Sorting orange fruit by machine vision and neural networks techniques

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Introduction

- Orange (*Citrus sinensis*) is one of the major fruit products in Iran. High production of this fruit calls for quality sorting both for domestic and global markets.
- Since quality sorting of fruits needs visual inspection, alternatively machine vision techniques can perform this task automatically and at lower costs.
- A lot of investigations have been carried out in this field.

- Brosnan and Sun (2004) used different computer vision systems for blemish and disease detection of horticultural products.
- Garcia-Ramos et al. (2005) reviewed non-destructive sensors used for fruit firmness determination.
- Butz et al. (2005) and Nicolai et al. (2006) compared different technologies to characterize the internal quality of fruits and vegetables.

- Among the indices of fruit quality, size is one of the most important identified by consumers; furthermore, size information is vital in packing houses.
- In recent years, application of Artificial Neural Networks (ANN) has been increased.
- Thai and Shewfelt (1991); Bardot et al. (1994); Wilkinson and Yuksel (1997) used ANN for prediction purposes.
- Lippmann, 1987 revealed that ANNs are suitable for modeling complex unstructured human judgment (Applegate et al., 1988).
- Miller (1995) compared three different classifiers to grade citrus fruits according to their external quality. He reports that Bayesian–Gaussian techniques had the best results and fruit was graded into two `classes (accepted or rejected) with the accuracy of 69- 86%.

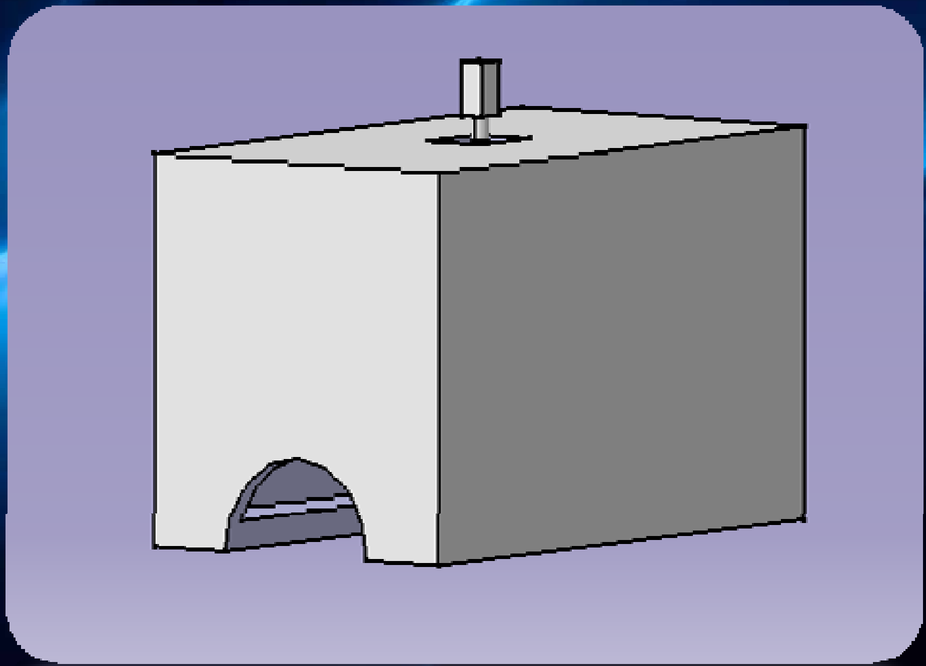
Objectives:

This study was devoted to combine image processing and neural network techniques for developing a comprehensive algorithm to sort orange fruits into size groups (Small, Medium and Large).

Materials and Methods

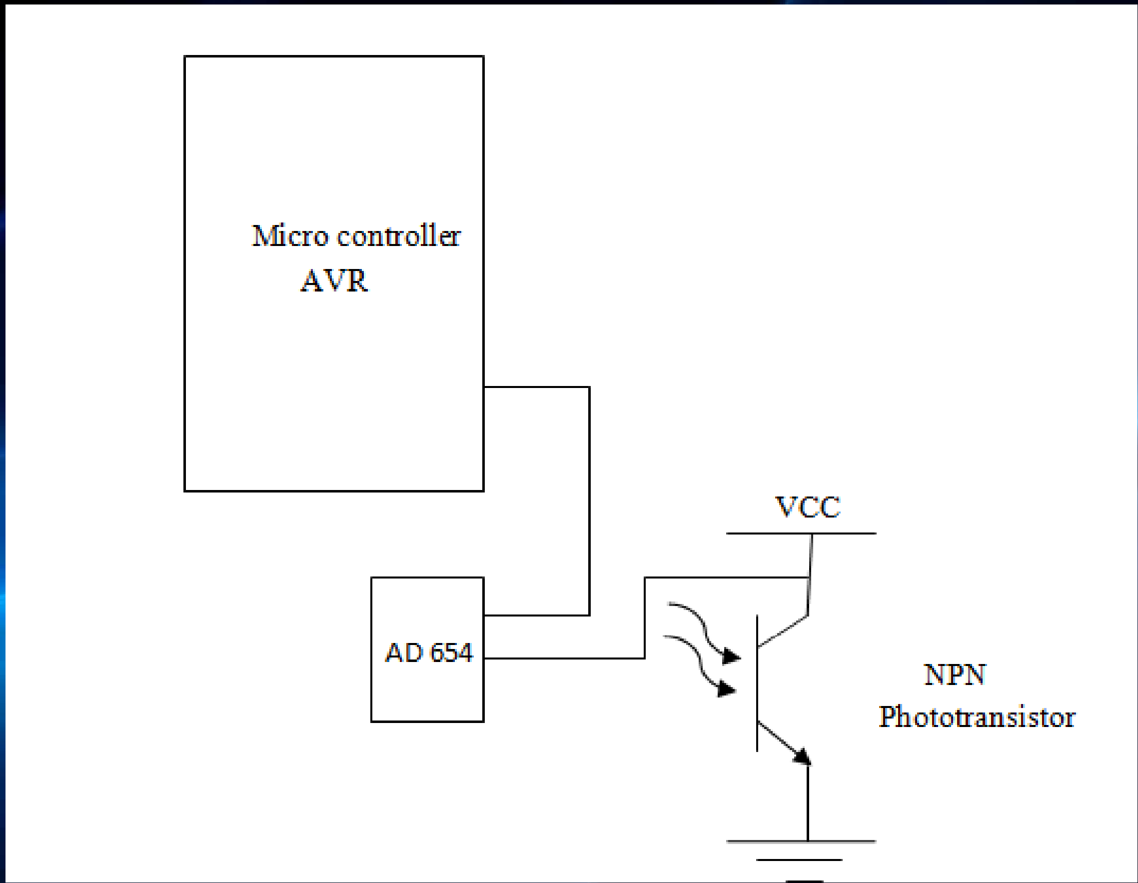
The Image Acquisition Unit included:

- An image acquisition platform with a black background
- A camera was installed on the top of the platform The webcam was connected to a computer (Pentium 4, Dual CPU, E2160 at 1.80 GHz).



- For illumination purposes six white LEDS were accomodated on the top inner side of the platform. The LEDs were used to avoid flicker effects. To prevent shadow and also to strengthen the light, the inner walls of the platform were white painted.

Light Intensity Controller



A light intensity controller circuit was designed and incorporated in the platform. This circuit included a photo-transistor, a V-F convertor (AD654 IC) and a microcontroller. As the phototransistor senses the light, it emits voltage which is converted to frequenc by a v-f circuit. The Microcontroller periodically counts the output frequency. If the frequency was lower than a specific level (in this study 30000 HZ) an alarm LED will switch on as a sign for immediate remedy.`

Performance tests

- Training stage
- Evaluation stage

Measurement as control

- At first, a batch of 165 orange fruits *(Novel variety)* was selected. For each fruit, three perpendicular axial dimensions were measured. The following relationship was used to calculate the geometric mean diameter (D) of each fruit as a criterion of the actual size of the fruit.

$$D = \sqrt[3]{abc}$$

Where a is the longest intercept, b is the longest intercept normal to a and c is the longest intercept normal to a and b

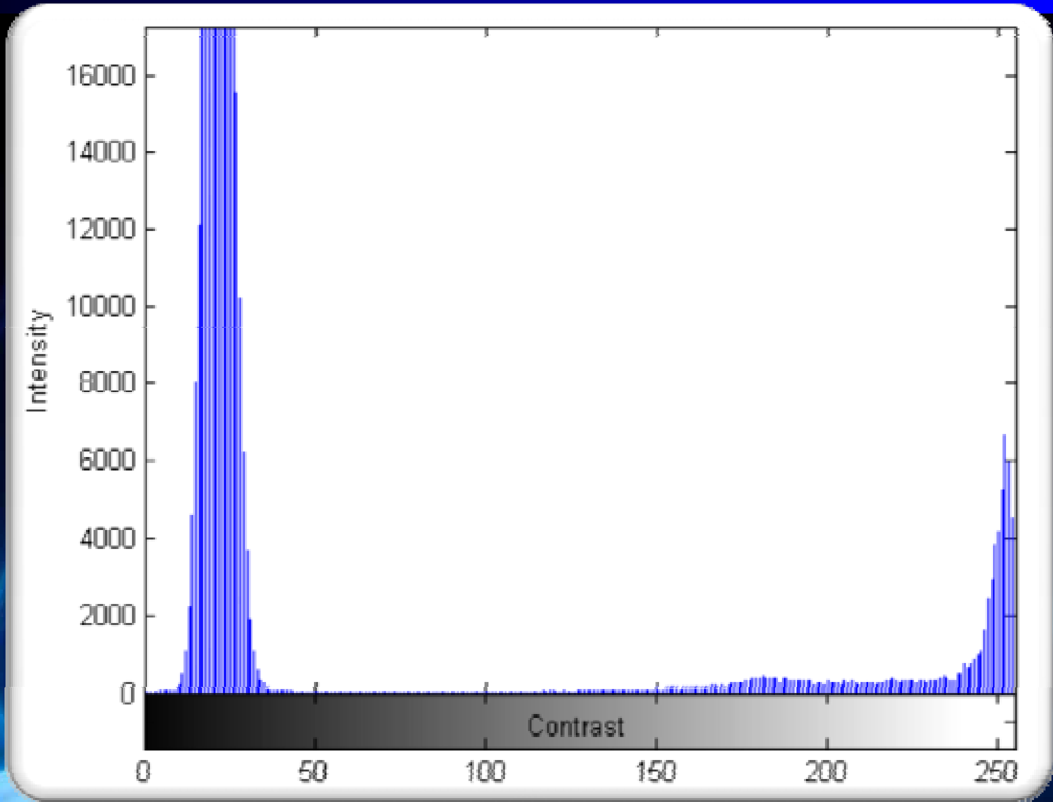
Training Batch & Evaluating Batch

The fruits were sorted into three size groups (small, medium and large) based on local consumer preferences expressed in terms of GMD. The fruits were then divided into two batches; training batch and evaluating batch. The training batch consisted of 115 fruits and evaluating batch comprised of 50 fruits.

- An image processing algorithm was developed and used to identify pixel values of four parameters (Area, Perimeter, Max-diameter and Min-diameter) of each fruit based on Red color intensity band. The algorithm started to segment the object and calculate pixel values relevant to one of the mentioned parameters.

Segmentation was used to determines the regions of an image correspond to the background and the regions that represent the objects itself. For segmentation purpose, the histogram of the Red color band of an orange randomly selected among the sample fruits was used.

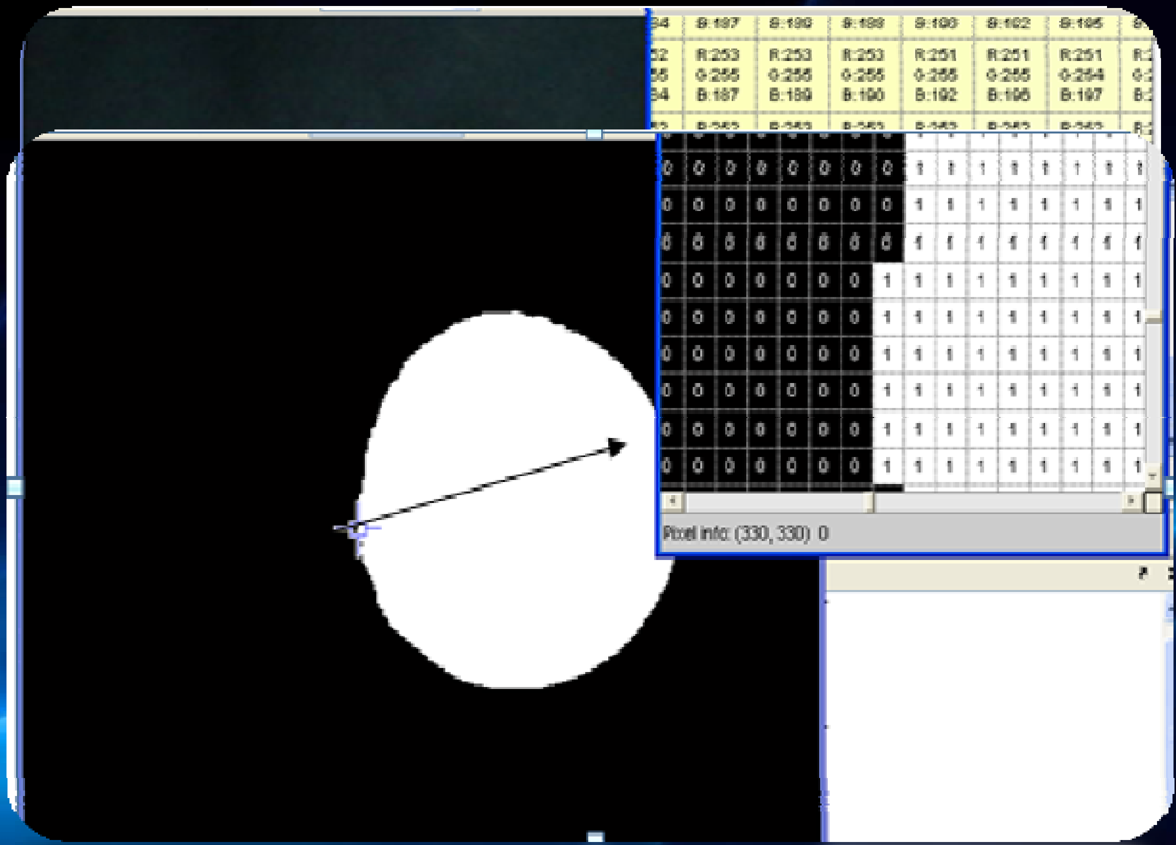
Histogram of red intensity color of an orange fruit



Left hand side of the figure represents the pixel values of the background and the right hand side exhibits the pixel values for the object itself.

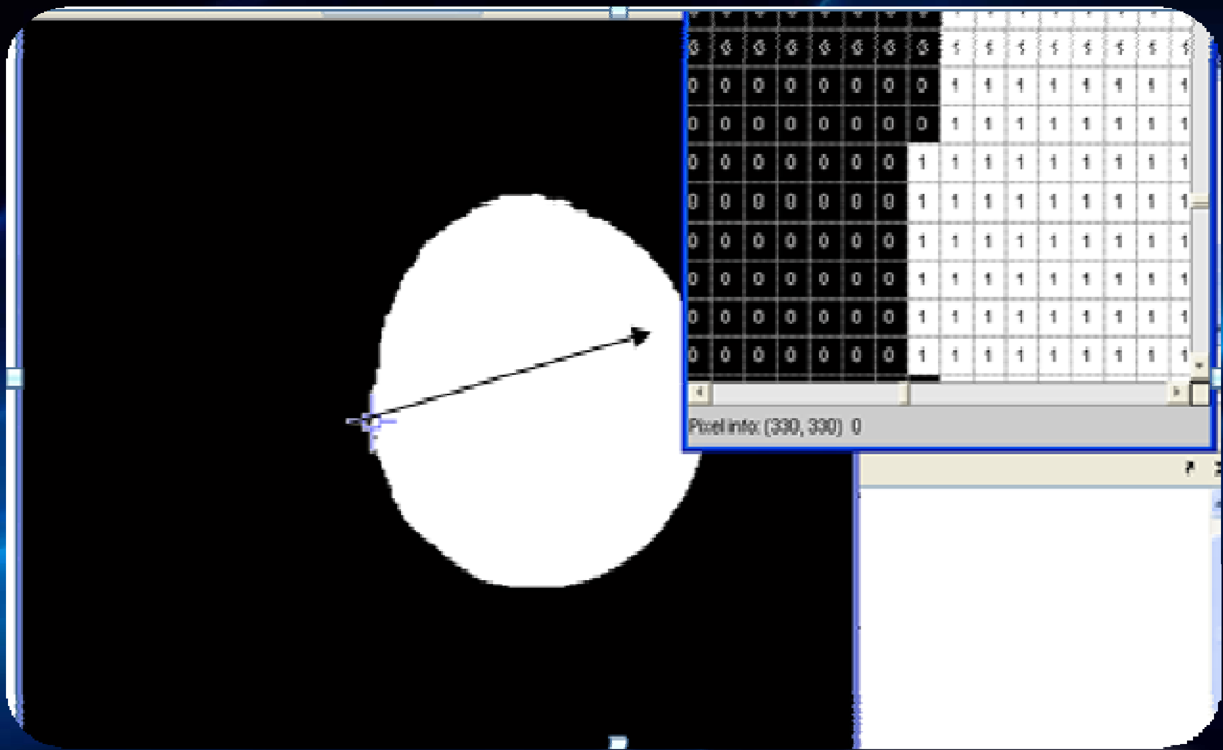
- Once the RGB image changed into the binary image,

the mentioned parameters were calculated as follows:



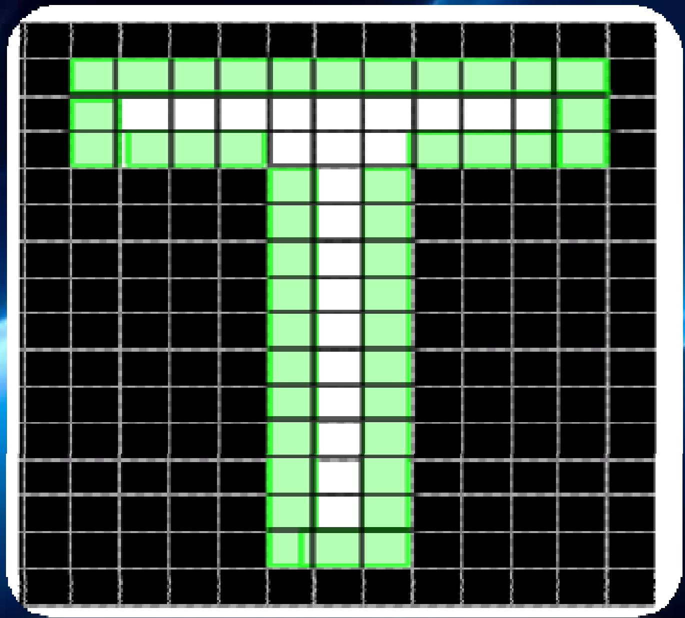
Area:

After making the binary image, the number of “on” pixels represents the area of the fruit in pixel.



Perimeter:

The perimeter of the fruit is represented by the number of pixels on the border of the fruit picture in the binary image.



Max diameter and Min diameter:

To determine the max and min diameters, the coordinate of each pixel of the binary image are first calculated and considered as a data point. Then the farthest point on the edge of picture was considered for calculating Max diameter and the farthest point on the edge of the picture, perpendicular to the Max diameter was considered for calculating the Min diameter.

Then, the data information of each algorithm was regarded as input to a series of neural networks classifier. The Multilayer Feed-forward Neural Network (MFNN) was used for orange classification. The MFNN model can be constructed with more than 1 layer and is able to learn nonlinear and complex relationships by using a training algorithm with a set of input-output pairs (Lertworasirikul, 2008).

For orange fruit classification, a back propagation network model with a number of training functions including Variable learning rate back propagation (MLP-GDM), Resilient back Propagation (MLP-RP) and Scaled Conjugate Gradient (MLP-SCG) were used for ANN modeling. A logarithmic sigmoid transfer function (logsig) was applied in the first layer of the network, and a linear transfer function (purelin) was used in the final layer.

- For ANN modeling, several hidden layers and nodes can be employed; But in general, one hidden layer has been found to be adequate, and only in some cases, a slight advantage may be gained by using two hidden layers (Hecht-Nielsen, 1989). In order to sort oranges into three size groups, one hidden layer was used for modeling; however, the number of neurons in the hidden layer differed from 1 to 6.
- The ANN models were trained by Training Batch.

Evaluation stage

For evaluating the algorithms and finding the most accurate neural network model with the optimum layers and epochs for classifying the fruits, the Evaluating Batch was used.

Eventually, Sorting records of each algorithm were compared to the relevant sorting data based on GMD and the most accurate algorithm was identified.

Results and Discussion

%Errors associated with neural network classification as compared to classification based on GMD

	Percentage of errors (%)					
Type of training function	Neural Network Structure					
	4-1-3	4-2-3	4-3-3	4-4-3	4-5-3	4-6-3
MLP-GDM	43.33	41.11	37.22	-	-	-
MLP-SCG	27.22	7.78	1.1* ✓	1.1* ✓	1.1* ✓	1.1* ✓
MLP-RP	28.33	7.78	1.1* ✓	5.55	1.1* ✓	1.1* ✓

*indicates the minimum error in classification

- **The results demonstrated that:**
- Multi Layer Perceptron with RP and SCG transfer functions have the least error (1.1%). Since increasing the number of neurons in each layer causes increase in time of processing. The number of neurons should be optimized. The optimum neuron for MLP-SCG is 4 neuron for the input layer and 3 neurons for the hidden layer and 3 neurons for the output layer. Similarly the optimum number of neurons for MLP-RP is 4 neurons for the input layer and 3 neurons for the hidden layer and 3 neurons for the output layer.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