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Robotics and Food Technology: A Mini Review

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Abstract

The use of robotics in the modern food industry has increased over recent years because of many advantages. However, the industry has not taken to the technology with the same pace as the automotive and other industries due to technical and some other reasons. The high investment rate, variable nature of food products, fragile and perishable characteristics of food items, hygienic and sterilization requirements, high production volume rates are making hindrance in usage of robotics in industry but the opportunity still exists to deliver significant benefits in terms of increased food shelf life, cost reductions and flexibility. The challenge is to develop low-cost, flexible, hygienic and intelligent machines for the food industry. This is a not tough as the technologies now exist to achieve it. The benefits that could be gained if systems are designed, installed and operated well could decide who will be the major food manufacturers of convenience foods in the future.

Keywords: Robotics; Food industry; Technology; Flexibility

Introduction

Food products with different nutritional value and flavor are naturally distributed all over the world depending on climate and environmental conditions. Some food products depend on seasonal temperature and humidity, so these types of food products require storage in order to be consumed in other seasons of the year. In order to provide foods throughout the whole year, foods are being stored in currently available storage conditions which are required to preserve the nutrition of the food products. These products are then packaged either as bulk or individually, and transported from one corner of the world to another. Food products require delicate handling and packaging because they are often very fragile and easily spoiled. In recent years, with increasing concern about individual health and well-being, as affected by consumed food and the environment, greater attention has been given to how food is produced, processed, packaged, stored, distributed and consumed. Aggravation among people is increasing day by day as diseases transmitted through food is increasing at alarming pace caused mostly by E. coli bacteria, hepatitis A, Norwalk virus which are communicable diseases. According to the data available at Centers for Disease Control and Prevention USA, 76 million people get illnesses, 350,000 are hospitalized and 5,000 deaths occur due to food-borne diseases in the United States. Automation can be defined as a technology that uses programmed commands to operate a given process, combined with feedback of information to determine that the commands have been properly executed. Automation is now often used for processes previously carried out by humans. When automated, the process can operate without human assistance or interference. In fact, most automated systems are capable of performing their functions with greater accuracy and precision, and in less time, than humans. The application of robotics and automation have been successfully achieved in a wide range of manufactured industries dealing with well-defined processes and products [1,2]. However there are particular research challenges associated with the use of robots in the food industries [3]. The first is that the objects being handled are variable in size, shape, weight and position, so that some form of intelligent sensing is required. The second is that the objects to be handled are often delicate and covered with either slippery or viscous substances, and so the end effect or must be carefully designed if it is to handle the objects at high speed with secure lifting and without bruising. The third is the concern for hygiene, quality and consumer safety. The hygiene issue is becoming increasingly important for human health. But all the three challenges have been accepted by modern robots.

Robot, from the Czechoslovakian word, “robota” meaning forced labor. A robot can be defined as a programmable, self-controlled device consisting of electronic, electrical, or mechanical units. More generally, it is a machine that functions in place of a living agent. According to British Robot Association, “An industrial robot is a reprogrammable device designed both to manipulate and/or transport parts, tools, or specified manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks.” The International Standards Organization (ISO) defines a robot as, “An automatically controlled, re-programmable, multi-purpose, manipulative machine with several degrees of freedom, which may be either fixed in place or mobile for use in industrial automation applications.” Robots are especially desirable for certain work functions because, unlike humans, they never get tired; they can work in physical conditions that are uncomfortable or even dangerous; they can operate in airless conditions; they do not get bored by repetition; and they cannot be distracted from the task at hand. The robot is powerful, reliable and can be used in hot temperature area where a human after working for so long can become sick and exhausted (Table 1).

Reasons for automating processes

- Need to reduce direct labor
- Can’t get people to do the job
- Need to increase quality
- Difficult to do the job manually
- Need to increase production

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Features	Benefits
Better process control	Easy to clean robot, minimum retention areas, connection protection
High reliability, high speed	Increased productivity
High dexterity, several mounting positions	Compact cell, less room required, simpler mechanical solution
Cleanliness	Better hygiene
Flexibility	Marketing innovative products and packaging
Vision and conveyor tracking	Product picked and controlled in process, in any position

Table 1: Features and benefits of Robotics.

- Difficult to meet specifications consistently
- Need to provide flexibility in processes
- Hazardous to personnel
- Eliminates a contamination source

Robotics is the branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition.

Robotics in food packaging industry

A large majority of the estimated 76 million cases of food borne illness that occur annually in the United States are a direct result of the contamination of food by food handlers in food processing facilities. Transient food borne microbes can be introduced from infected humans who handle the food, or by cross contamination from some other raw food product that a human recently handled. Food contamination can also occur when human hair, skin, nails, or other materials are found in food. Transient organisms are of particular concern because they are readily transmitted by hands unless removed by the mechanical friction of washing with soap and water, or destroyed by the use of an antiseptic solution. Transient organisms can be considered skin contaminants that are acquired from environmental sources and become attached to the outer epidermal skin layer. Robotics and automation in food processing and packaging are one of the many possible paths available to reduce the introduction of these bacteria.

While it cannot be overemphasized that clean, sanitary workers are necessary to produce clean, healthy food products, it is estimated in general society that between 30 percent and 50 percent of persons do not wash their hands after using the restroom. Employee sickness is also an issue if an employee stays on the job while he or she is sick. According to the Centers for Disease Control and Prevention, USA approximately 70% of all food borne disease is due to viruses spread by direct or indirect contact with infected individuals. In case, poor hygiene or sickness, an employee can easily spread pathogens simply by touching food. Automation is not new to food manufacturing. Manufacturers have continued to improve their operations to eliminate humans from the process and move toward sophisticated automated machinery and processes. The human operators have been reduced to only the most critical and demanding applications. In sanitary food processing and packaging, the development of process machinery has led the way in removing operators from the process and has even been responsible for improving quality and increased system performance. Primary packaging was an application that was slow to enter the high tech world of factory automation. Even though many of the actual packaging machines (horizontal flow wrappers, etc.) were developed to meet the sanitation and performance and requirements demanded by the application, the loading of these packaging machines remained a task for the human operator.

The human was able to deal with:

- Flexibility issues-produce multiple package configurations in a single shift
- Providing visual inspection to remove defective product
- Picking and placing products into wrapping machines at rapid rates

In the early 1990's, the first applications in direct food handling in the bakery industry was seen. These robots were performing simple pick and place operations at a reasonable rate of 55-80 cycles per minute. And vision guidance technology now had the capacity and reliability to provide pick locations to multiple robots operating at these high repetitive rates. Probably the most significant factor for robotics and vision technology was the continuous reduction of cost per unit of performance of these components [3]. One of the most significant "soft" justifications was worker related injuries such as repetitive motion injuries being identified in high volume packaging applications. This new food processing and packaging market, now identified, needed additional technology adapted to the specific requirements:

- Performance to exceed the labor payback hurdle
- Further improvements addressing sanitary standards

Many food companies and packaging machinery manufacturers have successfully applied robots in a wide variety of processes in the dairy, meat, baking, confection, frozen, snack and even in beverage industries [4]. Beyond handling unwrapped products, robotic packaging systems have successfully been implemented in:

- Placing products into the infeed buckets of side-loading cartoners
- Placing products directly into top-loading cartons
- Filling the product pockets in a form, fill and seal machine
- Creating product arrays or stacks at the in feed to a bagging operation
- Loading and unloading a retort process
- Descrambling bottles from bulk for the infeed of filling, capping and labeling machines
- Packing products into reusable or single-use trays
- Unloading various types of baked goods from pans
- Unloading and casepacking single-serve portion packages from filling machines
- Palletizing and depalletizing beverages, cases, bags, pails, totes, bulk containers, cans, bundles, etc.

Robotics in modern food industry

The history of robots and other automation technologies in the food industry goes back decades, mainly involved in palletizing tasks; so-called downstream applications. But as food industry giants continue converging and demand continues unabated from large warehouse outlets, grocery chains and consumers for fresh products quickly, newly emerging configurations in robots with related automation technologies, including vision systems and processing software, is seeing robot applications move upstream for picking and packing [5].

The most apparent reasons that are associated in installing of robotic systems in food industry are;

- Saving of manpower.
- Improved quality and efficiency.
- Ability to work in any hostile environment.
- Increased consistency and flexibility.

Increased yields and reduced wastage

The food processing industry combines an extensive diversity of products, packaging types and handling variations than almost any other industrial sector. There is a wide range of potential applications for robotics in food processing from the meat industry, where robots are used for cutting, sorting and packaging applications [3]. Working in a freezer or refrigerated storage boxes is not conducive to humans, but robots can work in such places without ever needing a break. Cutting and trimming carcasses can be very dangerous work, where a moment of distraction could cause serious injury; but robots can wield heavy and sharp knives with absolute precision. Human workers can taint foods with pathogens, whereas robots are considerably more sanitized, as they can be washed with high pressure water and solvents. Robots do not sneeze or get colds, reducing the propagation of germs and bacteria.

Standard robots have been in use for many years in many industries. However, the meat sector has been reluctant to introduce standard industrial robots for a number of reasons including:

- the harshness of the environment in the meat industry
- the speed, reliability and cost of the robots
- the complexity of the processes involving handling biological materials

The use of automatic equipment has therefore been the dominant feature for the meat sector [6]. During the last few years' industrial robots with names such as 'Clean Room Robot', 'Envirobot' and 'Shiny Robot' have been introduced to the meat industry. Industrial Research Ltd., New Zealand, has marketing the Envirobot for handling organic products in harsh environments such as the food industry. The Envirobot is made of stainless steel and resists harsh cleaning materials and the corrosive chilled environment in slaughterhouses [7]. Both from a working environment, a cost and a hygiene point of view, the evisceration process is an obvious candidate for automation. This has been done successfully by the DMRI in co-operation with the Danish company SFK-Danfotech. The automatic evisceration equipment is capable of handling 360 carcasses per hour including the necessary cleaning and disinfection. The pluck set and the intestinal tract are removed together by the robot, allowing separation to be done manually outside the carcass, thus improving hygiene compared with existing manual methods. The equipment also eliminates the heavy work of lifting the intestinal tract and the pluck set.

Robotic system is used for the intelligent cutting and deboning of a chicken, as it prepares to slice through the shoulder joint of a chicken, cutting close to the bone to maximize breast meat yield and ensuring food safety by avoiding creation of bone chips [6].

Robotics in diary industry

Automatic Milking Systems (AMS), also referred to as robotic milkers, were developed in Europe and became available there in 1992. This technology was introduced to the US in 2000. Robotic milking is a voluntary milking system, which allows the cow to set her own milking schedule. Following an initial training period, cows are milked with limited human interaction. Each cow on a robotic milking dairy is fitted with an electronic tag which allows the robot to identify her. When a cow enters the robot, her ID tag is read and she receives a feed reward customized to her level of production, the robot then cleans her teats, attaches the milk cups, and begins the milking processes when milking is complete, the cups disconnect as each quarter finishes milking and she exits the robot [8-15]. Milking occurs throughout the day and night. Milking by using robots has various advantages like:

- Economic benefit: Labor flexibility and not needing to manage hired labor were the biggest advantages reported by current users of robotic milkers.

Increased milking frequency: Milking frequency may increase to three times per day, however typically 2.5 times per day is achieved. This may result in less stress on the udder and increased comfort for the cow, as on average less milk is stored. Higher frequency milking increases milk yield per cow.

Management benefit: Management of the herd can be made more efficient. For a farmer who's never managed his cows properly the robot computer will force him to do so. It tells him about blood in the milk, conductivity, and yield per quarter.

Cow health and welfare benefits: Producers reported an improvement in cow health and a reduction in instances of mastitis following the transition to robotic milking. This was attributed to less stress on the cows and to having better access to information on their cows For example, benefits resulting from quarter-by quarter milking, which can help to reduce udder infections.

Robots are used in cheese packaging, cheese slicing, and curd slicing etc. In cheese production, robots stir curds, transfer cheese moulds, and turn, cut, portion, package and palletize the cheeses. Integrated sensors and measuring systems enable the simple implementation of complex processes. Blocks of cheese arrive on wooden planks at the robot picking area. The special gripper allows the cheese blocks to be picked and placed onto a conveyor for further processing [16].

The world's first commercial robotic milking rotary has been unveiled by Swedish dairy equipment company DeLaval at a pilot farm at Quamby Brook, Tasmania, Australia. Featuring five robots, the rotary has a capacity to milk up to 90 cows per hour, enabling the robots to reach the cow from the side. With the use of laser technology, the robots focus a red light to determine the location of the cow's teats, clean them and attach the cups. The first two robots clean and prepare the teats for milking, the second two attach the cups to the teats, and the last robot sprays the teats to disinfect them before the cows leave the platform [17,18]. Once the milking is done, robotic liquid filling and finishing systems get the product ready for market. These robots handle many types of bottles, vials, bags, and pouches with precision filling from micro liter to multi liter. The containers, once filled, can be closed using a screw cap, stopper, or crimp. They accommodate a variety of products; and deal with fill volumes, dispensing profiles, containers and closure types, making them ideal for clinical trials, full scale production and contract manufacturing [8,19,20].

Conclusion

Robots are primarily used by the food industry for packaging and pallestitaion, but new applications are emerging. The future of robotics in food industry is both exciting and interesting. As computers and control systems become are becoming more sophisticated, more intelligent and lower in cost, some of the more complex applications will become both possible and affordable. It will be interesting to see if the food industry will employ the same number of robots in the future as does the automotive industry at present. Technical and commercial difficulties blocking the use of robotic systems in food industry should be assessed.

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