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## Inexpensive Technology Is Providing Vision to Machines

By JOHN MARKOFF

It has been 36 years since an experimental robotic arm poured punch on itself during a cocktail party at the Stanford Artificial Intelligence Laboratory. At the time, the Stanford computer scientists had a good laugh at the expense of their hapless waiter. Its overworked processor had fallen behind the pace of its primitive vision system.

Giving machines the ability to "see" is an endeavor that has evolved considerably since then — most famously, perhaps, in the case of the Sojourner exploratory craft that guided itself over the surface of Mars in 1997.

And now, across town from the scene of the failed punch bowl experiment, a former Stanford graduate student's company, Tyzx is working on computer-vision technology that is meant to be sufficiently sophisticated, but inexpensive enough, to find its way into everyday applications.

Examples might include an inexpensive swimming pool alarm system that would see when small children wandered too near the water and alert their parents. Or a video game that might permit two people to simulate a boxing match, remotely.

And with public security a pressing concern these days, surveillance systems capable of spotting suspects in a crowd might be of interest to law-enforcement agencies — whatever the Big Brother issues.

"We are able to do three-dimensional imaging quickly and cheaply and at very low power," said Dr. John Woodfill, 42, a computer scientist who is a co-founder of Tyzx and who has been working on the technology since 1990, when he was a graduate student.

Like other companies intent on finding commercial applications for machines that can see, Tyzx (rhymes with physics) is benefiting from the inexorable trend of ever-cheaper, increasingly powerful silicon chips.

"Real-time 3-D vision systems have been something the computer vision field has been dreaming about since the 60's," said Eric Grimson, a computer scientist at the Massachusetts Institute of Technology. "It's taken a long time to get there."

At the Tyzx lab here, a small group of researchers is putting the finishing touches on an inexpensive system that yields striking real-time three-dimensional images.

A series of round colored dots on a workstation display screen slide in a ballet across the monitor — a synthetic computer-generated view from the top down of a group of five people who are moving around the room.

A separate window shows a side view of the same room and a third presents a view from the front.

If two of the people in the system hug one another, the Tyzx system can correctly track each individual when they separate.

The Tyzx vision system is based on stereo vision — two closely spaced inexpensive video cameras linked by a high-speed data channel to a custom processing card in a standard personal computer. The company is in the process of shrinking the entire system onto a single chip, an advance that would potentially bring real-time stereo vision to the masses.

The Tyzx advance has caught the attention of some of the nation's most respected computer-vision researchers.

"Stereo vision is conceptually a very easy problem, but it is computationally very intensive," said Takeo Kanade, an electrical engineering professor at Carnegie Mellon, who is a widely acknowledged pioneer in machine vision.

In 1995 a group of researchers working with Dr. Kanade fitted a minivan with a computer-vision system that enabled robotic controls to do virtually all the driving on a trip from Pittsburgh to San Diego. Dr. Kanade said he was impressed that the Tyzx researchers had refined the stereo-vision problem and driven down down the cost by integrating all the functions onto a single semiconductor chip.

Tyzx's approach to machine vision is implied in the four letters of the company's name. In computing a digital image, T represents time, X and Y represent height and width, while Z represents depth. In the Tyzx system, depth perception is created by comparing two images and calculating the precise shift in a particular pixel — or picture element — in each image.

The real trick is in comparing the two images and locating the identical pixels reliably as the images whiz by as fast as 132 stereo frames a second. To accomplish this, the Tyzx researchers embed highly evolved software algorithms, or mathematical formulas, in their chip.

Once the same pixel is located in each image, factoring in the physical separation of the two cameras makes it possible to generate a 3-D image, with a resolution that can discern objects and spaces a single millimeter in size.

This level of performance requires the chips to complete the equivalent of 50 billion operations a second, and data must flow from cameras to processor at 220 million bits a second — computing capabilities that only a few years ago would have required a supercomputer.

After leaving Stanford with a Ph.D. in computer vision in 1992, Dr. Woodfill went to work as a consultant at SRI International, the research center in Menlo Park, Calif., that is legendary for its pioneering work in machine vision in the 1960's. From there, Dr. Woodfill moved in 1993 to Interval Research, a computer research-and-development center in Palo Alto founded by Paul Allen, the Microsoft

co-founder, and David Liddle, a former computer scientist at the Xerox Palo Alto Research Center.

Subsequently, Interval sued SRI, accusing it of misappropriating Dr. Woodfill's software designs. The suit was quietly settled, and neither SRI nor Interval executives would comment on it. But several people with knowledge of the technology said that the software had made its way into prototypes of a Mars vehicle designed by SRI.

Currently, Tyzx is looking for commercial applications that will help pay for continuing to shrink its technology. Uses like detection of shoplifting might be possible.

Consumer marketers might also find uses, which is why some privacy-rights advocates are warily monitoring advances in computer vision. One such group is the Electronic Privacy and Information Center, an advocacy group in Washington that has been campaigning against the use of surveillance cameras.

Using Tyzx's system, called 3D-Aware, it might be possible, privacy-rights people fear, for merchants to track customers as they walk through stores and amass all sorts of potentially intrusive information about them.

"The question," said Marc Rotenberg, director of the electronic privacy group, "will always be who's behind the lens?"