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Design, fabrication and evaluation an automatic apple grading system

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ABSTRACT

A system was designed and fabricated to grade apples automatically based on their size using machine vision, in this study. The device included unites to single out, orient and grade apples. A cylinder container with circular hole in bottom which was equipped with agitator was built to single out the apples. This mechanism delivered apples to orientation unit, one by one. Two wooden rails with a specific form which was located on the ramp via adequate slope was used to orient the apples during rolling. After the orientation, apples were placed below the camera to take its photo. The photos were transferred to computer for image processing to determine the grade of apples based on their size. A belt conveyor carries the apples and set them in appropriate place regards to their grade. As a final point, the wind spray valve is opened and the apple is pushed to the marked box. In order to evaluate the constructed system, 10 red and golden delicious apples of each grade were chosen and the completely randomized design test was conducted. The results demonstrated that the most time consumed related to image processing. Almost%85 of apples were properly oriented in the orientation unit and graded correctly. The overall system performance was appropriate, thus the system can be used to grade apples automatically.

Introduction

Apples establish an important part of the human diet, correspondingly to other fruits, They are a source of monosaccharides, minerals, dietary fibre and various biologically active compounds, for instance vitamin C (ascorbic acid) and certain phenolic compounds which are identified to act as natural antioxidants (Podsedek*et al*., 2000).

Apples are one of the major products of the agricultural and gardening division in Iran, regarding the production of more than 2,660,000 tons annually. Iran is fourth country in view of the area under apple cultivation. In the past, Iran is the 15th among 231 countries,with 566,066 tons of gardening products to be exported, and now 317,890 tons of apples are exported from Iran. So, Iran is sixth in the world in apple product (Azizi and Yazdani, 2006)

Since the apple production and harvest are not mechanized in Iran yet, considerable amount of appleswere lost before export, due to improper package and grading mainly. Traditional methods are still used to grade the apples; that is why a considerable amount of them were lost because the improper conditions workers become tired. Each worker takes different decisions in different conditions of grading the apples, therefor the products are not graded in the same way led to less or lack of sale; Consequently, other countries have tried to grade and package automatically apples by machines to promote the quality of grading and packaging (Chen *et al*., 2002; Davies, 2005).

The fruits quality examination has been a subject interested by the researchers. Now the usable methods are harmless. A considerable work of the automated system to control the quality in nutritional industries is done by the vision sensor; it examines some factors such as color, size, superficial damages and others. If the method used along different waves, it may transfer some factors such as the damages under the peel and even the chemical qualities to the processing system (Chen *et al*., 2002). The main advantage of the vision system to control the quality of the products is the accurate and monotonous control process, because the products are verified qualitatively, continuously during passing on the conveyor belt in most factories (Davies, 2005).

Different devices have been designed and fabricated to grade agricultural products, using machine vision. Special methods were used in the machines to grade the products. The components of such devices include following elements:

1 – The units or sections to separate each product.
2 – The section to orient the products.
3 – The section to take photo.
4 – The software to process the image data.
5 – The unit to separate and grade products.
6 – The unit to control depending on the type of the product.

The system may have not some of above parts, according to the type of the products.

Some investigators have designed and created different systems with promoted potential to orient a lot numbers of apples; one of such systems includes a smooth and steeped surface, which they put apples and a paddle moved by a motor rolled apples (Whitelock*et al*., 2006). Narayanan *et al.* (2008) did a study by virtue of apples' physical specifications and inertia to orient the apples; they found that it is possible to use a steeped surface in order to orient apples so they conducted the potential to orient apples by two rails in special form to be located into the steeped surface; their findings indicated it is possible to use a steeped surface to orient apples.

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Considering fruits and vegetables are damageable it is not possible to use an uncontrolled mechanized method. Usually pneumatic and hydraulic force is used to grade fruits and vegetables or the mechanical grading system is fabricated in a way that no product is damaged.

The researchers used a wind cylinder under apples to grade and separate them from each other. The container with apples was emptied in any grade into the special channel in order to grade the products (Bennedsen*et al*., 2005). Ighbal*et al.* (2002) designed and fabricated a mechanism to grade apples. They used a roller in the system to separate apples one by one.The apples are separated from each other when put into the roller boxes and poured separately on the conveyor belt of the grading unit, in this system. The dimensions and size of the holes on the roller allow only one apple to be laid there. They used wind to separate the graded apples on specific time.

Other orientation devices have been established. Different variations of a wheel-cup were designed, where a small wheel, swelling into the bottom of a cup or cone contacts the fruit cheek, rotated until the stem or calyx moved over the wheel causing the fruit to break rotating, have been used with success for peaches (Hait and Kellog, 1960) and apples (Keesling,1965). Throop *et al.* (2003) advanced a system using a protruding wheel in a moving cup that oriented over 97% of 14 apples cultivars in about 7 second. Gardiner (1964) developed a complex shuffling machine that moved pears up an incline to reach orientation.

The photography unit in the grading systems based on machine vision is the main part and heart of the system (Chen *et al*., 2002; Davies, 2005). The photography systems used in agricultural sector take usually photos by reflection, distribution or fluorescence of agricultural materials under visible, light, infrared or ultraviolet light. A basic photography system includes a camera, a computer with a circuit to take photos and a lighting system. Beside that, a computer software is necessary on due time to transfer the command to the camera to take photos, develop them and transfer necessary commands properly (Chen *et al*., 2002; Davies, 2005). Other researchers have fabricated a special light box in order to take photos of all dimensions of the apples and put concave and convex mirrors into the box; they used two, four and six mirrors, respectively and computer software to eliminate common regions in the taken images from the apple's surface (Reese *et al.,* 2009).

Since physical and mechanical specifications of apple and its damageability during operation after the harvest is important, the scope of this study was designed and fabricated a machine to grade automatically apples based on the size using images processing technology.

Materials and methods

A system was designed to grade apples automatically based on the following step associated schema was shown in figure (1):

1 – First the apples were poured into a tank and then separated one by one from each other by a mixer and conveyor belt.

2- Separated apples are put on the orientation unit where from they fall into a tube by rolling wooden rails in defined direction (The peduncle would be vertical to the rolling direction) to become ready for taking photo.

3 –Properly oriented apples are put on the conveyor belt of the grading unit one by one and stop a moment under the camera; thus a picture is taken separately of each apple; then the image is analyzed by the image processing software and its size is defined according to the standard levels; the conveyor belt moves towards exit path and stop a moment in a special place depending on the grade of each apple to put into operation the wind sprinklers to push the apple into the defined basket; the electric tap is ordered by the electronic circuit of the control device and opens the gate to push the apple using wind.

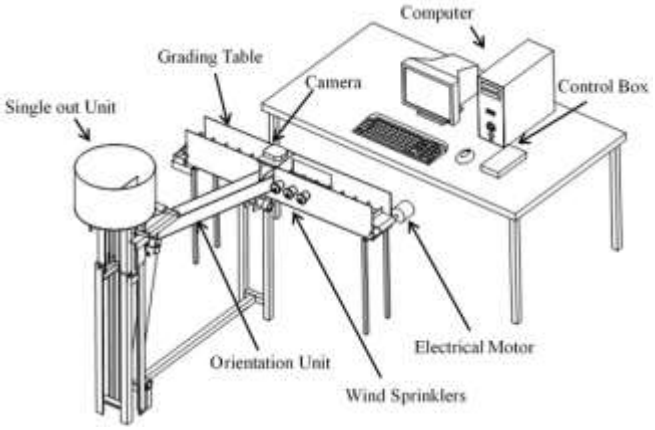

Figure 1. Schema of fabricated system

The single out unit

Similarly to plant potatoes system, a mechanism was used to separate apples one by one. Considering any damage to apples should be avoided the dimensions, size and material of the pieces and instruments were defined. A mixer was used to roll apples into the tank and throw them into the hole; the size and dimensions of the mixer were selected in a way that it rolls easily all the apples put in front of it without damaging them. Because an apple's diameter is maximum 85 mm, to avoid probable closure of the hatch, the hatchdiameter was designed 90 mmfor falling. The falling and holding tube's height was designed 10 cm, cause an apple may tolerate about 20 cm height. 9 cm distance was selected between the falling tube and the conveyor belt to separate from each other; the apples put into the falling tube are located between the wooden separators on the conveyor belt; such separators are used to hold and control the conveyor belt carrying apples in order to put them one by one on the orientation unit.

The orientation unit

In fact, this device is a steeped surface into which two wooden rails are located. The width, dimensions and size were taken into consideration by Narayanan *et al.* (2008); the angles of the rails were adjustable in the horizon surface in 12 and 19 degrees. The rails had to be of flexible and resistant material, thus rush wood was selected; the rails were put on a chassis into a pipe; one side of the chassis was fixed and other one was adjustable to regulate the steep. Two pipes into each other like telescope were used to regulate the steep angle; there were two holes on one of the pipes and one on another in a way that when they were in front of each other, it is possible to regulate the defined angle. The dimensions and size of the chassis are in a way that they are in harmony with the units to separate apples one by one and photography.

The grading unit

Separated apples were put on the conveyor belt to grade them in harmony with the orientation unit. A camera was installed on the conveyor belt which is of industrial rubber usable in nutritional industries; also it is black so the processing by the software was easy, because the background was black, to eliminate the apple's shade and peduncle. Each apple was put between the wooden separators on the conveyor belt to be solely under the camera; the camera has been already installed above the conveyor belt.

The transfer unit

The graded apples were transferred to related basket by wind. When the apple is graded the conveyor belt moves and

stops in front of the related electric tap then the tap is ordered by the control unit and the wind is blown. Finally the apple is rolled from the conveyor belt. The wind was blown properly to avoid damaging the apples (About five bars).

The Control box

An electric circuit was designed and fabricated to control the move time of the motors, operation of conveyor belt, stops, imaging and electric taps properly to grade and separate apples; the circuit includes a microcontroller (AVR- Atmega 16) which control the moves and stops of the motors to put into operation conveyor belt and open and close the taps on due time according to the apple's grade. Figure (2) shows the control circuit fabricated of the device.

Figure 2. Electronic board of control box

The camera

A digital camera (model: Canon power shot A70) was used to take apples photos; the camera may take photo with the clarity of 204 x 1,536 in RGB colorful frame (24 bits). Considering the importance of measuring apple dimensions in the project the light control is not necessary during taking pictures so the photos were taken in the environment light.

The image processing software

In the first, the file was created into which the taken photos should be put and then the file path was defined for the software. Then the button was pressed to process automatically the images one by one; having processed each image the operation stops for 30 seconds and then the next image process begins; during the stop the camera takes photo and it is transferred to the file. The software was closed automatically, if no other photo was taken interval.

Evaluation of system performance

The Table (1) shows the criterion to grade apples and put the each one in a special grade. The main and lateral diameters from above are the biggest and smallest dimensions of the apple, respectively. The least diameter or height is a dimension of the apple with the most size on the lateral dimension.

Table 1. America apple grading standard

Class number	Minimum diameter (mm)	
1	70.4	
2	67.2	
3	64.3	
4	60.8	

In order to evaluate the performance of units, the system was test after assembling the units. The fabricated system was shown in figure (3). 40 apples where diameters measured by caliper were selected; ten ones for each grade. The apples were put on the rails in three different positions in each test and each test was repeated ten times for each apple. The positions were as follows:

1 – Standing position or vertical to the rail.
2 – Horizontal position in a way that the peduncle and end of the apple were vertical to the move orientation.
3 – Angular position; the peduncle and end of the apple were at 45^{o} angle to the rails.

Collected data was analyzed according to the completely randomized design test.

Figure 3. The fabricated system

Results and discussion

Evaluation of orientated apples

The results of analyze of data tests indicated that the apples with heterogeneous form were oriented worse than the apples with monotonous and symmetric form. Beside that, there was a relation between the apples size and their potential to be oriented in a way, that the apples with more heights are oriented better than the shorter ones, probably. Because, the apples gravity center of the bigger ones is in a higher position, so they move and change place in a way that the center of gravity is horizontal, thus they are oriented better.

Having examined the data it became known that the apples with sphericity about 0.95 are oriented better and more than ones with sphericity near one and less than 0.95. Also. if the apples have high sphericity potential, the way to be under the camera is unimportant due to little difference between the main diameter and the height.

Results of analyzed the data showed that 85% of the apples are oriented properly. The apples classoneand threewere oriented better than the class two and four, were shown in figure (4). Also, the apples grade fourwere oriented properly very less than others. Result of examined the data and compared the main dimensions of the samples was concluded that the apples grade two and three were oriented improperly 13%, so there was error potential in their grouping.

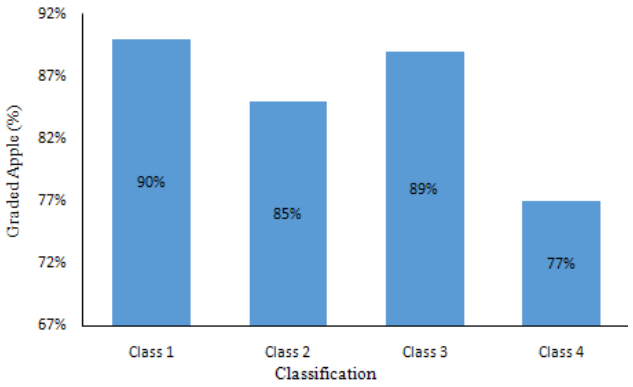

Figure 4. Percentage of sorted apple in every mode

The factor led to improper orientation was heterogeneous form and lack of monotonous surface; heterogeneity and lack of monotonous surface mean the apple has bigger and smaller parts. A sample of such apples is shown in figure (5).

Table 2. Time need of sorting by part of device

Part	Time (s)
Single out	5
orient	1
Video recording	6-8
Image processing	26
Grading	6-18

Absence of monotone surface leads to roll improperly on the steeped surface and rails and oriented in improper direction.

Figure 5. Image of abnormal shape apple

Evaluation of image processing unit

The results of testing image processing software indicated that the precision of detect the apples size were 91 up to 96%. The error of software, prepared and used in this study, was occurred related to applespoorpositioning on orientation unit. The figure (6) and (7) show the appropriate and inappropriate situation of apples were placed below camera, respectively.

Figure 6. Corrected locate of apples below camera

Figure 7. Uncorrected locate of apples below camera

Evaluation of system performance

In sum, the all part of system operated correctly. Considering the produced system functioned properly it may be concluded that it is possible to grade automatically apples completely. Table (2) shows the time necessary for the device in each section separately. The total time to grade apples was about one minute. The most time consuming part to grade was related to the image processing.

The similar findings concerning grading machines have been reported by other researchers (Throop *et al*., 2005; Lefcourt*et al.*, 2009). Whitelock*et al*. (2006) found that the high amounts of big apples are oriented well than the small ones. Narayaran*et al*. (2008) used a steeped surface in order to orient the apples and the study data indicated about 80% of the apples were oriented by this method; in the study the proper orientation means the axis among the apples was vertical to their move direction. Other researchers designed and fabricated a device to grade qualitatively the apples and concluded if the peduncle is removed, the distinction potential of the device to grade qualitatively the apples is promoted from 95.33 to 99.04 percent (Pordarbani*et al*., 2009**)**.

Conclusion

The designed and fabricated systemwas functioned properly to grade apples without damaged the product during operation. Although 15% of the apples were oriented incorrectly, %85 of them graded correctly in four class. This error was duo togeometric form of apples. The heterogeneous form apples were oriented worse than the apples via monotonous and symmetric form.The total time to grade apples was about one minute. The most time consuming part wasrelated to the image processing by computer. Therefore the system was designed and fabricated in this study can be used to grade apples automatically.

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