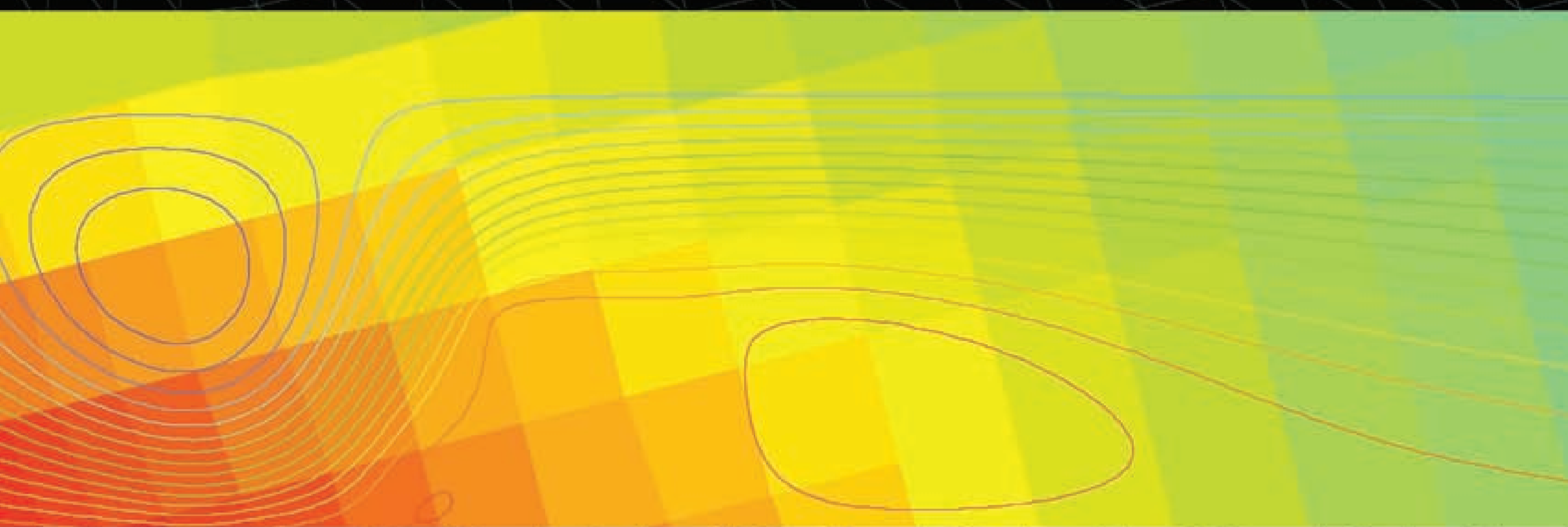
ILLINOIS INSTITUTE OF TECHNOLOGY

VECTORS



MMAE VECTORS MAGAZINE

NOVEMBER 2006

MECHANICAL,

MATERIALS

AND AEROSPACE

ENGINEERING

DEPARTMENT

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The cover symbols represent flow pattern of electrically driven liquid film and bubble deformation within a diverging electric field.

MESSAGE FROM THE CHAIR

The MMAE Department moved forward significantly in academic year 2005/2006 in every aspect of its mission (education, research, and service). MMAE enrollment continued to experience steady growth. The freshman class size reached 100, an increase of 20 percent compared to fall 2005. Total undergraduate enrollment this year reached 347, an increase of 18 percent compared to last year. Graduate enrollment also continued its growth, reaching 194, an increase of 11 percent since last year (see page 10 for more details). The Department added three new online graduate programs beginning this fall (see page 10 for more information).

MMAE Department graduate programs in Mechanical Engineering and Aerospace Engineering both ranked again among the top 50 programs in the nation, based upon *U.S. News and World Report's* list of "America's Best Graduate Schools." External research funding in the department exceeded $3M last year. Among MMAE faculty, currently, 25 percent are fellows of professional societies and 20 percent are editors or associate editors of top journals in their corresponding fields. We have made significant progress toward establishing the National Coalition for Manufacturing Innovation, an IIT Armour College of Engineering initiative led by the MMAE Department (see page 7 for more information).

I am very proud of and grateful to our alumni for responding to last year's IIT $1M Matching Campaign. The MMAE Department received $1.25M in campaign funding to improve the state of our undergraduate teaching laboratories. More details are provided on page 8. Next year, we will be naming several of our undergraduate laboratories in honor of the major donors.

MMAE faculty are committed to continuing their efforts to further improve the quality of our teaching and research (at both the undergraduate and graduate levels). MMAE undergraduate enrollment is expected to exceed 450 by 2011. We will maintain total graduate enrollment at 200, but focus on improving the quality of our graduate students. To maintain a 1/15 (faculty/undergraduate) ratio (as a private program), the number of faculty should reach 30 by 2011. Reaching a faculty of this size will tremendously impact our undergraduate and graduate programs. We will be able to offer new courses and maintain small classroom size. This increase in faculty size will significantly impact the department's research program as well. Our plan is to attract two top senior faculty in the core areas of Advanced Manufacturing and Aerospace Systems. Subsequent hiring of faculty at the junior level will be linked to these two senior positions and MMAE research initiatives.

In recognition of Professor Andrew Fejer and his many contributions to IIT, the MMAE Department is establishing the *Andrew Fejer Memorial Fellowship* (see page 27 for more information). In conjunction with this effort, next year we will initiate a new campaign to raise funds for graduate fellowships to attract highly qualified U.S. citizens and permanent residents to our graduate programs. The United States is facing top competition in science and technology. To maintain global competitiveness, U.S. students need to complete degrees in engineering beyond the B.S. level. The campaign will launch in Spring 2007 and will target a $5M endowment that will support 10 top domestic graduate students per year.

In closing, I again thank our alumni for their support. I am looking forward to yet another productive and successful year in the MMAE Department.

Jamal Yagoobi
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Multimodal Reverse Engineering: A New Paradigm for Shape Digitization

PROFESSOR QIAN

The ability to obtain a digital geometric model directly from physical objects marks a revolutionary step in the information era. Three-dimensional (3D) digitization, a.k.a *reverse engineering* in the engineering field, is a process to create such three-dimensional computer models from a physical object. Recently the 3D digitization technology, fueled by the rapid progress of various 3D sensors such as laser scanners and 3D shape reconstruction algorithms, has seen explosive growth in its usage. Such reconstructed 3D shape models have become increasingly important in a variety of applications such as product design and manufacturing in aerospace, automotive, and die and mold industries, patient-specific medical device design and analysis, as well as target recognition and scene understanding in homeland security and military applications.

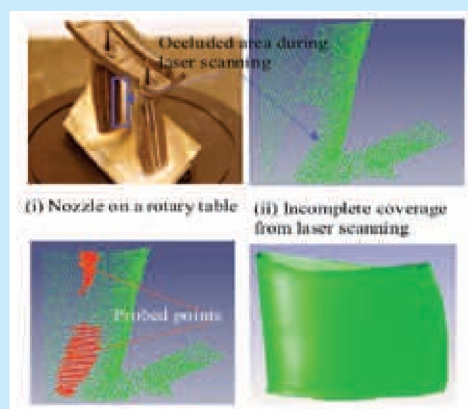
Despite its growing usage and rising importance, current 3D shape digitization has several bottleneck issues. For example, the digitization process is laborious and far from automatic. The reconstruction process is susceptible to sensor noise and data incompleteness, which commonly takes place in optical sensing due to occlusion and poor reflection conditions.

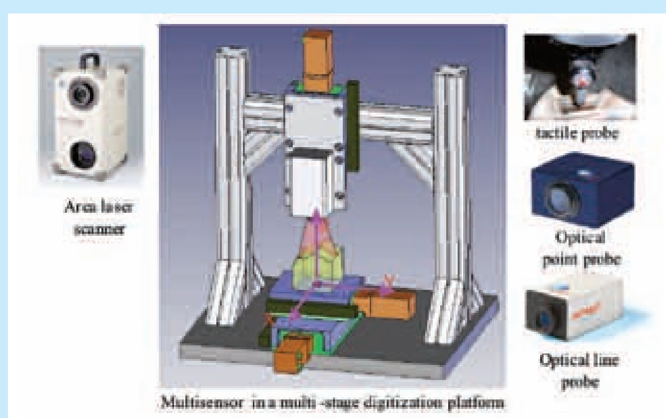
To overcome these fundamental challenges, Professor Xiaoping Qian and his research team at the Computational Design and Manufacturing Lab in the MMAE Department are currently developing a novel multisensor shape digitization approach. They are integrating 3D sensors of different modalities into one platform. They use these multimodality sensors to provide better sensing coverage and more accurate measurement, which will result in autonomous, robust, accurate and complete shape digitization. These multimodality sensors, tactile, optical, acoustic, and/or X-ray based, possess different sensing capabilities for various part geometry and surface conditions, and different sensing characteristics such as resolutions and field of views. Consequently, accurate surface representation can be obtained by reducing/eliminating areas of missing data, and autonomous and robust segmentation can be achieved by using more accurate sensor data.

Qian and his research team believe their multimodal systems provide great opportunities to take a quantum leap in shape digitization automation and in surface quality improvement. Their research has been under the sponsorship of the *National Science Foundation, National Institute of Standards and Technology, General Electric,* and *General Dynamics-Advanced Engineering Information Systems.*

Besides reverse engineering, Professor Qian and his research team at the Computational Design and Manufacturing Lab are also conducting other shape-related research in the broad area of computational design and manufacturing.

For more information on this topic, please visit http://mmae.iit.edu/cadcam/





Magnetic Nano-Particles in Blood Flow: A Collaboration Between Fluid Mechanics and Medical Science

PROFESSOR REMPFER

The research group of Professor Dietmar Rempfer at the Fluid Dynamics Research Center (FDRC) of the MMAE Department at Illinois Institute of Technology (IIT) is entering the field of bio-fluid dynamics with a research project that may ultimately lead to the development of compact and highly efficient separation devices that can selectively and rapidly remove blood-borne toxins or excess drugs from the blood circulation, or alternatively direct drugs inserted into the blood flow to a specific area of the body in order to implement targeted drug therapy. The research under this project is carried out jointly at IIT and the University of Chicago. At IIT, Professor Rempfer's team is primarily focusing on numerical simulations and the establishment of theoretical test modules useful for subsequent evaluation in flow models. At the University of Chicago, a team headed by Dr. Rosengart at the Biological Sciences Division and the Departments of Neurology and Surgery (Neurosurgery) will perform validating flow experiments and be responsible for the magnetic separator prototype design.

In contrast to magnetic separators employed in industry and for *in vitro* purposes, the design and development of a separator technology for high-efficiency capture of magnetic spheres from the human blood stream (i.e., blood is briefly circulated through an extracorporeal tubing system) as studied here will incorporate strict biomedical boundary conditions such as biocompatible magnetic carriers, externally applied magnetic fields, avoidance of activation of the blood clotting cascade, and portability to facilities out-of-hospital and for emergency deployment.

A typical magnetic filtration unit as considered in this project will consist of an assembly of ferromagnetic elements attached to an external limb of the body (e.g. wrapped around an elbow as shown in Fig.1). An ideal unit would be designed in such a way that the collection of carriers in a single pass is maximized while its weight is restricted to a few hundred grams.

Fig. 2 shows an example of a magnetic separator design together with some results from numerical simulations that have been performed for this project.

Fig. 1 Conceptual rendition of application of a designed portable magnetic separator

As part of the efforts, the combined role of a permanent block magnet and ferromagnetic elements of smaller size (not necessarily permanently magnetic, but able to reach larger magnetizations and thus larger magnetic fields) is investigated (Fig. 2). This hypothetical single-pass magnetic separation system will be further investigated using a theoretical model developed in Professor Rempfer's group. The parameters considered in this study include the blood velocity, the presence, number and dimensions (height) of the ferromagnetic prisms and the ferromagnetic properties of both ferromagnetic prisms and permanent magnet.

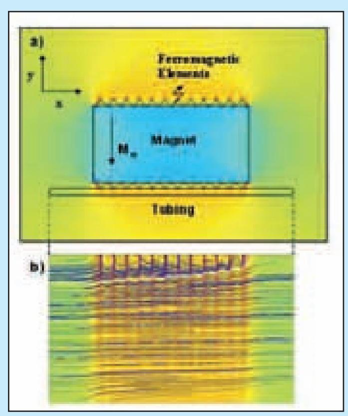


Fig. 2 Schematic of the magnetic separator demonstrated, and typical magnetic drug carrier trajectories obtained from simulations as they flow through the tubing in contact with the magnet separator (b).

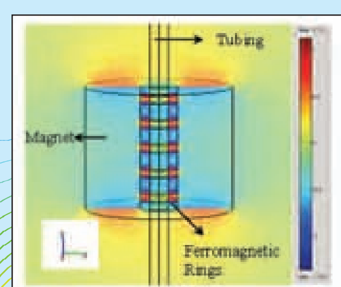


Fig. 3 Magnetic Separator design example 2 (3D), composed of a permanent donut magnet and ferromagnetic rings (inside the bore). The ferromagnetic rings used here are made of Fe/Fe alloys. The slice is on y-z plane and passes through x=0. The colors represent local magnetic field strength.

Linking the Properties, Microstructure and Chemistry of High Performance Materials

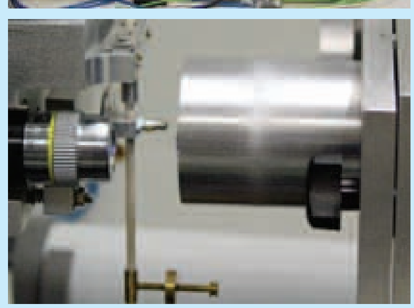
PROFESSOR TIN

Materials scientists and engineers are constantly seeking to develop novel new materials and improve upon existing ones in order to promote technological growth. For example, remarkable improvements in the performance and efficiency of advanced turbine engines for aerospace applications can be attributed to the integration of innovative materials in the high-pressure turbine or "hot stage" of the engine. Refinement of alloy chemistries combined with advanced manufacturing processes designed to control the grain structure of the turbine blade components have resulted in a ~1.4% reduction in specific fuel consumption. For a large commercial jetliner, such as a Boeing 777, this corresponds to a fuel savings of over 200,000 gallons per year and an annual 4 million pound reduction of harmful CO_2 emissions!

Professor Tin's research group is currently working on novel methods to develop new, stronger materials, and extend the temperature capability of high performance alloys for aerospace applications. In order to develop new materials or enhance the properties of existing materials, one first must understand the fundamental mechanisms that govern failure of the component. This requires detailed characterization of the microstructure and knowledge of the intrinsic behavior of the material. Linking the properties, microstructure and chemistry of high performance materials is extremely important as it enables us to devise engineering solutions to overcome inherent material limitations. Professor Tin is currently applying these principles towards the development of new Ni-base superalloys that will be utilized in ultra-efficient gas turbine engines like those on the Boeing 787 Dreamliner and Airbus A350XWB.

In collaboration with Professor Philip Nash and the research staff within the MMAE Department's Thermal Processing Technology Center (TPTC), Professor Tin has established a High Temperature Structural Materials Laboratory (HTSML) at IIT. Housed within the HTSML is a new MicroMaterials NanoTest platform capable of measuring critical mechanical properties, such as hardness and reduced modulus, corresponding to the discrete constituent phases present in the microstructure at temperatures up to 750°C. This NanoTest platform enables us to perform detailed characterization of the micro-mechanical properties of virtually any material on the nano-scale. This particular system possesses the ability to conduct nano-indentation tests at elevated temperatures and is the first system with this capability to be established in the U.S. The only two other systems with this unique capability are located within Europe. This system consists of a nano-indentation unit with a high temperature furnace for heating the specimen and separate heating system for maintaining the temperature of the diamond or sapphire tip. The system is enclosed within an environmental chamber (<0.01% O2) to prevent oxidation and environmental degradation of the indenter tip and specimen at elevated temperatures. It is also worth noting that the NanoTest platform is extremely versatile, and can be used to assess the mechanical properties of a wide range of materials (metals, ceramics, polymers, biological, etc.) and miniature MEMS devices. *Please refer to: http://mmae.iit.edu/profiles/faculty_tin.html and http://tptc.iit.edu/*

MicroMaterials NanoTest platform is contained within a temperature controlled environmental enclosure



Loads of 0.1mN to 500mN are used to assess the micro-mechanical properties of samples using a diamond-tipped nano-indenter