Vol. 2 Issue 2

MERITS OF PITTSBURGH

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Medical Robotics and Information Technology for Medicine and Surgery

Centers of Excellence for Western Pennsylvania:

- *Research*
- *Clinical Programs*
- *Economic Development*
- *Education*

In prior issues of this newsletter, we have focused on the robotics side of MERITS. In this issue, we turn our attention to the "IT" (information technology) side of MERITS. Medical information technology is far more than electronic sharing of information. And while that is a noteworthy and hugely important step in improving the efficiency and cost effectiveness of healthcare, it only scratches the surface relative to the promise of information technology in medicine. Accurate maintenance and instant transfer of patient records are pedestrian in comparison to assisting the clinician in finding and discerning important facts that may have a bearing on how he treats his patients. The modern clinician has a myriad of information sources available to him, many of which barely intersect his particular specialty.

Healthcare is all about making informed decisions; there are two phenomena that ironically make it both increasingly possible and increasingly difficult to make them. First, there is an explosion in the amount of data available to the healthcare and biotechnology communities. Growing federal and industry budgets for biomedical research mean rapid growth in basic, applied and clinical research results. In particular, the National Institutes of Health (NIH) will soon require that grant recipients make results of sponsored research publicly available. Second, the means to access biomedical data are becoming increasingly powerful and fast as repositories of biomedical data, published reports and libraries are available via the Internet.

What does this mean to the healthcare professional? Quite simply, here is an overload of data. All of these resources and channels, for the most part, increase the availability of data. But data is not the same as information. In many regards, the situation is only slightly different than it always has been: the biomedical professional must assemble data from multiple sources, examine it, decide what to believe and what to discount, draw their own conclusions and determine their implications.

So the biomedical professional needs techniques and technologies that help her make sense of all this available data – tools that provide her with information, not just raw data. In this issue, we present research that helps clinicians make sense of medical image data, a technology referred to as Computer Aided Diagnosis – tools that help the clinician understand what medical images actually mean.

Information technology is also a natural companion to medical robotics in the sense that the very tools and technologies that are part of the therapeutic or interventional regimen are also the means to acquire unambiguous, unbiased record of the therapy itself. For example, when surgeon uses navigation and image guidance to make a procedure more accurate, the very technologies used for preoperative planning and intraoperative guidance create a complete record of how the patient was treated. Coupled with postoperative evaluation, and across multiple patients, this provides the surgeon the means to evaluate the process itself and use that information to improve her technique.

Having both the motivation and expertise to forward these and other new forms of medical information technology, Pittsburgh is in a great position to establish leadership in the area.

"Pursuing perfection in healthcare through innovations in robotics and information technologies for medicine and surgery."

News

2002 Awards

Anthony M. DiGioia III, M.D.

- Pittsburgh Business Times, 2002 Health Care Hero Finalist, for achievement in the category of Health Care Innovation & Research
- Pittsburgh Innovators Honor, Pittsburgh Magazine
- Maurice E. Muller Award for Excellence in Computer Assisted Surgery, 2nd Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Funding

1. Carnegie Mellon's Medical Robotics Technology Center received an equipment grant from the Health Resources and Services Administration to enable research in computer-assisted surgery, rehabilitation, medical-imaging informatics and micro-medical technologies, as well as other infrastructure enhancements to facilitate collaborations.

2. Carnegie Mellon and Allegheny-Singer Research Institute (ASRI) have received a grant entitled "Cancer Informatics: From Molecules to Clinical Outcome." Yanxi Liu, research scientist in robotics, Takeo Kanade, the U.A. and Helen Whitaker University Professor of Computer Science and Robotics, are co-principal investigators on the segment of the grant, "Semantic-based Biomedical Image Informatics." Dan Farkas, professor, University of Pittsburgh Medical Center and visiting principal research scientist of robotics at Carnegie Mellon, will lead the research focused on "Novel Optical Imaging Technology for Cancer Analysis."

3. Cam Riviere (Carnegie Mellon) and Marco Zenati, M.D. (UPMC) received a grant from the Pittsburgh Foundation to develop robotic tools for minimally invasive surgery on the beating heart. They will prototype a miniature mobile robot capable of traversing the heart surface and doing vascular interventions.

4. Damian Shelton, a Carnegie Mellon Ph.D. student in medical robotics received a fellowship from the Whitaker Foundation.

5. Led by Prashant Kumta (Materials Science and Engineering), a collaboration among Carnegie Mellon's Bone Tissue Engineering Center (BTEC), the Institute for Complex Engineered Systems (ICES) and Materials Science & Engineering (MSE) entitled "Ink Jetting of Nanostructured Matricies for Controlled Gene Delivery" received funding through the National Science Foundation (NSF). The goal is to design and develop a novel biomimetic extracelluar matrix (bECM) that incorporates 3D spatial distributions of plasmid DNA (pDNA) bound to non-viral, high-efficiency, nanoscale calcium phosphate carriers. The nanoscale calcium phosphate (CaP) carriers are referred to as NanoCaPs. The bECMs will be manufactured using a novel ink-jet printing process.

6. Branko Jaramaz (CAOS) received a grant from the Pittsburgh Tissue Engineering Inititative (PTEI) for work on "Image Guided Decompression and Bone Grafting in the Treatment of Osteonecrosis of the Femoral Head.

7. CASurgica, Inc. was awarded a Phase I, Small Business Technology Transfer (STTR) grant from the NIH for work on "Ultrasonic Registration of Knee Anatomy to MRI Images." The project is also being supported through a grant from the Albert B. Ferguson, M.D., Orthopaedic Fund of the Pittsburgh Foundation.

8. Bonecraft, LLC received PTEI's first Senior Management Fund Grant. Vin Jannetty has joined Bonecraft as full-time chief executive officer.

MERITS of Pittsburgh

Research

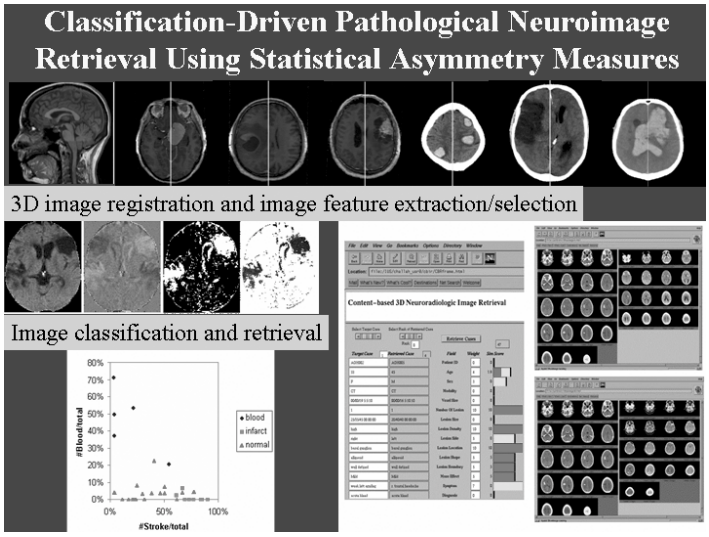
Biomedical Image Technology Lab

Dr. Yanxi Liu and her research team in the Medical Robotics Technology Center of Carnegie Mellon University work in the interdisciplinary area of computer vision, pattern recognition and statistical learning for the sake of biomedical image analysis, interpretation and understanding. The common thread in their research is finding semantic structures in biomedical images: discriminative, unambiguous, objective meanings that reveal underlying physical causes.

Discovering hidden patterns requires a) creative image feature extraction methods and b) effective feature space reduction approaches. Liu's team has developed new discriminative "subspace induction" methods that maximize discriminative power with reduced dimensionality. They have applied these methods to challenging real-world biomedical image sets, including:

Project #1 - Image content-based indexing and retrieval for large, 3D pathological neuroimage databases

They have developed a robust algorithm to automatically find the brain's midsagittal plane from normal and pathological CT and MR images. With respect to this plane, a large set of statistical brain asymmetry measures can be collected, forming an initial image indexing feature space. Using machine learning methods the feature space dimension is reduced 5- to 10-fold, while the classification rates are improved 5% to 29%. Their results demonstrated, for the first time, that statistical brain asymmetry distributions can be used for pathology classification, indexing and retrieval in neuroimage databases. An extensive study is being conducted now where various types of image features are extracted from volumetric neuroimages

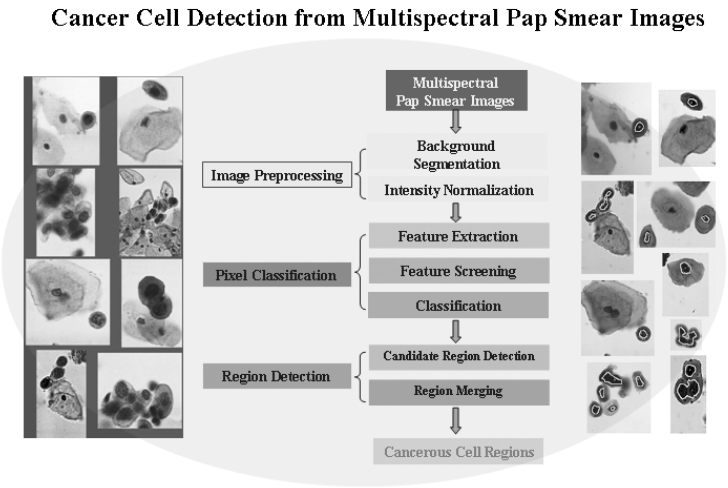


Top row: automatically extracted midsagittal planes from pathological neuroimages.
Middle left: brain asymmetry image feature extraction
Bottom left: pathology distributions in 2D
Bottom right: A JAVA user interface of an semantic-based 3D Neuroimage Retrieval System.

to distill the most discriminating feature subset for image indexing and retrieval.

Project #2 - Cancer cell detection from multispectral microscopic images

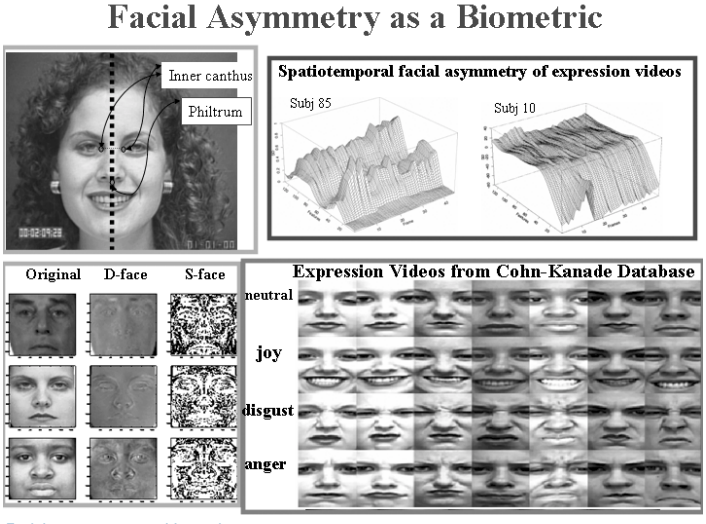
Finding abnormal cells in Pap smear images remains a "needle in a haystack" type of problem: tedious, labor-intensive and error-prone. Liu's team developed a bottom-up methodology for pixel-level to region-level image classification using multispectral Pap smear images with wavelengths ranging from 400 nm to 700 nm. Nearly 10,000 image features were examined, and nearly 4,000 spectral and texture image features were computed to locate a feature subspace of less than 50 dimensions. Importantly, the cancer cell detection system achieved a true positive classification rate of 97.6% with less than a 1% false positive rate on an initial test set of 150 cells. Currently, in collaboration with local pathologists, Liu's team has begun a series of quantitative validations for cancer cell screening with higher levels of difficulty.



A hierarchical structure for multispectral Pap smear image screening. Input (left): multispectral Pap smear images, Output (right): Pap smear images with labeled cancerous regions

Project #3 Facial asymmetry quantification

Biometrics – the statistical study of biological phenomena – is currently receiving a great deal of attention in security and defense applications. In her investigation of statistical facial asymmetry as a biometric, Liu's findings show that the asymmetry measure of automatically selected facial regions captures individual differences that are invariant to facial expressions (smiling, frowning, etc.). Combining these asymmetry features with other methods results in 38% to 100% improvement rates in identity classification accuracy. Facial asymmetry quantification is also used for evaluation of joy expression of paralysis patients. Liu and her collaborators won First Place in the Clinical Science Category and the Best Paper overall at the Combined Annual Conference of the Robert H. Ivy and Ohio Valley Societies of Plastic and Reconstructive Surgeons for their work on "Measurement of Asymmetry in Persons with Facial Paralysis."

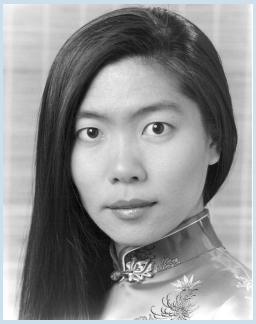


Facial asymmetry as a biometric.

Liu has been and will continue establishing many close collaborations with area hospitals and with the fast-growing biomedical informatics industry.

Biography

Yanxi Liu



Dr. Yanxi Liu received her undergraduate education in Beijing, China, in the fields of physics and electrical engineering. She obtained her Ph.D. in computer science from the University of Massachusetts (UMass) at Amherst. Before joining the faculty of the Robotics Institute at Carnegie Mellon in 1996, Liu was an assistant research professor at the computer science department of UMass Amherst. She has recently completed a textbook on Symmetry Groups and Its Application in Robotics Assembly Planning, which will be published by Marcel Dekker.

Liu's research interests in biomedical image understanding and analysis expand into several different applications, including: human brain asymmetry analysis, pathological (physiological or psychological, e.g. schizophrenia) neuroimage discrimination and biomedical image database applications, deformable volumetric registration between pathological or pediatric brain images and a statistical digital atlas, automatic learning of discriminating image features in microscopic, endoscopic and multispectral images for cancer screening and cancer staging evaluation, and facial asymmetry quantification for human identification and facial paralysis patient recovery evaluation.

In collaboration with University of Pittsburgh, Liu is leading a Carnegie Mellon team supported by an NIH National Cancer Institute grant under the Unconventional Innovation Program to work on "Non-Invasive Optical Imaging in vivo for Early Detection and Advanced Diagnosis of Cancer." Liu, jointly with a team composed of researchers from AGH, UPMC and Carnegie Mellon, received a (Tobacco) grant from the Pennsylvania Health Department to work on "Cancer Informatics: From Molecules to Clinical Outcome" with a focus on "Semantic-based Biomedical Image Informatics," specifically for lung cancer causal network analysis.

MERITS of Pittsburgh Internship/Fellowship Program

ICAOS and the MRTC have many graduate and undergraduate students working on various research projects year round. The labs also support a minimum of 3 to 4 summer interns per year. Each summer intern is assigned projects to work on during their time in the lab. These assignments include the areas of code writing, programming and mechanical design. MERITS faculty play an active role in advising the students.

This summer, the MERITS of Pittsburgh interns have come from places as far as Orange Park, Fla., as well as our own back yard. MERITS of Pittsburgh is proud to acknowledge the hard work that these students have contributed this summer. Here are examples of what some of our interns worked on this summer.

Aaron Cois, a fifth-year bioengineering and computer science major at Pitt, explains his summer work, "I am working in Dr. George Stetten's research lab, developing image analysis software as a part of the National Library of Medicine insight Toolkit, with graduate student colleagues Robert Tamburo, Damian Shelton and Wilson Chang. Our project focuses on image analysis using medial-based features, as well as the development of the Toolkit as a whole."

Matthew DiCicco, E'03, a Carnegie Mellon mechanical engineering student from Flanders, N.J., says, "I am spending the summer constructing a lightweight orthotic exoskeleton to be used by handicapped patients to aid in performing useful every-day tasks such as pointing, grasping and pinching. Along with construction of the exoskeleton I will be working with EMG sensors to control the device from the patient's latent muscle signals."

Matt Fagan, HS'04, a Carnegie Mellon philosophy student is working on virtual reality for rehabilitation. "Our goal is to develop rehabilitation procedures for patients who have suffered a stroke or debilitating brain injury. Many times, these patients do not move within a range of motion that they easily could, or they do not exert forces that are well within their capacity. Our research looks into whether we can use a virtual environment to encourage patients to exert more force than they think they can do."

Bernice Ma, CS'04, spent her summer working on the Ultrasound Registration Project. She designed a user-interface that would allow the user to calibrate a tracked ultrasound sensor. She also wrote a "testing" application that allow the user to take multiple images of any surface and display the curves to the user that is able to be manipulated using mouse interactions. Lastly, she wrote code that performed coarse registration between CT and ultrasound data and used the registration to display CT slices based on the ultrasound probe.

Do Hyun Jee, CS'03, spent his summer working on software to manage data related to implant files. He also completed range of motion studies.

Hooman Radfar, a computer science graduate from the University of Pennsylvania, now a Carnegie Mellon School of Computer Science graduate student, worked on computer-based planning of 2D digital x-rays.

Jim Strathmeyer, CS'03, spent his summer working on software for the pre-operative planner for total knee replacements (TKR), as well as writing code for slicing a bone. He will continue working with MRCAS throughout the school year on the work on the ACL project.

Tawnie Thiessen, CS'03, a Carnegie Mellon computer science student from Orange Park, Fla., describes her summer: "I just finished working on improving an algorithm to automatically find landmark points on 3D surface models of a femur. Currently I'm working on implementation of a virtual tracking server. This allows you to manipulate trackers (small objects that the camera can recognize) and locate them with a camera in a 3D representation, without needing an actual camera or trackers."

Upcoming Events

2003 ORS 49th Annual Meeting
Feb. 2-5, 2003
New Orleans, La.
www.ors.org

2003 AAOS 70th Annual Meeting
Feb. 5-9, 2003
New Orleans, La.
www.aaos.org

Computer Aided Surgery around the Head CAS-H
February 27- March 1, 2003
Interlaken, Switzerland

Workshop: Augmented Reality in Computer Aided Surgery ARCS
http://cranium.unibe.ch/CAS-H/ARCS

1st Annual IEEE EMBS Special Topic Conference on Neural Engineering
March 20-22, 2003
Capri, Italy
www.dartmouth.edu/~makay ne2003.htm

4th Annual IEEE EMBS Special Topic Conference on Information Technology Applications in Biomedicine
April 24-26, 2003
Birmingham, United Kingdom
www.mis.coventry.ac.uk/biocore/itab2003

First Annual Less and Minimally Invasive Joint Reconstructive Surgery (Fact and Fiction) "MIS Meets CAOS" Symposium
May 31, 2003
Pittsburgh, Pa.
www.mismeetscaos.org
info@mismeetscoas.org

International Robots & Vision Conference, also the site of the 2003 International Symposium on Robotics (ISR)
June 3-5, 2003
Rosemont (Chicago), Illinois
Conference attendees are looking for practical solutions to their automation challenges, as well as an opportunity to learn more about the latest trends in technology in the robotics and machine vision industries.

www.roboticsonline.com/public/calendar/

CAOS 2003
June 18-21, 2003
Marbella, Spain

Pittsburgh Bone Symposium
Jeff Hollinger
August 19-21, 2003
Pittsburgh, Pa.

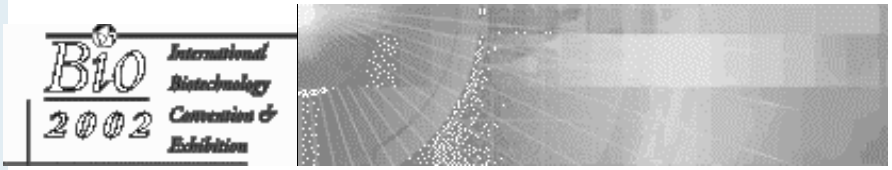
25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society
September 17-21, 2003
Cancun, Mexico
http://itzamna.uam.mx/cancun

Also check out:
www.meritsofpittsburgh.org/links/conferences.html

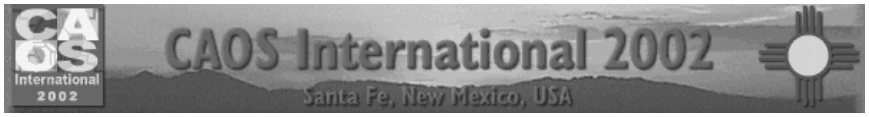
www.cmu.edu/biotech/

www.health.pitt.edu/Webcalendar

Updates



Last June Toronto hosted the world's largest biotech convention. More than 15,500 participants from 52 countries took part in the four-day conference, which included more than 1,000 exhibitors and speakers discussing everything from science and medicine to business development, ethics and religion. Pennsylvania was represented in force, and MERITS exhibited as part of the Pennsylvania Pavilion team. MERITS is looking forward to BIO2003 scheduled to be held June 22-25, 2003, in Washington D.C.!



The second annual meeting of the International Society of Computer Assisted Orthopaedic Surgery took place last June in Santa Fe, N.M. Following this great convention, a CAOS Surgical Academy was held at the Sweeney Convention Center. The society's goal is to serve as a forum for the exchange of information from investigative and clinical nature, as well as to bring together individuals who are interested in the computer-based technologies for orthopaedic surgery. A total of 285 people were able to see and hear presentations on topics such as: Hybrid Reality Visualization, Total Joint Replacement and Osteotomies.

Carnegie Mellon Biomedical Engineering Department "Launch"
September 17, 2002
This event included an education panel "Biomedical Engineering Education for the Real World," tours of the Medical Robotics Lab & BTEC, as well as a research panel on "Biomedical Engineering Research for the Real World."

University of Pittsburgh: Science 2002, Synergy in Science
September 18-19, 2002
www.science2002.pitt.edu
MERITS participated in this celebration of science, which focused on research under way in our community that is not only interesting and important but relevant to our regional economic development.

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