Innovations in Robotic Technology and Implementation:
Understanding growth in robotics purchasing, and evaluating advances in robotic technology, vision, and multitasking reinforced through an examination of the SIG Pack Delta robot

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Introduction to Innovation

"The key to optimizing organizational performance in the short-term and succeeding in the long-term is through innovation. Innovation is the only way to effectively close the gap between customer demands and decreasing resources. Innovation allows us to do more with less." These words were spoken by Andrew Papageorge, President and Founder of Go Innovative!, a consulting firm dedicated to developing clients' creative abilities in a modern global economy. Companies which do not adapt to industry changes and create new ways to gain competitive advantage cannot realize their full potential. Through increasing acceptance and use of robotic applications, firms are achieving their economic goals by reducing material waste, downtime, and labor costs while increasing line speed.

Robot Growth and Advances

Robotics purchases have been increasing worldwide for several years, especially in North America and Asia. According to the Robotics Industries Association, North American orders increased 17% in the 1st quarter 2004 as compared to 2003. This increase represented over $226 million dollars of investment by North American firms in one quarter alone ("First Quarter", 2004). Additionally, Asian purchases of robotics have increased 100% in the past two years, compared to a 30% increase for North America over the same time frame (UNECE, 2005). Figure 1 shows world robot purchasing trends from 1996-2004 and illustrates the recent surge in robotics purchasing, particularly in Asia.

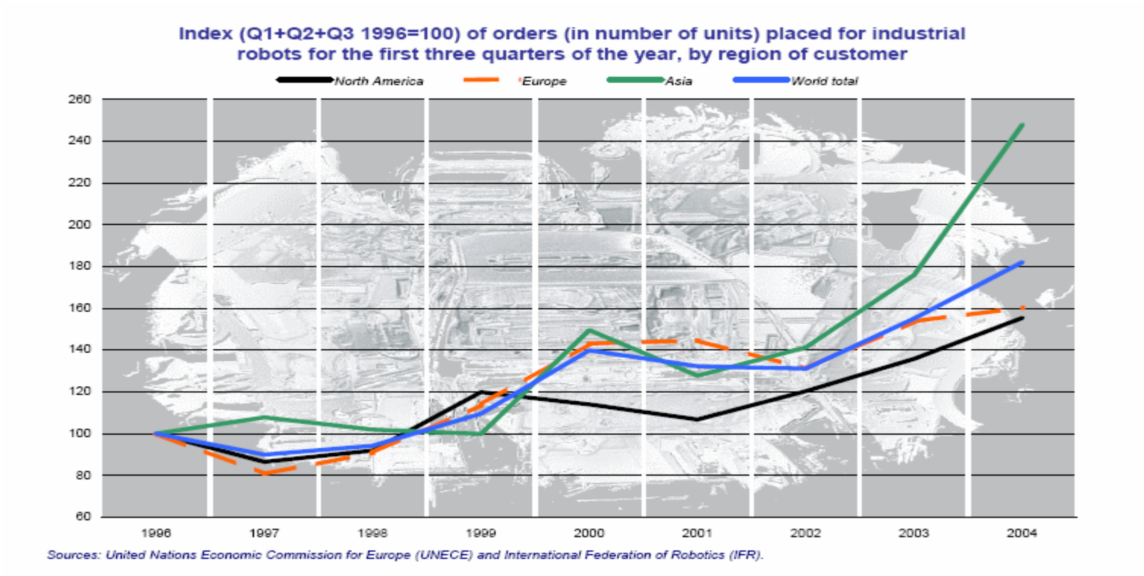


Figure 1: orders for new robots, (UNECE)

Increases in robotics purchasing can be attributed to three key factors. First, robots can easily and economically perform tasks on high speed/ high volume lines where manual labor is no longer sufficient, cost effective, or safe ("Robots are Sweet on," 2005). Second, robots lower labor costs by eliminating worker positions, particularly those involving repetitive movements or those performed under harsh conditions (Grahl, 2003). Third, robot multi-tasking and flexibility is increasing while technological advances are improving robot accuracy and efficiency (Higgins, 2005 and Koss, 2002). An explanation of robotics, worker replacement economics, and vision and multi-tasking innovations is provided in this paper, along with detailed descriptions of various implementations of robots. The SIG Pack Delta robot is used to highlight these advances in robot vision and flexibility.

What are robots?

According to the Robot Institute of America, robots are "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks." In the packaging industry, many different materials are used and a variety of tasks preformed in order to combine a product with a package and prepare it for distribution. While it may seem that robots can be used on any packaging line, certain criteria must be considered when implementing robots in a factory setting. For example, a line must be producing at a high volume and require repetitive tasks to justify the cost of purchasing a robot ("Making Automated Packaging," 2004). A line of hot bricks waiting to be put onto a pallet are therefore a better candidate for robotics than a line of custom made teddy bears waiting to be boxed. This fact is bolstered by a comment from SIG Pack VP of marketing Bernard Fenner. He stated, "It is not economical to fully automate the packaging of low-volume product formats" ("Robots are Sweet on," 2005).

High volumes may justify robotics purchases in terms of lowering unit cost, but robot flexibility is the key to successful robotic transition in a plant. Not only must robots be able to repeat one task over an over, but they also must be able to be programmed to perform a wide assortment of tasks on packages of any dimension, weight and shape (Koss, 2002). A tray loader produced by Bosch not only loads trays, but also check weighs, performs quality control tests, and loads cartons and cases (Forcinio, 2004). Additionally, breakthroughs in robotic software development have allowed companies to essentially eliminate changeover delays common with older automated lines (Kirgis, 2004).

One of the most significant benefits of robot implementation is the reduction of workplace risk, yet a large debate exists over the ethics of robots replacing human jobs. ("Robotics Potential." 2004). In the UK alone, over 1.2 million workers suffer from problems like back pain and strain injuries caused by repeated lifting of heavy loads and torsion of the wrists and shoulders (“Making Automated,” 2004). With ever increasing workplace regulations from governments and workers’ unions, companies are trying to find alternatives to manual labor in situations where repetitive motions and/or harsh conditions do exist. Pepperidge Farm’s implemented the use of 20 robots on their specialty cookie lines in an effort to remove its workers form dangerous situations. In doing so, not only were many potential injuries prevented, but labor savings of more than $1 million were realized (Swientek, 1993). While the introduction of robotics in a plant may eliminate some of the more mundane jobs with high turnover ratio (Grahl, 2003), jobs are also being created. Technicians need to be employed and trained to maintain the robots, and robot fabrication facilities require manual labor for assembly.

Commonly Used Robots

In the past, robots were task specific and could perform only a handful of functions. With increasing development of robot software and the actual robot hardware, packagers have gained much more flexibility when using robots. There are three main types of packaging related robots: Feed placement robots, pick and place robots, and palletizing robots. Feed placement robots are used to position products on a conveyor, providing greater accuracy further down the line. With advances in robotic optics, misaligned products on a conveyor can be handled with slight adjustments to robot arm trajectory and make feed placement robots less used than the pick and place or palletizing robots (“Making Automated Packaging Efficient,” 2004).

“Pick and place” are an extremely popular form of robotics in the packaging industry as they perform a large range of tasks. Originally, pick and place robots were designed to place products into trays or secondary packages ("Making Automated Packaging Efficient," 2004). With advances in technology, pick and place robots now move sheets of cookies, cling to frozen pizzas, and even grab delicate products like pretzels and chocolates. At a Pepperidge Farms bakery, vacuum grips \ take the top of a cookie and join it to an icing coated bottom to within tolerances of 1/8th inch (Swientek, 1993). The flexibility of pick and place robots makes them one of the leaders in packaging robotics.

Palletizing robots not only load pallets, but unload them as well. This feature is particularly important in a bottling or canning facility where cans are brought in empty, filled, and then palletized for distribution. Palletization is an area where robotics is helpful as it can eliminate jobs that are often associated with high occurrences of strain and fatigue. As Christine Grahl reported in September 2003, Commercial Brick Corporation has employed the use of robotics in its packaging department, reducing the number of employees from 36 to eight and cutting the total packaging time from 24 to 12 hours for the 400,000 bricks that leave the facility everyday. The palletizing robots used at Commercial Brick not only reduce labor cost, but make employee turnover less of a factor. Before the robots were purchased, the company had a difficult time retaining workers as conditions were so harsh. Now, that problem has disappeared (Grahl, 2003).

Technological Advances in Robotics

One major limitation of manual labor is the fact that human hands can perform a very limited number of functions over short periods of time. This inefficiency is solved with robots. While a human hand may be able to move two cookies at a time, some robotic arm attachments allow up to eight cookies to be moved. While speed is important, it does come at the expense of payload. Large payloads can only be moved slowly, as to ensure proper stability and placement of final product. However, in the food industry, most products weigh only grams and can be cycled extremely fast. For instance, Roland Pretzels can move over 134 kg of pretzels per hour from a conveyor into individual packages ("Making Automated Packaging Efficient," 1004).

Robotic Vision Upgrades

One of the most important technological advances in robotics has been in the area of vision and optics. In years past, effective robotic vision had been crude, if non-existent altogether. The robots, instead of visualizing the exact location of a product, would move to a predetermined spot every cycle. If the product was off-center or misaligned, damage could occur to the product and line operations could be interrupted (Grahl, 2003). In the past few years, robotic vision has become more advanced, and has come to the point where specific vision systems are crafted, tested, and integrated into almost any line.

Commercial Brick Corp. employs a multi-camera system for each of its robots. The first photo taken is focused on a pre-programmed, theoretical position where a brick is supposed to appear. If a brick is situated correctly, the robot picks it up and moves it along in the process. However, if the brick is misaligned, signals are sent through a Programmable Logic Controller (PLC) to adjust the robot's position. A second photo determines if the realignment was successful, and if so, the brick is picked up and sent on its way. While a short period of time is required to adjust the robot to each brick (+/- two seconds), the process is much faster than can be done manually. Additionally, the company says that the new cameras have increased the accuracy of brick pickup to 98%, much higher than when moved by hand (Grahl, 2003).

A Canadian company, Braintech Inc., has recently been issued a patent for a single camera that guides robotics by allowing 3D vision. The company claims the 3D camera allows the robots to essentially see whatever part or product needs to be moved. For example, the new camera allows a robot to look into a bin, evaluate the angle at which the product is resting, grab the part and either palletize it or place it in a bin. This sort of vision system would be useful in an automotive packaging system where parts like oxygen sensors or fuel gauges are being placed into bins ("Patent granted," 2004).

Improvements in robotic vision have led to decreases in product damage and increased line speed, and they have also increased efficiency. At Roland Pretzels, six pick and place robots are used to gently handle and pack the pretzels. Each robot possesses a single camera that surveys the conveyor, relaying the precise locations of each pretzel to the computer. Instead of picking the first pretzel in line, the software actually calculates the shortest distance from the conveyor to the container, and in doing so, allows the robot to pick the pretzel closest to it. This technology functions correctly because of the load balancing mechanisms installed in the robots. These systems prevent the first set of robots from picking most of the pretzels, distributing picking duties evenly among the six robots and providing backup if a pretzel is missed ("Making Automated Packaging Efficient," 2004).

Improved robot vision and optics systems increase line speeds, reduce product damage, and increase overall robot efficiency. While most of the vision enhancements are utilized on pick and place and palletizing robots, quality control vision systems are being developed, most notably in the frozen French fry industry. The new optics easily spot moldy or undesirable fries, but existing robotics systems are not able to remove the fries from the line. Therefore, robotics manufacturers are teaming with the potato industry to provide a compatible robot to compliment the breakthrough quality control vision software (Higgins, 2005).

When Pepperidge Farms installed vision systems on its Milano cookie line in the late 1980's, the inspection systems were undeveloped, slow, and inefficient. Today, with implementation of vision systems capable of geometric pattern matching and color recognition, broken and discolored cookies are left on the line and not packaged or sent to distribution. The operation now runs five to ten times faster than 1980's speeds, allowing costs to decrease and output to increase. It is for reasons like these that the food and beverage industry will continue to be one of the largest segments for robotic vision development (Higgins, 2005).

Importance of Multi-tasking and Flexibility

While upgrades in robotic vision and optics increase line speed and efficiency, the ability of a robot to perform a wide range of functions is the principal justification for their purchase and implementation. The benefits of multi-tasking and flexibility of robots are numerous. They include quick changeovers, less maintenance requirements, increased repeatability, capacity to run variable sized products, and reduction of worker strain and injury ("Robotics potential is high," 2004).

Bosch recently designed a tray loader that picks up vials and loads them into pattern-fit trays for shipping or freeze-drying. The robot places vials in a four-sided tray, and also places them into a tray with the holding ring already in place, a task previously preformed by a worker leaning over the line. In combining these two tasks, Bosch eliminates risk to the worker and allows the robot to function with two different tray types. Additionally, moving from a mechanical, automated system to a robotic system eliminates the use of cams, gears and levers, allowing for easy maintenance and ease of changeover from one tray style to the next (Forcinio, 2004).

Tooling employed at the end of a robotic arm allows robots to execute a wide variety of tasks quickly and in a manner that reduces product damage. For example, some robotic arms have different sets of grippers that are used, depending on the product (see figure 2). An airflow-vacuum style gripper (far left picture) is used to pick up delicate products, while a suction gripper (middle picture) is used to pick up a product with an uneven surface. Finger grippers (far right picture) are used to pick up products with fragile tops, like snack cakes with icing on top (Kirgis, 2004). Ideally, the tooling requires very short times for changeover and cleaning.

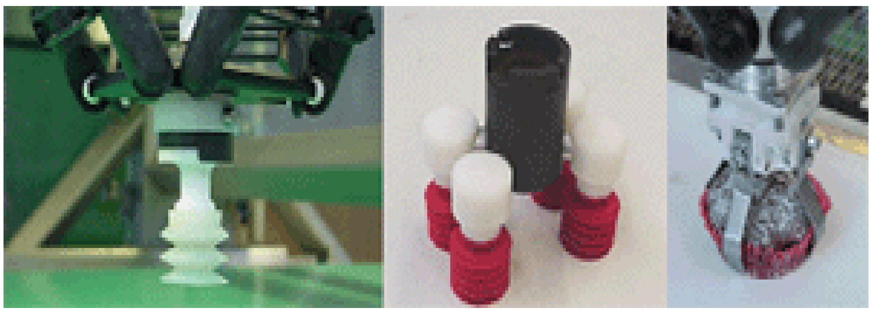
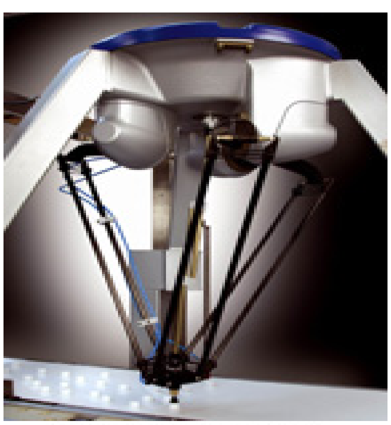


Figure 2: grippers (roboticsonline.com)

The advantages to multi-tooling on a single robotic arm are many. For instance, multiple handling tasks are performed by one machine. Using an example from above, on one day, snack cakes are run that require a finger grip, and the next day, frozen pizzas are run that require a suction grip. Instead of having one robot for each job, technological advances allow one robot to execute each task. In doing so, return on investment is maximized and plant floor space is opened up (Swientek, 1993).

Pepperidge Farm's was awarded the 2004 Food Engineering Magazine Plant of the Year for their use of robotics at its Bloomfield, Connecticut facility. The plant utilizes five ABB robots that handle an inventory of over 26,000 pans. These robots move and transfer pans of different shapes and weights, a job previously performed by employees at much slower speeds. Furthermore, the robots are all linked via a PLC to manage pan placement and operator inputs. A similar system exists at Tillamook County Creamery in the state of Oregon. The automated storage and retrieval system (AS/RS) uses robots to handle and manage 12 levels of cold storage capable of handling 35 million pounds of cheese. By integrating the robots through a PLC, the robots effectively work as a team, each one performing a slightly different task than the other, in order to complete a task (Higgins, 2005). The ability of robots to handle a variety of shapes, sizes, finishes, and stacking heights while taking up less floor space than older machines continues to make them an appealing alternative to both manual labor and mechanical, line based automation.

Vision and Multi-tasking exemplified in the SIG Pack Delta



courtesy of SIG Pack

Figure 3: Delta robot, ("Robots are...," 2005)

SIG Pack's Delta style robot is a prime example of a robot that possesses both up to date vision capabilities and multi-tasking functions. The Delta robot is a style robot that looks similar to a crane, as seen in Figure 3. The robot uses a series of parallelogram shaped arms that currently provide up to four axes on which the arm can move, allowing for great range and flexibility. The newest version of the robot has moved away from PLC control and uses a PC controlled system. The PC control system is superior, but software compatibility across the world now presents the greatest challenge to SIG Pack (Campbell, 2005).

The SIG Pack Delta (SPD) robot is used in a variety of applications including pharmaceuticals, chocolates, frozen foods, and snack foods packaging. Tooled one way, the SPD is known as a MonoPacker, used in high volume product flows like candies and baked goods. After a quick changeover, the SPD is transformed into an AssortmentPacker, used for chocolate and pharmaceutical blister packs. In addition to its varied functionality, the SPD is made of a material that is permanently coated with an anti-microbial protective layer designed to reduce bacterial growth (Pierce, 2003).

Chocolat Frey, Switzerland's largest chocolate manufacturer, recently purchased eight SPD robots that manage 40 different packages every day. The robots' main job is that of a pick and place model (see figure 4); chocolates are taken from a conveyor and placed into blister packs, as well as blister pack cartons. The flexibility of the SPD allows for a variety of chocolates and packages to be used on the same line.

Figure 4: Pick and Place Delta robot, ("Robots are...," 2005)

A progressive vision and optics system distinguishes one chocolate from the next and allows it to be placed accurately into the blister packs. The vision system is also important during the cartoning process where a certain blister will only fit in a certain box ("Robots are Sweet on," 2005).

The tooling of the SPD is also very important as the gripper that picks up chocolates is not the same gripper that places the blister packs into cartons. A suction head is used to pick the chocolates off the conveyor and place them into a blister pack. When the blister pack is transported, a specially designed tool picks up the filled blister by means of high air flow in combination with soft grippers. This arrangement of tool functions proves the most effective way to transport the delicate blister without damage. The special tool also places pads into the boxes before another SPD closes them ("Robots are Sweet on," 2005). The SIG Pack Delta's versatility and vision systems allow to be considered one of the top robot modules in the world today.

Conclusion

The SIG Pack Delta robot serves as a shining example of the innovative spirit of the robotics industry. Not only does it employ the latest in vision systems, but it is flexible enough to handle a variety of chocolate shapes and carton sizes. Robots are increasing the efficiency at which production facilities run their lines while reducing worker injuries and eliminating positions in harsh environments. Quick changeovers of tooling and smaller floor space usage are providing economic benefit through reduced downtime and effective use of plant space. The purchases of robotics will continue to grow as long as multi-tasking abilities and efficient vision systems are adapted to the ever changing needs and requirements of the packaging world.

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