PROSPECTS OF COMPUTER VISION AUTOMATED SORTING SYSTEMS IN AGRICULTURAL PROCESS OPERATIONS IN NIGERIA

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ABSTRACT

The paper presents the recent development and application of image analysis and computer machine vision in sorting of agricultural materials and products in the food industries. Basic concepts and technologies associated with computer vision, a tool used in image analysis and automated sorting are highlighted.

For the ever-increasing population, losses in handling and processing and the increased expectation of food products of high quality and safety standards, there is need for the growth of accurate, fast and objective quality determination of the characteristics of food and agricultural products. Computer vision and image analysis, are non-destructive and cost-effective technique for sorting agricultural products during handling processes and commercial purposes. Different approaches based on image analysis and processing identified are related to variety of applications in food and agricultural products.

Suggestions were made on the ways of adapting the growing trends to agricultural and food industries in Nigeria.

Keywords: Sorting, automation, image processing, machine vision

INTRODUCTION

Technological advancement is gradually finding applications in the agricultural and food industries, in response to one of the greatest challenges i.e. meeting the need of the growing population. Efforts are being geared towards the replacement of human operator with automated systems, as human operations are inconsistent and less efficient. 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. However, there are some basic infrastructures that must necessarily be in place in automation. For instance, in Nigeria, the erratic power supply, the low-level of technological know-how are the factors that may hinder the adoption of the emerging technologies in agricultural products handling. Unless these factors are addressed, the application of automated sorting of agricultural materials in Nigeria will remain an illusion.

The technology of image analysis is relatively young and its origin can be traced back to the 1960s. It has experienced tremendous growth both in theory and in application. It has found application in areas such as medical diagnostics, automated manufacturing, aerial surveillance, remote sensing and very recently in the automated sorting of agricultural products. Computer

vision is a novel technology for acquiring and analyzing an image of a real scene by computers and other devices in order to obtain information or, to control machines or processes (Sun, 2003). In Timmermans (1998) opinion, computer vision includes the capturing, processing and analyzing images to facilitate the objective and non-destructive assessment of visual quality characteristics in food products. The techniques used in image analysis include image acquisition, image pre-processing and image interpretation, leading to quantification and classification of images and objects of interest within images.

Harvesting and packing account for the major portion of the effort and cost incurred by farmers producing fresh market fruits and vegetables. However the processing and manufacturing sectors require product sorting for commercial and production purposes. There is continuous growth in the development of mechanical harvesting system, and the need for automated inspection, as well as grading systems so that the losses incurred during harvesting, production and marketing can be minimized. With these, the need arises to not only grow and harvest a quality crop, but also to pack in a consistent and acceptable manner to gain or to maintain market share as well as prepare materials which suits processing operations. These cannot be achieved without sorting.

Sorting of agricultural products is accomplished based on appearance, texture, shape and sizes. Manual sorting is based on traditional visual quality inspection performed by human operators, which is tedious, time-consuming, slow and non-consistent. A cost effective, consistent, superior speed and accurate sorting can be achieved with machine vision assisted sorting. Automated sorting had undergone substantial growth in the food industries in the developed and developing nations because of availability of infrastructures. Computer application in agriculture and food industries have been applied in the areas of sorting, grading of fresh products, detection of defects such as cracks, dark spots and bruises on fresh fruits and seeds. The new technologies of image analysis and machine vision have not been fully explored in the development of automated machine in agricultural and food industries. There is increasing evidence that machine vision is being adopted at commercial level (Locht *et al*, 1997), but the slow pace of technological development in Nigeria and state of the art sensing system which are not available are among the factors that will limit the processes that requires computer vision and image analysis.

The method used by the farmers and distributors to sort agricultural products is through traditional quality inspection and handpicking which is time-consuming, laborious and less efficient. Sun *et al* (2003) observed that the basis of quality assessment is often subjective with attributes such as appearance, smell, texture and flavour frequently examined by human inspectors. Francis (1980) found that human perception could easily be fooled. It is pertinent to explore the possibilities of adopting faster systems which will save time and more accurate in sorting of crops. One of such reliable method is the automated computer vision sorting system.

Advances in computer technology have produced a surge of interest in image analysis during the last decade and the potential of this technique for the guidance or control of agricultural and food processes have been recognized (Raji *et al,* 2000). Series of studies have been conducted in recent years to investigate the application of computer vision technology to sorting and grading of fresh produce. Yam and Spyridon (2003) used a simple digital imaging method for measuring and analyzing colour of food surfaces and found that the method allows

measurements and analysis of the colour of food surfaces that are adequate for food engineering research. Payne and Shear*er* (1990) developed a machine vision algorithm for grading of fresh market produce according to colour and damage while Alchanatis *et al* (1993), used a neural network based classifier and colour machine vision instead of the conventional use of black and white cameras and geometric features for automatic classification of tissue culture segments of potato plantlets. It was found that instead of using only geometric features combining it with colour significantly increased the separability of the classes in the feature space.

Real time detection of defects in fruits using a general hardware and image processing techniques was reported by Delwiche and Crowe (1996). Two fruits (apples and peaches) were tested at the rate of five fruits/second to evaluate system performance. They developed an algorithm to acquire and analyze two combined near infrared (NIR) images of each fruit in real time with a pipeline image processing system. Their result showed that the system was capable of executing the sorting algorithm at a rate of 14 fruits/second, which was greater than conventional fruit conveying rates. In this submission, it was observed that acquiring more than 2 images per fruit and using more than 6 lines of structured illumination per fruit would reduce the sorting errors slightly in the case of the apples and greatly improve the system performance with peaches. Algorithms were developed by Panigrahi and Misra (1990) to measure fractal-based feature and dimensions (length, width, area and perimeter) of ear corn images to discriminate among various shapes. The analysis showed that the combination of the feature is able to discriminate the shape differences while Carrion *et al* (1998) described sorting based on an unsupervised vision system.

Raji (1999) developed an algorithm for determining the area of 2-dimensional objects by image analysis. This can be adapted in detection of leave type as a form of sorting to select the desired ones during harvesting. The discrimination of leave from weed using feature identification by analysis was investigated and reported by Tsheko (1998).

Bull (1992) observed the image capture techniques, which could be or are being used in the agricultural and food industry to generate image that can be analysed and used as feedbacks for an automated systems. The appropriate technique to be adopted by each industry would depend on the property of the sample to be monitored, the nature of the sample, its environments and other practical restrictions such as imaging time. With increased awareness and sophistication on the part of the consumers and the expectation for improved quality in consumer food products which has increased the need for enhanced quality monitoring in agricultural and food industries, there is the need to develop various techniques of image analysis to meet the demand of the growing population. Quality is the sum of these attributes that can lead to the production of products acceptable to the consumer when they are combined.

In the food industries in developing countries, there is growing need for automation due to the fact that the labour intensive manual processes are not efficient, accurate and effective. In the developed countries on the other hand Gunasekaran (1996) observed that the food industry is now ranked among the top 10 industries using this technology. Agricultural and food industries in Nigeria and other developing countries despite the associated need to study and gradual adopt some of the automated sorting techniques to meet the ever increasing population and food production. Nigeria, especially, is blessed with seasonal fruits but presently faced with huge

losses due to improper handling and storage hence the use of appropriate automated sorting and storage technology will enhance an all year round availability.

This study therefore sets out to review the state and level of application of image processing and machine vision in automated sorting with a view to recommend its application and steps to be taken in improving and developing the emerging technology beyond its present state to agricultural products sorting in Nigeria

TECHNIQUES IN IMAGE PROCESSING

Equipment and Techniques

A computer vision system consists of two basic components which are image acquisition: illumination and image capture device (camera) and image analysis: an image capture board (frame grabber or digitizer) and analysis software. A typical laboratory set for image processing is as shown in Figure 1.

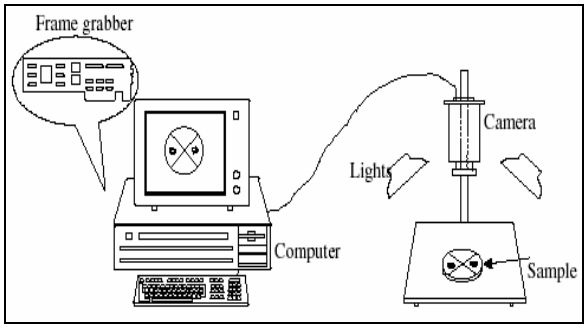


Figure 1: Components of a computer vision system (Wang & Sun, 2002a).

IMAGE ACQUISITION

Illumination

Vision systems are affected by the level and quality of illumination as with the human eye. The performance of the illumination system greatly influences the quality of image and plays an important role in the overall efficiency and accuracy of the system. Illumination systems are the light sources as shown in Figure 1 above. The light focuses on the materials (especially when used). Lighting type, location and colour quality play an important role in bringing out a clear image of the object. Lighting arrangements are grouped into front- or back-lighting Gunasekaran (2001). Front lighting serve as illumination focusing on the object for better detection of external surface features of the product while back-lighting is used for enhancing the background of the object. Light sources used include incandescent lamps, fluorescent lamps, lasers, X-ray tubes and infra-red lamps.

Image Acquisition

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 scanners, ultrasound, X-ray and near infrared spectroscopy. However, in machine vision, image sensors used are the solid state charged coupled device (CCD) (i.e. camera) technology with some applications using

thermionic tube devices. Recent technology has seen the adoption of digital camera, which eliminates the additional component required to convert images taken by photographic and CCD cameras or other sensors to readable format by computer processors. Images captured or taken by digital camera maintain the features of the images with little noise due to its variable resolution.

IMAGE PRE-PROCESSING

This refers to the initial processing of the raw image. The images captured or taken are transferred onto a computer and are converted to digital images. Digital images though displayed on the screen as pictures, are digits, which are readable by the computer and are converted to tiny dots or picture elements representing the real objects. In some cases pre-processing is done to improve the image quality by suppressing undesired distortions referred to as "noise" or by the enhancement of important features of interest.

The images or pictures are transformed into computer digital readable format (i.e. digitised) if they were not taken by a digital camera by the image board digitiser. The digitised format is then transferred and used as the input data by the image processing software to carry out the necessary processes. Each or a combination of the digits represent the feature a small portion of the image called picture element (pixel). Objects are described as black and white pictures which are represented by digits ranging from 0 to 255 where 0 is black and 255 is white. Each pixel in coloured pictures is represented by 3 digits representing RGB [Red, Green, Blue] components with each being (0 to 255) darkest to lightest RGB. An arrangement of these digits in row-column format gives a representation of the image. With this arrangement the analysis in image processing is done by using the matrix theory. Further details can be obtained in Tsheko (1998), Raji (1999), Raji *et al* (2000) and any text or reports on image processing and computer machine vision.

Image acquisition and image pre-processing are categorised as low-level processing while the intermediate and the high level processing stages as classified by Sun (2000) (Figure 2) are further processing stages required when integrating the preprocessing stages into an application device such as a sorter.

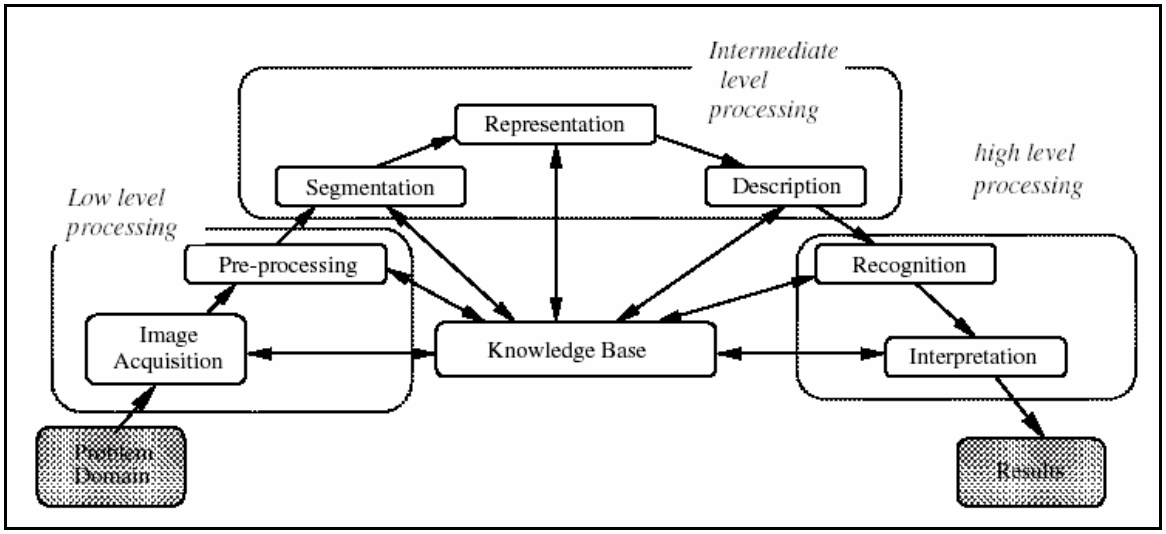
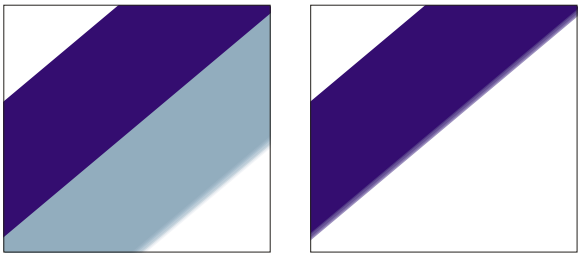


Figure 2: Different levels in the image processing (Sun, 2000).

The intermediate-level processing involves image segmentation, image representation and image description. Image segmentation is a process of cutting, adding and feature analysis of images aimed at dividing an image into regions that have a strong correlation with objects or areas of interest using the principle of matrix analysis. Segmentation can be achieved by the following techniques: thresholding, edge based segmentation and region based segmentation.

Thresholding is used in characterising image regions based on constant reflectivity or light absorption of their surface. This shows that regions with same features are characterised and extracted together. Figure 3 shows a thresholding process where only the dark region is of interest, the other regions are converted to the background colour in the threshed image before further processing such as sending signals to a device to take a feature based decision. This process is useful in colour (maturity) and feature based (defect and damages detection) sorting.



Original image Threshed image

Figure 3. Thresholding

Edge based segmentation relies on detection by edge-to-edge operators, which detect discontinuities in grey level, the pixel, colour, texture etc. Edge detection is useful in shape and size sorting. An example of edge detection result is shown in Figure 4. The application of this process was reported by Raji *et al* (2000) who demonstrated the detection of defects in the shape of bread and biscuit samples on a processing line.

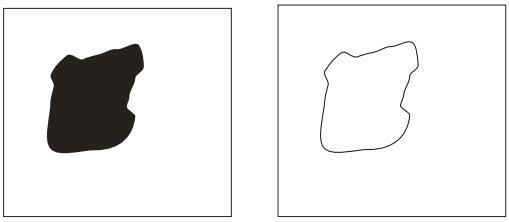


Figure 4. Edge based segmentation

Region based segmentation involves the grouping together and extraction of similar pixels to form regions representing single objects within the image. (Figures 5). In this process the other regions are deleted leaving only the feature of interest.

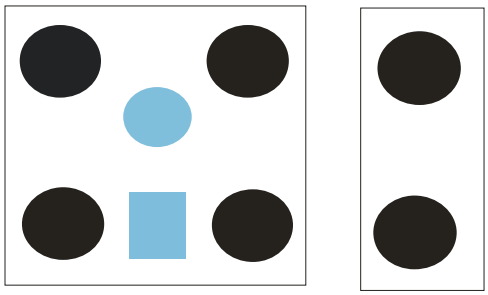


Figure 5. Region based segmentation

High level processing deals with recognition and interpretation, typically using statistical classifiers or multiplayer neural networks of region of interest (Brosnan *et al*, 2003). These steps provide information necessary for the process or machine control for quality sorting and grading.

Interactions of all these levels and knowledge database are very important and essential for more precise decision-making and is seen as an integral part of the image processing process. These theories when applied to images of products taken can be used to extract features which are needed for the necessary processes. Generally, edge detection to determine shape and feature extraction to determine differences in colour are useful in sorting and harvesting.

APPLICATIONS IN AGRICULTURAL AND FOOD PROCESSING OPERATIONS

Computer vision systems are being used increasingly in food and agricultural industries for quality assurance purpose. The system offers the generation of precise descriptive data and reduction of tedious human involvement. Computer vision has proven successful for the objective, online measurement of several food products with application ranging from routine inspection to the computer vision guided robotic control. (Sun and Brosnan 2003).

Some of the areas where the techniques have been applied in agricultural and food processing which need to be developed further for commercial purposes include.

Bakery Products

Appearance of baked products is an important quality attribute which influences the visual perceptions of customers and hence potential demands of the products. The appearance of the internal and external features contributes to the overall impression of the products quality. Computer vision has been used to measure characteristics such as colour, size and shape with a view to sorting them to products with same characteristics before packing.

Raji *et al* (2000) developed a programme in FORTRAN using the principle of edge detection in image analysis to determine the edge of sliced breads and biscuits (round and rectangular) with a view to detecting defects (breakage). Scott (1994) described a system, which measures the defects in baked loaves of bread, by analysing its weight and slope of the top. The internal structure (crumb grain) of bread and cake was also examined by machine vision (Sapirstein, 1995). Dos Mohammed *et al* (2000) also developed a system for the automated visual inspection of muffins.

The application of this method is therefore a promising approach to solving quality control inspection in the bakery industries. This will improve the quality of baked products in

Nigeria where there are no standard sizes, shape and texture. The required system though may add to the cost of production but the added advantage will far outweigh the initial cost involved.

Fruits

External qualities i.e. sizes, shapes and colour are considered of paramount importance in the marketing and sale of fruit. Presence of blemishes influences consumer perceptions and therefore determines the level of acceptability prior to purchase. Computer vision has been used for the automated inspection and grading of fruit to increase product throughput.

The number of fruits (ripe and unripe) on a tree has been counted by image analysis prior to harvesting. This process involved the development of fruit location algorithms (Molto *et al*. 1992). Images were taken from a distance of about 150cm and all the fruit on the tree placed within the vision field of a camera were counted. The visible fruits were considered to be those that the human eye can distinguish on the monitor. Algorithms based on the red/green relation and on threshold achieved the highest detection percentages on citrus fruit.

Defect detection and quality based decision in fruits based on the feature analysis in image processing involve detection of dark regions, or regions differing in feature and nutritive values or colour from the real colour. Some of the successful attempts made include Steinmetz *et al.* (1999) non-destructive prediction of sugar contents of apples with an online result of 3.5 fruit per second at 78% accuracy. Ahmada *et al* (2000) also evaluated the sugar content of orange fruit using features such as fruit colour, shape and roughness of fruit surface related to the pH. In order to give the consumer a more uniform product, the classification and separation of mixed nuts into lots of uniform shape and size in desirable. Pearson and Toyofuku (2000) developed a non-invasive inspection method using machine vision for the identification and removal of pistachio nuts with closed shells from processing streams. This automated system had a throughput of approximately 40 units per second and an accuracy of 95% comparable with current mechanical devices without any of the damage associated with this mechanism.

This method will be of immense benefit to the ever increasing large scale mechanized farming in Nigeria. The adoption can also be extended to the peasants through tractor hiring bodies or by forming cooperatives to acquire such devices which only need to be attached to a tractor. The problem of unplanned fruit trees which may make machine movement very difficult will also need to be addressed. The high losses incurred presently on fruits in the market comes as a result of the damages and bruises as well as potential damage region inflicted on the fruits falling from the trees due to the method of harvesting of shaking the trees or the branches presently adopted in Nigeria.

Vegetables

The need to be responsive to market demands places a greater emphasis on quality assessment resulting in the greater need for improved and more accurate grading and sorting practices. Computer vision has shown to be a viable means of meeting these increased requirements for the vegetable industries.

Plantlet segments of potato were subcultured for classification by colour machine vision system by Alchanatis *et al.* (1993). In related development, two algorithms were developed for analysing digital binary images and estimating the location of stem root joints in processing

carrots (Batchelor and Searcy, 1989). Both algorithms were capable of estimating the stem/root location with a standard deviation of 5mm. Also Howarth and Searcy (1992) classified carrots on surface defects, curvature and brokenness. A line scans images with discrete Fourier transform was developed for the classification of broccoli heads for assessing its maturity (Qui and Shearer, 1992). For the 160 observations from each of three broccolis cultivates, an accuracy of 85% was achieved for multiple cultivars.

Mushrooms' discolouration is undesirable in mushroom houses and it reduces market value. The colour and shape of the cap is the most important consideration of fresh mushrooms. Felfodi and Vizhanyo (2000) used mushroom images recorded by a machine vision system to recognize and identify discolouration caused by bacterial disease. The method identified all the diseased spot as 'diseased' and none of the healthy mushrooms parts were detected as 'diseased'. Reed *et al* (1995) used camera-based technology to select mushroom by size for picking by a mushroom harvester.

Image analysis and machine vision in general from the foregoing can be said to offer a fast and reliable process in product sorting, separation and detection of some other facilities. Table1 shows the speed of operation for different processes. From the table it can be observed that manual method cannot in anyway be compared with these methods in operation.

Table 1: Throughput of selected online apparatus of computer vision (Sun et al., 2003)

Area of Use	Speed/Processing time	Accuracy (%)
Pork lion chops	1 sample per second	90
Fish identification	0.21m/s conveyor	95
Detection of bones in fish and chicken	10000/hr	99
Estimation of cabbage head size	2.2seconds/sample	-
Location of stem root joint in carrots	10/second	-
Apple defect sorting	3000/min	94
Sugar content of apples	3.5seconds/fruit	78
Pinhole damage in almonds	66units/seconds	81
Bottle inspection	60,000/hr	-

PROBLEMS OF AUTOMATED SORTING

The major problem of automated sorting is one of socio-economic effects, which tend to reduce employment when the number of operators required in the processing line is reduced. It is not suitable in processes where manual skill is necessary or economically more attractive. It requires higher initial and maintenance cost and there may be the need for a precise understanding of the process for programming to achieve the required product quality Equipment associated problem involves radiance on accurate sensors to precisely measure process condition

and the increased risk, delays and cost if the automatic system fails. The farm layout and very low production level which may make it uneconomically viable has also been highlighted.

PROSPECTS OF AUTOMATED SORTING

The adoption of this emerging technology by first putting more effort into researches on the appropriate methods and ways of application will be of immense benefit to this country. Some of the other associated benefits include increased production rates (e.g. through optimisation of equipment utilization), more efficient operation, production of more consistent product quality, greater product stability and safety

With the above in mind, the fruit and vegetable processing and marketing industries in Nigeria stands to gain from this emerging technology. This is because the losses incurred in Nigeria during the harvesting season on fruit are enormous. This results from large number of products to be handled and sold at the same time. These products consist of ripe and unripe fruits. The introduction of automated sorting will encourage the sorting of the unripe (which can be kept for a relatively longer period) from the ripe, which are to be sold immediately. Presently the practice at the fruit market in to sell baskets of fruits containing both ripe and unripe. These products are found to get spoilt before they get to the final destination.

One of the major hindrances to the introduction of this technique to the Nigeria community is the level of production, which remains at the peasant level. Most of the products found in the markets are owned by a number of individuals with each controlling not more than 4 to 5 baskets, which will be too small for the adoption of an automated technique. However, encouraging wholesalers and retailers for groups and cooperatives in marketing as practiced in the village level for maize shelling will be a way out.

The development of this technique, adoption and introduction will also means preparing for the period when the level of production will rise and technical know how would have risen in this country. The technique is also useful for the ever increasing food processing industries in Nigeria.

CONCLUSION

The paper presents the recent development and application of image analysis for agricultural materials as well as food industries. Basic concepts and technologies associated with computer vision, a tool used in automated sorting was highlighted. It was observed that systems of automation is a high level means of quality control, getting inputs to processing machine design in food industries. The automated objective, rapid and hygienic inspection of diverse raw and processed foods can be achieved by the use of computer vision systems.

RECOMMENDATIONS.

With the increasing nature of computer vision and image analysis, there is need for increased computer capabilities and greater processing speed of algorithms to meet the necessary online speeds.

There is need for large scale agricultural and food processing industries in Nigeria to adopt the technology of computer vision in their operation due to its flexibility and non-

destructive nature of its techniques. To maintain the freshness and the attractiveness of agricultural materials for a longer time this technology needs to be employed.

Also computer vision and analysis should be adopted as a curriculum in Agricultural Engineering, Food Technology and in Agronomy. It is also recommended that the Nigerian government should address the problem of power supply so that farmers and food industries will be interested in adopting the system.

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