Orange Grading Based on Visual Texture Features

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Abstract

Plenty of researches carried out for grading citrus fruits using machine vision. Citrus grading is normally achieved based on external visible criteria including size, shape, and color of the fruits. However, identification of the internal characteristics of the fruits is not possible by computer vision which uses visible spectral imaging. These investigations require some other expensive solutions such as hyperspectral imaging. Thickness of the fruit skin is one of the important factors for consumers so it can be considered as a grading criterion. Citrus fruits with thin skins are more desirable but it calls for spectral solutions. However, internal quality of the fruits can be evaluated if there is a correlation between the internal and visible external characteristics. In this study it was hypothesized that fruits with coarser skin would have thicker wall and vice versa. Coarseness of the skin could be verified by normal visible imaging. An innovative approach is described for fast description of texture while retaining the accuracy of high resolution images. Three strips having a width of one pixel were selected from the images. Moving average filtering and second order differentiation was used to determine the number of inflection point as coarseness factor. Correlation achieved between the coarseness and thickness of the oranges which showed a good agreement between these two factors. The experiment demonstrated that this method can be used for non destructive grading of orange or other citrus fruits to evaluate skin ratio of the fruit with a simple and inexpensive machine vision system.

Key words: orange, grading, machine vision, texture.

1. Introduction

Citrus grading machines are one of the well known grading equipments used in many parts of the world. Although there are some similarities in overall performance of all grading systems but different aspects are considered in designing a grading system.

Feature extraction is the backbone of image processing methods toward the desired application. The overall appearance of each object comprises color, shape, texture, and some user defined features which can be extracted for a distinct application. Texture feature, is an important image feature which has been applied extensively in agricultural engineering and food industry for automatic quality evaluation and inspection. Kondo et al. [6] investigated a non-destructive quality evaluation of oranges using fruit color, shape, and roughness of fruit surface included R, G color components ratio, Feret diameter ratio, and textural features by means of machine vision system and neural networks. Machine vision tries to recognize the objects using these features [2-11]. In some cases accurate decision making needed to implement fuzzy logics [9] or artificial neural networks [6] to enhance the object recognition.

Generally there is a compromise between the speed and accuracy when a machine vision system is used. Real time applications such as agricultural robots [5,10] and sorting machines call for higher speed of recognition. For this reason low resolution images are used that reduce the detection accuracy.

Inspection of internal quality of the fruits is normally done with the aid of hyperspectral imaging including ultraviolet fluorescence, reflective near-infrared radiations. Slaughter et al. [8] used machine vision techniques for non-destructive investigation of freeze damaged
oranges, found that small dot pattern visible on the oranges when illuminated by long wave UV light can be used to identify fruit with moderate to severe levels of freeze damage. They reported that the UV fluorescence method had an overall accuracy of classification about 70% and the accuracy increased to 86% for fruits with no UV fluorescence or for those fruits with moderate to severe levels of freeze damage. Aleixos et al. [1] developed a multispectral camera for citrus inspection to acquire visible and near infrared images from the same scene. Their specific algorithms implemented a specific board based on two DSPs working in parallel, which allowed dividing the inspection tasks in the different processors and saving the processing time. They evaluated size, color and defects of the citrus on 5 fruit/second range. Results for orange showed that their method had 94% coincidence with human classification in the worst situation when the fruit is changing color from green to orange. Accuracy for lemons and mandarins obtained 93% and 94% respectively.

Leemans et al. [7] proposed a method to compare each pixel features of apple images with standard values of pixel that was previously defined. Investigation on the defects of Golden Delicious apple was so that if they were matched with the normal pixels they were introduced as normal texture otherwise they would be known as defected apples. It also was done by Blasco et al. [2] for oranges, peaches and apples grading. They reached an accuracy of 86% when apples were classified in terms of blemish detection, which was similar to those of manual grading performance.

The literatures show that inspection of internal quality of the fruits is almost impossible when visible imaging is directly used. But it is hypothesized that in some cases where a considerable correlation exists between the apparent characteristics and internal quality of the product, such correlations can be used as criteria for internal quality assessment of the fruit. Approximation of the skin thickness is desirable for both customers and sorter designers and it would be worthwhile if it is achieved by means of simple RGB imaging.

Therefore the objectives of this study were to:

1- Extract some texture features from the images captured in visible spectra from citruses with different skin thicknesses.
2- Determine the skin thickness factors of the samples from the cross sectional images.
3- Investigate the correlation between the textural features of the images and skin thicknesses of the fruits.

2. Materials and methods

It is commonly known that citruses with coarser surface have a thicker skin while smooth and thin skin is more preferred (Fig. 1). To provide a wide range of data for such verification, oranges with various skin roughnesses were collected. Images were taken by means of a normal RGB camera with a resolution of 2592X1944 pixels. To investigate the correlation between the coarseness and thickness of the skins two separate measurements were made as following.

2.1. Texture feature extraction

Surface roughness is a quality which can be interpreted by some textural features of the images. There are varieties of texture description methods including co-occurrence matrices and frequency based methods. The most important drawback of common texture descriptors is that they are highly time consuming which makes them unfavorable for real time applications. This problem increases when images with high resolution are used for better inspection. Therefore, to achieve a real time performance, some extents of accuracy is sacrificed for rapid recognition.

In this study an innovative approach is described for fast description of texture while retaining the accuracy of high resolution images. To extract the texture descriptors following procedure was performed.
2.1.1 Illumination

Special illumination was considered to enhance the variations in pixel values and emphasize the difference between coarse and smooth textures. In this illumination, light rays were projected on the oranges just from one side. Such illumination impresses the shadows due to ridge and indent, yielding a manifest texture.

2.1.2 Image acquisition

Images were acquired from top of the oranges and cropped to a square with dimensions of 1500×1500 pixels. Preliminary studies showed that red component of the images were the best representatives of orange texture comparing to blue and green. Therefore red component of the images was used for the next steps.

2.1.3 Image strips

Three strips having a width of one pixel were selected from each image at different locations of 475, 950 and 1425 pixels (±25% length from the image center) in the direction of lighting. Although one strip was sufficient to express the texture, three strips were used to eliminate the effect of pedicle when placed under one of the strips (Fig. 2).
A sample of oranges with coarse and smooth surfaces is shown in the Fig.3. As it can be seen the variation in the R value of the pixels is much higher for coarse skin than that of smooth skin.

In this stage, determination the variation in the R values would not release an acceptable result because both large and small changes would be added together while the main difference between the cases is the large variations not small ones. Therefore a moving average filtering was used on the data to remove the negligible variations in R values.

FIGURE 3: Variations in R value of the pixels along the strips for cases a) Coarse skin orange b) Smooth skin orange

2.1.4 Moving average filtering
To determine the best size of the moving kernel, a preliminary study was done on the R value graphs which showed that the large variations almost occurred in a range around 15 pixels wide. Thus the moving average filter comprising 15 pixels were used to remove the small local variations before counting the main changes. An example of using this filter is shown in Fig. 4.

2.1.5 Differentiation
Significant difference was represented between the R value graphs for coarse and smooth surfaces after filtering. As it can be seen, the difference is the number of fluctuation on the graphs. To make a quantitative difference criterion, second derivative was calculated for the red values of the pixels placed on the strips respect to their row coordinates i.e. $\frac{d^2 P}{dr^2}$ where p is the red value of the pixel and r is the row coordinate of the corresponding pixel. In as
much as second derivative changes sign at the inflection points, it could be a good idea to write a program to count these points.

![Graph](image)

**FIGURE 4:** Variations in R value of the pixels along the strips after using a moving average filter for cases a) Coarse skin orange b) Smooth skin orange

2.1.6 Coarseness factor
Comparison between the numbers of fluctuations for various textures leads us to define a coarseness factor on this basis. Counting the inflection points of the red value curves provided a tool to define the coarseness. It must be noted that absolute number of inflection points could not be used because when the length of the orange strip is longer it would definitely provide larger number of inflection points while the texture might be still the same. Therefore a correction should be made on this number to define a criterion irrespective of the size of the orange. To do this, the number of inflection points was divided by their effective length. Effective strip length was considered as the distance where the pixel values change. This is the portion of the strip that includes the orange excluding the background zero values.

\[
\text{Coarseness Factor} = \frac{N_p}{100000L_e}
\]

\(N_p\): Number of inflection points on the red value graph
\(L_e\): Effective strip length (pixels)

2.2 Skin thickness measurement
Actual thicknesses of orange skins were measured on the cross sectional images captured from the same samples whose coarseness factors were determined in last steps. For each of the cross sectional images, skins were manually segmented from the pulps and then the skin area was measured. In as much as large oranges have more skin area, the skin area measurement was normalized by dividing to the cross sectional area of the orange as following:

\[
\text{Skin ratio} = \frac{\text{total skin area}}{\text{cross sectional area}}
\]

3. Results and Conclusion
Coarseness factors were correlated to skin ratio for each of the orange samples. The results are shown in Fig. 5 which states that change in coarseness of the skin is in good agreement with thickness of the skin. Such correlation graphs can be further used for approximation of the thickness of the orange in a non destructive method. It would be useful for sorting machines to separate the citruses based on their skin ration by means of a normal inexpensive visible camera.
FIGURE 5: Variations in R value of the pixels along the strips after using a moving average filter for cases a) Coarse skin orange b) Smooth skin orange

4. References