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Review Article

APPLICATION OF ROBOTICS IN DAIRY AND FOOD INDUSTRIES: A REVIEW

Subhash Prasad
Assistant Professor, Dairy Engineering Department, College of Dairy Science,
Kamdhenu University, Amreli, Gujarat-365-601
E-mail: prasadsubhash91@yahoo.com

Abstracts: Robotics maybe feasible to automate many of the complex and epetitive tasks that are carried out in the dairy and food industry. Dairy and food industry has been lagging behind other industrial sectors in implementing robots, due to the fact that food products are highly variable both in shape, sizes and structure which poses a major problem for the development of manipulators for its handling. However, there is a broad range of potential applications for robotics in dairy and food industries are grading of food products, pick and place operations, packaging and palletizing, meat processing, milk and milk product production and processing. Even though robots bring with them so many advantages like safety, consistency and efficiency but some disadvantage like the high costs involved and the requirement of skilled engineers. Hence there is immense potential of research in robotics for those specialized in automation, while educational institutions have an equally important role in imparting the advanced knowledge to keep the dairy and food industry at par with other more advanced sectors.
Keywords: Robotics; Food industry, Automatic milking systems; Cyber Physical System.

1. Introduction

Dairy & food processing industries is highly labor-intensive, with sometimes labor costs at anything up to 50% of the product cost. Improving productivity and reducing labor costs will therefore have a significant impact on profitability. Much of the manual work in dairy and food industry requires rapid, repetitive, and monotonous movement and, consequently, low levels of motivation among workers. This leads to poor quality control and a high incidence of industrial accidents. 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 (Hurd *et al.*, 2005). However there are particular research challenges associated with the use of robots in the food industries (Peters, 2010). 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

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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. But all the three challenges have been accepted by modern robots.

The International Federation of Robotics (IFR) reports showed that 178,132 industrial robots were sold worldwide in 2013, out of 6,200 (3.5%) constituted for the food and beverage industry (DLG Expert report, 2015). In 2015, sale of 240,000 units marked for the first time, revealed 8% global year-on-year growth. New installations of industrial robots of about 1.3 million are speculated during 2015-2018. These figures demonstrate the significant usage of robots over the course of time. Dairy and food industry aimed the use of robots for various applications to improve the efficiency and reduced work space (Zongwei, 2015) and to reduce the cost (Rene *et al*., 2010). Food industry manufacturers have recorded an increase in productivity of +25% after employing robotics as compared to the work done by a human chain. However, the speed of execution varies in different food sectors (Gebbers & Adamchuk, 2010).

In food industry, earlier use of robots was limited to packaging of food and palletizing in dairy, beverages, chocolates and food tins. In 1998, the launch of the Flex Picker robot revolutionized the food industry as it is the world’s fastest pick and place robot. Potential benefits of incorporating robots in automation include improved operational efficiency, reduction in material movements and vehicle activity and reduced in-process stages. They are always demonstrating clear preferences for well-informed high-quality products. Given this subject is of great importance to scholars, practitioners and academicians, this paper will increase industry awareness and the implications of robotics in the dairy and food industry.

2. Robot:-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. The International Organization for Standardization (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 vacuum; they do not get tired by repetition; and they cannot be distracted from the task at hand (Agrawal *et al.,* 2014; Nayik *et al.,* 2015).

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. Characteristics of Robotics are easy to clean robot, minimum retention areas; connection protection; Increased productivity; Compact cell, less room required, simpler mechanical solution; Better hygiene; Marketing innovative products and packaging ; Product picked and controlled in process, in any position (Anon., 1996)

The function of different component are, Processor: It is brain of the robot, calculates the motions and the velocity of the robot's joints, etc. Sensors**:** To collect information about the internal state of the robot or to communicate with the outside environment. Software: Operating system, robotic software and the collection of routines. Roveror Manipulator: Main body of robot (Links, Joints, other structural element of the robot). Actuators: Muscles of the manipulators (servomotor, stepper motor, pneumatic and hydraulic cylinder). End Effecter: The part that is connected to the last joint hand of a manipulator Controller: Similar to cerebellum. It controls and coordinates the motion of the actuators (Massy *et al.,* 2010).

3. Types of robot used in dairy and food industries:-

The recent developments in the food industry, different types of robots were put into operation for several purposes. The old model SCARA (selective compliance assembly robot arm) robots for pick and place, spider robots for high speed picking and placing of light weight objects are the recent examples of robots used in the industry. SCARA robots are one of the types of stationery robots also known as horizontal articulated arm robots, with motions same as human arm. Its reliability for fast and repeatable movements make it fit for packaging palletizing, loading and unloading purposes (Brumson, 2011). Delta robotsis also known as Parallel Link Robots are the category of modern day robotics. Delta robots are designed for high-speed handling of lightweight products and offer lower maintenance due to the elimination of cable harnesses and absent of multiple axis. Parallel robots are deployed into many food processing steps. Again they offer high speed transfer food stuffs, primary (unpacked) or secondary (packaged) through manufacturer lines and a multitude of processes.

4. Specifications for a food sector robot:-

A variety of robotic systems, developed for such sectors, are readily available from international companies, and are often offered as manufacturing solutions for the food industry. Any design should meet the guidelines for food-handling equipment (Lelieveld *et al.*, 2007) and be ideally of stainless-steel grade AISI-304 and construction with ingress protection rating to IP67, and all parts visible and accessible for inspection and manual cleaning. The standards of hygienic design required will depend on the application, being higher in processing poultry and fish products than in processing dry-food products, such as biscuits or bread. A general purpose robot, which could potentially be used to process any type of product, should meet the highest standards of hygienic design.

5.0 Application of Robotic in Dairy and Food Processing industries:-

The food industry is a highly competitive manufacturing area, but with relatively little robotic involvement as compared to the automotive industry. This is due to the fact that food products are highly variable both in shape, sizes and structure which poses a major problem for the development of manipulators for its handling (Chua *et al.,* 2003). So far, commercial application of robots in food industry is widely spread at the end of processing lines like packaging and palletizing. However there is a broad range of potential applications for robotics in food processing: in the grading of food products, pick and place application, packaging and palletizing, meat, dairy and baking lines to handle hot trays.

5.1 Grading of food products: The grading robot system made various effects like, labour substitution, objective grading operation without human subjective judgment, data accumulation for traceability and farming guidance to producer. Kondo et al. (1996a) developed a fruit harvesting robot for use in Japanese agriculture systems which commonly produce crops in greenhouses and in small fields. Reed et al. (2001) developed an end-effect or for the delicate harvesting of mushrooms. A grading system using robots has been developed for use with deciduous fruits such as peaches, pears, and apples. System automatically picks fruit from containers and inspects all sides of the fruit (Kondo, 2003).

5.2 Pick and Place operations:-The growth in products packaged for the market, the increasingly strict hygiene regulations, the need to reduce risks at work, cut costs, and control product quality are all calling for the development of technologies that enable robots to be used for these tasks. In fact, robotics has a great opportunity in this industry and in particular for Pick & Place operations (Wilson, 2010). Examples of robots for this purpose include ABB IRB-660 and IRB-360. The former is a serial robot used for high demanding payload transfer while the latter is based on PKM mechanism (ABB, 2007) and is designed for high-capacity collating, picking and placing of products onto trays, cartons or feeding of other machinery.

5.3 Packaging and palletizing:- 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 (Purnell, 1998).

Beyond handling unwrapped products, robotic packaging systems have successfully been implemented in: Placing products into the in feed buckets of side-loading cartons. 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 in-feed of filling, capping and labeling machines. Packing products into reusable or single-use trays. Unloading various types of baked goods from pans. Unloading and case-packing single-serve portion packages from filling machines. Palletizing and depalletizing beverages, cases, bags, pails, totes, bulk containers, cans, bundles, etc. 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 (Adl *et al.,*1991).

5.4 Meat processing:-The potential applications of robots in the meat processing industry have been investigated for several years. The main aim of using an industrial robot is to reduce production costs and occupational injuries while improving process efficiency and hygiene. The strength of robotics, particularly in boning rooms where labour costs are inherently high, is in their ability to perform the required repetitive tasks more efficiently and consistently than is currently possible (Food Science Australia). Georgia Tech researchers have developed a system that uses advanced imaging technology and a robotic cutting arm to automatically debone chicken and other poultry products. This 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 (Calderone, 2013). In beef production the first use of robotic equipment was in splitting complete carcass into carcass sides. The Meat Industry Research Institute of New Zealand (MIRINZ) has in particular been very active in automation of sheep and lamb slaughtering. The Danish company SFK-Danfotech has, in cooperation with the Danish Meat Research Institute (DMRI), has developed a series of dedicated robots for automation of pig slaughter line processes (Madsen & Nielsen, 2002). After the meat is cut and deboned, it is then sliced, packaged, and shipped to the customer. Vision-guided robots are speeding up these practices to make certain that the pieces are accurately portioned and cut, while packaging equipment is incorporating volumetric scanning systems.

5.5 Robotics in dairy industry:-Automatic milking systems (AMS) or milking robots are one of the most successful and important application of robotics in the dairy industry. 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 (Butler *et al.,* 2012; Higgs & Vanderslice,1987).

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 (Legg, 1993).

Milking by using robots has various advantages likes (a) Economic benefit: Labor flexibility and not needing to manage hired labor were the biggest advantages reported by current users of robotic milkers.(b) 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. (c) 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. (d) 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 ((Nayik *et al.,* 2015)

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 (Kempthome, 1995). Cheese portion multiplexing in one of the latest inventions on use of robotics in dairy industry. The robot can make up to 12000 portions per hour. They are found to be more hygienic than manual operations. They also have high productivity. There will be return on investment in less than 6 months (Suganya *et al.,* 2011).

5.6 Robots in freezers and ovens: - When handling food, robots are located in freezers or near ovens, while these environments generally do not harm robots, some defence must be made to ensure the robots operates efficiently. The robots based inside freezers for palletizing operations preclude undesirable frosty condensation from building up on ice cream packages (Suganya *et al.,* 2011).

6. Limitations:- Robotic systems and robots are limited to their functions and only the programmers really known what those functions are, unless artificial intelligence is highly sophisticated, robots may not respond properly in times of an emergency of when some unexpected variance. Since artificial intelligence is becoming more sophisticated and robots will be entering more households, there may be important negative effects on the human family system (Suganya *et al.,* 2011).

7. Future challenges and opportunities of R&D in robotics: -A very recent trend is to apply the concept of Cyber Physical System (CPS) in dairy and food industry. Bridging the physical world with the virtual world, CPS is a recent multi-disciplinary research domain based on the concept of Internet of Thing (IoT) that finds potential to streamline end-to-end supply chain in food sector. CPS can play its role to achieve the highest level of certainty in food safety (Khan et al., 2014b). Food industry together with agricultural sector is listed as one of the priorities where CPS is anticipated to have significant impact in future. In the long term milestone, the whole production and supply chain will witness communication of smart food labels so as to give in-depth insight of where exactly the food is coming from (Piramuthu & Zhou, 2016). Also, future CPS in emerging sectors like dairy and food industry will be beneficiated by cloud robotics.

8. Conclusion

Robots are primarily application of dairy and food industry are packaging and pallestitaion, but applications range now widen. The future of robotics in dairy and food industry is both exciting and interesting. 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. Hence there is immense potential of research in robotics for those specialized in automation, while educational institutions have an equally important role in imparting the advanced knowledge to keep the food industry at par with other more advanced sectors. Bridging the physical world with the virtual world, CPS is a recent multi-disciplinary research domain based on the concept of Internet of Thing (IoT) that finds potential to streamline end-to-end supply chain in dairy and food sectors. The serious requirement is to integrate various sorts of technology and engineering areas to realize competitive and innovative solutions.

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