

SEAS Robotics Lab Develops Computer Vision, Imaging Systems

Devices Can Sense and Move Objects

SEAS researchers are developing computer-controlled devices that can sense, manipulate, and understand their environment, devices that will become the household and industrial robots of the future.

The work is being done at the General Robotics and Active Sensory Perception Lab, directed by Dr. Ruzena Bajcsy and Dr. Samuel Goldwasser. Dr. Richard Paul, an eminent researcher in the field of robotics who recently joined the SEAS faculty, is also now involved in this research.

Bajcsy and Goldwasser and their colleagues are working on both the hardware and software to build intelligent robots that will be able to sense and adjust to their environment. In the future such robots would be able to do delicate jobs both in the workplace and in the home, such as sorting and testing parts on an assembly line, remotely pinning a vehicle or setting the dinner table.

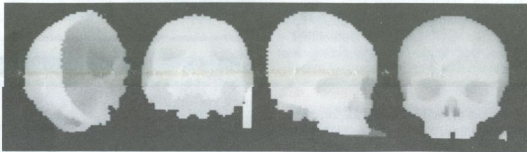
In addition to its use in robotics, their software developments have led to new types of 3-D computer imaging. (See the related story.)

"The robots commonly used in industry perform very specific and limited tasks under programming that is almost totally fixed," said Bajcsy. Such a robot would make a disaster of a simple household task that required flexibility, such as setting a dinner table.

However, the SEAS robotics system will enable some robots to distinguish, for example, a coffee cup from a wine glass or a soup bowl and then pick up each with the appropriate grasp.



Dr. Ruzena Bajcsy (left) and Dr. Samuel Goldwasser have developed robotics systems that use cameras and a tactile sensor to identify objects by vision and touch.



The computer stacks series of CAT, NMR or PET scan pictures into 3-D images that can be manipulated to aid in medical diagnosis and surgical planning.

Since there are a variety of grasps, the particular one used by the machine will indicate whether the object was properly identified.

Bajcsy explained that developing a computer vision system required a thorough understanding of how humans see and that it was necessary to study what researchers in psychology, physiology, and other fields have learned about human vision.

The robotics system she and her colleagues have developed has a computer database containing images of real world objects. Each object, such as a cup or a bowl, has been reduced to its most fundamental and unchangeable characteristics; the difficult part was eliminating the non-essential characteristics while keeping everything that is vital to the object's identification.

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3-D Images Can Be Used in Diagnosis

In addition to its work in robotics, the SEAS General Robotics and Active Sensory Perception Lab is developing advanced computer imaging systems to help in medical diagnosis and surgical planning.

The computer systems process and enhance standard medical imaging devices such as X-rays and CAT scans. They are designed to find narrowing coronary vessels; to identify body structures, such as those in the brain, that cannot be identified by other means; and to create 3-D images of a person's skull or spinal column that can be rotated and sliced open for better views.

In one project a series of CAT, NMR or PET scan pictures is taken in collaboration with Dr. Martin Reich of the Cardiovascular Research Center of Penn's Medical School. The computer systems then stack the individual pictures into a 3-D image that a diagnostician can manipulate. For example, a 3-D image of a skull can be displayed on a computer screen and using the computer keyboard, it can be rotated in any direction for a variety of views. The 3-D image can also be electronically sliced open to reveal internal structures.

Since the various components of the body show up in different shades of gray, the computer can isolate such things as bones and skin or tumors. These can also be manipulated to show their relationship to surrounding tissue and veins.

"This kind of technology has just become available," said Dr. Samuel Goldwasser, who along with Dr. Ruzena Bajcsy directs the lab. "Systems of this sort are being used experimentally. Our system is fully interactive and manipulates images in real time. Any new view requires less than 1/15 of a second. It probably is the fastest system of its kind."

In other systems, there may be a delay of twenty seconds or longer from the time the move instruction is given the computer until the image actually moves on the screen. That makes precise manipulation of the image difficult.

"The advantage to real time motion is that it gives certain depth cues, and you can gradually adjust it to see certain structures. For example, you can rotate the image of a spinal column to see down the spinal cord. You couldn't adjust it that accurately if there were a twenty second or even a one-second delay in the image movement," said Goldwasser.

The imaging system could be used not only in the diagnosis of tumors and other medical problems, but also in surgical planning; for example, in facial reconstruction. Using an electronic scalpel, a surgeon could model a face on the computer screen first.

The SEAS researchers are working on other enhancements to the system.

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\$4.4 Million Given SEAS for AI Research

A \$4.4 million, three-year grant to establish a center for computer artificial intelligence research was awarded recently to SEAS by the U.S. Army Research Office.

The money will be used for artificial intelligence research areas already being investigated in SEAS labs and will be used to purchase equipment, to support faculty and professional staff, and to fund graduate student fellowships.

The Army Research Office has an option to add another \$2.8 million to extend the grant an additional two years and to bring the total funding up to \$7.2 million over a five-year period.

The total funding for artificial intelligence research at SEAS is now at least \$12 million for the next five years. The new award will complement a recent \$3.8 million National Science Foundation grant and will be used for expanding research in two primary areas:

- Interaction between man and machine to make computers easier to use with natural language, formal language, and graphic interfaces.

- Interaction between machine and its environment to make more flexible computers and robots that can learn from and adjust to their environment.

Dr. Aravind K. Joshi, Henry Salvatore Professor of Computer and Cognitive Sciences, said that about \$1.3 million of the \$4.4 million will be used for equipment, including sophisticated work stations for natural language work, and specialized hardware for graphics, computer vision, and robotics. The balance of the money will support faculty and professional staff and about twenty-six graduate student fellowships during the three-year grant period.

"The grant is extremely important in terms of equipment and support for graduate students," said Joshi. "We will be able to attract the best students because the fellowships are so distinctive. We will be able to add faculty. The professional support staff will also be good, and their salaries will be close to industry levels. To mount a substantial research effort, you need substantial resources."

Penn already has ten faculty members engaged in artificial intelligence research; some of their specific research areas are:

- Better natural language systems for computers that would not presume the user has the same view of the knowledge base as the system's own view.

- Better artificial computer languages, graphics interfaces, and interfaces that combine natural language, computer language, and graphics and that would allow the user to pass from one to the other depending on which is most useful.

- Improved computer and robot recognition and manipulation of three-dimensional objects. Improved computer vision combined with other forms of sensory input, especially sound and touch. Development of natural-language, query-driven vision systems.

- Computer simulation of work situations that allow the user to specify and modify the configuration of the work stations and the procedures of the people and robots who work in them. ■

Rather than have the computer compare a perceived object to every image it has stored, they designed software that enables the computer to compare the perceived object to a small field of representations in its data bank.

In addition to the software developments that have provided the brains for the robotics system, the researchers have also come up with innovative hardware designs for vision and tactile sensing.

The robot vision system consists of two TV cameras with motorized zoom, focus and iris controls, mounted on a motorized platform and combined with a lighting system. This allows the computer the same flexibility that a person has to view an object from several angles, move closer to it or change the lighting on it.

"The camera will move to a particular point and take a picture," said Goldwasser. "The program will analyze it and determine whether or not the picture contains the object the computer is interested in. If not, the camera will move to another place and look for it."

"If it is the object the computer is interested in, the computer might zoom in closer or adjust the angle of view

slightly. Most of those adjustments are already under computer control; the camera's zoom, focus, and iris controls will be added shortly."

A unique aspect of the project is that the robotic vision is combined with tactile devices—a mechanical hand and a sensor that is shaped like a rigid finger.

The finger, which is mounted on a robot arm, contains 133 pressure-sensitive sites covered by a conductive foam. It can be used to trace the shape of an object, determine its surface texture, and find cavities in it, such as the hole and handle of a cup.

If the computer were searching for a cup and found a cylindrical object that appeared to have a handle on its side and a hole in its top, it could use the finger to determine whether the apparent handle and hole were real or just shadows. (It could also change the lighting or angle of view to accomplish the same task.)

Once an object has been identified, the computer can use a specially designed mechanical hand to grasp the object properly—an easy task for a person but a very difficult one for a machine—and then to manipulate it. ■

tem, such as a higher-resolution image, interaction using a 3-D tracking ball (similar to, but more complex than, the 2-D type used in computer games) to replace keystrokes as the image manipulation control, and a system that would allow the user to manipulate many imaged objects independently of one another.

Two other imaging systems are under development in the lab. An "expert" system is being developed to automatically find narrowing coronary vessels that can cause heart disease.

This type of diagnosis is currently done by taking an X-ray, adding dye to the system and taking a second X-ray. By subtracting the two images, the things that don't change over time should be eliminated and changes in intensity picked up. A radiologist would then read the image and make a diagnosis.

The computer system uses the same X-ray subtraction system. It has one "expert" system that understands anatomy and a second that understands image processing. It compares the information it "sees" in the image to its database and makes a diagnostic decision.

The other imaging system is for identifying body structures that cannot be identified by other means.

In this system a 3-D atlas of brain structures is put into the data bank, and the system tries to match the objects with which it is presented to the structures in its atlas by stretching one over the other like a piece of rubber.

Anomalies such as tumors or injured regions in the brain can be isolated because the system will be unable to match these with the atlas reference database even after deformation.

"Ultimately," said Goldwasser, "These three technologies—the interactive 3-D display, the image processing expert, and the anatomy atlas—will be integrated into a 'medical workstation,' creating a system with unparalleled computation power and sophistication." ■