Kiva Systems' automated guided vehicle (AGV) robots, which can move individually or in multi-vehicle "swarms," pick up shelving units, which are movable racks, at a distribution center.

THE ROBOT REVOLUTION

Talk about culture shock. Advancements in artificial intelligence and more powerful, yet affordable, technology are moving robots out of enclosed environments and integrating them into the workforce.

BY STEPHANIE NEIL

Robots are going where no man has gone before. They rove around Mars and explore the ocean floor. They even dig under debris looking for survivors after a catastrophic event. Now, robots are beginning to do something that until this point has been unimaginable: interact with human beings.

Dubbed human-centric robotics, the stage of robot development now upon us will be life-changing, observers say. Robots will assist physicians in surgery, act as personal attendants to the elderly, and become an extension of human workers on the factory floor.

"If you take the paradigm from the medical room to the shop floor, it's the same," says Bruno Siciliano, professor of control and robotics at the University of Naples, Italy, and co-editor of the *Springer Handbook of Robotics*, published in May. "Robots can extend human dexterity. So it's not about replacing humans with a machine, but getting close to the machine to do something together."

This is very different from the traditional view of deployment that has kept robots isolated in separate work cells.

"The new, advanced industrial robot will share the working environment with the user," Siciliano says. "This is a revolution compared to the use of robots behind fences."

There are a number of reasons that robots are beginning to break out of the cages that have contained them for so many years. First, a new set of safety standards is defining how a robot can be deployed as an integrated part of the factory — not as a separate entity. Second, price reductions in computing power, vision systems, and sensor technology make the investment more affordable for even small and medium-sized businesses. To that end, programming these complex machines and integrating them with other control technologies are becoming easier. And third, artificial intelligence and probabilistic algorithms are allowing robots to learn repetitive tasks. Robots are getting smarter, and, as a result, they are becoming a more important part of manufacturing.

New robot makers, such as Seegrid Corp. and Kiva Systems, are emerging in the area of automated guided vehicles (AGV) and applying multi-processing computing, workflow algorithms, and on-board intelligence, for example, which allow robots to operate in multi-vehicle "swarms" or even to move individually on their own around a warehouse or office.

Meanwhile, traditional robot vendors, such as FANUC Robotics, are building small-footprint systems that can handle smaller payloads used in new applications such as mixing test tubes. And these same vendors are finding new uses for their big system models in the industrial setting.

"We are at a tipping point. A lot of the things that people have been talking about for a long time we are starting to see," Claude Dinsmoor, general manager for controller product development at FANUC Robotics America, says, referring to developments such as integrating safety control with robot function; running machine vision natively within the robot, which eliminates the need to synchronize communication protocols; and integrating the robot into the industrial network.

Adding more functionality into the robot, itself, lowers the cost and simplifies the robot by using one control program rather than switching between programs. "The technology is reliable, cheap, and now we are going from 'wouldn't it be nice' to 'when can I do this because the technology [is ready] for industrial applications,' " Dinsmoor says.

More eyes are on robots as a way to rejuvenate manufacturing in America. FANUC Robotics, for example, has launched an initiative, called "Save Your Factory," that highlights the use of robots to cost-effectively manufacture product in the United States while maintaining high quality.

"There is a focus on the health of manufacturing in this

Photos courtesy: Kiva

country," says Jeffrey Burnstein, executive vice president of the Robotic Industries Association. "We are hearing about companies sending manufacturing overseas because it is cheaper and it is the only way they can compete, but we don't believe that. We believe it is cost-effective to produce a product in the U.S., and there are a lot of reasons for that."

Some of the reasons stem from the potential loss of intellectual property, shipping costs, and the need to control quality, Burnstein says. Keeping manufacturing in the United States or even moving it back to the United States is feasible and cost-effective. "Robots are a critical part of the equation," he says.

Indeed, while pundits like Siciliano see the potential for robots and humans to work together, some people see robots as a way to solve the workforce shortage — or in some cases, the workforce expense.

"The new, advanced industrial robot will share the working environment with the user." — University of Naples' Siciliano

Take Evergreen Solar, a solar panel manufacturer that, under a joint venture with a German company, will be using 100 robots between its German plant and a new plant being built in Massachusetts.

Without robots, "we couldn't compete," says Peter Kane, a principal engineer for Evergreen Solar. "If we couldn't automate [the movement of solar panels], the labor cost would kill us ... and we'd have to move everything to China."

Evergreen Solar is a good example of a company in a growing industry that is beginning to make use of robots. Robots have always been associated with the automotive industry, and, indeed, that is still where most robot sales go. But there are signs that things are changing.

According to the RIA, North American robot sales rose 24% in 2007, a reversal of the 30% decline in 2006. While the majority of growth is a direct result of the cyclical buying patterns in automotive, other industries are finding ways to use these mechanical companions. Although orders to non-automotive markets accounted for just 36% of all orders, RIA saw a 16% increase in sales to life sciences/pharmaceutical/biomedical companies, and an 8% rise in sales to food and consumer goods companies.

RIA is aggressively targeting industries such as food, medical, pharmaceutical, and even plastics, and trying to educate companies on robots' productivity potential through case studies and tutorials that outline business justifications and practical applications. "Education is key," Burnstein says. "A lot of companies are not aware of what is possible with a robot, or they may not be aware of the successes that companies are having using robots."

THE REPLACEMENTS

One of the biggest business issues confronting companies now is retiring baby boomers.

"There is a great concern in our company that within the next five to seven years, we'll be seeing a fairly significant labor shortage," says Pete Rector, executive vice president of Genco, a third-party logistics provider that runs distribution centers for large CPG companies such as Unilever.

Genco has 37 million square feet of distribution space in North America and is trying to figure out how to operate warehouses in the future with fewer people. The company is tackling the problem in two ways: refining processes by training workers in Six Sigma disciplines that ensure that workflow is efficient, and increasing productivity through the use of technology — specifically, robots.

Robots, Rector and other Genco executives decided, could offset the unproductive travel time that occurs when a forklift driver is moving pallets and products from one end of a building to the other. But it can't be just any robot. It has to be flexible — a term not typically associated with these mechanical creatures.

AGVs, which are moving robots, have always relied on special tapes, wires, magnets, or lasers that keep them on a track. The problem

A mind of its own? Seegrid's autonomous robots can interpret their surroundings and move independently.

Photos courtesy: Seegrid, Bruno Siciliano

is they are very inflexible, and track and workflow process changes can cost hundreds of thousands of dollars. About a year ago, however, a new company entered the scene. Seegrid, a company with an idea that originated in the labs of Carnegie Mellon University, created an autonomous robot that can interpret its surroundings and move on its own.

The technology includes a vision system that takes pictures of the environment and software that interprets and models the surroundings. The robot first learns about its environment from a human, who leads it down the specific path it needs to go, and instructs it to perform certain actions at points along the path, such as stop and pick up a pallet. The information is stored in memory — basically a computer hard drive — which enables the robot to move down every aisle or path it has been instructed to travel.

The current versions of the Seegrid robots, which include the model GP8, a motorized pallet jack, and the GT3, which can pull carts (replacing a forklift, for example), can travel 15 miles and store more than 10,000 paths in memory. In the future, as computing power rises, these robots will be able to travel 30 miles and understand hundreds of thousands of paths, the company says. "Our goal is to create an autonomous robot that can think, see, and move on its own," says Greg Cronin, Seegrid's executive vice president.

Of course, the robot is not thinking, Cronin concedes; it just reacts to paths defined by humans. But as probabilistic algorithms increase with computing power, robots will start to perceive the environment better and interact more with humans and with other systems.

"Most robots don't interact with the environment because in classical industrial applications of the 1980s, robots were nothing more than pre-programmed automated machines used to execute repetitive tasks without any adaptability," Siciliano says. However, using cameras, range finders, sophisticated software, and sensors — or even artificial skin — for tactile perception, robots will soon become more human-like.

"The modern robot is a customizable robot which the worker can use as a tool," Siciliano says. For example, a robot could be taught to handle a pair of scissors for cutting fabric. While some early work is under way, a robot's ability to manipulate objects requires a high degree of sensory fusion coupled with artificial intelligence, which is still a bit futuristic.

For now, flexible robots are used in warehouses, but even that is a big step forward, as they are finally cost-effective.

Seegrid's autonomous robots can travel 15 miles and store more than 10,000 paths in memory.

"Robots have been used for a long time to assemble cars. There are a lot of things that make a robot cost-effective for building a $35,000 car, but not cost-effective for moving pallets of laundry detergent," Genco's Rector says. As the technology has evolved, and become affordable, it has put robots within reach of companies that are finding new applications.

"There is certainly a place where robotics can perform tasks that don't need to be done by people, such as the repetitive moving of [products] from point A to point B that doesn't take a lot of skill," Rector says. "Robots can do that and leave the things that require skill to humans."

Another new AGV vendor is tackling the warehouse with swarms of robots. Five-year-old start-up Kiva Systems has created a massively parallel processing material handling system that uses robots working collectively to

perform complex tasks. For example, hundreds of Kiva "bots" can work together to help warehouse operators fill more orders per hour. Rather than individuals roaming the warehouse and reaching for products on shelves, the robots bring products to a stationary worker standing at a picking station. In its largest deployment, a swarm of 500 Kiva bots are picking up shelving units, which are movable racks, at a distribution center for office retailer Staples, Kiva officials say.

Working in the 802.11 wireless spectrum, each Kiva robot includes on-board intelligence that communicates with a server system. The systems respond to workflow algorithms, which can, for example, predict which items will be ordered simultaneously, or automatically sort and re-slot items so that seasonal or popular products are easily accessible.

More important, the Kiva system is designed for the average user. "There is a lot of sophisticated programming, but it is packaged up in an appliance," says Mitch Rosenberg, Kiva's vice president of marketing. And while the technology is interesting and important, "the workflow is the magic," he says, as it is what coordinates hundreds of robots to reliably and safely navigate together.

SAFE TRAVELS

Safety has always been a worry when it comes to robots, as there is a risk of injury if one crosses paths with a six-axis robot arm that won't stop for anything. That's why Evergreen Solar keeps its ABB flex picker robots and Adept SCARA robots away from people. "We avoid, at all cost, people being anywhere near these things," Evergreen Solar's Kane says. "They are dangerous."

However, there has been progress made in safety. In the AVG arena, both Kiva and Seegrid have configured robots to stop if something crosses their paths. And for traditional pick-and-place robots used in assembly, standards organizations are working on ways to enable robots and people to work closely together.

FANUC Robotic's Dinsmoor is helping to define a new ISO-sponsored standard, ISO 10218-1, that would move safety control into the robot — rather than as a separate controller — and would refine how the robot operates, how fast it travels, and the floor space it uses. The standard would also pave the way for emerging industrial robot technologies, such as wireless teach pendants, collaborative robots, and simultaneous motion, for which the standard outlines safety guidelines. A draft of part 2 of the standard is due this summer, and this could be the dominant standard within the next year or two, Dinsmoor predicts.

Similarly, robot control is increasingly becoming integrated with other systems. Seegrid, for example, is exploring how robots can interact with manufacturing execution systems and warehouse management systems.

Meanwhile, Rockwell Automation has designed a system that integrates robot and motion controllers with software and custom function blocks needed to incorporate a robot into an application. The Kinetix Integrated Motion solution incorporates kinematics technology, which links different coordinate systems — for example, robot and motion control. In this scenario, Rockwell's Logix programmable automation controller (PAC) is used with delta robots, which are small, three-arm systems that move light loads short distances. The robots, also known as spider robots, work well in picking, sorting, packing, and palletizing applications. While it's not a free-moving system, the safety issue must still be addressed.

"One of the benefits of having control of the robot in Logix control is that it uses the same safety solution," says Bob Hirschinger, Rockwell's product marketing manager for Logix motion. "It also has common drives and motors and common I/O." Customers have been demanding integration of multiple control systems, Hirschinger says. And the number of industries using robotics is on the rise, which is why Rockwell, which is not a robot vendor, went down the path of tying robots together with main line control systems.

So what does all of this mean?

There is no doubt the technology is improving dramatically, and robots are finding their way into new applications. But more interaction with these automated — and sometimes autonomous — machines will require more education for their human counterparts. "The social and ethical implications of using and interacting with robots is more crucial [to understand] than any other technical field because of the physical and cognitive interaction between man and machine," Siciliano says.

This could, in fact, be a new level of culture shock. Soon, you could have a new workmate. And if you're working alongside a robot, you'd better understand what makes it tick. ■

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