Sorting and Grading of Cherries on the Basis of Ripeness, Size and Defects by using Image Processing Techniques

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ABSTRACT: Sorting of different fruits according to their ripeness, size, color, appearance, and also proper separation of impurities and appropriate supply to markets of great importance in the fruit trade. In this research, Image Processing Techniques were used in order to analyze the ripeness of cherry and its sorting. The samples were picked from Mashhad black cherry varieties gardens during four stages and with interval of 5 days. Using a CCD camera and in controlled environment, 250 photographs of the samples were taken. For analyzing the fruit ripeness, simultaneously with imaging of the samples, the percentage of their Total Soluble Solids (TSS)(index for ripeness of corps) was measured by Refractor meter. By data analysis and review of images in different color spaces, RGB space was detected as the best space to study fruit ripeness. Analyzing the correlation of different functions between color component sand the index for cherry ripeness showed that the red color component has the highest correlation with TSS($R^2=0.9$). Also the results showed that the algorithm accuracy in sorting cherries according to their ripeness was 92 %. The results showed that the average accuracy of algorithms on sorting defective cherries was more than 90%, among which the highest accuracy was related to worm-eaten cherries, and the least accuracy was related to squashed cherries. The results for analysis of algorithms in different conditions showed that the maximum accuracy of the algorithm for sorting the cherries is related to sorting due to size (accuracy of 96%).

Key Words: Image Processing, Total Soluble Solids (TSS), Cherry, Sort, Machine Vision.

INTRODUCTION

Among the various fruits produced worldwide, cherry fruits (cherries, sour cherries, peaches, plums, apricots, etc.) are greatly important in human nutrition. According to the statistics of World Food Organization (FAO), Turkey, United States of America and Iran are three countries which are considered the world's largest producer of cherries. In 2007, Turkey with producing 392 thousand tons of cherries has had the first rank, and USA with 270 thousand tons and Iran with 225 thousand tons were in the second and third rank (FAO 2007). For grading agricultural corps, usually physical properties such as color, size, diameter and area are used. Compared with mechanical systems, using machine vision systems in fruit sorting has increased dramatically in recent years. Benefits of using machine vision and image processing technique using grading fruits include Increase the efficiency and accuracy of weighing, the possibility of increasing gout put capacity, computer processing and data storage simultaneously with separation process, and the early detection off laws in product quality (Amini, 1387). The ripeness of the fruit is an important indicator which is not usually possible to identify by regular sorting machines. Unripe fruit has lack of sufficient growth in the crop and lack of the color change of
all or part of the fruit, along with fruit firmness. An unripe fruit is a fruit that more than half of it is unripe, and its flavor is bitter and / or a stringent. Most fruits, including cherries, are not climacteric therefore, if harvested as unripe fruit, ripening after harvest operation is not possible. So sorting fruits based on ripeness when supplying to the market is really important. Researchers have shown that in most agricultural products, ripeness of fruits is highly correlated with the color. The most important criteria in determining ripeness in Cherry is the percent of Total Soluble Solid (TTS). Zhigiinget al.(1999) used a digital camera to detect the flaws in apple fruit. In that research, the fawn spotson the apples were diagnosed with the accuracy of 66/66 %. Blasko et al. (2009) designed and applied an automatic machine in order to grade the pomegranate seed isolated for packaging and increasing the potential consumption of pomegranate in Spain. Isolated pomegranate seeds were classified in to four classes. Ranking were based on color.

The results showed that the success rate of the datais90%. Zhang et al. (2009) designed and evaluated a device for sorting the cherry tomatoes. This device consists of three CCD cameras whose captured images covered 90% of the fruit surface. Diagnosis was performed based on the Principle Component Analyses (PCA)and Linear Discriminant Analysis(LDA). The rate of the device was sorting 7 Cherry tomatoes per second, and the method could correctly classify the cherries with the accuracy of 94.9% of the total sample in each group. Most researches in the field of sorting and classification of fruits using vision machine is performed based on fruit surface defects detection. The importance of external standards maybe more for consumers, but if they were not sure of the internal quality of fruit, a significant loss will certainly occur at the purchasing of the product. So sorting the fruit based on the ripeness can be more effective in its desirability in the market. The goal of this study is to evaluate the correlation between the index of ripeness of the cherry and the features extracted from the image.

MATERIALS AND METHODS

Preparation of the samples

The research was performed on Mashhad black cherry varieties. Samples were obtained from the gardens of Agriculture Research Center in the spring 2012. In order to having fruits with the different percentage of ripeness, samples were picked with an interval of5 days and in four stages. After isolation of the cherries, the samples were transferred immediately to the laboratory and were photographed. Photos were taken using a digital camera(SONYDSC-W200 model)and in the lighting box.

The container for preparation of images is with dimensionsof50 × 50 × 40cm, and some round vents with radius of3.5cm were provided on the sides of the box for the installation of lamps. This feature allows the user to adjust the angle of the light bulb for each specific application. LED lamps with white light are used for lighting of the container. In order to reduce reflection of light from the fruit surface, polarized filter is used in front of each lamp. Early image processing was performed in MATLAB and using the threshold method, the noise and background were eliminated. Then, using image processing techniques, the light reflected from the image which caused noise in the image and errors in the calculation of average of R, G, B, was eliminated. With creating binary images, the area of fruits was calculated in pixel, and according to the black spots in binary images, and the ratio of black to white spots, detection on defects was also studied. The Total Soluble Solids(TSS)is an important index of ripeness in the cherries. To measure the TSS, the refractometer model was used. The TSS samples were in the range of9-25.According to their ripeness (the amount of TSS), cherries were classified into three classes: unripe class(TTS 9-14), semi-ripe class (TTS 14-17) and ripe class(TSS>17)(Figure 1). The appropriate algorithm to calculate the average color components of Cherries was written in HSV, YCBCR, RGB and CMYK spaces. In order to analyze the ripeness of cherries, correlation between the staining intensity and percentage The Total Soluble Solids(TSS) were tested in different color spaces.
RESULTS AND DISCUSSION

Classification of cherries based on ripeness

In this research, cherries are classified based on their amount of their Total Soluble Solids (TSS, index for ripeness). The results of analyzing the images in different color spaces indicated that the RGB color space, in which the gray level of each component of image is between 0 to 256, is the most appropriate space for image analysis. Using the following relations, the correlation between the average of red, green and blue components of the cherries and the amount of TSS in this space was examined:

- **Red** = \( \frac{r}{(r + g + b)}\) * 100
- **MR** = \( \frac{r}{\text{Number of pixels}} \)
- **MG** = \( \frac{g}{\text{Number of pixels}} \)
- **MB** = \( \frac{b}{\text{Number of pixels}} \)

where:
- **r** = sum of the gray area of cherry pixels in red components;
- **g** = sum of the gray area of cherry pixels in green components;
- **b** = sum of the gray area of cherry pixels in blue components.

\[ \text{MR} = \frac{r}{\text{Number of pixels}} \]
\[ \text{MG} = \frac{g}{\text{Number of pixels}} \]
\[ \text{MB} = \frac{b}{\text{Number of pixels}}. \]

According to the table 1, a correlation of 95% was obtained between the red component and value of TSS. But there was not a good correlation between green and blue components and the value of TSS. Fruit color is one of the general criteria used to determine harvest time. The survey results showed a high correlation between cherry color and its ripeness. In RGB color space, by increasing the amount of gray area and approaching to 256, the fruit colors becomes brighter and nearly will be close to white. Therefore, the less these three components are, the darker fruit color is. This is due to the fact that fruit ripeness is negatively correlated with the red component. When harvesting, the color of black cherry varieties should be red dish brown. Dark red cherries are the most preferred to bright red ones, probably because of their sweetness (Kaplan et al., 1996). Drak et al. (1987) showed that by increasing the amount of redness in cherry, its TSS will also increase. Sorting accuracy based on ripeness was 92%.

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>.949(a)</td>
<td>.900</td>
<td>11.92198</td>
</tr>
<tr>
<td>G</td>
<td>.362(a)</td>
<td>.131</td>
<td>5.00183</td>
</tr>
<tr>
<td>B</td>
<td>.156(a)</td>
<td>.024</td>
<td>5.56938</td>
</tr>
</tbody>
</table>
Classification according to area defects

By converting images into binary image, morphological defects in cherry were studied. Defects were classified into three types of surfaced effects and imperfections including damage or pecking of fruit by birds, adherent cherries and squashed cherries. Defective cherries and their binary images are shown in figure 3.

In order to separate the intact cherries from defective cherries, we used the area of defective cherry ($A_d$) and area of the same cherry without considering its defect ($A_o$) (differential area criterion). And the amount of defect was defined as below:

$$\text{DA} = \frac{(A_o - A_d)}{A_o} \times 100$$

DA= differential area criterion;
$A_o$= area of cherry when defective;
$A_o$= area of cherry when intact.

The greater the DA index value is, the more defective the cherry is. The results of analysis of different images showed for detecting small stains ,the DA index should be considered higher than 10 %, and smaller
stain scan be considered as intact cherry. Then the accuracy of diagnosis algorithm for morphological defect was studied indifferent cases, and it accuracy's shown in Table 2. Results showed that the algorithm accuracy in detecting pecked ness defects is higher than that of other defects, and the accuracy of detecting the squashed cherries was the lowest. Considering that the color of defective area in the cherry with a pecked ness defect is different than the color of the surface of healthy fruit, when converting the images, this difference can be determined with great distinction, and the percentage of accuracy in detection algorithm increases. Furthermore, the error occurred at this stage is due to placing of the defective surface in the bottom of the fruit. In analyzing the adherent fruits, because of the color conformity and lack of gross color difference, the error percentage increases. The lowest percentage was acquired in classification of squashed cherries. Since the cherry which is squashed, has largely maintained its same color and shape, and only the value of reflection and brightness in the surface of the fruit was different than the healthy cherries.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damager</td>
<td>95%</td>
</tr>
<tr>
<td>Pecking of fruit by birds</td>
<td>89%</td>
</tr>
<tr>
<td>adherent cherries</td>
<td>85%</td>
</tr>
<tr>
<td>squashed cherries</td>
<td></td>
</tr>
</tbody>
</table>

*Classification Due to Size*

The size of cherries was calculated based on the area of related images. The area of cherries was calculated by counting the number of related pixels after removal of the background, and implementation of the defect detection algorithm. Although the area for each fruits calculated in pixels, since these areas are used in doing the classification, the units of area will not affect the results. In order to evaluate the accuracy of the algorithm in classification, before processing, the cherries were classified into three groups, small (diameter smaller than 1 cm), medium (diameter between 1 and 1.5 cm) and large (diameter larger than 1.5 cm), and the amounts were converted to pixels in the same way that small cherries were in the range of smaller than 8000 pixels, medium cherries were between 8000 and 12000 pixels, and large cherries were more than 12000 pixels. In order to sort the cherries in the unit of square centimeter, the value of area in pixel can be multiplied in a certain number. In this case, sorting will be possible based on physical units. The calculated number for converting pixel to the equivalent square centimeter was $1.25 \times 10^{-4}$. The accuracy for sorting due to size is shown in table 3.

<table>
<thead>
<tr>
<th>Area of cherry when defective</th>
<th>Intact</th>
<th>Area of cherry when squashed cherry</th>
</tr>
</thead>
</table>

Figure 4. binary images.

Table 2. accuracy of sorting according to defected cherries.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>small cherry</td>
<td></td>
</tr>
<tr>
<td>medium cherry</td>
<td></td>
</tr>
<tr>
<td>large cherry</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8. classification due to size
Table 3. Accuracy for sorting due to size

<table>
<thead>
<tr>
<th>Size</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>95%</td>
</tr>
<tr>
<td>Medium</td>
<td>94.6%</td>
</tr>
<tr>
<td>Small</td>
<td>96%</td>
</tr>
</tbody>
</table>

CONCLUSION

Using image processing, sorting the cherry according to its ripeness, size, and defect was performed with an appropriate accuracy. The algorithm based on size was expanded by using binary images of cherries and converting the area to a physical unit. Sorting the cherries according to their ripeness was done by color criteria and the TTS in fruit. In order to minimize the error rate in calculating the average color components, the reflected light in the images were removed. The written algorithm is able to sort the defective cherries from the intact cherries by considering the color change and the value for area with a good accuracy. Sorting due to size, ripeness, and defect was performed respectively by the accuracy of 96 %, 92 %, and 90 %.

REFERENCES

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