Intelligent Stacking, Tracking and Packing

Warehouses are a blur of activity. Every day, they dispatch hundreds of packages and thousands of products. Advanced robotic and computer systems not only locate containers and stack boxes neatly on pallets; they also ensure that nothing goes astray.

If you’ve ever moved, you know what it’s like to pack up an entire household into countless identical boxes — and how long it takes before everything is finally in its proper place again. But beware. If the boxes haven’t been labeled properly, you can expect some major headaches! That’s when the bottle opener gets lost, and the screws for the kids’
bunk beds are nowhere to be found. But with hundreds of items to remember, mere mortals quickly lose track.

But for warehouse professionals, who have to handle thousands of articles in hundreds of boxes, packages and containers every day, things are obviously quite different. The pros can cope with chaos, not least because they are increasingly assisted by sophisticated computer programs and inventory management systems. Elevators whizz up and down towering shelving units. Muting to the choreography of computer control, they stack clothing, screws and large appliances such as washing machines onto pallets and into bays. The computer system records where everything is located. Different items are stored according to different criteria. For example, those in high demand are placed where they can be easily retrieved. Modern mail-order companies, such as Germany’s Otto and Klingel, have as many as five million articles in stock. Such companies can pack 5,000 parcels per hour, which are then dispatched to 5,000 different addresses. And it’s very rare that one goes astray.

**Seamless Positioning and Tracking.** In the final analysis, it’s the blanket use of bar codes that has made such perfect logistics a reality. Each product, each box and each pallet is given its own bar code containing product data, batch numbers and even address information.

Whenever goods enter or leave a warehouse, at forks or intersections in the conveyor system, the bar codes are automatically read by a laser scanner, just as they are at any supermarket checkout. In this way, sweaters or shirts on a conveyor belt can be assigned to a specific customer order, just as letters in a mail sorting center are allocated to a particular zip code.

In the most modern warehouses and shipping facilities, the bar codes once affixed to products have been replaced by devices called transponders (see *Pictures of the Future*, Fall 2002, p. 19). In contrast to bar codes, these new labels are read by radio and therefore work without any line-of-sight contact. And they are much less sensitive to physical damage. Individual items even report to the system of their own accord, thereby ensuring that they never get lost, a function made possible with special mini-transmitters developed by Siemens. The system, which is known as Moby-R, guarantees rapid positioning. Moby R’s transponders consist of a small data chip, a tiny antenna and a battery. At regular intervals, they transmit an individual radio signal in the microwave frequency range over a maximum distance of several hundred meters to a nearby receiving antenna.

**Chaotic Containers.** By calculating the propagation time of the signal, the central computer can automatically determine the precise location of an item, which might be, for example, inside a container in the middle of a massive shipping terminal. Every five minutes or so, the computer updates an on-screen graphic indicating the position of each container. “This means that containers can be stored using the same chaotic principle that is employed in the high shelving units of a warehouse,” explains Heinrich Stricker, head of business development for the Moby

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**PUTTING PANTS IN THE RIGHT BOX**

*Siemens Dematic and German mail order giant Klingel* have created the world’s first fully automatic packaging line. The system folds cardboard boxes, attaches labels, and sorts socks, sweaters and shirts with unerring ease. For a mail-order company, highly automated warehousing and vast shelving systems are only half of the story. Packaging is the other half, and here human hands are normally required. In conventional mail-order companies, the goods go to packaging tables, where employees first assemble boxes and then hand-pack socks, pants and skirts until the order is complete. It’s a process that’s sure to produce errors, and complaints are a certainty.

A powerful alternative is the fully automated packing and distribution line that was recently completed in Pforzheim, Germany, by Siemens Dematic, Klingel and Hamburg-based Pierau Planung. The new system is full of fascinating details. Whereas in the past cardboard boxes had to be assembled by hand, a machine now does this automatically and then slides the empty boxes onto a conveyor belt. The merchandise rides along the same belt and is then packed into the boxes at “hub stations.” There are about 100 such stations positioned along the conveyor belt, like parking lots on a busy thoroughfare. First a box is maneuvered into a hub station and lowered on a small platform lift. Then the contents arrive — shirts and pants, for instance. Thanks to bar code labels, the system knows which items have to be placed in which boxes. Once the box has been filled, it is dispatched one level lower onto a second conveyor. There, a catalogue, complimentary gifts and a printed invoice are also placed in the box. Finally, the box is automatically sealed, a bar code is applied and an address label attached. Regardless of the order in which the boxes roll along the belt, the computer is able to identify them by their bar codes. As many as 30,000 packages leave the new packaging line every day — which adds up to about 100,000 individual items.

“The major challenge involved in creating this new system was to link all the components with one another,” explains Wilfried Lampel, who is head of Mail Order systems and E-Commerce at Siemens Dematic in Offenbach. After all, it’s crucial that the various units — including box assembly, box identification, box sealing and invoice printer — should harmonize with one another, so that the end result is a perfectly packed and properly addressed package. Some 800 to 900 “packages” of information must be exchanged between individual stations in real time before a box has been fully packed.
Transponders, which use radio technology, can simplify supply logistics by enabling retailers to track goods all the way from delivery to the checkout counter. Here, the radio antenna is clearly visible on the label.

Automobile manufacturers and logistics companies have been using transponders for quite some time. Pilot studies show that these small chip-based labels are set to make inroads into our daily lives and will soon begin to compete with bar codes. Indeed, the advantages of transponders are so great that experts agree this technology has a great future. Unlike bar codes, transponders are both readable and writable without any line-of-sight contact, and they function even when they are dirty or have suffered surface scratches. Using transponders, containers, luggage and even letters can be tagged and then registered in a fraction of a second. The technology is known as Radio Frequency Identification — RFID.

The major obstacle in the path of large-scale application of RFIDs in retail environment is price. However, costs are falling — so much so, in fact, that one day mass applications will become a viable option.

Reading Hundreds of Labels Simultaneously. Siemens Venture Capital has been working with Australia’s Magellan Technology since early 2000. Magellan — one of the leading names in the field of mass transponder applications — has launched a system comprising various readwrite units plus a range of tags. The system is not only good value for money but also prevents signal overlapping. This is particularly important, as there are often problems in simultaneously reading a large number of transponders — for example, when they are bunched together in a pile of small components. To prevent the radio signals from overlapping and interfering with one another, Magellan uses a procedure known as frequency hopping, where the transponders change frequency at regular intervals. The read/write unit also simultaneously transmits and receives radio signals on several channels. This accelerates data transmission substantially, so that several hundred tags — as might be found in a box full of letters at a mail-sorting center — each located at a distance of approximately 50 centimeters, can be read simultaneously in matter of milliseconds. In fact, Japan plans to use transponders alongside stamps sometime in the foreseeable future.

Transponders in Department Stores. A recently completed pilot project conducted by Siemens Business Services and German retailer Kaufhof involved the use of some 20,000 transponders to label clothing. Kaufhof was interested to see if the new technology would help accelerate and simplify its transportation logistics as well as reduce the loss of goods. Siemens Automation and Drives provided the read/write units used to transmit and retrieve information to and from the transponders. The units were installed in a major warehouse to record incoming and outgoing goods and in a Kaufhof department store, where they were mounted at check counters. This meant goods could be tracked over the entire logistics chain. In the store itself, employees equipped with mobile reader units were able to check on stock levels within seconds, while reader units mounted on the shelves provided a digital overview of inventory.

Intelligent Toolbox. Transponder technology is currently undergoing testing in many sectors and has many potential fields of application. For example, researchers from the Auto ID Center at the Massachusetts Institute of Technology (MIT) are investigating which transponder applications are truly viable and can be realized at acceptable costs. To this end, various pilot projects have been launched with a number of companies. An aircraft manufacturer, for example, has helped develop an “intelligent toolbox” that facilitates jet maintenance. The toolbox notices if one of the tools, each of which has been equipped with a transponder, is missing. By sounding an alarm at the end of the shift, the toolbox eliminates the risk of the tool being left behind in a critical part of the aircraft. In a move to help accelerate the development of transponder applications, Siemens is also involved in activities at the Auto ID Center. In addition, Siemens is a member of various committees at the German Association of Engineers (VDI) and the German Automobile Industry Association (VDA), which plan to advance the application and standardization of RFID technology.
Markets. Although the warehouse stacking system at Siemens Automation and Drives. This is because the computer always knows where everything is. Such a system is of particular interest wherever there is rapid turnover of goods and where forklifts constantly have to move containers to make space for new arrivals. Thanks to the transponders, time-consuming searches for lost containers are a thing of the past. Moreover, the new system should also enhance protection against theft.

On the downside, transponders are still comparatively expensive. That’s why bar codes are still the labels of choice for identification applications. Experts forecast that this is unlikely to change in coming years, although RFID technologies are making major inroads in many sectors (see article opposite). After all, to print and attach a bar code label, all you need is a little paper and film.

Stacking Robots. Engineers at Siemens Dematic in Offenbach, Germany, are also bank-system functions more or less fully automatically, stacking a stable and tightly packed pallet with boxes of many different shapes and sizes still requires the trained eye and muscle power of a human worker. "It’s a backbreaking job," says Gregor Baumeister, head of Robotic Picking Systems at Siemens Dematic and the person responsible for development of the fully automated palleting system. "On any given day, a worker will shift several tons of goods from the conveyor to the pallet."

The new system is the product of a complex interplay between robots, conveyors and sophisticated control technology. The principle calls for a robot to repeatedly take various boxes from the supplier’s pallet and place them on a conveyor belt. A second robot removes the boxes and then positions them on the customer’s pallet. No matter whether the boxes are large or small, the goods are stacked into a tightly-packed, stable pallet — just as if the work had been performed by expert human hands.

By grasping the right tool — a process that takes just a few seconds — a robot can pick up boxes of different shapes and sizes.

It sounds simple, but the process is in fact extremely complicated. First of all, a robot has to be able to identify the exact position of the boxes on the supplier’s pallet so that it can then pick them off one by one. It uses a camera for this purpose. The big challenge was to create software capable of converting a simple camera image into the position-related information required to control the robot gripper. Engineers also had to ensure that it was possible to change the robot’s grippers within a few seconds in order to quickly handle boxes of different sizes. The grippers are specially coated metal plates that use suction to attach themselves to the boxes. Each box that is picked up is automatically given a bar code label. The robot that stacks the customer’s pallet then follows intelligent and flexible computing rules to arrange the boxes in such a way that the pallet space is used as efficiently as possible.

New box sizes are scanned into the system upon arrival at the warehouse, ensuring that they will be recognized later by the robots.

The new system is already achieving packing densities substantially over 80 percent of the available space. An experienced human packer will manage a maximum of 75 to 80 percent. The robot, which is about the size of a horse, first places large boxes at the pallet corners and then begins to fill the space in the middle. Finally, any remaining space is crammed with small boxes. The robot can stack as many as 350 boxes an hour without errors. Enhancement of the various processes involved should increase this number substantially.

As Baumeister explains, future systems will be developed to suit specific jobs. "For example, we’re likely to see individual modules from the pilot system go into operation at different warehouses," he says. Thus the gripper unit might be used in one area for unloading pallets and putting boxes on the conveyor, while the palleting system could be used in another location.

Robots that Navigate. Meanwhile, scientists at Siemens Corporate Technology (CT) have developed a robot of a completely different kind. MobMan — or "Mobile Manipulator" — is mounted on wheels and is equipped with a gripper arm. The robot can be used in warehouses to remove items from a bay and place them on a conveyor or hand them to a human — a feature that obviously saves a lot of time and effort.
MobMan is equipped with the Siemens Navigation System for Autonomous Service Robots (SINAS), which is considered to be the world’s most advanced robotic navigation system (see Pictures of the Future, Fall 2002, p. 59). Robots equipped with this technology can find their way around even in a changing environment.

MobMan’s gripper arm is fitted with laser-controlled proximity sensors that guide it unerringly toward an object. Similarly, tactile sensors calculate the exact pressure required for the gripper to firmly hold an object without crushing it.

Gisbert Lawitzky, who is in charge of the Siemens Robotics team, refuses to speculate whether warehouses will one day be populated by hundreds of MobMen. “Whether it makes economic sense to use one of these sophisticated pieces of equipment is ultimately a question of cost,” he admits. But where price is not the decisive factor, such as in wealthy private households, a simpler version of the robot could eventually be put to use as a kind of electronic butler.

**Digital agents could be used to negotiate conditions and track thousands of goods.**

**Logistics Agents.** Michael Berger, project manager for Intelligent Autonomous Systems at CT in Munich, is also interested in digital assistants. Unlike MobMan, however, Berger’s inventions consist of bits and bytes rather than metal and cables. Berger specializes in so-called digital agents — computer programs that manage limited tasks for humans. The digital agent concept is already used by Internet auction houses such as eBay. The prospective buyer merely names a price, and the software then handles the negotiations.

In the world of warehousing, such agents could one day help to ensure smooth and prompt deliveries. For example, they might be used to negotiate conditions with shipping companies and look around for the best deal on the market. Some people might still hesitate at the idea of placing so much trust in a computer. However, Berger is certain that agent technology will move in this direction.

“We’re currently involved in a project with a software producer that is designed to improve how individual orders are tracked,” says Berger. “Such a program will make it easy to determine quickly and precisely whether goods have been lost, stolen, or are simply late.” Goods are scanned in at the manufacturer, at the shipping company, at the warehouse and at the customer’s location. So in theory it would be possible to determine the precise location of an item at any given time.

The problem at the moment, however, is that not everyone in the logistics chain uses the same data-processing system. The result is often a muddle of faxes, phone calls and e-mails. Thus, the primary task of a digital agent would be to communicate with these various systems and extract the relevant data. Today, it’s impossible for a shipping clerk to track thousands of orders at once, but that’s exactly what a digital agent would do. For the warehouse clerk, the resulting information would make a crucial difference, allowing contingency plans to be made in case a delivery fails to arrive on time.

In the future, digital agents could even take over planning for crisis measures and shipping alternatives. After all, the ultimate aim is to optimize procedures along the entire logistics chain. This means minimizing inventory, for example, to ensure that capital isn’t tied up unnecessarily, while also ensuring that shelves are well stocked.

The future will determine whether warehouses will one day be managed and operated exclusively by an intelligent combination of virtual agents and robots.

**Tim Schröder**

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**Boom in Worldwide Product Shipments**

Even though the world’s economy remains generally sluggish, logistics is still a growth market, with Asia serving as a strong driving force. At the moment, 98 percent of all goods transported between continents are moved by ship. Furthermore, according to a 2002 transportation & logistics analysis conducted by HVB Equity Research, this logistics segment is expected to grow by 5.6 percent annually worldwide until 2010. Starting in 2005, a new generation of mega-container ships capable of carrying 12,000 TEU containers (Twenty-foot Equivalent Unit, about 6.1 x 2.4 x 2.6 meters) will be ready to enter service. By comparison, today’s biggest container ships can carry “only” 7,500 TEU containers.

The air freight segment is expected to register a 5.9 percent annual increase worldwide through 2010, according to HVB Equity Research’s data. Reacting to this boom, European aircraft manufacturer Airbus is planning to produce a freight version of the huge A380 jetliner, which will be known as the A380 Freighter. By 2008, this plane will be transporting payloads of 150 tons nonstop over distances of more than 10,000 kilometers — a dramatic advance over the A300F transporter in use today. This aircraft is capable of hauling a maximum of 51 tons of cargo over a distance of nearly 4,800 kilometers, nonstop.

Overland freight transport is realized with trains, barges and trucks. Annual growth expectations for road transports are 3.3 percent within Europe through 2010. According to a forecast for the year 2015 made by the German Ministry of Transport, Building and Housing, the goods transported on roads will