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Special System for Classifying and Sorting Walnut Base on Image Processing

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Abstract: One of the exhausting and pricy works in the agriculture is sorting product. It is crucial to choose the best sorting method for Walnut because there is colossal number of Walnut farms in Iran. In this study, properties of the 100 walnuts (*Juglans regia* L.) shape, such as thickness, width, length and shape index were investigated experimentally. The imaging system especially the pre-processing level was designed to modify any noises. The binary process implemented to identify the objects on white color sample in black background. According to the range of indicators, all walnuts were divided into three groups including small, medium and large. The proposed machine learning method was development by regression analysis with sigmoid function for find relationship between output variable from one or more input variables. Thus, the correlation coefficient of R^2= 0.9. This research focuses on postharvest processing, specifically the advantages of machine learning for sorting system.

Keywords: Postharvest; Sorting; Image Processing; AI; Walnut

1. Introduction

A walnut (*Juglans regia* L.) is a basic fruit in the diet of Central Asia population. According to statistics, it stands at the second rank of nut production after almonds. There are more than 1,500,000 metric tons of walnuts in all over the world. The majority of mentioned products are cultivated in different countries and the main important of them are United States, China and Iran, respectively the percentage of total global production are 25, 20 and 11%.[1] The popular and Consumption walnuts are available around the world include *J. regia* Linn, *J. cinerea* Linn and *J. nigra* Linn. Regarding cultivated area and merchandising importance, the valid type is the persian walnut (*J. regia* L.).

Also, nuts are larger and sweeter than other kinds of walnuts. Moreover, it is convenient to separate from their thin shell (in slang, it named paper shell).[2] Walnut cultivars distinguish from each other by ability of producing light-colored kernels under variety of climatic conditions. Some cultivars like Sebin, Chandler, Serr, and Hartley are usually light in color. However, some of them have darker kernels in warm weather.[3] One of the important parameters in designing postharvest devices and machines is coefficient of friction between walnut and various surfaces. In recent studies, the tendency of analysis physical and mechanical properties are increase between researchers,[4-29] such as macadamia nut;[4] castor nut;[5] raw cashew nut;[6] almond nut and kernel.[7]

Physical properties like dimension of fruits have a commercial worth in packing, sorting, separating, and manufacturing appropriate sorter. Some sorters were designed including cucumber,[8] long type watermelon,[9] Spheroid Fruit[10] sorters. Therefore, there are a colossal number of researches which were conducted to analyze the shape of sheer variety of fruit by these useful approaches. These methods contain grading of pistachio nuts using Fourier descriptors,[11] evaluation of apple shape by principal component analysis and Fourier descriptors,[12] Analyzing fruit shape in sweet cherry,[13] classification of fresh-cut star fruits using automated machine vision system,[14] Apples shape grading by Fourier expansion and genetic program algorithm,[15] Automatic sorting of satsuma segments using computer vision and morphological features,[16] shape description of almond cultivars,[17] pomology observations, morphometric analysis, ultrastructural study and allelic profiles of olivastra Seggianese[18] and Comparison of Different Image Processing Methods for Segregation of Peanut (Arachis hypogaea L.) Seeds infected by Aflatoxin-Producing Fungi.[19]

2. Material and methods

The essential of intelligent system is shown in Fig. 1, including walnut, image analyze, extraction of features and artificial intelligence for classify the walnut.

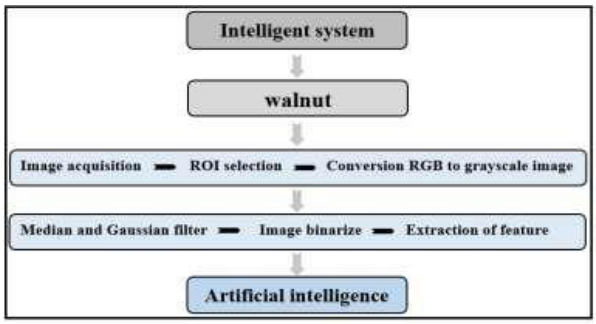

Fig. 1. Experimental procedures

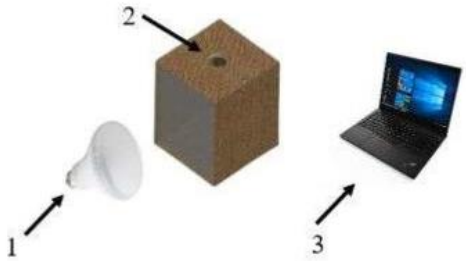

Fig. 2. Design of imaging system: (1) LED light bulb (2) Smart phone (3) Laptop

2.1. Sample collection

In this study, one hundred walnut samples were randomly collected from the garden in Urmia city, Iran.

2.2. Apparatus

The mechanism of system for take the image from the walnut is shown in Fig. 2. This box was simulated in 3D sketch on SolidWorks software (2021) and made of wood and glass to eliminate effects of environmental noises. Dimensions of box in length, width and height are 20, 20 and 20 cm, respectively. The light Blub contains a 7W SMD bulb. One of the most important stages in walnut morphological analysis is the uniform orientation of the light, influence from the glass and spread it throughout the box, so there will be not shadow on the sides of walnut on imaging time. They used imaging system (Digi Eye) includes digital camera, illumination box and computer to obtain the images.[20]

They used Digifood to obtain morphological parameters, which is better than CIELAB coordinates of image processing.[21]

We used Nokia 5.4 smartphone to RGB (color) images. The camera of phone is 3000×4000 pixels in horizontal and vertical directions, respectively and focus length is 5 mm. Smart phone was fixed approximately 200 mm in horizontal distance from the center of the walnut sample. Data information transferred through a USB cable to laptop for image processing operations. A Lenovo TM laptop with following specifications was employed for the experiments; windows 10 Enterprise, Intel® Core TM i5, NVIDIA Geforce GT740M and installed memory (RAM) is 4GB.

2.3. Image Analysis Methods

The required images were saved in .jpg format via a camera of mobile and processed by MATLAB® (MathWorks, Inc., USA) with using an algorithm to detect the walnut which contains 2 steps:

Fig. 3. Input RGB image (ROI)

Fig. 4. Grayscale image

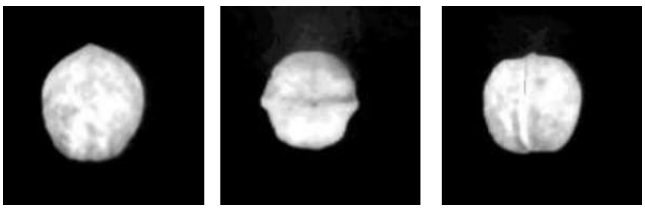

Fig. 5. Enhancement image

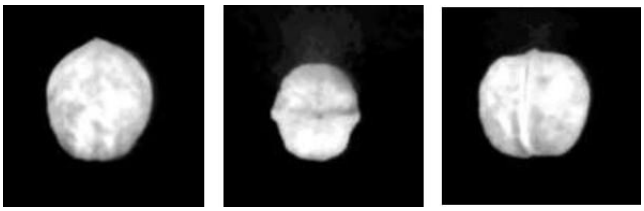

Fig. 6. Applied Gaussian and median filter

a) Image pre-processing: assessing the best process approach, comprise of filtering and segmentation.
b) Image analysis: expositive area of the light pattern is gained from the image to extract feature of optional pixels.

2.4. Preprocessing

Modifying any noises of image during the examination course and furnishing compulsory information about the walnut are the objective of pre-processing. Firstly, useful information must be extracted from the RGB image, which is substantial to divide the significant zone of image from primary image. This zone is reputable as ROI (zone of interest). ROI of input image is shown in Fig. 3. It is limited to walnut seperetation in 1701×1621 pixels.

After that, the image was converted (Fig. 3) to grayscale mode in order to extract the morphological characteristics. Color range between black and white for each pixel (Fig. 4) is demonstrated by the level of grayscale severity [0-255].

Fig. 5 shows an operation that increases the contrast of the 8-bit images to perform the image polarity. In this section, by applying a coefficient of intensity [0.01-0.99] to the image (Fig.4), which is obtained in practical tests, intensity of bright and dark pixels value promoted in image.

Utilizing the low-pass filter operation is one of the main steps in pre-processing. It is applied on the images for tracking some effective relationships between the spatial and frequency domains. Signal

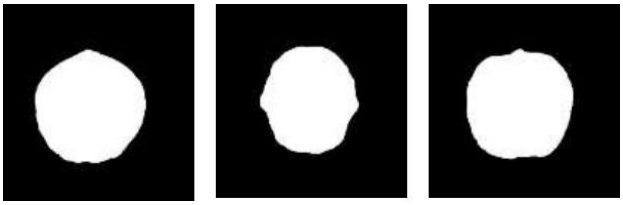

Fig. 7. Binary image

Fig. 8. Schematic of the imaging system.

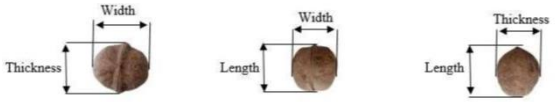

Fig. 9. Different orientation of walnut positions.

components with high spatial frequencies was removed by Gaussian and median smooth filtering. Regarding Fig. 6, this filter with 3×3 mask was obligated to plunge the noise of image and identify the walnut.

Binary process helps to detect the stuffs on white color sample in black background. Binary function was promoted by Otsu thresholding method to enhancement the grey level image depending on threshold with using binary function (Eq. 1). It is minimizing the interclass variance of black and white pixels to get a binary image (Fig. 7).

$$I_{binary} = \begin{cases} 0 & if\ I_{image} \leq T_{otsu} \\ 255 & otherwise \end{cases} \quad (1)$$

2.5. Image Calibration

To validate the extracted feature, calibration is essential. As shown in Fig. 8, image calibration which taken by the camera in landscape mode, The ROI region image was 100 mm or 1621 pixels wide and 100 mm or 1701 pixels length. So, with this method, image pixels count deforms by a proportion of millimeter unit; difference between the centimeter size on the real environment and image processing method result accuracy is less than 0.01 mm.

2.6. Walnut analysis criteria

Shape Index (ST) was used to calculate the spherical or oval shape of walnut. If Shape Index of walnut is less than 1.25, it indicates spherical shape.[22] Otherwise, it is recognized oval shape (Eq. 2). Dimensions of length (L), width (W) and thickness (T) of the walnut are crucial for identifying Shape Index Fig. 9.

$$\boldsymbol{SI} = \frac{\boldsymbol{2L}}{\boldsymbol{w+T}} \quad (2)$$

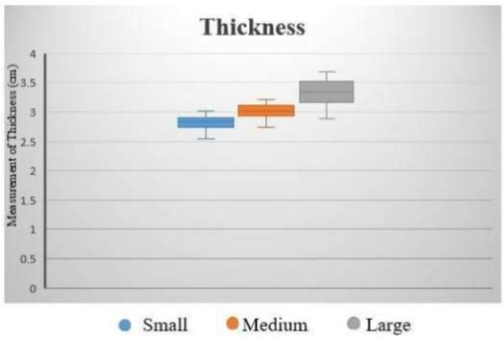

Fig. 10. Different orientation of walnut positions.

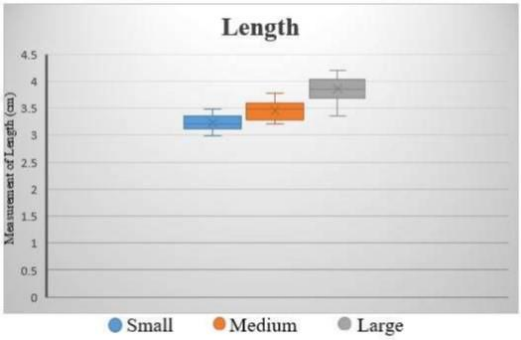

Fig. 11. Plot of length parameter.

Table 1. Indicate the shape index (SI) of walnuts

Shape index (SI)	spherical	Oval
Number	84	16

3. Results and Discussions

The results represent to intelligent system from walnut images, separation of three classify such as small, medium and large, in this way we had choices the one hundred walnuts from different sizes.

3.1. Thickness

According to Fig. 10, the thickness unit shows in three different parts, first range is between 2.71 to 3.01, second range is between 2.74 to 3.18 and the third one between 2.88 to 3.68 respectively for small, medium and large. The average ranges from three parts shows 2.9, 3.1 and 3.4 respectively for small, medium and large.

3.2. Length

Fig. 11 shows the length parameter in three ranges are 2.98 to 3.45, 3.2 to 3.77 and 3.36 to 4.21, then the average of this ranges are 3.3, 3.5 and 3.9 respectively shows small, medium and large.

3.3. Width

Fig. 12 shows the width parameter in three ranges are 2.6 to 2.97, 2.77 to 3.28 and 2.94 to 3.7, then the average of this ranges are 2.8, 3.1 and 3.5 respectively shows small, medium and large.

3.4. Shape index

Table 1, Shows the number of spherical and oval walnuts, so there are 84 spherical and 16 oval shapes and according to shape index (SI) Eq. 2, most walnuts are spherical.

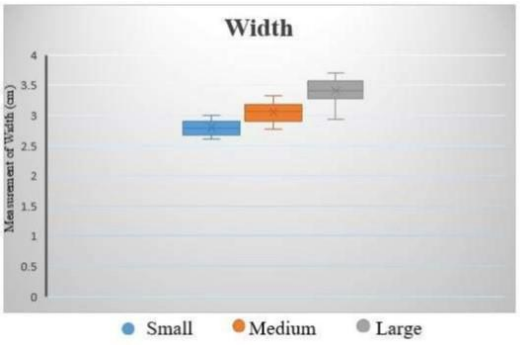

Fig. 12. Plot of width parameter.

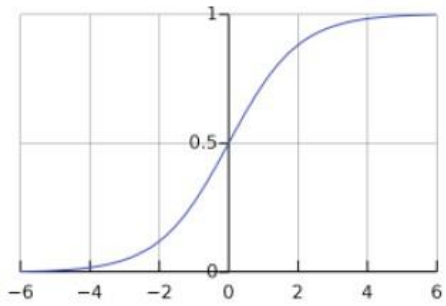

Fig. 13. Sigmoid function chart.

3.5. Machine Learning

3.5.1. Regression

Regression analysis is one of the useful form of statistical modeling for find relationship between output variable from one or more input variables. Statistical modeling such as linear, generalized linear, and nonlinear models and the machine learning to predict or stimulate with different regression functions. In this research, we focus on the structure hidden layers and neurons on the sigmoid model regression and more powerful to variety of fields employing it to handle prediction tasks.

3.5.2. Sigmoid Function

The sigmoid function is used as an activation function in neural networks and it was able to analysis mathematical function between the different descriptions in different inputs without adding many new parameters that would further complicate the model. The sigmoid formula based on regression analysis to prediction of variables, shows on Eq. 3.

$$S_{(x)} = \frac{1}{1+e^{-x}} \quad (3)$$

Where x is variable and the general statistics of cumulative distribution functions and that shows on sigmoid curves, therefor the results indicate between 0 and 1 on Fig. 13.

The learning based algorithms focus on learning the criteria from images. Fig. 14 shows the regression model in 3 input data, 9 hidden sigmoid layer and pooling layer form to predict the output layer. The average pooling layer applied to reduce the spatial size of input and figure out spatial dimension when allocate space for the output.

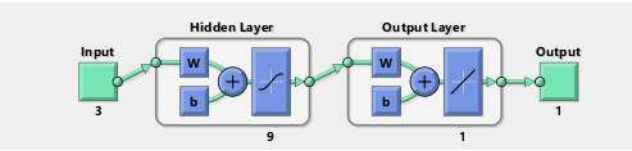

Fig. 14. Overview of layers

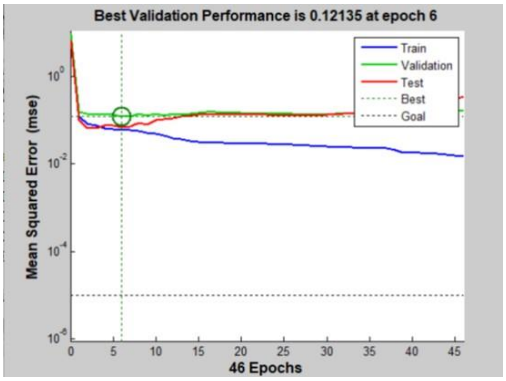

Fig. 15. Training- Validation procedure in the proposed LM algorithm.

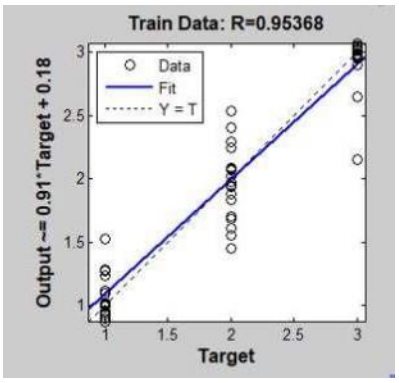

Fig. 16. Correlation factor between variables.

The Levenberg-Marquardt algorithm (LMA) is a technique to synthesize the gradient descent and Gauss-Newton for extract the parameter, shows on Eq.4.[23]

$$[J^T W J + \lambda I] h_{lm} = J^T W (y - \hat{y}) \quad (4)$$

Accordingly, the large values of λ and the small values of the damping of λ, respectively update the results of gradient decent and Guess-Newton.[24] This detailed process of the entire LM algorithm is a follow: the training parameters to 46 epochs and the beast validation performed at epoch 6, Fig. 15.

The Length, Width and Thickness parameters on different sizes with correlation coefficient of R^2=0.9 and the correlation between two variables is R=0.95, shows on Fig. 16.

4. Conclusions

The results obtained in this research provide important indicators of the different sizes of walnuts, which analysis with image processing method and calculate the limits for classification. Also, the relevant indices such as thickness, width and length diameter of walnut and extract the shape index (SI) from the criteria. This paper originally

proposed assessment the walnut, which the samples were large, medium or small, therefore the shape of them were spherical or oval based on image processing with high accuracy. The walnut dimensions of all samples could be classified to three values: Large, medium and small. Additionally, the machine learning analysis with the useful form of regression, powered by sigmoid function that obtained the results R^2=0.9 to predict the acceptable method for extension the design the machine to analysis the high number the walnut in the online form. In this study, 100 walnuts were considered based on shape and size characteristics. This method might be assured technique for sorting, packing, and classifying walnut.

Conflicts of Interest

The authors declare no conflict of interest.

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