Beautiful vision

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Professor Roberto Cipolla of Cambridge University rotates a cardboard model of a ship's hull a few degrees. With a slow, fluid motion, a robotic arm swings forward and simulates a weld on the complex model as the youthful, bespectacled Mr. Cipolla narrates the action in the hushed voice of a golf commentator. A camera on the arm refocuses, and the arm moves again to make its weld at the exact same spot. Mr. Cipolla is clearly excited by what he sees. This apparently mundane task actually represents a major leap forward -- a robot that can see.

A leading researcher in the field of vision and robotics, Mr. Cipolla built the robot, a prototype of a machine that will be used at a Danish shipyard, with a team of researchers at the Speech Vision and Robotics Group laboratories in Cambridge, England. The robotic arms, cameras, and computers pose a stark contrast to the medieval quadrangles outside.

Artificial vision is enabling robots to do things that were impossible for them just a few years ago. Scientists have built seeing robots that can drive cars and buses, play badminton, put out fires, and pick up objects for handicapped persons. And many more applications, especially industrial ones, are now becoming possible as a result of artificial vision.

Early robotic vision systems were expensive and provided very limited visual acuity. With the recent dramatic drop in the cost of components, however, along with faster silicon chips that have enabled these systems to process the vast amounts of data necessary for sight, researchers have made several key advances over the past three years. Perhaps the most important of these is that robots can now see and react to objects in three dimensions. "What has prevented robots from doing many of these things was that they could not sense, and the most important sense is vision," says Mr. Cipolla.

Since the '80s, robots have performed repetitive tasks for the automotive industry. But the "seeing" robot has several advantages over its forerunners. A digital camera that can recognize a 3D object in space relays messages that allow the robotic arm to make last-second adjustments -- such as when a part has shifted slightly in transit -- and still make its weld in the proper place. Older-generation sightless robots could only perform programmed tasks in highly structured environments; moving a robot just an inch to one side would have resulted in misplaced welds on hundreds of cars.

"We have made a major step forward, but we have only scratched the surface," says Mr. Cipolla. The researchers' next goal is to enable a robot to recognize and react to an object without having to feed it the computer-aided design of the part, he says. This way the robot can teach itself to weld or assemble almost any object.

On the other side of the Atlantic, researchers at several universities are making great strides with advanced vision systems. For example, researchers at the University of Maryland are using innovative 360-degree cameras on robots that may soon be used for military applications, such as in unmanned spy vehicles or rescue operations (see "Calculated Risks"). And researchers at Carnegie Mellon have been experimenting with using 360-degree cameras to pilot helicopters by remote access. Yet so far the complex actions of a human helicopter pilot have proven too difficult for programmers to emulate.

Until recently, machine vision had only limited applications and was extremely expensive. But with cheaper components, especially PCs and digital cameras, the cost of producing a robot with artificial vision has dropped by a factor of ten over the past five years, falling from $50,000 to less than $5,000 for a basic unit. As a result, several robotics companies are now able to afford these systems, and many more applications are being considered.

New computer technologies using simple digital cameras have also made vision systems more versatile -- for example, enabling them to operate in any kind of ambient lighting. In addition, faster processors have made managing the large amounts of data required by vision systems feasible on a standard PC. "The combination of falling prices and technological advances is making more applications possible," says Steven Gordon, president of Intelligent Automation Systems, a leading producer of seeing robots. Because of 3D vision research, for instance, industrial robots can perform many more functions.

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Machine vision is particularly suited to measuring and inspecting industrial and high-tech components, because the visual cues passed to the robot's computer brain are actual 3D coцrdinates. Intelligent Automation is using its 4DI imaging system to build an application for aircraft engine manufacturers that allows them to inspect turbine blades. These vision systems are able to make the minute measurements turbine blades require. Machine vision is superior to human vision because it is more accurate, and machines can make the measurements much faster. According to Mr. Gordon, the 4DI system can complete its measurements in 20 seconds; the same task would take an employee using a handheld measuring device more than 30 minutes.

Artificial vision is also helping robots perform more mundane tasks, such as assembling cookies or icing cakes. But it is the rapidly expanding number of applications and the falling prices that are leading to impressive growth in the market for seeing robots. "The fastest growth is in the semiconductor and electronics industries," says Charlie Duncheon, senior vice president of sales and marketing at Adept Technology, a supplier of advanced robot systems. Robots are particularly well suited to building electronics, as the components are difficult for human hands to manipulate.

Vision is also enabling robots to operate in environments they could not have functioned in before. Moreover, these sight-enabled robots are easier to set up than their predecessors. "Previously, the implementation of a new robot required a team of computer scientists and engineers for calibrating and programming in order for it to perform properly," says Mr. Duncheon. This has allowed for far greater acceptance of robots in new industrial applications, he adds.

While the number of machine vision units sold in North America increased by 29 percent in 1999, the falling prices of the units meant that the revenue generated grew only 6 percent, to $1.68 billion, according to the Automated Imaging Association. The AIA predicts that the North American market will grow to $5 billion by 2003. Analysts predict even faster growth of this market in Asia due to the region's burgeoning electronics industry.

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Researchers and producers agree that this is a watershed time for robots because of the advances in artificial vision. But it has been a long time in coming. "One of the problems was that robots did not live up to the promises of the '70s and '80s," says Mr. Cipolla. The problems that scientists have encountered over the past few decades were much more complex than they had originally anticipated. Many of these problems were due to the fact that robots could not sense their environment. As a result, many universities and private investors became disenchanted with the potential of robotics, and funding subsequently declined.

As prices continue to come down, acceptance of sighted robots in non-industrial applications is likely to grow. "This is a wonderful time for us old-timers in robotics," says Mr. Duncheon. "In the '80s, it was the exception to the rule that robots would be considered in a particular role; now it has become an exception when they aren't."

With improved vision, perhaps robots could some day even perform household chores like vacuuming the rug or cutting the grass. "The new robots can move within their environment without running over the household cat," says Mr. Duncheon.

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