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Automation in Dairy and Food Processing Industry

Ashwin Judal, A. G. Bhadania
Department of Dairy Engineering, SMC College of Dairy Science, Anand Agricultural University, India

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Abstract

Automation generally refers to the science and technology to carry out the process which maximum accuracy and efficiency. The basic aim of having automation in various fields is to achieve higher precision and efficiency in all operations and processes. The control of process parameters in processing of milk and manufacture of different products is one of the essential requirements to achieve desired quality product. In addition to consistency in product quality, automation also provides scope for operational flexibility, energy conservation and safety in the plant. Automation has done wonder in the field of packaging of dairy and food products. The dairy equipments such as milk reception and processing equipments, Ice-cream freezers, packaging machines, UHT plants, milk evaporators, spray dryers, equipments for dairy plant utilities etc. are available with adequate level of automation in the system. Automation in dairy industries is presently viewed as a versatile tool for solving crucial problems of the process and production control, plant supervision and management as well as for solving the accompanying financial and organizational problems. Food processing industry globally forms one of the largest economic and employment sectors. Within it, current automation and engineering practice is highly variable, ranging from completely manual operations to the use of the most advanced manufacturing systems. Yet overall there is a general lag in the use of automation technology compared with other industries. Rapid advances in computer technology and heightened expectations of consumers and regulatory agencies for improved food quality and safety have forced the food industry to consider automation of most manufacturing practices. This paper includes on the importance of automation in food processing industry and is focused on the tools of automation such as robotics, online sensors and machine vision technologies.

1. Introduction

Technological advancement is gradually finding applications in the agricultural and food products, in response to one of the greatest challenges i.e. meeting the need of the growing population. Efforts are being geared up towards the replacement of human operator with automated systems. Automation means every action that is needed to control a process at optimum efficiency as controlled by a system that operates using instructions that have been programmed into it or response to some activities. Automated systems in most cases are faster and more precise (Narendra et al., 2010). The extent of industrial automation depends a great deal on the type of industry. Food industry now ranks among the fastest growing segments for plant automation. For example, the food industry is among the top ten in using machine vision technology, a key component in plant automation. Most systems are isolated, batch-type operations that target a specific task. In order for automation to be successful, it must be integrated into the overall manufacturing system design and provide on-line, continuous control capability. Though the food industry presents many unique challenges to complete automation, the industry has been successful in putting many automatic processes into place.

2. Need For Automation

Corresponding Author,
E-mail address: aj1992tech@gmail.com

Food processing is highly labor-intensive, with labor costs at anything up to 50 percent of the product cost. Improving productivity and reducing labor costs will therefore have a significant impact on profitability. Much of the manual work in food processing requires rapid, repetitive, and monotonous movement and, consequently, low levels of motivation are often found. This leads to poor quality control and a high incidence of industrial accidents. Automating repetitive tasks will improve quality control and efficiency and reduce the high level of accidents. Today, the increasing technological development and sophistication of modern societies impose new quality and safety standards to the food producers. Consumers demand more and more information about the products they buy, demonstrating clear preferences for well-informed high-quality products. To assurance the quality and safety of food products, automation can play a key role. The need to automate industrial processes is driven by several key requirements for competitive success and, in some industries; viability of the manufacturing plants.

3. Basic Considerations on the Automation of Food Processing

One of the most important obstacles in the automation of food manufacturing is the biological variation in size, shape, and homogeneity of the raw materials. Some materials (e.g., dairy) lend themselves readily to automatic processing because the raw material (milk) can be handled in bulk. Accordingly, the dairy industry is among the most automated. But materials such as fruits, vegetables, meat, etc., need to be handled on a more individual unit basis. This has hampered automation tremendously. Thus, food industry automation requires a level of flexibility uncommon to other mature industries.

4. Tools of Automation In Dairy & Food Industry

4.1 Automation Through Machine Vision System

Machine vision is becoming one of the most important non destructive, rapid, economic, consistent and objective inspection and evaluation technique in the food industry (Gumus et al., 2011). This inspection approach is based on image analysis and processing and has found a variety of different applications in the food industry. Considerable research has highlighted its potential for the inspection and grading of fruits and vegetables based on shape, size and color. Computer/ Machine vision also has been successfully adopted for the quality analysis of meat and fish, pizza, cheese, and bread. Likewise grain quality and characteristics have been examined by this technique (Brosnan & Sun, 2004).

A machine or computer vision system can be used as low cost alternative to colourimeters and spectrophotometers. In machine vision system (MVS) image capturing devices or sensors are used to view and generate images of the samples. Some of the devices or sensors used in generating images include charged coupled device (CCD), scanners, and ultrasound, X-ray and near infrared spectroscopy. The colour image is analyzed by a computer program/software and quantifies colour values in a relevant colour scale (Minz et al., 2013). As a result automated visual inspection is undergoing substantial growth in the food industry because of its cost effectiveness, consistency, superior speed and accuracy (Lochtetal, 1997 and Sun, 2000).

4.2 Principle of Operation for Machine Vision System

Machine vision is the construction of explicit and meaningful descriptions of physical objects from images (Sonka et al., 1999). Timmermans (1998) stated that it encloses the capturing, processing and analysis of two-dimensional images; with others noting that it aims to duplicate the effect of human vision by electronically perceiving and understanding an image. These systems work by capturing the image of an object, processing the image to measure the desired parameters, comparing these parameters with predefined inspection criteria, and then helping to make decisions / taking some type of corrective action on the object or the manufacturing process. The sample is incidental to a light object, where its image is captured by camera and analyzed through frame grabber. Then, if it is defected it gets rejected or otherwise is being accepted. The whole system is works on PLC based image analysis system. All the parameters in system are set as per the final requirement of the products.

4.3 Components of Online Machine Vision System

Recent developments in machine vision and supporting technologies has resulted in general acceptance of the feasibility and profitability of implementing visual inspecting systems in quality assurance operations of food producing lines. Machine vision benefited the most from the increase in processing and storage powers of modern chips, and from the emergence of megapixel sensing and imaging devices. Machine vision technology utilizes image processing techniques for the purpose of extracting visual features about an object for a variety of qualitative, quantitative and control applications (Alhusain et al., 2012). The technology is used in a variety of different industries to automate the production, increase production speed and yield, and to improve product quality. A typical machine vision system consists of several components of the following (Minz et al., 2013)

- Digital or analogue camera (black and white or colour) and lens for taking close-ups
- Camera processor interface (the so-called frame grabber) and device I/O (input/output), or communication links
- Processor (this is usually PC or embedded processor)
- Illumination system
- Software to the imaging and detection of features in common image (image processing algorithm)
- Sync-sensor to detect objects (this is usually an optical or magnetic sensor), which gives the signal for the sampling and processing of image
- Regulations to remove or reject products with defects

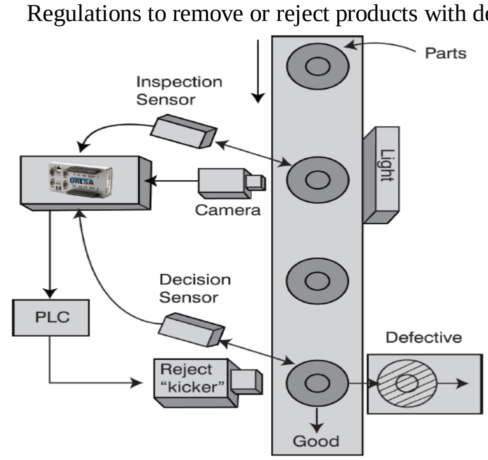

Fig: 1. Principle of Machine Vision System

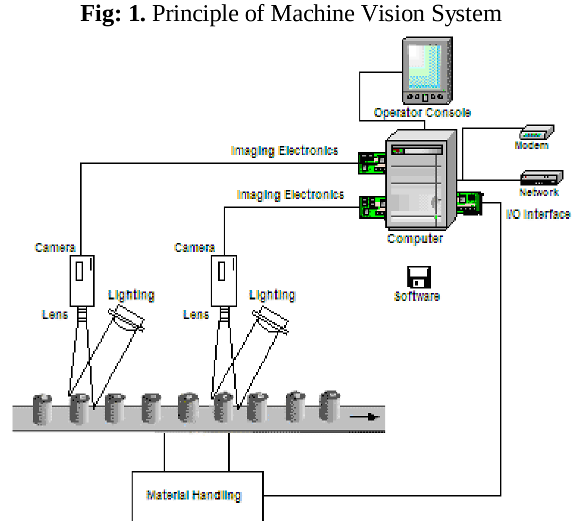

Fig: 2. Components of Online Machine Vision System

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4.4 Online Solution of Machine Vision in Dairy and Food Industry

The system offers the potential to automate manual grading practices thus standardizing techniques and eliminating tedious human inspection tasks. Machine vision has proven successful for the objective; online measurement of several food products with applications ranging from routine inspection to the complex vision guided robotic control (Gunasekaran, 1996).

4.5 Fruit and Vegetables

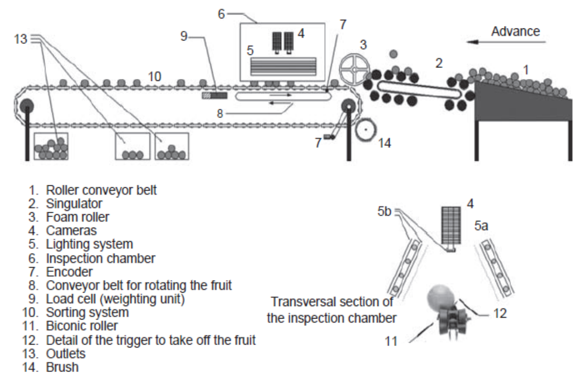
Shape, size, colour, blemishes and diseases are important aspects, which need to be considered when grading fruits and vegetables (Kanali et al., 1998; Chatli et al., 2013 and Mahendran et al., 2013). Colour provides valuable information in estimating the maturity and examining the freshness of fruits and vegetables. The automated inspection of produce using machine vision not only results in labor savings, but can also improve quality inspection objective (Kanali et al., 1998). Machine vision is being implemented for the automated inspection and grading of horticulture produce to increase product throughput and to improve objectivity of the industry (Brosnan and sun, 2004). Narendra and Hareesh (2010) reported variety classification, defects detection and segmentation, identification of stems and calyxes and sugar content prediction in apples. Marakeby et al. (2013) also studied on fast quality inspection of food products using computer vision.

Golmohammadi (2013) developed a machine vision system for online evaluation of potato sorting. To separate potatoes, an accelerator system based on pneumatic control valves and air pressure was used. As the system was online, all of timings related to image processing, product transferring and accelerators operation were calculated and applied based on the speed of the potatoes being fed to processing and sorting system. For the primary evaluation of the system, 100 kg of potatoes were manually sorted into three categories. Then the same potatoes were fed to the system, which has sorted them out with an accuracy of 97.4% with the speed of two potatoes per second. Rajin et al. (2013) evaluated the quality of grapes using non-destructive machine vision system. Singh and kamal (2013) used machine vision system for tea quality determination based on tea quality index (TQI). Gumus et al. (2011) identified the aquatic food processing line based on sorting by species, by size, and by visual quality attributes, as well as automated portioning. Aquatic foods is grouped as determination of composition, measurement and evaluation of size and volume, measurement of shape parameters, quantification of the outside or meat color of aquatic foods, and detection of defects during quality evaluation. It can provide fast identification and measurement of selected objects, perform quality evaluation of aquatic foods, and their classification into categories based on shape, size, color and other visual attributes.

4.6 Online Egg Sorting

Online poultry inspection by a multi-camera system can be employed to accurately detect and identify carcasses unfit for human consumption (Chen et al., 2002). By automating this process, the level of accuracy in identifying defective eggs increases; and the rate of sorting is higher. The 1.4 Megapixel cameras are positioned in such a fashion as to capture images from every angle as the eggs roll down a conveyor belt. The cameras monitor the quality of eggs passing through the system and the images are analyzed digitally, with complex algorithms identifying any hairline cracks or detritus on the egg's surface.

Commercial Machine Vision Sorter



Virtually all electronic classifiers currently available have a series of elements in common. Basically, they all consist of a feeding system that individualizes the fruit, a transport system, an inspection system formed by sensors that measure parameters related to product quality, a system that processes these measurements and makes decisions on quality, a system for synchronization, a system for separating the production categories, and an user interface and a software that manage the whole machine

4.7 Automatic Process Monitoring

Application of machine vision has been reported for controlling drying process of sliced apple (Fernandez et al., 2006). The vigilance of a drying process was provided due to online image analysis and correlation of image attributes (area, colour and texture) with physical parameters of drying (moisture and quality). A relationship between area shrinkage and moisture content was used for online estimation of actual moisture content. A relationship between color intensity and quality was used for online estimation of quality degradation during drying of ginseng roots (Martynenko, 2006). Strickland (2000) reported the use of digital imaging technology for the automatic monitoring of dry sugar granules and powders. This system provides particle size data to production line operators for process control and product quality improvement.

5. Automation Through Robotics

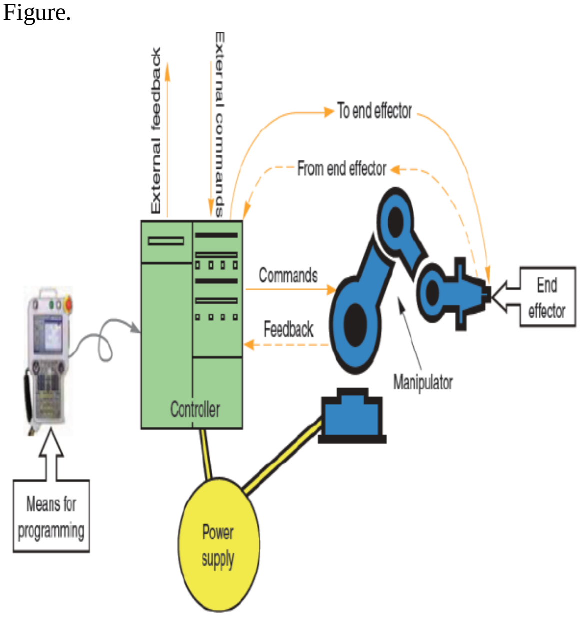
Advanced research and updates in every area of food sector and technology have raised the curtains to a entirely new world of automation process in food industry globally. The food industry is now looking increasingly towards automation and robotics to help lower production costs further. This is possible in large processing units which are fumbling to reduce the human labor costs and resort to a totally sophisticated use of robots to fulfill all their operational needs. Robotics has an increasingly important role in maintaining a food supply that is safe, efficient and cost-effective.

An industrial robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. Food industry has been lagging behind other industrial sectors in implementing robots, as food products by their very nature differ significantly in consistency and shape. However there is a broad range of potential applications for robotics in dairy and food industries. Automatic milking systems (AMS) or milking robots are one of the most successful and important application of robotics in the dairy industry. While, commercial application of robots in food industry is widely spread at the end of processing lines like packaging and palletizing, there is a broad range of potential applications for robotics in food processing.

Robots are distinguished from other types of machinery mainly on the basis of their programmability and ability to be adaptable to different tasks. Industrial robots can improve the quality of life by freeing workers from dirty, boring, dangerous, and heavy labour. The benefits of robots to industry include improved management control and productivity and consistently high quality products. Industrial robots can work tirelessly night and day on an assembly line without any loss in performance. Consequently, they can greatly reduce the costs of manufactured goods. As a result, industries that effectively use robots will have an economic advantage on world markets.

5.1 Parts of a robot

Robots come in many shapes and sizes. Robots consist of a number of components that work together: the controller, the manipulator, end effectors, a power supply, and a means for programming (Schilling, 1990). The relationship among these five components is illustrated in Figure.



The controller is the part of a robot that coordinates all movements' of the mechanical system. It also receives input from the immediate environment through various sensors. The heart of the robot‘s controller is generally a microprocessor linked to input/output and monitoring devices. The commands issued by the controller activate the motion control mechanism, consisting of various controllers, amplifiers, and actuators. An actuator is a motor or valve that converts power into robot movement. This movement is initiated by a series of instructions, called a program, stored in the controller‘s memory.

The manipulator consists of segments that may be jointed and that move about, allowing the robot to do work. The manipulator is the arm of the robot which must move materials, parts, tools, or special devices through various motions to provide useful work. The end effector is the robot‘s hand, or the end-of-arm tooling on the robot. It is a device attached to the wrist of the manipulator for the purpose of grasping, lifting, transporting, maneuvering, or performing operations on a workpiece. The power supply provides the energy to drive the controller and actuators. It may convert ac voltage to the dc voltage required by the robot‘s internal circuits, or it may be a pump or compressor providing hydraulic or pneumatic power. The three basic types of power supplies are electrical, hydraulic, and pneumatic.

The means for programming is used to record movements into the robot‘s memory. A robot may be programmed using any of several different methods. The teach pendant, also called a teach box or hand held programmer teaches a robot the movements required toper form a useful task. The operator uses a teach pendant to move the robot through the series of points that describe its desired path. The points are recorded by the controller for later use.

5.2 Robotic Milking

Milking cows by machine, to replace the practice of milking by hand, has been known for more than century. Automatic milking systems (AMS) or milking robots are one of the most successful and important application of robotics in the dairy industry. The world's first commercial robotic milking rotary has been unveiled by Swedish dairy equipment company DeLaval at a pilot farm at Quam by Brook, Tasmania, Australia. Milking robots are different from the ordinary milking machines in one crucial aspect: the robot uses sensors to find the teats of the cow and then connects the cups to the teats with a robot arm (Halachmi et al., 2000). So milking is done without intervention of the farmer. This saves the farmer serious amount of labour (Butler et al., 2012). In an AMS situation cows are expected to visit voluntarily a milking stall several times daily (Rossing et al., 1997). The milking robot uses an ultrasonic or a laser sensing system to locate the position of teats and a robot arm that move the teat cups to the teat end to attach the cup on the teat.

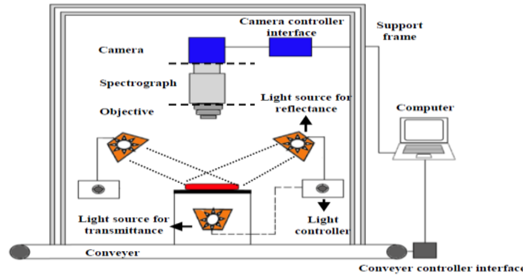
6. Robotic Food Processing

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 meat industry, robots are used in slaughtering, deboning, cutting, sorting and packaging applications, while in cheese production they stir curds, transfer cheese moulds, and turn, cut, portion, package and palletise cheeses. Robots can also be used for picking and placing items such as cookies, hamburgers, chocolate pralines, croissants, chicken fillets or pan cakes into primary packing. Additionally, robots are already used in baking lines to handle hot trays. Reducing demands on labour can be a big plus point for robots especially when labour is expensive and in high demand. Moreover, robots minimize the human workers direct contact with the products.

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.

6.1 Automation through hyperspectral Imaging Technology

By combining two mature technologies of imaging and spectroscopy, hyperspectral imaging has recently been widely studied and developed; resulting in many successful applications in the food industry for quality and safety evaluation .A typical hyperspectral system consists of a light source, a wavelength dispersion device, and an area detector. The images are acquired over the visible and near-infrared (or infrared) wavelengths to specify the complete wavelength spectrum of a sample at each point in the imaging plane. These images are then combined and form a three dimensional hyperspectral cube, with two dimensions for describing spatial information and the third one for spectral information. Therefore the measured spectrum indicates the ability of the sample in absorbing or scattering the exciting light, representing the inherent chemical properties of a sample.



7. On-Line Smart Sensor In Dairy And Food Processing Operations

As food companies recognize more and more the necessity to measure, optimize and control the sensory properties of the food. Food industry demands for new sensing technologies stimulate the development of smart sensor that can provide a cost-effective quality evaluation/control operation. The rapid development and emergence of smart sensor and field network technologies have made the networking of smart transducers a very economical and attractive solution for a broad range of measurement and control applications. In some cases automation must ensure their inactivation to guarantee food safety and shelf life. Development of new process control sensors for the food industry, in parallel with developments in process control technology, has the potential to increase the levels of process automation in the food industry. In moving towards the automation smart sensors have big role to automate the processes. Hence sensors and associated measuring instrumentation circuits in the food processing industry pose a challenge for sensory scientist towards the development of low cost and intelligent sensing system needed to achieve automation. This review paper also pays attention to the importance and adoption of smart sensors, their development and application in food industry.

8. Conclusion

In the dairy and food industries, there is growing need for automation. The adoption of newer automation techniques will be of immense benefit to dairy and food processing industry. The increased zeal in industrial automation is mainly due to the explosive growth in computer hardware and software technology. As computers invade almost every aspect of our daily lives, the public at large has come to expect a high level of automation in every facet of the manufacturing processes. However, most systems are isolated, batch-type operations that target a specific task. More complex systems are needed for the automated grading of fresh produce because of the greater range in variability of quality and also as produce orientation may influence results. Image processing is recognized as being the core of machine vision with the development of more efficient algorithms assisting in the greater implementation of this technique. Robotics has the potential to become next frontier in the dairy and food industries. Manual handling of foods is not going to end soon, but still the acceptance of automation and robotics in the industry is increasing. Even though robots bring with them so many advantages like safety, consistency and efficiency, the challenges that lies before food robotics are 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 food industry at par with other more advanced sectors. The next significant development will be to integrate the batch type operations into overall system of plant automation, from receiving raw materials to shipping finished products.

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