatics
SUMMER INSTITUTE

The Bioinformatics and Bioengineering Summer Institute (BBSI) hosted by Virginia Commonwealth University is a collaboration between Biomedical Engineering and the Center for Biological Complexity. The Institute is co-directed by Dr. Gerald Miller, Chairman of Biomedical Engineering and Dr. Greg Buck, Director of the Center for Biological Complexity. The NSF and NIH funded Institute attracts students from both VCU and numerous other universities. The students attend lectures in both bioengineering and bioinformatics and work in research laboratories with faculty mentors. The Institute receives over $800,000 in funding for four years and the students spend two consecutive summers in this program, during which they work with a faculty advisor at their home institution during the intervening school years between the two summers in the Institute. BBSI was recently renewed for another four years of support, with VCU one of only three universities to have their support renewed. In the five year existence of BBSI, over 100 students have completed their studies and research at VCU as part of the Institute.

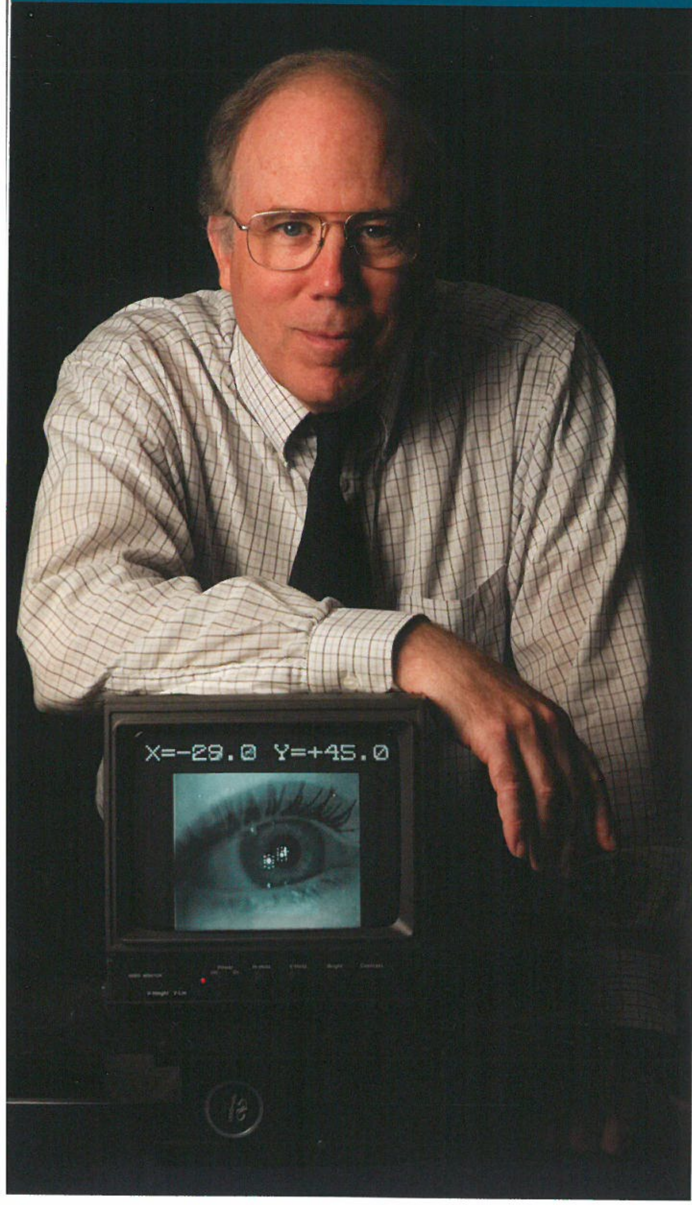
VCU Biomedical Engineering student, Justin Owen, is working under the direction of his faculty mentor, Dr. Dianne Pawluk. Dr. Pawluk's research involves the development of devices and systems to aid the blind and visually impaired. Justin is working on the development of a method for blind individuals to be warned of the approach of a hybrid vehicle. Those who are blind normally can hear automobiles approaching and know not to proceed into an intersection. However, the proliferation of quieter hybrid vehicles is a danger to the blind pedestrian, as they cannot hear the approach of such vehicles. Justin and Dr. Pawluk are working on a means of warning the blind via either a device worn by the blind pedestrian or a sensor placed on hybrid vehicles.



Justin Owen, VCU Biomedical Engineering Student and
Dr. Gerald Miller, Chairman, Biomedical Engineering

BIOMEDICAL

Eyes on Parkinson Disease

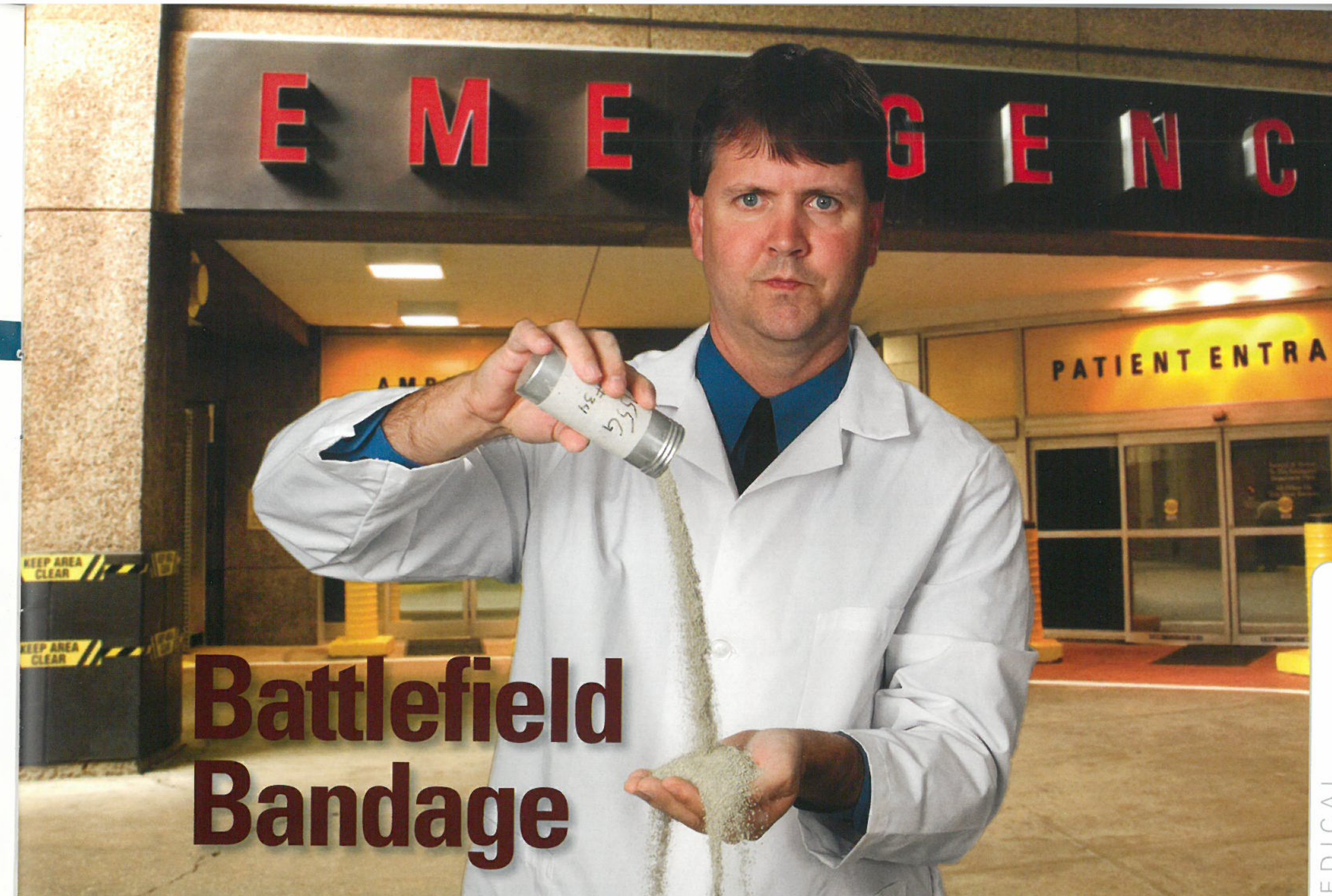


Dr. Paul A. Wetzel
Associate Professor, Department of Biomedical Engineering

Parkinson disease (PD) is a progressive neurological movement disorder with no known cure or preventative treatment presently available. Symptoms resulting from PD are the result of reduced levels of dopamine, a vital chemical produced in the brain whose loss leads to difficulties with motor control in the form of tremor, limb stiffness and jerkiness of motion. As the disease progresses, it can also affect cognitive abilities as well as sensory and additional motor functions such as changes in postural reflexes, gait, speech, facial gesturing, visual and perceptual factors and eye movements. Present treatments include the initial use of medications which are designed to increase the level of dopamine within the brain and later surgical procedures such as deep brain stimulation which may be considered when medications become less effective or cause intolerable side effects.

To effectively acquire and extract visual information requires a coordinated relationship between eye and head position resulting in periods of stable fixation. The stabilization and control of eye movements during fixation is critical for the acquisition of visual information. Individuals with PD frequently report difficulty with visual tasks that require stable fixation such as reading or other visual activities. Although movement manifestations of PD are the most widely reported symptoms, impairment of eye movement control and function are a common problem that can limit a person's ability to perform everyday visually related quality of life activities. Surprisingly, visual impairments in PD can be difficult to detect and can be easily overlooked during clinical examination. Further, the specific deficits and their implications have not been adequately studied.

In collaboration with other neurologists we are currently interested in the early detection, assessment, affects and treatment of PD on eye movement control. This is accomplished by objectively measuring the patient's eye and head movements during fixation and other visual tasks. The stability and behavior of eye and head position is then analyzed and compared to those of similar age without the disease. To date, our results show that PD disrupts the normal stability of eye movements during periods of fixation. We have also found that even at the earliest disease stages and before administration of treatment medications, patients with PD often show subtle but measurable unstable, non-rhythmic eye movement behavior which can affect their ability to see clearly. Eye tremor becomes more prominent as the disease becomes more severe. We have yet to establish a direct relationship between eye movement behavior and clinical measures of disease severity but this distinction may be due to differences in pathophysiology or an ineffective response to targeting medications. Eye and head measurement offers a rather simple, rapid, non-invasive means to define eye movement abnormalities and monitor medication effects in the clinic. If specific abnormalities can be consistently demonstrated near the onset of clinical disease, these techniques might also serve as an early, sensitive indicator of PD and assist in the continuing treatment and assessment of the disease.



Battlefield Bandage

BIOMEDICAL

Dr. Gary L. Bowlin
Associate Professor, Department of Biomedical Engineering

The overall goal of tissue engineering is to apply the foundations and innovations of biology, medicine, and engineering to develop and manipulate viable, three-dimensional physiologic substitutes that are capable of reinstating, sustaining, or recovering the function of tissues and organs. Tissue engineers historically have used some formulation of cells, scaffolds, and chemical and/or mechanical conditioning in attempts to fabricate the desired product. Since its inception, the field of tissue engineering has been pursuing the holy grail of an "ideal" scaffold in terms of production method, composition, and performance. Scaffold selection with regard to biomaterial choice and structure is an essential instrument and template utilized by a tissue engineer. To this end, Dr. Gary Bowlin has been a pioneer in the utilization of the electrospinning process to develop novel nano- and micro-fibrous scaffolds that mimic the native structural architecture and composition of various tissues including skin, blood vessels, cartilage, and liver. These advanced scaffolds will allow cells to be placed or migrate into a three-dimensional environment containing the necessary molecular cues in a physiologic temporal and spatial manner allowing tissue/organ regeneration and improving the quality of life of patients in need. Dr. Bowlin holds five U.S. patents and is a co-founding inventor of NanoMatrix, Inc. based on the electrospinning tissue engineering scaffold technology.

The development of a hemostatic agent, which can stop uncontrolled arterial bleeding, has been an interest to Dr. Bowlin and his collaborators for many years. This is due to the overriding fact that uncontrollable blood loss is the leading cause of death in a military conflict and the second leading cause of death in civilian trauma cases. This tremendous need has placed a great importance on the development of an effective hemostatic product. In collaboration with colleagues in Emergency Medicine and Biochemistry, Dr. Bowlin has helped develop a granular, mineral product which when placed in an incompressible, hemorrhaging wound bed can develop a seal to stop rapid blood loss. In a recently published study, this product has been successful in quickly stopping traumatic bleeding in pre-clinical trials, thereby demonstrating the potential to save countless lives threatened by traumatic injuries.

Developing Economically Viable Biofuels

Dr. Stephen S. Fong
Assistant Professor, Chemical and Life Science Engineering

Current gasoline consumption in the U.S. is approximately 140 billion gallons annually. It is projected that the U.S. rate of gasoline consumption will double in less than 50 years. With the combination of increased demand and rising prices, viable gasoline alternatives are being sought. Biofuels are renewable energy sources that are made from converting organic matter into a combustible fuel and thus can potentially supplement or replace gasoline.

Commercially, biofuel production typically involves pretreatment, hydrolysis, fermentation, and distillation processing steps. Large-scale production of biofuels is hindered by inefficiencies at the various processing steps, especially at the pretreatment and fermentation stages. Ongoing research is focused on improving the pretreatment step. This initial step begins with raw, unprocessed feedstock (corn stover, grass clippings, newspaper, etc.) and attempts to extract all of the usable sugars (cellulose and hemi-cellulose) from the feedstock. For different feedstocks, different processing conditions net different yields of usable sugar. Pretreatment parameters are being optimized for a variety of feedstocks in relation to feedstock composition through variations in chemical, temperature, and pressure parameters using a specialized high-temperature, high-pressure reactor.

In parallel with this project, a bio-based approach to biofuel production through engineering microbes is being developed. Micro-organisms contain diverse metabolic capabilities and it should be possible to engineer an organism to efficiently produce biofuel. Initially, two bacteria are being studied that are capable of producing high yields of ethanol, *Zymomonas mobilis and Clostridium thermocellum*. By constructing computational metabolic models of these organisms based upon genetic information, we are able to quickly evaluate the affect of different design strategies on ethanol yield. Following these computational simulations, designed strains are constructed that use molecular biology techniques for genetic modification and test the function of the generated designed strains. The long-term goal is to not only increase the ethanol yield (fermentation step), but to also improve the capabilities of these organisms to process cellulose, hemi-cellulose, and raw feedstocks. In the future, engineered organisms might be viewed as biorefineries where the pretreatment, hydrolysis, and fermentation steps all occur simultaneously inside a microbial cell.

Genomics

Dr. Yuan Gao
Assistant Professor, Computer Science

It is well-known that VCU is a national leader in gene sequencing. Now, VCU's capabilities will increase by an order of magnitude or more with the addition of the Illumina® Genome Analyzer by Dr. Yuan Gao, a new Assistant Professor of Computer Science and Life Sciences.

Dr. Gao was recruited to the VCU School of Engineering and VCU Life Sciences from Dr. George Church's renowned genetic sequencing lab at Harvard Medical School.

The development and application of high throughput technologies and computational methods to the study of genomics and systems biology is an area of focus that is growing exponentially. Specifically, Dr. Gao's lab is developing reliable, simple and multiplex methods to identify sequence variations in whole human genome, certain regions of a genome, or a set of specific sites in a genome.

Genetic sequencing is regarded as the "Gold Standard" to identify disease-causing mutations. The advent of a new generation of sequencing technologies at VCU will give researchers unprecedented opportunity for large scale sequencing study of genetic diseases such as cancer and neurological diseases. Currently, work with the new Illumina® Genome Analyzer is ongoing in identifying mutations in human head, neck, and lung cancer. Similar studies of Down's syndrome, Alzheimer's disease and Autism are projected for the near future.

Spintronics

By **Dr. Supriyo Bandyopadhyay**
Professor,
Electrical and Computer Engineering

Traditional electronics has always been concerned with encoding information in electric charge. Information in the digital world (e.g. digital TV, computers, cell phones, etc.) is always encoded in a string of two digits: 0 and 1. These two digits are called "binary bits". When a broadband internet connection is downloading information at the rate of 30 megabits per second (30 Mbps), it is actually downloading 30 million bits of either 0 or 1 every second.

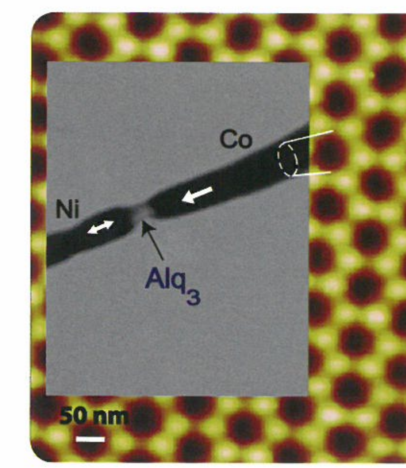
In almost any electronic gadget extant today, the bits 0 and 1 are physically represented by different amounts of electric charge stored in a tiny device called a "transistor". The bit 0 is represented by a small amount of stored charge, and the bit 1 is represented by a large amount of charge. Whenever we switch from bit 0 to 1, or vice versa, we have to change the amount of charge stored in the transistor. This would require moving charge in and out of the device causing a current to flow. It takes energy to drive a current and this energy is dissipated as heat. In today's transistors, the amount of energy that is dissipated when we change bits is about 0.1 femto-Joule, or one tenth of 1 quadrillionth of a Joule. However, this energy is dissipated over a very small duration of time, typically 10 picoseconds, which is just 10 times larger than one trillionth of a second. Therefore, the rate at which this energy is dissipated, which is called the "power", is quite high, about 10 microwatts or ten times larger than one-millionth of a watt. That does not sound too bad, except that there are at least 10 million transistors in every square centimeter of an electronic chip like the Pentium IV. Therefore, the power dissipated per unit area is about 100 watts per square centimeter. If that does not sound like much, consider the fact that a good toaster oven dissipates about that much power when it is toasting bread. So, then why does the computer chip not fry? The answer is that we have excellent heat removal technology that can quickly remove all the accumulated heat from the chip and ensure that its temperature does not rise too much above room temperature.

All this appears reassuring, but there is a looming problem. The economics of the electronics industry is driven by an empirical law promulgated by Gordon Moore, one of the founders of Intel. This law posits that the density of transistors on a chip should double every 18 months for the electronics industry to maintain its current growth trend, meaning that we should be able to cram an ever increasing number of transistors in every square centimeter. Soon, we will require 1 billion transistors per square centimeter if we wish to keep up with Moore's law. Unless we can reduce power dissipation, each of these transistors will be dissipating 10 microwatts. That will cause a power dissipation of 10 kilowatts per square centimeter on the chip (i.e. the heat generated by 100 toaster ovens squeezed within an area of 1 square centimeter), and our current heat removal technologies could never cope with that. Therefore, we must reduce the power dissipation in every transistor. Today, this is one of the primary challenges facing electronics.

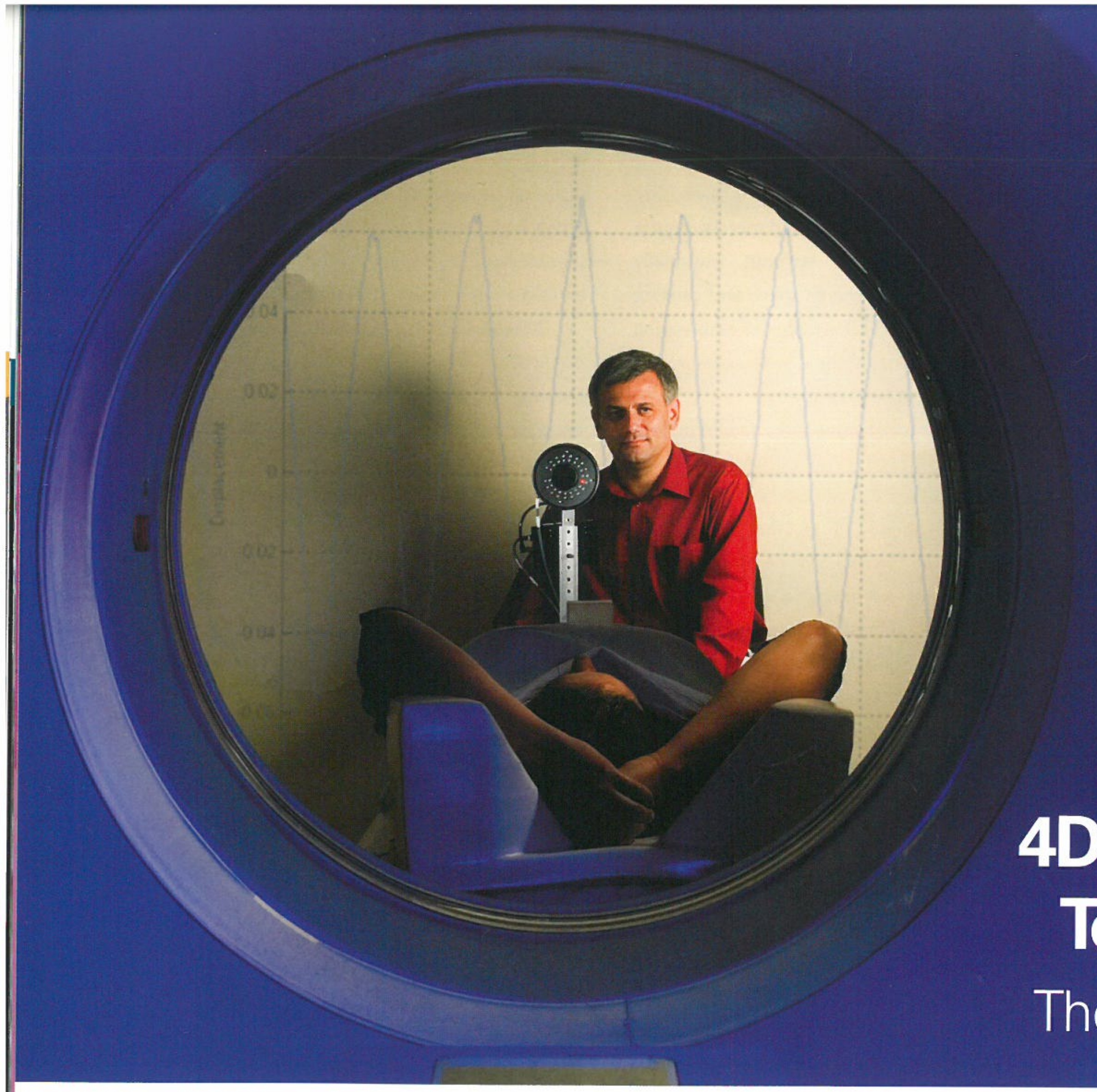
It is difficult to reduce power dissipation if we stick to the paradigm of switching bits by causing current flow. As long as we use charge to represent information, there is no way out of this. In 1994, Supriyo Bandyopadhyay, then a faculty member at University of Notre Dame, and two of his colleagues proposed a radically different idea. Electric charge is carried by sub-atomic particles known as electrons. An electron not only carries charge, but it also acts like a tiny magnet with a miniscule magnetic moment. This moment is associated with a quantum mechanical property called "spin". If an electron is placed in an external magnetic field, the spin can assume only two orientations – parallel or anti-parallel to the external field. These two orientations could represent the bits 0 and 1. Switching bits, encoded in spin, would merely require flipping the spin, without physically moving the electron in space and causing a current flow. This strategy of eliminating current flow can reduce power dissipation by a factor of 1000 or more.

Bandyopadhyay and his collaborators have proposed and analyzed many electronic circuits that can be realized with spin. They showed in 1994 that any arbitrary computing circuit can be implemented using spins of single electrons housed in ultrasmall semiconductor structures known as "quantum dots". The idea of using spin to store, encode, process and transmit information has burgeoned into a serious engineering and technological enterprise known as Spintronics. There are challenges in Spintronics too, and one of the more difficult ones has to do with fidelity of information. The spin of a single electron in a quantum dot can flip spontaneously causing loss of information. Any time this happens, the circuit encounters an error. If this error builds up, the circuit can malfunction. The average time between spin flip events is called the 'spin relaxation time'. The longer it is, the lower the probability of data corruption caused by spontaneous spin flips. In most materials known until recently, the spin flip time was one billionth to one millionth of a second. That is not long enough. Last year Bandyopadhyay and his collaborator Prof. Marc Cahay from University of Cincinnati studied organic nanostructures and measured the spin relaxation time in these materials. They found that the relaxation time was nearly one second at a temperature above the temperature of liquid nitrogen. This is extremely encouraging since it heralds the advent of spin based computers that can operate with an error probability of 1/10,000,000,000 and yet cram 1000 times more bits per unit area than present day electronic chips can, because they dissipate 1000 times less energy per bit flip. These computers will be made out of organic materials which can be flexible unlike inorganic semiconductor chips. That is the icing on the cake. They will probably have to be cooled with liquid nitrogen, but this is a small price to pay. Many high performance computers today require liquid nitrogen cooling, and this is certainly not a major inconvenience.

Stefano Sanvito, a noted spintronics researcher from the Trinity College, Dublin, Ireland while commenting on Bandyopadhyay's work writes in the journal Nature Nanotechnology, Vol. 2, page 204, 2007: "The electron spin is the ultimate information bit because its orientation is quantized and can only point up or down… The work of Bandyopadhyay and coworkers is an important step forward in this fairly young field as it demonstrates that spins in organic semiconductors remember their initial state over extremely long times." Perhaps, in not too distant a future, long spin relaxation times will be demonstrated even at room temperature, portending a quantum leap in computing technology.



Accompanying figure: The background shows a porous ceramic matrix containing 50 nanometer sized pores. 1 nanometer is 100,000 times smaller than the diameter of a typical human hair. A layer of nickel, a layer of organic known as Alq3 and finally a layer of cobalt were deposited inside the pores using a variety of techniques. This resulted in a "spin-valve" structure shown in the foreground. This structure was used to extract the spin relaxation time in the organic Alq3. The spin relaxation time was found to be nearly 1 second at a temperature of 100 K, which is above that of liquid nitrogen.



Dr. Alen Docef
Associate Professor,
Electrical and Computer Engineering

4D Computed Tomography

The New Frontier

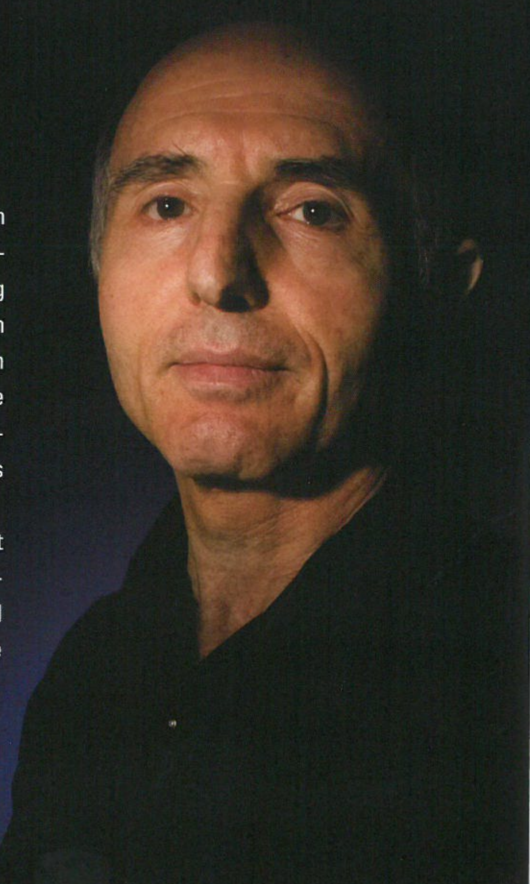
Volumetric medical imaging has advanced to the point that highly detailed three-dimensional images of human anatomy can be constructed using the techniques of computed tomography (CT), magnetic resonance (MR), and ultrasound (US). These images are essential to the planning and delivery of radiation therapy treatments. However, a conventional 3D image is by necessity a static "snapshot" of the anatomy, while the patient is a living subject exhibiting breathing, heartbeat, muscle movement, and tissue deformation. The next frontier in medical imaging is the development of four-dimensional images that can portray time-changing volumetric image data. These images will be used to design and deliver time-dependent radiation treatments that adapt to a patient's moving anatomy.

The Department of Radiation Oncology at VCU has recently installed a cone-beam computed tomography system. A cone-beam CT device rotates a two-dimensional projection x-ray imaging system around the patient, acquiring a complete set of volumetric data in a single rotation. In its conventional implementation, cone-beam CT reconstructs a static 3D image from the projections, using the established principles of computed tomography. However, given its imaging rate of 30 frames per second, a cone-beam system essentially records an x-ray fluoroscopy video that captures internal breathing and other motion effects while the imaging viewpoint rotates. By combining the principles of 3D CT with motion tracking in 2D x-ray fluoroscopy images it becomes possible in principle to construct a time-dependent 3D CT of the patient – i.e., a 4D CT – with a time resolution of 1/30 of a second.

A novel 4D CT reconstruction technique is being developed to exploit the high time resolution of a sequence of cone-beam projection images. This method creates a sequence of simulated cone-beam CT projections from a time-dependent 3D model of the patient. The patient model, which is initially derived from a conventional CT, is iteratively deformed such that the sequence of simulated projections matches the actual CT projection data acquired during the scan. By incorporating a time coordinate into the anatomical deformation model, the process can track anatomy that moves while the cone-beam CT projections are acquired. By tracking motion frame-by-frame, this method of constructing a 4D CT will make a factor-of-ten improvement over the time resolution of present-day 4D CT technique. The research is supported by the National Cancer Institute as part of grant number R01 CA 123299.

Let It Shine

Dr. Hadis Morkoç
Founders Professor, Electrical and Computer Engineering



Current lab initiatives encompass synthesis of semiconductor and complex oxide systems with the long term goal of enhancing device performance, reducing size and weight, increasing efficiency and finding new paradigms to replace the old and cumbersome approaches. Among the semiconductors GaN based and ZnO based heterostructures and devices based on them are investigated. Among the oxides, two groups are under investigation, one exhibiting high piezoelectric coefficient and one with high magnetic permeability with large magnetic stricture coefficient. The concept here is to bring these two in atomic contact to allow for electrically tunable microwave passive components for a whole host of communications and ranging systems such as in particular portable phased array antenna.

The semiconductor GaN is continually penetrating the market place by providing bright red and green emitters which are used for signage in general and traffic lights in particular for better visibility, and energy and manpower savings. In the last few years, lasers based on this material began their debut in recording and reading high density disk as the ones used in the Playstation®3. What is gigantic is the application of blue LEDs to white light generation wherein the LED pumps a yellow dye. Bright white light generated by this phosphor LED combination is being pushed to its limits in the race to produce the most efficient and brightest light source for general illumination. Already these sources are much brighter than fluorescent light bulbs and definitely much brighter than newer compact fluorescent light bulbs. Besides, LEDs can be dropped, they do not mind being turned on and off as many times as deemed necessary, they do not mind being cold, and pointedly they do not pollute the earth with mercury.

Despite the progress, however, the efficiency is limited to about half of what it could possibly be. The main limitation has to do with the efficiency of LEDs although tremendous strides have been and are being made to extract just about every single photon generated. To get over this hump requires more efficient sources. One very attractive option is the use of vertical cavity surface emitting lasers (VCSELs) which challenge the deposition and fabrication technologies, particularly in light of the fact that GaN does not enjoy the presence of an affordable lattice matched substrate. Novel deposition and fabrication methodologies are being employed in the lab to bring about electrically injected surface emitting lasers which are very likely to be the pump sources used for white light with very high efficiency. One step further is the use of polariton laser concept constructed of GaN or better yet ZnO which has more than twice the excition binding energy as compared to GaN as the active region of the device. In polariton laser, the cavity and excition polariton modes interact to produce lasing which is not based on population inversion and thus very low threshold lasing can be obtained for high efficiency pump sources for white light generation in addition to optical communication.

A Wearable Wireless Health Monitoring System

Dr. Esther Hughes
Assistant Professor
Department of Electrical and Computer Engineering

Dr. Esther Hughes is currently engaged in the design and implementation of a wireless medical prototype for monitoring various vital signs including skin temperature, core body temperature, metabolic heart rate, carbon dioxide (CO_2) levels and blood oxygenation levels.

Her involvement with the sensor suite design began a few years ago when she began working with Drs. Azhar Rafiq and Ronald Merrell of the NASA Research Partnership/MITAC on a tethered version of a similar system. The former design was tailored to monitoring an astronaut's vital signs while she is engaged in extravehicular activity (EVA), i.e., activity outside of the space vehicle. Currently, Dr. Hughes, along with her collaborators and several graduate students, is engaged in designing and implementing a wireless VMote (VCU mote) system based on the Crossbow MicaZ mote. A mote is defined as a low-power processor with a radio link that monitors one or more sensors. The custom device combines a microcontroller and digital spread-spectrum radio with multiple commercial off-the-shelf medical sensors integrated into a custom data acquisition prototype board. For the wireless prototype, the sensors are embedded into the rim of a baseball cap to be worn by the subject during data collection. As such, it is easy to don. The current system provides critical readings in real time.

Main contributions of the VMote system include: a means to analyze data online, as compared to other offline data analysis systems; the capability of acquiring and interpreting data from both analog and digital devices thus making the system compatible with analog and digital sensors; the capability of processing large amounts of data which directly facilitates the integration of more physiological sensors and variables; and the ability to support multiple, networked users thus allowing the healthcare provider access to a group of patients instead of data from a single individual.

Additional areas of application include the monitoring of athlete physiological conditions, sleep pattern research, and healthcare for residents of rural or remote areas. Similarly, the system could be used to remotely monitor the elderly as well as members of the disabled population. Additionally, these efforts propose the development of a patient-centric semi-autonomous monitoring system as a model for local area monitoring of patients with disabilities. More specifically, it will serve as a model for monitoring children with disabilities such as autism and cerebral palsy in a classroom environment. Oftentimes these children are unable to communicate their physiological deviations prior to onset of self-destructive behaviors. Future considerations include enabling preventive alerts that forecast medical events as opposed to solely monitoring them. Due to the sensitive nature of medical information, various data encryption techniques are currently being investigated for incorporation into the system.

Electrospinning Aligned

Dr. Gary Tepper
Professor, Mechanical Engineering

A VCU Mechanical Engineering team has invented a new process for the creation of polymer-based materials consisting of aligned arrays of nanofibers.

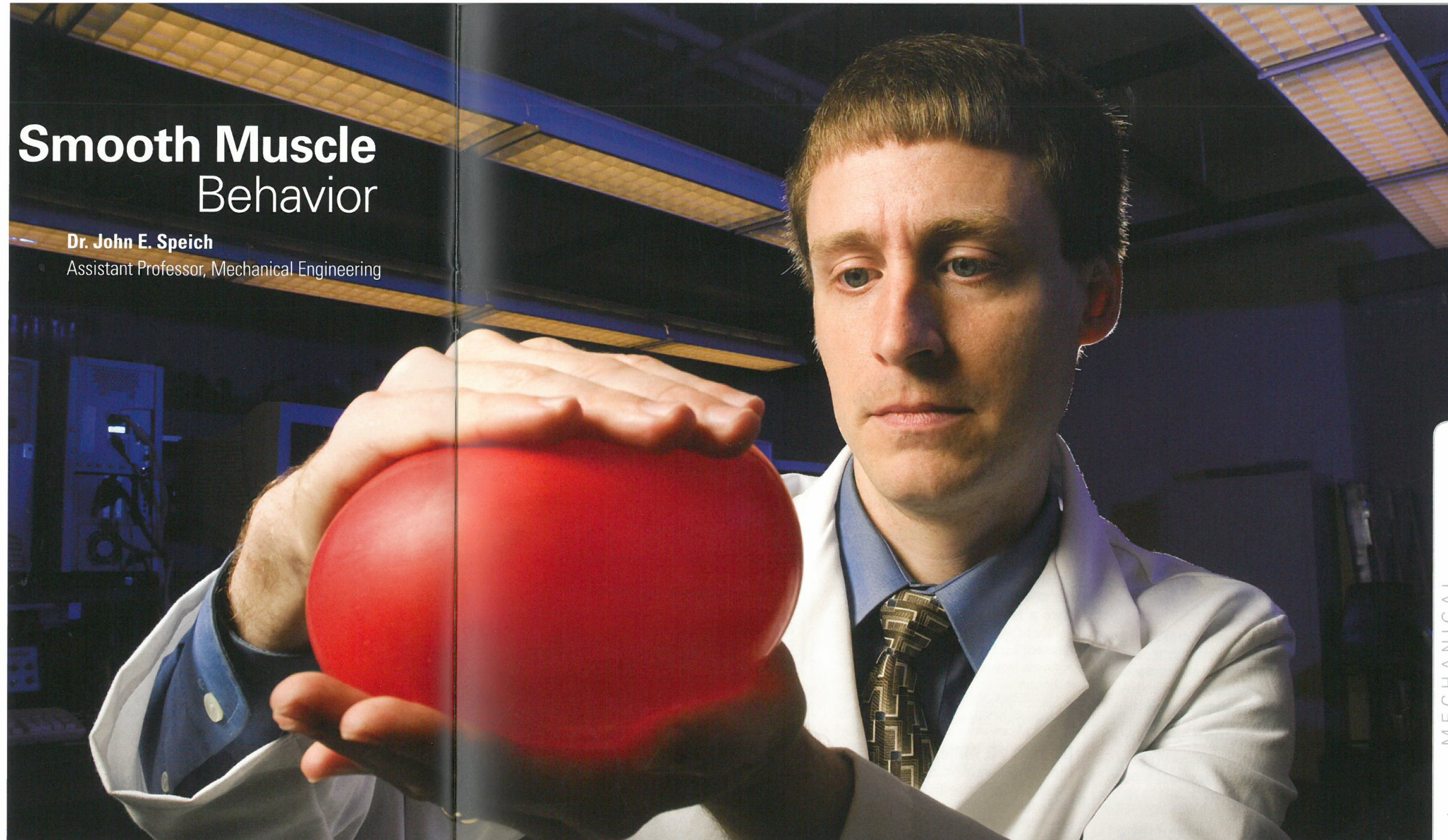
The new method, dubbed "Biased AC Electrospinning" is described in the May 2007, issue of the journal *Macromolecular Rapid Communications,* by Professor Gary C. Tepper and his graduate student Soumayajit Sarkar.

Electrospinning is a technique that is being used throughout the world to produce polymer nanofibers for various applications. However, until now it has been impossible to control the structure of electrospun materials because the electrically charged fibers are inherently unstable and whip around randomly during production.

The new method invented by Tepper and Sarkar completely eliminates the inherent fiber instability in the electrospinning process and opens the door for the creation of a host of new nanostructured polymeric materials for applications ranging from air filtration, tissue engineering, sensing and medicine.

Understanding **Smooth Muscle** Behavior

Dr. John E. Speich
Assistant Professor, Mechanical Engineering



Have you ever blown up a rubber balloon, released the air, and found it much easier to blow up the balloon a second time? If so, you have observed strain softening, which is an essentially irreversible loss of stiffness at a lesser strain due to a previously greater strain. Dr. John Speich and his colleagues recently discovered that bladder (detrusor) smooth muscle (DSM) also exhibits this property, and that structures within the muscle cells can reestablish the lost stiffness, effectively enabling them to adjust the bladder's stiffness[1-3]. The bladder dilates slowly to accommodate urine during filling and constricts quickly to eliminate stored urine during voiding. Failure to appropriately or adequately perform this function can lead to chronic bladder contractile disorders, such as overactive bladder which affects millions in the U.S. and throughout the world. These disorders can not yet be effectively treated because our knowledge of bladder physiology remains surprisingly incomplete. At VCU, our multidisciplinary research team from the departments of Mechanical Engineering, Biochemistry, Pediatrics and Surgery is seeking to more fully understand the regulation of the mechanical behavior of DSM and to gain knowledge essential to the discovery of novel treatments to specifically target bladder contractile disorders.

Bladder constriction is produced by DSM cells that contract when myosin motors are activated and cyclically attach as crossbridges to actin filaments. The "rowing" action of the actomyosin crossbridges causes relative sliding of actin and myosin filaments, which shortens the cells and develops tension (T). The level of active tension (Ta) produced is dependent on the number of active crossbridges producing positive work, which is dependent on muscle cell length (L). Muscle cells do not have a "reverse" motor to re-lengthen them after they have shortened, so hollow organs utilize filling pressure to re-lengthen the relaxed, passive muscle cells. Re-lengthening to a specific muscle length that is optimum for a subsequent contraction is controlled by the degree of passive tension (Tp) that accommodates or resists the load exerted by filling pressure. In striated muscles such as the heart, the passive length-tension (L-Tp) curve is exponential and generally considered to be "fixed" over the short-term (i.e., there is a single steady-state Tp value for each length). Most importantly, there is a single very narrow length range, termed the optimum length (Lo), where Ta is maximum (To). Ta is weaker at shorter and longer muscle lengths, forming a parabolic L-Ta curve. A "fixed" L-Tp curve permits accurate coordination between passive muscle cell re-lengthening and the strength of Ta upon muscle activation. Thus, the L-Tp curve can function to "reset" muscle cells to Lo such that the next contraction occurs at To.

Recent research on airway smooth muscle has shown that Ta and Tp can adapt to ambient muscle length relatively quickly and has challenged the paradigm of "fixed" L-T curves in smooth muscle. Our recently published studies of rabbit DSM show that steady-state Tp maintained at a given muscle length in a Ca^{2+}-free (i.e., passive) condition is reduced as a result of strain to a longer length, revealing strain softening behavior, and is increased upon muscle activation with KCl at short muscle lengths[1-3]. Thus, DSM is both strain-history and activation-history dependent, and there is not a single Tp value for a given muscle length. Our work demonstrates that within the physiological working length range of the bladder there exists a variable L-Tp curve displayed as a family of L-Tp curves, and we have termed this phenomenon adjustable passive stiffness (APS)[2]. Furthermore, we have found that APS is regulated by rhoA coiled coil kinase (ROCK), indicating that the structures responsible for APS are intracellular[3]. Moreover, we have shown that APS can modulate steady-state total tension (Ta+Tp) at a given muscle length with relatively little change in Ta, which suggests that structures responsible for APS act in parallel with the contractile apparatus because adjustable Tp and tonic Ta appear additive[1].

The significance of passive stiffness in smooth muscle, including our identification of APS, was the focus of a recent editorial by Ford and Gilbert in the *Journal of Applied Physiology*[4]. Passive stiffness during bladder filling is critical, because it directly affects the signals responsible for urgency and positions the crossbridges in preparation for voiding. Tp maintains the bladder's shape, which is important because for a given bladder volume, a change in shape can cause a significant change in surface area, and therefore cell length and crossbridge spacing, just as squeezing a spherical water balloon increases its surface area and wall tension. In the bladder, APS may function to maintain spacing between actin and myosin filaments to enable efficient Ta generation throughout a broad range of bladder volumes. Our objective is to gain a precise understanding of the molecular mechanisms responsible for APS in the bladder, how APS adjusts Tp during filling, and how Tp affects Ta during voiding. We hope to provide information essential for the timely discovery of therapies targeting bladder contractile disorders, such as overactive bladder that involves involuntary contractions during bladder filling, interstitial cystitis that involves increased urgency and voiding frequency, and underactive bladder that causes incomplete bladder emptying. Furthermore, we are investigating smooth muscles found in the stomach, airways, and arteries to determine if APS is present and if it plays a significant role in these tissues.

1. Speich JE, Dosier C, Borgsmiller L, Quintero K, Koo HP, Ratz PH. Adjustable passive length-tension curve in rabbit detrusor smooth muscle. *J Appl Physiol.* 2007;102:1746-55.
2. Speich JE, Quintero K, Dosier C, Borgsmiller L, Koo HP, Ratz PH. A mechanical model for adjustable passive stiffness in rabbit detrusor. *J Appl Physiol.* 2006;101:1189-98.
3. Speich JE, Borgsmiller L, Call C, Mohr R, Ratz PH. ROK-induced cross-link formation stiffens passive muscle: reversible strain-induced stress softening in rabbit detrusor. *Am J Physiol Cell Physiol.* 2005;289:C12-21.
4. Ford LE, Gilbert SH. The significance of variable passive compliance in smooth muscle. *J Appl Physiol.* 2007;102:1735-6.

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BIOMEDICAL

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Research Topics
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- Human motor control physiology
- Development of brain-computer interface-based device for patients with movement disorders
- System development of motor imagery-based motor learning for stroke rehabilitation
- Development of algorithms and graphic-user interface for investigating brain neuronal connectivity
- Development of algorithms and systems for computer-aided diagnosis
- Algorithm development of neurophysiological signal processing and classification
- Multi-modal functional neural imaging

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Research Topics
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- Electrostatic endothelial cell seeding techniques and transplantation/transfection

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Research Topics
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- Magnetic resonance imaging (MRI) techniques for studies of vessel properties and vascular hemodynamics
- Telemedicine

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Research Topics
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Research Topics
- Animal bioacoustics
- Tinnitus
- Speech perception
- Hearing and balance

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Research Topics
- Artificial hearts - analysis and design of a multiple disk centrifugal blood pump
- Man-machine interfacing - analysis and design of voice recognition systems
- Rehabilitation engineering - analysis and design of devices to aid the disabled

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Research Topics
- Haptic displays for blind and visually impaired individuals.
- Human factors analysis during minimally invasive surgery and telesurgery.
- Tissue modeling for surgical simulators, development of simulators.
- Application of tactile feedback for prosthesis design.
- Use of haptic devices for rehabilitation.

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Research Topics
- Articular Cartilage: Normal Function, Reparative Techniques, Tissue Engineering
- Experimental and Computational Modeling of Diarthrodial Joint Function
- Ligament and Tendon Mechanics
- Structural Stability of Fixation Constructs

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Research Topics
- Primary research emphasis is the development of Human–Machine Interfaces based on eye movement and visual analysis

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Research Topics
- Polymer Synthesis, Characterization, and Biofunctionalization
- Tissue Regeneration
- Nanomedicine
- Dendrimer-based Drug Delivery, Controlled Release, and Gene Transfer
- Brain-targeted Drug Delivery and Gene Therapy
- Bioactive and Environment-responsive Surfaces for Pharmaceutical and Biomedical Applications

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Research Topics
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- Evolutionary biology
- Metabolic engineering
- Molecular engineering
- Molecular evolution
- Computational modeling

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Research Topics
- Advanced polymer coatings for highly selective membranes and sensors
- Preparation of nano-structured materials using supercritical fluid technology
- Controlled and targeted delivery of therapeutic agents
- Processing biomaterials for improved biocompatibility

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Research Topics
- Diffusion in polymers and devolatilization processes
- Chemical kinetics and reaction engineering, especially polymerization reaction engineering
- High temperature degradation of organic solvents
- Supercritical fluid processing, especially supercritical fluid swelling of and infusion into glassy polymers
- Chemical process synthesis, modeling and simulation, especially dynamic modeling and stochastic simulation of batch processes

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Research Topics:
- Polymer solution behavior at high pressures
- Scattering phenomena in polymer solutions at high pressures
- Supercritical fluid solvent technology

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Research Topics
- Improving vascular graft efficacies using locally delivered novel promoter factors
- Pathway discovery via microimaging NMR for delivery of local chemotherapeutic agents in the treatment of skin cancers

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Research Topics
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- Regenerative Medicine
- Cellular/tissue engineering
- Genomics
- Biomaterials
- Biosensors

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Research Topics
- Polymer surface science
- Fluoropolymer science
- Silicone science
- Functional polymer surfaces including biocidal polymers
- "Green" processing and synthesis in super-critical CO2
- Nonlithographic patterning of functional inorganic and polymeric materials

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Research Topics
- Single molecule protein biophysics
- Optical biosensors
- Functional biomaterials
- Surface science
- Micro- and nanofabricated devices

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Research Topics
- Medical applications, database, networks, graphics, performance evaluation, simulations

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Research Topics
- Software engineering
- User interface design and specification

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Research Topics
- Compilers, functional programming, logic programming and expert systems
- Consultant to IBM Kingston

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Research Topics
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- Graph theory
- Combinatorics

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Research Topics
- Biomedical informatics
- Data mining
- Learning algorithms

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Research Topics
- Computational Biology
- Genome Sequencing
- Algorithm design and analysis
- Data Mining
- Computer and Biological Networks

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Research Topics
- Software Analysis, Testing and Verification (ATV)

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Research Topics
- Biomedical signal processing and medical informatics
- The use of advanced signal processing methods to extract diagnostically useful information from large medical databases.

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Research Topics
- Database systems, operating systems and concurrency

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Research Topics
- Artificial neural networks,
- Machine learning
- Knowledge-based systems
- Parallel algorithms
- Ethics

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Research Topics
- Programming languages
- Compiler design
- Automatic generation of software

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Research Topics
- Multimedia systems
- Computer networking
- Wireless networks
- Digital image/video processing

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Research Topics
- Micro/Nano Fabrication
- Smart Materials
- Sensors and Actuators
- Biochips
- Microelectromechanical Systems (MEMS)

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Research Topics
- Nanoelectronics
- Hot carrier transport in submicron devices and quantum wires
- Quantum devices and single electronics
- Architectures for nanoelectronics and circuit design
- Quantum computing and cryptography
- Mesoscopic superconductors
- Self-assembly of nanostructures

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Research Topics
- Medical image processing
- Efficient, error-resilient, network-optimized image and video coding
- Document compression for archiving
- Signal processor architectures

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Research Topics
- Artificial neural networks and their application to control problems, intelligent systems, biological modeling, and signal processing issues.
- Research in the area of engineering education include introducing service learning into science, mathematics, engineering and technology programs and the development of K-12 programs to promote interest in engineering.

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Research Topics
- Reconfigurable computing
- Computer networking
- High performance computing
- Embedded systems

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Research Topics
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- Linear and Nonlinear Control Theory
- Neural Networks
- GPS Applications

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Research Topics
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- Bioinspired circuit-systems and their applications
- Development of related computer-aided design and analysis tools
- Nonlinear circuit-systems
- Device modeling

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Research Topics
- System-level performance and hybrid modeling
- Hardware/software codesign, hardware description languages
- Digital system design
- Parallel algorithms for design automation problems

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Research Topics
- Nitride Semiconductor Heterostructures
- Light Emitting Diodes
- Group III-V Semiconductors.

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Research Topics
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- Computer vision
- Robotics
- Human computer interaction

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Research Topics
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- Parallel processing
- Hardware and software for embedded microprocessor systems
- VHDL based FPGA design
- Reconfigurable logic
- Boolean equations and Boolean calculus

MECHANICAL

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Research Topics
- Fluids in motion
- Flow control
- Viscous pumps and microturbines
- Microtechnology

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Research Topics
- Manufacturing processes and systems
- Product and process design
- Micro/nano-manufacturing
- Design and manufacturing of alternative energy devices (such as fuel cells) and medical devices
- Design and manufacturing of nano/micro-scale functional surface structures
- Deformation mechanics, tribology and process in material forming plasticity
- CAE applications in design and manufacturing

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Research Topics
- High-precision control of piezo-based positioners for atomic force microscopes
- Precision positioning of shape memory alloy actuators for micro/nano-surgery
- Iteration-based feedforward control
- Mechatronic systems design for high-precision positioning applications

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Research Topics
- Multiphase biofluid transport with applications to respiratory and cardiovascular therapies
- Transport of toxic and therapeutic aerosols and vapors in the respiratory tract
- Multiscale modeling of respiratory dosimetry down to the cellular level
- Development of next-generation inhalation devices for therapeutic aerosol delivery
- Simulating the role of particle hemodynamics in vascular diseases
- Microcirculation transport and thrombosis occlusion models
- Optimal design of vascular prostheses (grafts and stents)

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Research Topics
- Photovoltaic materials and devices
- Power generation
- Energy conversion systems
- Engineering education
- Optical characterization of semiconductor materials

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Research Topics
- Heat transfer
- Thermal management of electronic equipment
- Computational fluid dynamics (CFD)
- Finite element analysis (FEA)
- Numerical optimization
- Artificial intelligence

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Research Topics
- Electrical and mechanical characterization of smart materials and their applications in aerospace, automotive, medical, and electrical fields.
- Materials and their response to different environments and the variation of their properties under different temperatures and boundary conditions (fluid mechanics, controls, equivalent circuits, mechanic of materials, etc.)

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Research Topics
- Design innovation through arts
- Computational mechanics
- Biological composites
- Design engineering
- Neural networks and computational intelligence
- Nanotechnology and biomolecular motors
- Smart materials and structures

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Research Topics
- Smooth muscle biomechanics
- Developing robotic devices for medical applications
- Robotic devices for delivering rehabilitation therapy
- Robot-assisted surgery
- Robotic devices to aid persons with disabilities
- Telemanipulation - especially scaled bilateral telemanipulation
- Human-robot interaction and haptic interfaces
- Compliant-mechanism-based robots and devices

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Research Topics
- Modeling and Experiment on Waterjets and Nozzle Cavitation
- Aerosols Flows and Nanoparticle Filtration
- Nanoparticle Focusing and Deposition
- Fluid Transport in Fibrous Porous Media
- Heat and Mass Transfer
- Molecular Dynamics Simulation of Granular Materials

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Research Topics
- Nanomechanics
- Nanobiomechanics
- Nanomanufacturing
- Nanoelectronics

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Research Topics
- Chemical and biological sensors
- Nanomaterials
- Molecularly imprinted polymers
- Radiation detectors
- Supercritical fluids
- Electroprocessing of polymers

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Research Topics
- Experimental and computational fluid dynamics
- Turbomachinery design and applications
- Bench-to-bedside development of medical devices
- Artificial organs research, especially for the pediatric population
- Prediction and quantification of blood trauma and thrombosis in medical devices
- Cardiovascular modeling and univentricular Fontan physiology

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