Success Story

"Medical imaging is computationally intensive, and the need for more detailed visualization continues to be a significant issue in our research. SGI was superior in both areas, so choosing SGI hardware was an easy decision."

—Dr. Aly Farag,
Professor,
University of Louisville

The Challenge

- Create a facility in which professors could use advanced visualization to teach computer vision and its uses and assist in concentrated research efforts in the fields of computer vision and medical imaging
- Develop an advanced visualization solution that would facilitate highly complex computational and graphics (3D modeling) projects

The SGI Solution

- SGI® Reality Center™ technology
- A 24-CPU SGI® Onyx® family system with R10000® microprocessor
- A 40-CPU Silicon Graphics® Onyx2® system with R12000® microprocessor
- ImmersaDesk self-contained large-scale visualization system

The Result

- SGI Onyx family systems have enabled significant strides in medical imaging, specifically in creating 3D models used to assist surgeons during actual procedures and in research projects to advance medical education
- SGI Reality Center technologies have been instrumental in securing research grants and other funding

Thinking in 3D

University of Louisville and SGI Add New Dimensions to the Academic Landscape

Using supercomputers and advanced visualization to inspire students to turn their two-dimensional world into a 3D learning experience is priority one at the Computer Vision and Image Processing (CVIP) Lab on the University of Louisville campus. In fact, the CVIP Lab envisions its teachings as one day becoming a permanent part of the university's curriculum.

The CVIP Lab was established in 1994 to teach computer vision and its uses and to assist with the university's research efforts. Computer vision is a set of computational techniques aimed at estimating or inferring the geometric and dynamic properties of the 3D world from digital images. Today, under the direction of Dr. Aly Farag, professor of electrical and computer engineering at U of L, the CVIP Lab carries out its mission with concentrated research efforts in the fields of computer vision and medical imaging.

Some innovations in computer vision taking place within the CVIP Lab include developing vision systems that create and use 3D models to assist in projects ranging from reconstruction of the human jaw to vehicle navigation. Other projects involve creating large-scale visualization for modeling and simulations of physical systems and applications in virtual reality.

The CVIP's medical imaging successes are equally fascinating and include building a functional model of the human brain for research in learning, aging, and dysfunctions, as well as creating miniature vision systems to assist surgeons during endoscopic surgery.

SGI® high-performance computing power and SGI Reality Center technologies have been the driving force behind the CVIP Lab from the very beginning. Dr. Farag and his colleagues chose SGI hardware after touring various academic institutions in the U.S. and abroad. According to Farag, "The research labs that required high-speed computing and advanced visualization were relying on SGI hardware to further their research efforts and they were very satisfied with the results they were seeing. High-speed performance in these two areas was, and still is, very important to the CVIP Lab. Medical imaging is computationally intensive, and the need for more detailed visualization continues to be a significant issue in our research. SGI was superior in both areas, so choosing SGI hardware was an easy decision."

> *"SGI high-performance computing and visualization capabilities have been instrumental in advancing the CVIP Lab's computer vision research and the department's education efforts."*
>
> *—Dr. Aly Farag, Professor, University of Louisville*

Leading the Way at CVIP Lab

Dr. Farag, who has been with the University of Louisville since 1990, is also the founder of the CVIP Lab. During his tenure, SGI high-performance computing capabilities have enabled Farag to make significant contributions in the areas of active vision system design, volume registration, segmentation, and visualization. Among the most notable contributions are those in the following areas of research:

- Image segmentation looks to classify the content of 2D images and 3D volumes. In the case of image-guided neurosurgery performed on brains that have experienced trauma injury, image segmentation begins with neuroimages acquired through an MRI or CT. If performed manually, the surgeon then selects, by hand, points of interest on the image that will create an outline of the area to be segmented. This painstakingly slow process must be repeated for each image scan. The images are then overlaid to create a 3D image. Dr. Farag's use of the Silicon Graphics Onyx2 system at the CVIP Lab is helping to automate the segmentation process and reduce the time for segmentation from hours (sometimes days) to minutes or seconds.

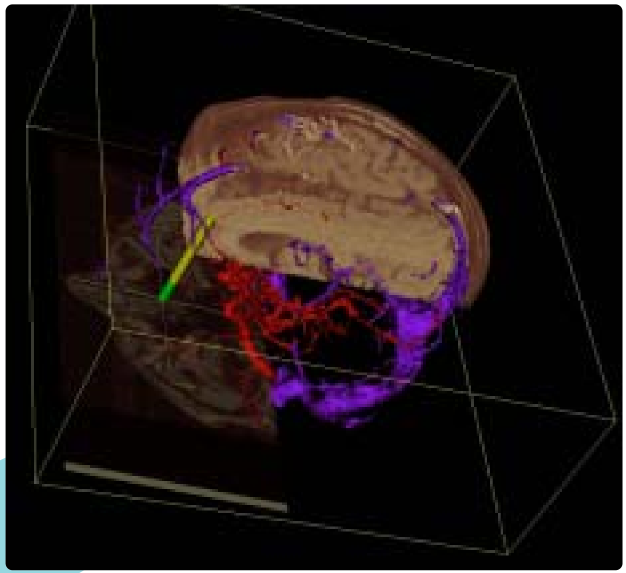
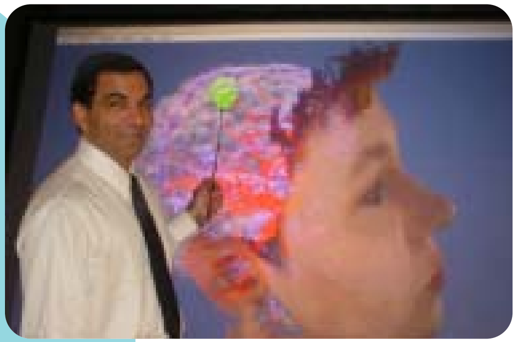


Illustration of registration of the vascular tree (extracted from MRA and MRV scans) on an MRI stack. This is used for building a detailed model of the brain.



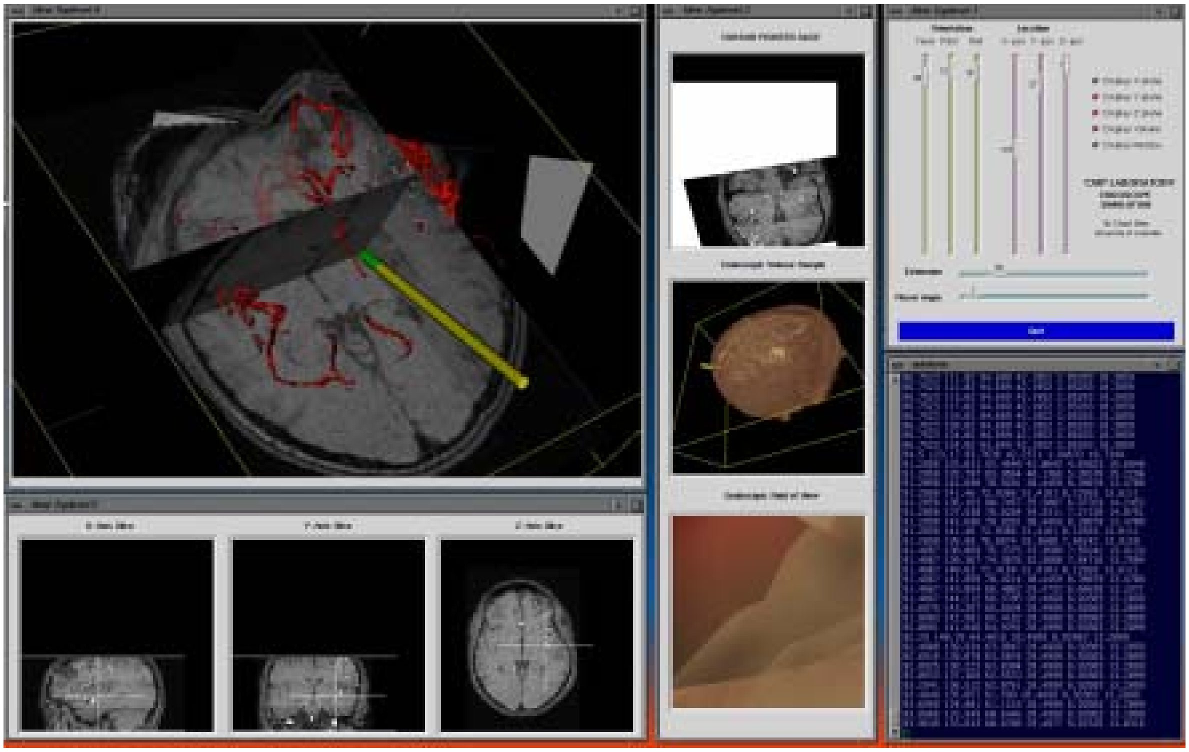
Dr. Farag illustrating a display of a 3D volume formed by MRI, MRA, and laser scanning.

Segmentation and registration of multimodality images (CT and MRI) to form a detailed 3D model of the head.

- Surface registration is used to determine the correlation between common attributes shared by two different data sets, such as CT and MRI. A technique called multimodal volume registration precisely aligns the attributes to create a single image. Fast and accurate registration of images is essential during the preprocessing stages of neurosurgical procedures. Dr. Farag and fellow researchers are looking for ways to advance neurosurgeons' ability to quickly and accurately incorporate preoperative CT or MRI volumes with MRI volumes taken during the actual surgery.

- 3D volume and surface reconstruction is extremely useful in building 3D models of spatial environments. One such system designed in the CVIP Lab to create 3D models using surface reconstruction is called CardEye, a (patent-pending) trinocular vision system. The main components of CardEye are three cameras mounted on a frame, a laser range finder, and a structured light-pattern generator. Working together, the lenses and light mimic the workings of the human neck and vision system—including functions such as pan, tilt, roll, vergence, and iris control, plus auto-zoom and auto-focus—to capture the spatial data that is used to create 3D surface reconstructions. The CardEye system is capable of object recognition and object tracking and can be used in robot navigation.

The University of Louisville CardEye active vision system designed by Dr. Farag to generate 3D models of various objects using combination of laser, optical, and structured light sensors.



Layout of virtual endoscopy system to be used for minimally invasive surgery. Pre-operative MRI and CT scans are used to create a calibrated 3D model of the head. Images of the endoscope are registered with respect to the 3D model. Knowing the location of the endoscope, proper registration of the 2D images of the endoscope to the 3D model will create a way to navigate through the brain, which can be used to visualize the progress of the minimally invasive surgical procedure.

"In each instance," Dr. Farag said, "SGI high-performance computing and visualization capabilities have been instrumental in advancing the CVIP Lab's computer vision research and the department's education efforts. One of our main goals is to continue to advance the technological achievements of the lab and evolve computer vision to the point that it becomes a permanent part of the university's curriculum. We also envision our research projects, specifically medical imaging, as being key contributors to the advancement of surgical capabilities at Louisville-area and other hospitals."

"The volume registration research that we use to develop 3D medical images is, computationally, very demanding ... you must also have a graphics engine that can quickly render the images available for display. The SGI systems are ideally suited to perform in both of these areas."

—Dr. Aly Farag, Professor, University of Louisville

Inside the CVIP Lab

Dr. Farag's funded research projects and initiatives have had a positive impact on the CVIP Lab and the entire U of L research infrastructure. The CVIP Lab is home to two SGI supercomputers and a host of other SGI systems. SGI supercomputers currently in use at the lab are a 40-CPU Onyx2 system with an R12000 microprocessor and a 24-CPU Onyx® family workstation with an R10000 microprocessor. Advanced visualization output is viewed in 3D using stereographic glasses on ImmersaDesk, a self-contained, large-scale visualization system from FakeSpace Systems.

CVIP Lab presentations may be viewed both on and off campus. The lab currently has a direct link to U of L's Medical Center and the Belknap and Health Science campuses, as well as Louisville's Jewish and Norton hospitals.

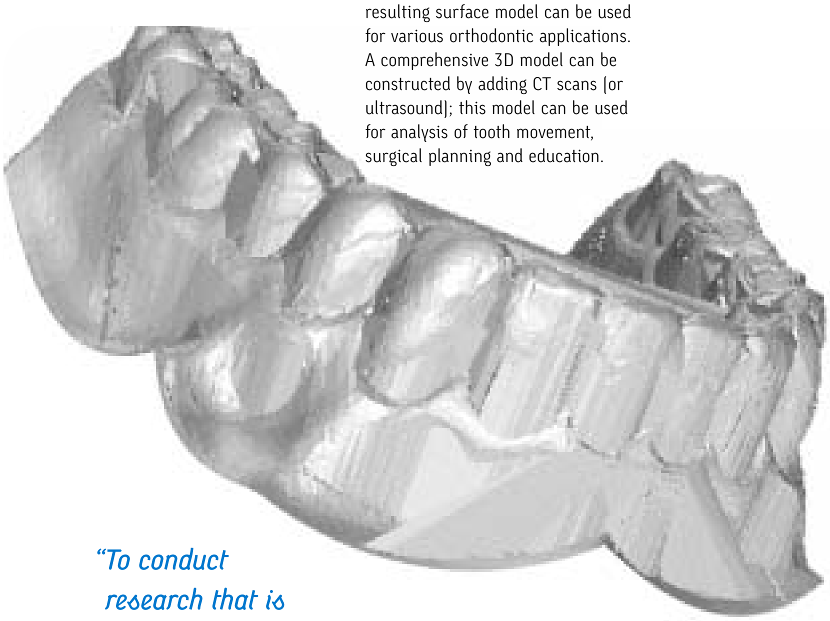
"SGI hardware is our adopted vehicle for computing and visualization." said Dr. Farag, "The volume registration research that we use to develop 3D medical images is, computationally, very demanding. A 3D volume registration created from a CT scan or an MRI scan are two examples of 3D medical images. When the two volumes must be fused together to create a single 3D volume registration, the computational requirements are further magnified. At this point, you must also have a graphics engine that can quickly render the images available for display. The SGI systems are ideally suited to perform in both of these areas."

As an example, Norton Hospital, located in Louisville, is working with the CVIP Lab to send preoperative CT and MRI scans from the hospital directly to the Onyx2 supercomputer at the lab. The Onyx2 system uses the raw data to create 3D images and immediately send them back to the hospital for viewing on an SGI workstation located in the vicinity of one of the operating rooms. Research currently being conducted by the CVIP Lab is helping the hospital move closer to its ultimate goal of merging preoperative scans with those taken during actual surgery, thereby enabling surgeons to track the progress of surgical procedures in real time.

CVIP Lab Projects

The CVIP Lab is a hub of constant activity. Among the biomedical research projects currently under way at the lab are:

- Image-guided, minimally invasive surgery: Dr. Farag and his team are developing a system to help neurosurgeons locate and visualize, in realtime, the tip of the endoscope and its field of view during minimally invasive neurosurgical procedures. The goal is to map 2D endoscopic video images to corresponding positions on a 3D model of the human brain constructed from preoperative MRIs and integrate a 3D position sensor into the tip of the endoscope to help determine the camera's focal point. Together they would allow neurosurgeons to determine the exact position of the endoscope during actual surgery. In addition, the team is building a 3D brain phantom that will allow testing of various minimally invasive procedures.



The Jaw Project at the CVIP Lab. Video imaging is used to construct the upper and lower jaw. The resulting surface model can be used for various orthodontic applications. A comprehensive 3D model can be constructed by adding CT scans (or ultrasound); this model can be used for analysis of tooth movement, surgical planning and education.

"To conduct research that is above and beyond what is expected, and to use the equipment purchased by one grant for other subsequent projects, SGI supercomputing power and visualization technologies have proven to be an invaluable means to an end."

—Dr. Aly Farag, Professor, University of Louisville

- Human jaw reconstruction: Dentistry requires the accurate 3D representation of the teeth and jaws for diagnostic and treatment purposes. Dr. Farag and fellow researchers are looking to create a computer-model-based vision system for dentistry that will replace traditional, less accurate means of diagnosis (visual examination and assessment, x-rays) and enhance treatment planning, surgical simulation, and prosthetic replacement. The system uses an intraoral video camera to reconstruct a 3D model of a patient's dental occlusion. Using a modified shape from shading technique, Farag extracts 3D information from a sequence of 2D images of the jaw. Data fusion and 3D registration techniques are then used to develop the complete jaw model, followed by the creation (via rapid prototyping) of a solid 3D model. The value of such 3D modeling would be significant in performing various dental procedures, including implants, tooth alignment, and craniofacial surgery, and have wide applications in dental education and training.

These and other ongoing research efforts conducted at the CVIP Lab using SGI Reality Center technologies have boosted the lab's visibility in the eyes of academics, researchers, medical professionals, and the engineering community.

CVIP Lab Project Funding

During his tenure at U of L, Dr. Farag has written more than 15 successful grant proposals. In the past six years, Farag has attracted over $4.4 million of funded research from the National Science Foundation (NSF), the Department of Defense (DoD), the National Institutes of Health (NIH), the Whitaker Foundation, and private organizations.

"To be successful at securing adequate research and educational funding," said Dr. Farag, "an institution must meet several basic requirements. First, you must have the expertise to carry out the research. Second, your proposal should be within the focus areas of the institution that you represent. Third, you must show that you have the infrastructure to carry out your proposal. Our proposals have continually fallen within these parameters."

An additional component of securing research funding that has benefited the CVIP Lab has been what the NSF, NIH, and similar funding organizations refer to as "added value" research—the ability to continually produce findings and results that go beyond what is proposed and/or expected. "To conduct research that is above and beyond what is expected, and to use the equipment purchased by one grant for other subsequent projects, SGI supercomputing power and visualization technologies have proven to be an invaluable means to an end," said Dr. Farag.

The Lab of the Future

Moving forward, Dr. Farag will continue to expand the role that computer vision plays in the lives of his students and colleagues and, ultimately, make it a standing component of the curriculum at the University of Louisville. "The goals for the CVIP Lab are ongoing and always evolving, We have the support of the university to pursue our agenda, and we will continue to work with SGI technologies to enhance and improve our computer visioning and advanced visualization capabilities," stated Dr. Farag.

sgi®

Corporate Office
1600 Amphitheatre Pkwy.
Mountain View, CA 94043
(650) 960-1980
www.sgi.com

North America 1(800) 800-7441
Latin America 1(650) 933-4637
Europe (44) 118.925.75.00
Japan (81) 3.5488.1811
Asia Pacific (65) 771.0290

3349 (12/03/2002) J14080