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ESSENTIAL | FROM INCEPTION TO IMPLEMENTATION—I.T. THAT MATTERS

technology

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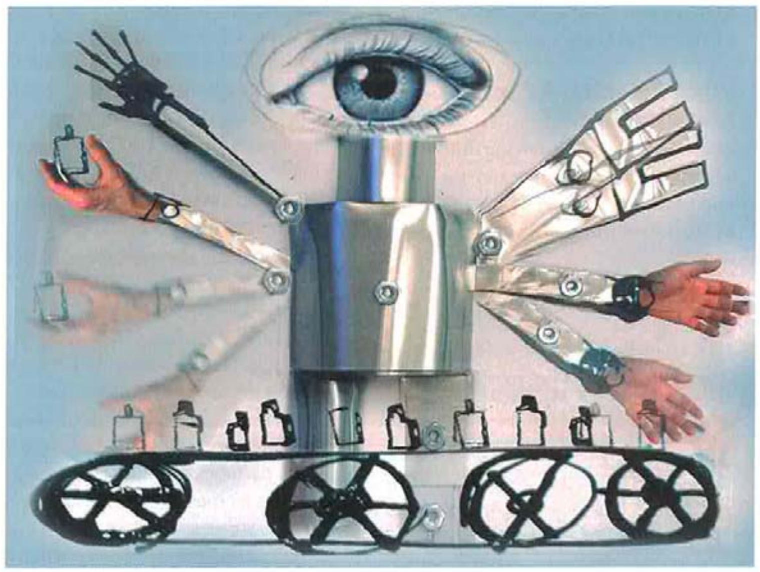

Machines that "see" parts on assembly lines, 3-D printers that prototype products in hours—let's take a look at adaptive manufacturing

Factories of the Future

BY FRED HAPGOOD

MANUFACTURING | When a new idea about manufacturing arises, a new crowd of players jumps into the game and manufacturing's technology rules change dramatically. In the first third of the 20th century, the philosophy of continuous flow and assembly line technology gave American industry an edge over the European industrial powers. In the last third of the 20th century, U.S. manufacturers got caught off guard by the rise of "lean manufacturing" and the war on waste.

Perhaps the next time one of these turning points appears, the U.S. manufacturing sector will leapfrog its competitors and make up ground lost over the past few decades. That next turning point may the emerging trend of adaptive manufacturing, manufacturing that morphs on the fly as companies respond to chaotic economic changes.

Consider this scenario: Sooner or later, the central banks of Asia—China, Japan, Hong Kong and Korea—will make the value of the U.S. dollar fall because they stop buying the currency or, worse, start selling.

This shift would be bad news for U.S. industries associated with imports, but export businesses—making or managing physical goods, not services—would fare better. They'd need new, 21st-century manufacturing infrastructure, dominated by informa-

ILLUSTRATION BY ANASTASIA VASILAKIS

tion processes and information management issues. A U.S. manufacturing revival would be managed by CIOs.

Already, today, manufacturing is becoming more about moving bits than atoms. Companies seeking greater manufacturing efficiency and greater competitive opportunity have much to gain from emerging technologies in adaptive manufacturing such as 3-D printing and sensor networks.

What's Behind Adaptive Manufacturing?

Several factors are driving interest in adaptive manufacturing and the rising importance of information management in manufacturing, as outlined by Eric

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Beinhocker in his recent book, *The Origin of Wealth*. One is an ongoing, if quiet, revolution in the way economists think about markets and economies. For most of the past century, markets were viewed as quasi-mechanical processes that ground their way to equilibrium, defined as the point at which supply and demand balance. Today, an increasing number of economists see markets as essentially chaotic: complex, nonlinear and as unpredictable as the weather.

Under the old theory, the job of managers was to tune the mission of the company to the equilibrium points. That was called defining a sustainable competitive advantage. The new theory abolishes that responsibility, since it is the essence of a chaotic economy that competitive advantages can vanish almost overnight.

The new idea: As a tool in business, managers should use natural selection—a law of nature that enables species to grow and progress in a landscape as chaotic as any economy. That means defining a portfolio of experiments appropriate to the available competencies of the organization, running these against the market, shifting resources according to outcomes, then exposing a new set of experiments to the market and so on.

Natural selection is not new to capitalism: Channeling investment into successful ventures is evolution at work. Many companies put out products and services with slight variations, like different flavors or colors, and shift resources to the variations that sell better. But adaptivity is much harder to achieve in industries that move physical goods. By their nature, such companies are wedded to long production runs

On-Demand Collaboration

"Competency rallying"—where companies come together to make up for manufacturing capability gaps and win a specific piece of business—is already working in Europe. Since 1996, one transnational manufacturing culture has utilized the concept, in a community set on Lake Clarence (also called the Bodensee) in the center of Europe, embracing parts of Germany, Switzerland and Austria. Dubbed the "Virtuelle Fabrik," the system involves precision machining and specialty manufacturing firms, whose clients might be a carmaker that wants a special steering wheel or a cell phone maker that wants a button.

The Virtuelle Fabrik provides a system for connecting market needs with the skills of all the participating firms (or at least a subset of the firms, depending on the project). When a customer approaches firm A with a concept, that firm can circulate the idea around the entire group. Firm A organizes the response from the point of view of getting a satisfactory product into the hands of the customer at a good price and in a short time.

According to Kevin Crowston of Syracuse University, who recently wrote a report on the Virtuelle Fabrik with Bernhard Katzy of the University of the Federal Armed Forces, Munich, the Fabrik was organized by using small teams to develop the basic rules of participation. Unnecessary duplications, like inspections each time a part crossed a firm's boundary, were identified and rooted out. Each guideline was voted on by all the project partners.

The result: More products flow more rapidly through the entire Fabrik. The increased product flow rate enhances the development of competencies within the Fabrik partners, effectively stretching the skill sets. Since firms know they can find partners for most of the functions in the productive cycle, some have been able to become super-specialists, raising the value of their services.

Katzy and Crowston point out that the future of such associations across the globe depends in part on whether CIOs can provide the tools needed to build trust and community across cultures.

A possible example of such a tool might be video walls—immersive videoconferencing in two or more offices in different parts of the world, left on continuously, so people could build relationships by chatting.

Recently, four other regions in Switzerland and Germany have organized manufacturing networks on the model of the Virtuelle Fabrik, Crowston reports.

–F.H.

and long-term design commitments (for example, Detroit's bet on the SUV). They tend to have highly centralized, bureaucratic, risk-aversive managements.

To do adaptive manufacturing, a company has to be able to crank out a mix of products that is in constant flux.

Getting there requires not only a new set of tools but also a new management structure and philosophy. Fortunately, CIOs, with their hands-on grounding in information management issues, are not strangers to the challenges of change management.

Assembly Machines That See

What kinds of technology will enable an adaptive manufacturing environment? Machine vision is an important example of the sort of technology that is converting manufacturing into an information-based process. Machine vision does not mean recording or registering a raw image, as a camera would, but recognizing the actual objects in an image and assigning properties to those objects—understanding what they mean. Vision in this sense makes every aspect of manufacturing—inventory, transport, tooling and assembly operations—much more efficient.

If a manipulator (like a paint gun) can recognize and adjust to the orientations and positions of parts in a bin or on a line, you do not need to pay for the design, construction and management of structures to hold those parts in fixed, stable positions. If a machine can recognize a part visually, you don't need to pay for affixing an RFID or stamping a bar code on every item.

A seeing machine can inspect not only the items flowing through it but also the objects and processes in its environment, potentially lowering the costs of maintenance and quality control.

This might sound fantastical, but machine vision is a real industry. The consultancy Vision Systems International pegs the total value of the North American market at around $1.5 billion. At present, the technology is used mostly for inspections, especially in the semiconductor and electronics industries, but improvements are coming rapidly. One of the newest applications is "servo vision": controlling the interaction of a tool like a paint gun with a line of continuously moving, swaying objects.

Vision represents the simplest way of programming the assembly of different sets of parts into many small runs of different product designs. Ed Roney, manager of the Robot Vision Group for Fanuc Robotics, based in Japan, points out that robots already use vision to assemble kits—to collect one list of items from a group of part bins, package them into kit A, then collect another list of items for kit B and so on.

The Chicago Museum of Science and Industry uses Fanuc robots with machine vision to let museum-goers design their own toy (a top), which the robots then build while they watch. As for using machine vision to build integrated products, Roney says vision and robots are used to build cell phones now, and robots are used in the assembly of many products, including pens and cars.

By late **2006**, the machine-vision market in North America had an estimated value of **$1.46B to $1.48B**.

SOURCE: Vision Systems Design

Prototyping in Hours, Not Weeks

In another example of a technology enabling adaptive manufacturing, desktop manufacturing, or 3-D printing (3DP), rapidly speeds up prototyping. This family of technologies makes it possible to produce a physical implementation of a 3-D CAD/CAM file in a few hours at most.

How does it work? A representative technique might be depositing a layer of powder on a flat surface and then spraying that layer with a liquid that binds the powder in a pattern defined by taking a slice of a CAD file. (Flour and water are enough to demonstrate the concept.) The printer moves through the stack of the layers or slices, laying down one on top of another. When enough layers have been deposited, you pick the object up, shake off the excess powder, and there you have your doohickey in glorious 3-D. Physical properties like color, strength and so on are controlled by using different powders, binders and "infiltrants" (chemicals that soak into the matrix).

Right now this industry is focused on

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making demonstration items (since most clients understand 3-D physical models better than blueprints). But 3DP is already playing a role in short-run manufacturing.

Typically, the first step in making a metal part is to make the tools required to make the part. (Sometimes you have to make the tools to make the tools to make the part.) Designing and fabricating these special tools is not cheap and takes time, but that's what you have to do if you need many thousands of copies.

For a smaller run, like a hundred or so, you can use 3DP to make the desired number of molds, then cast the parts in the molds instead of machining them. (As the chemistry of the process gets smarter, it will probably become possible to use 3DP to print metal parts directly, using metal powders.)

Tim Dodge, chief engineer at Dent Manufacturing, a specialty hardware shop, uses a 3DP from Z Corp. in just this way. Dodge says that a representative part of Dent's market is made up of architects and interior designers interested in designing custom hardware (like door knobs) for a specific project. In the old days, these orders required special tooling. Today, Dodge says the 3DP machine has sped up turnaround on such orders from weeks and even months to days.

More on Machine Vision

Go to the online version of this story at **www.cio.com/010107** for a link to the **AMERICAN ASSOCIATION FOR ARTIFICIAL INTELLIGENCE'S VISION PAGE.**

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Smart Sensor Networks

Both machine vision and 3DP sit inside the realm of ambitious new manufacturing technologies: high-resolution sensor and actuator networks. Sensors (accelerometers, thermometers and machine vision sensors) register changes in the environment; actuators (switches, motors, valves and 3-D printers) introduce changes. Any kind of manufacturing is composed entirely of these two functions.

> 3-D printing is already playing a role in short-run manufacturing. For prototyping, this technology lets you produce a physical implementation of a 3-D CAD/CAM file in a few hours.

The more actuators, the more points of control; the more sensors, the more focused and intelligent that control becomes. Network these devices, and you can exert that control from anywhere. Until recently, this last step required pulling wires through the factory floor, but wireless technology has improved, and CIOs will be more and more intimately involved with the deployment and organization of such wireless sensor networks.

The immense increase in flexibility allowed by technologies like sensor networks and 3DP makes it possible to incorporate new constituencies—managers, clients, business partners—more deeply in the manufacturing process. Making these collaborations work securely will also be the job of the CIO.

New World Collaboration

Adaptive manufacturing promises one other interesting challenge for CIOs: competency rallying. In the old days, manufacturing managers could take aim at a niche and either train their personnel to the skills or make appropriate long-term hires. The central argument of adaptive manufacturing is that we live in a world in which niches come and go quickly and unpredictably, and in that world companies can no longer count on having the time to grow the skill sets they might need.

The alternative is to develop a new and counterintuitive kind of collaboration, building short-term partnerships with companies that have the desired skills—even if those companies are, in other contexts, competitors. Conversely, you might "rent out" your company's core competencies to colleagues and competitors. (That's not an entirely new idea: For example, Caterpillar sells capacity on its logistics and distribution network to other companies.)

In this scenario, if you have only three of the five skills needed to attack a given opportunity, you do not need to pass: You can mobilize the other two from other industry participants. Kevin Crowston, professor of information studies at Syracuse University, says that what he calls "competency rallying" depends on high levels of information transparency and a tightly integrated culture.

In parts of Europe, some specialty manufacturing companies are already making it work. (See "On-Demand Collaboration," Page 44.) Crowston thinks that CIOs will be challenged to find ways to use technology to develop operating cultures that feel regional but are physically global.

When might U.S. CIOs face the adaptive manufacturing challenge on a large scale? This clock is not powered by technology issues but by economic incentives. Right now, the dollar is strong, and in that context it pays to import manufactured goods rather than make them. When the value of the dollar goes down, the U.S. manufacturing game will change. In the meantime, adaptive manufacturing technologies like 3-D printing and sensor networks have plenty of appeal for tactical problems of efficiency. CIO

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