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Design and implementation of a low cost computer vision system for sorting of closed-shell pistachio nuts

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Iran is one of the most important producers and exporters of pistachio nuts in the world. Certainly, the quality of pistachio is very important for customers. Sorting of pistachio nuts is a post-harvesting process which is currently performed using a mechanical apparatus called "pin picker". Due to the possibility of kernel damage by the pin picker, mechanical methods of closed-shell pistachio removal are gradually being replaced by other appropriate systems. Low cost systems for post-harvesting processes such as computer vision-based sorting systems are experiencing rapid growth. In this paper, a low cost intelligent system is implemented for pistachio sorting using computer vision. The system uses a combination of two flat mirrors and one low cost camera to obtain suitable 3 dimensional images from pistachios which are processed to detect closed-shell nuts. The experimental results for the three varieties of pistachios nuts shows 92.7 and 86.7% average removal accuracy, respectively for open and closed shell pistachio nuts.

Key words: Pistachio, closed shell, sorting, computer vision.

INTRODUCTION

Based on FAO statistics, Iran, as the first producer of pistachio nuts, produced 35% of the world's pistachio crop in 2008 (http://faostat.fao.org). The quality of produced pistachio nuts is an important factor in consumer acceptance. In this regard, improvement of post-harvest processes is vital. One of the common methods of sorting pistachio nuts is dividing them into open (split) and closed (unsplit) shell categories. These groups are treated differently in subsequent processing. Pistachios are principally served as roasted nuts and they are usually marketed as snack food. For this end, use unsplit pistachios are considered undesirable because they are difficult to open and they may contain immature kernels. Therefore, the sorting of open and closed shell pistachio nuts is an important part of the post-harvest operations (Figure 1).

A major problem in pistachio sorting is the use of harmful mechanical equipment or expensive intelligent systems. Closed shell nuts are currently separated from open shell product by a mechanical device called "pin picker". Although pin pickers have high capacity, they may damage the kernel of open shell nuts by inserting a needle into the kernel meat. The hole created by the needle can give the appearance of an insect tunnel, and lead to rejection by the consumer (Pearson et al., 2000).

Various techniques including optical, mechanical, electrical, and acoustical methods have also been used for classification and/or sorting of pistachio nuts. Machine vision was introduced for detection of stained and early split pistachio nuts (Pearson, 1996). Ghazanfari et al.

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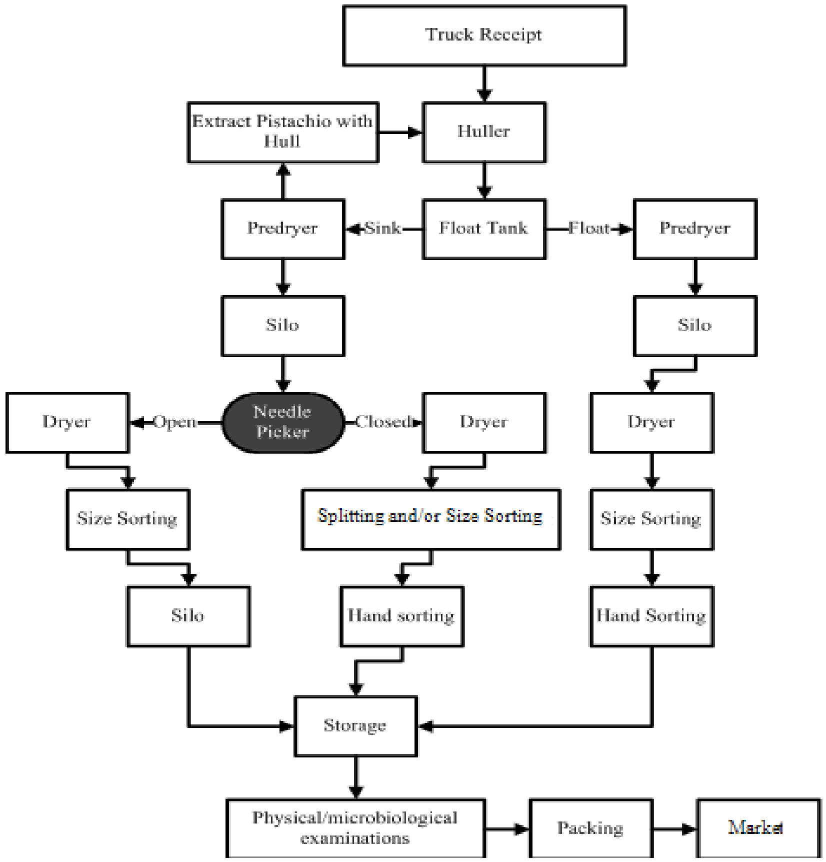

Figure 1. Post-harvest processing of Pistachio (www.viraman.com).

(1997; 1998) utilized Fourier descriptors and gray level histogram features of two-dimensional images to classify pistachio nuts into one of three USDA size grades or as having closed shells. Use of Fourier descriptors is very time-consuming and they are not suitable for real-time applications. Pearson's system demonstrates that, pistachios with either split or unsplit shells can be distinguished by using gray-scale images. Later, an automated machine vision system was developed to identify and remove pistachio nuts with closed shells from processing streams (Pearson and Toyofuku, 2000). The system includes a material handling mechanism to feed nuts through three high speed line-scan cameras without tumbling. The camera output signals are input into digital signal processing boards which extract image features characteristic of closed and open shell pistachios. The classification accuracy of this machine vision system for separating open-shell from closed-shell nuts in two passes is approximately 95%. Although the system has a throughput maximum rate of 40 nuts per second, its cost is too high for many producers in Iran.

As an alternative for vision systems, impact acoustic emission was used as the basis for a device that separates pistachio nuts with closed-shells from those with split-shells (Pearson, 2001, Cetin et al. 2004a, b). The proposed algorithm used a small number of features and achieved a classification accuracy of 91.5% on the validation dataset. Later in 2009, an intelligent pistachio nut-sorting system using a combination of acoustic emissions analysis, Principal Component Analysis (PCA) and Multilayer Feed forward Neural Network (MFNN) classifier was developed and tested (Omid et al., 2006, 2009). This system is cheaper than Pearson's vision system although it is slower.

In this study, a high performance low-cost computer vision system for automated removal of closed-shell pistachio nuts, with closed shells is designed and developed. The major contribution of this article is using two-mirrors for 3D imaging of pistachio, and implementation of a low-cost self-tuning sorter system. Ability of this system for high performance sorting is shown by the results of the experimental evaluation of the system.

MATERIALS AND METHODS

Taking a suitable image from pistachio nut is one of the major problems in the classification of pistachios using computer vision. Axial rotation of the nuts cannot be mechanically constrained as they are conveyed. This requires acquisition of three images

Figure 2. Common varieties of Iranian pistachio nuts (split and unsplit).

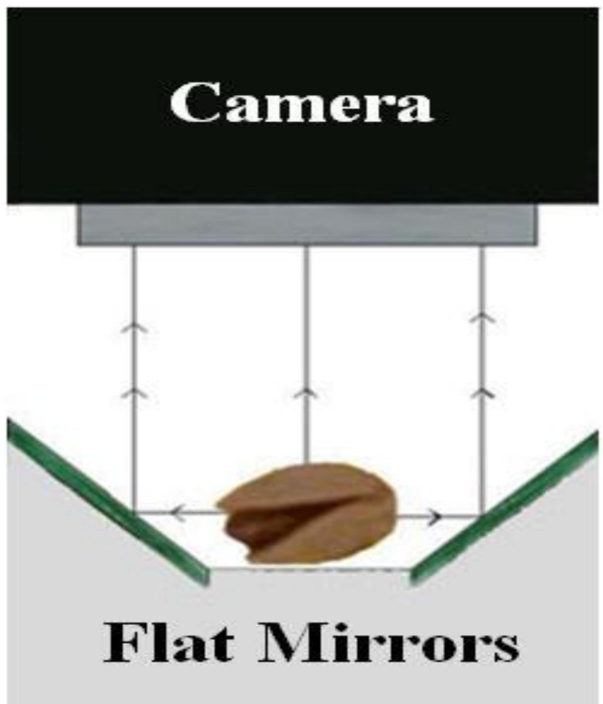

Figure 3. Arrangement of mirrors and camera.

around the perimeter of the nut in order for the whole surface to be inspected. In this study, three varieties of Iranian pistachio nuts, namely, Akbari (Ak), Kalle-Ghuchi (Ka), and O'hadi (Oh), are considered for training and analyzing. Samples of these nuts are presented in Figure 2.

For whole surface inspection, Pearson used three line-scan cameras to take several linear images from all directions of pistachio during free fall. This method of obtaining images is very expensive. To alleviate this, three cameras were replaced by one camera and two flat mirrors. This allows the system to view every side of the nut which eliminates system sensitivity to pistachio orientation. The idea is demonstrated in Figure 3. Four major possible pistachio orientations are shown in Figure 4. It can be seen that, using this method, cleavage of open shell pistachios in any orientation can be detected by only one camera.

The sorter system should be fully automatic to achieve appropriate processing. Therefore, the system should have a discrete controller with discrete events, such as pistachio arrival in the imaging corridor or sorting area. The general configuration of the designed system is shown in Figure 5.

Subsystems of the proposed system can be listed as follows:

Feeding subsystem

The feeding subsystem includes a hopper over the vibrating feeding chute. The feeding chute is vibrated by means of a spring and cam mechanism. As shown in Figure 6, rotation of the cam is obtained using an AC motor. This mechanism causes the nuts to move continuously down the chute.

Exposing subsystem

The exposing subsystem is used for correct positioning of the nuts in front of the camera. To have a constant controlled velocity, a DC motor gearbox is utilized to drive the pulley of the conveyor. The conveyor guides the pistachio nuts in a path having two inclined flat mirrors on two sides. Each pistachio is immediately detected when it crosses the path of IR rays at which time, the camera takes a

Figure 4. Main Configurations of pistachio nuts on the conveyor.

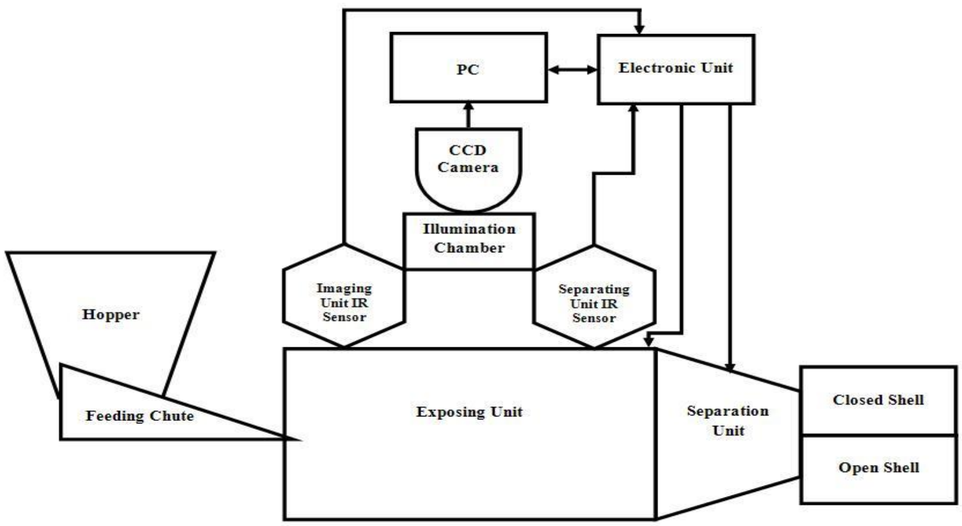

Figure 5. Block Diagram of the proposed system.

picture of the pistachio and its background after a certain delay. Therefore, no high frequency camera is required for this system.

Imaging subsystem

Sufficient illumination of the imaging chamber is achieved using two GU5.3 11W daylight lamps. This illumination is selected just for performance evaluation of the system and can be improved. A very inexpensive (POS-968A camera with SONY1/3"CCD) camera is used to acquire suitable images from nuts.

Divider subsystem

Separating subsystem includes a DC motor that provides for sideway movement of a divider vane to right or left.

Electronic subsystem

The electronic subsystem includes:

i) 12v DC power supply
ii) Two set of IR emitter and receiver sensor
iii) 12v DC conveyor driver motor-gearbox
iv) Divider vane driven by 6v DC electromotor
v) COM to USB communication cable

Low level control of the system is implemented using a microcontroller. The discrete-event based controller provides for high system performance. The communication between several subsystems and the computer is effected trough the microcontroller and USB port, which is adaptable with any personal computer. Image processing algorithm is programmed in real-time and high performance Delphi programming environment.

Sequence of system operation

The camera takes an image when a pistachio interrupts the infrared beam being detected by an IR sensor. This image is rapidly checked for split or unsplit status and the result is appended to a result queue which can consequently be used to control the sorting mechanism.

Learning and Image processing algorithm

In the real-time application, many restrictions appear and applications of many methods such as Fourier methods, spectral

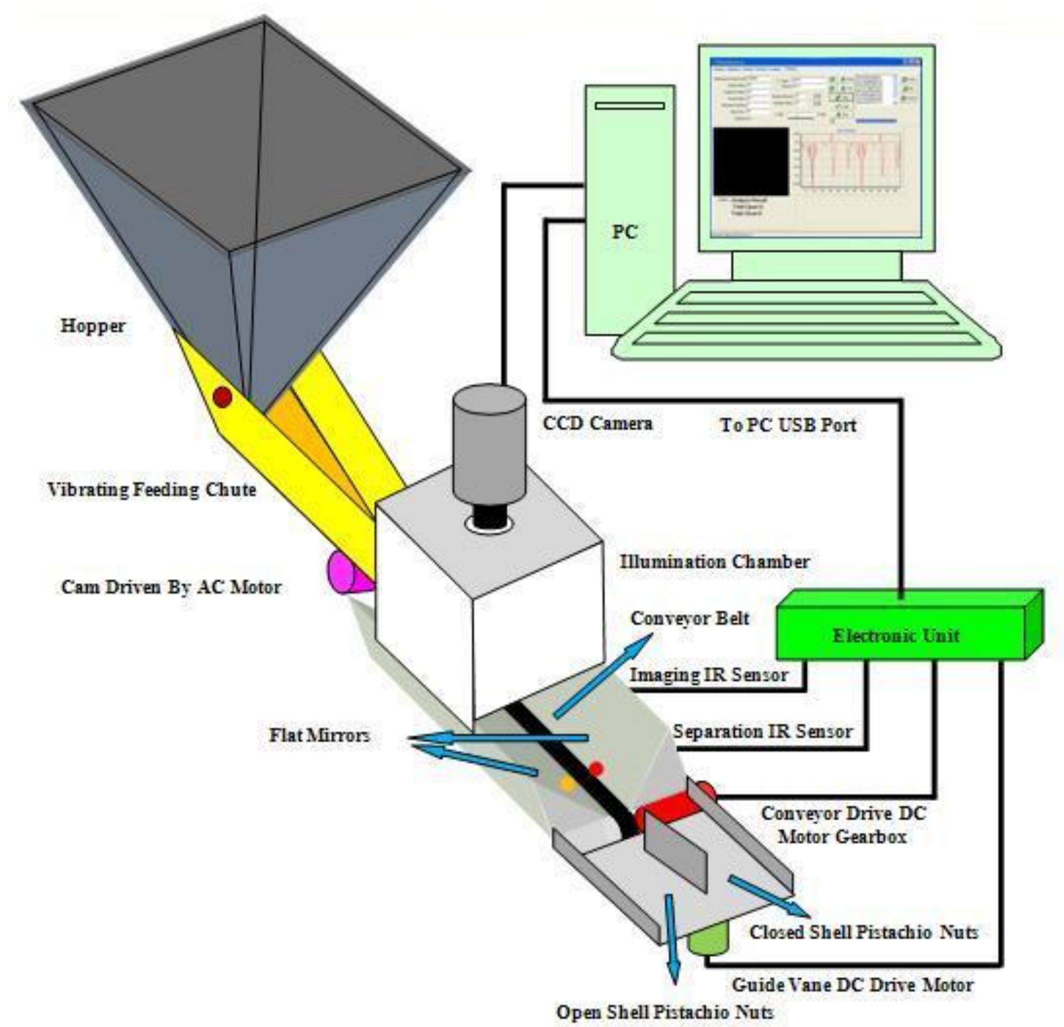

Figure 6. Schematic shape of sorting system.

methods, or active contours, are difficult to utilize. Therefore, simple methods are appropriate and should be completely analyzed and optimized off-line.

Thresholding segmentation of images is a subset of high speed methods in real-time image processing applications. In this study, these are optimized and implemented for unsplit pistachio sorting system. To the best of our knowledge, little work is published on the implementation of pistachio sorting systems using low cost and simple systems. A very inexpensive camera is employed which is bound to produce high-noise and low-resolution images. Moreover, the frame rate of the camera is confined and this restriction leads to serious problems for segmentation and evaluation of pistachio images in split or unsplit form. In order to solve these problems, multilevel thresholding is utilized for image processing.

The unknown parameters of image processing algorithm are tuned with PSO algorithm. Particle Swarm Optimization (PSO), developed by Kennedy and Eberhart, is one of the most well-known evolutionary optimization techniques (Kennedy and Eberhart 1995, 2001). PSO idea is based on social interactions such as bird flocking and fish schooling. Similar to genetic algorithms, PSO is population-based and evolutionary; with one key difference from genetic algorithms in that all chromosomes or potentials in the population, endure the entire search process. The PSO algorithm used here is explained in the following steps.

TRAINING AND TESTING OF EXPERIMENTS

Two hundred pistachio nuts were randomly selected for each variety in the training process. These include 100 open-shell and 100 closed-shell pistachios. The nuts used for training are passed through the sorting system to acquire and save the images. The system can be used under any lighting condition. Moreover, it contains mirrors which reflect the light into the camera lens. The diaphragm of the camera automatically changed in many times and this can be harmful for Multi-step threshold algorithm. Therefore, it is suitable to have background image for any image of pistachio. The training images for each variety included 400 pictures from pistachio nuts and 200 pictures from background. Thereafter, the unknown parameters of the system were tuned by PSO algorithm for each variety. Then the unknown parameters,

Table 1. Results of experiments.

Variety	Training percent	Testing percent	
		Open shell (%)	Closed shell (%)
Akbari	94	91	90.2
Ohadi	91.5	94	83.3
Kalle-Ghuchi	97	93.1	86.6

Table 2. Compare between several methods of sorting.

Parameter	Mechanical pin picker (%)	Pearson's machine vision system (two passes) (%)	Cetin's acoustics system (%)	Machine vision system designed in this study (%)
Open-shell	97	96.4	91.5	92.7
Closed-shell	95	93.2	91.5	86.7

tuned by PSO, were sent to the sorting program. Results of training and testing are presented in Table 1.

Conclusion

A low cost system for sorting of unsplit pistachio nuts was designed and implemented. Evaluation of the system in training and testing stages indicates that the system is very flexible for different varieties. The capacity of the system in initial tests is approximately 5 pistachios per second. Pearson's system is reportedly able to sort 40 pistachios per second. Since the fabrication cost of the proposed system is approximately $750 and Pearson's system is $15000, so to do the same job, we need eight of these machines ($6000). Therefore the amount of primary enterprise of this system is better than Pearson's system.

In the experiments, the system was trained for sorting Akbari and Kalle-Ghuchi varieties. But the training of the system to sort O'hadi variety is difficult. This may be because of its smallness and thin split area. The average train is 94.2% and testing is 89.7%. These results are encouraging and the system is completely implemented and analyzed. Table 2 shows a comparison between several methods for separating open shelled pistachio nuts from those with closed shells.

Future work in this field can be fulfilled by improving the whole subsystem such as feeder, exposing, separator, illumination and camera, and optimization and image processing algorithms. Multi-line systems can also increase the system capacity.

REFERENCES

Braquelaire J, Brun L, (1997). Comparison and Optimization of Methods of Color Image Quantization. IEEE Transactions on Image Processing. 6(7):1048-1052.

Cetin AE, Pearson TC, Tewfik AH, (2004). Classification of closed and open shell pistachio nuts using voice recognition technology. Transactions of the ASAE. 47(2):659–664.

Ghazanfari A, Irudayaraj J, Romaniuk M, (1997). Machine vision grading of pistachio nuts using fourier descriptors. J. Agric. Eng. Res. 68(3):247-252.

Ghazanfari A, Wulfsohn D, Irudayaraj J, (1998). Machine vision grading of pistachio nuts using gray-level histogram. Canadian Agric. Eng. 40(1):61-66.

http://faostat.fao.org.

Kennedy J, Eberhart R (1995). Particle Swarm Optimization. Proceedings of the IEEE International Conference on Neural Networks, Perth, Australia, pp. 1942-1945.

Kennedy J, Eberhart R (2001). Swarm Intelligence. Academic Press, 1st ed., San Diego, CA.

Omid M, Mahmoudi A, Omid MH (2009). An intelligent system for sorting pistachio nut vareties. Expert systems with applications 36:11528-11535.

Pearson T (1995). Machine vision system for automated detection of stained pistachio nuts. Lebensm Wiss, U Technol, 29:203-209.

Pearson T, Toyofuko N (2000). Automated sorting of pistachio nuts with closed shell. Appl. Eng. Agric. 16(1):91-94.

Pearson TC, Slaughter DC, (1996). Machine vision detection of early spilt pistachio nuts. Transactions of ASAE. 39(3):1203–1207.