Evaluation of the Quality of Grapes Using Machine Vision

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Abstract: - Machine vision is becoming one of the most important non-destructive visual inspection technologies in the food industry. Using machine vision to effectively detect and sort fruits can reduce the operating time and cost while increasing the efficiency. Machine vision is also used to monitor and maintain the quality of post-harvest food item by detecting any rots, damages or any drop in quality. This paper presents classification of homogenously coloured fruits' quality using real time edge detection algorithm. Here, grape samples are taken as a homogeneously coloured fruit. The skin textures of the grapes are used to define the quality of the grapes which are being inspected in this experiment. Result shows that using edge detection technique is not only faster, but also reliable. An accuracy rate of more than 96.67% is shown using this method.

Key-Words: -Quality Evaluation, Machine vision, Grapes, Non-destructive, Edge detection, Canny, Classification.

1 Introduction

Machine vision is one of the rapidly growing technologies in today's world. Especially in the food industry it plays an important and challenging role. The reason being is due to its non-destructive property, which means that machine vision can extract physical information of any sample without physically damaging or destroying it [1]. However extracting features may be quite challenging mainly due to the influence of many factors, such as lighting conditions, sizes and orientation, on detection result. Therefore real time detection system must be able to locate the target object while discarding most part of the image. Real time detection system is very useful for sorting and grading fruits and vegetable during packaging in the food processing industry. It helps to distinguish the good quality product from the damaged product before being packed for the market. In this way the price or the value of the food item can be determined for the market.

One of the parameter which is used to define the quality is the size of the fruits. Size is measured either by calculating the area, the perimeter or the diameter [2]. Others use colour as the parameter to grade fruits quality [3].However, the quality of grapes cannot be defined solely on the size and colour.

Traditionally, grape quality was evaluated by visual and taste assessment which was done by evaluating the Total Soluble Solid (TSS) and acidity of the grape [4]. These types of evaluations involve destroying the grapes' physicality. Machine vision, however, evaluates the quality of the fruit while keeping it intact or undamaged.

The application of machine vision can be extended to monitoring the quality of post-harvest food item in the supermarkets by detecting any rots, damages or any other drop in quality thus determining the shelf life of the food product [5]. The non-destructive property of machine vision makes it more demanding in the market.

Traditional method using human perception is tedious, time consuming and it can be fooled [6]. For this system to work the process needs to be less time consuming and more efficient.

In this paper, we use edge detection technique to classify the quality of three different types of grape which were stored in a monitored environment (4 ^{o}C) for 12 days during the experiment. The grapes of different colour mainly red green and black were chosen to create a variation of colours in the detection technique. We use Principal Component Analysis (PCA) approach to distinguish and find a pattern of the different quality of grapes in different interval of time.

2 Methodology

In this paper, green grapes, red grapes &black grapes (*Vitis Vinifera)*were used as the different experimental samples. The diversity in colours helps to illustrate the detection of any type of grapes for this system.

2.1 Sample Acquisition & Treatment

Grapes were bought from the super market, were washed and kept in a monitored environment of 4 degree Celsius temperature. Everyday 5 samples of grapes were taken out from the freezer, dried and used for the experiment for 12 consecutive days.

2.2 Machine Vision

The Machine Vision System consists of three basic components; Illumination chamber, digital cameras and Graphical User Interface (GUI). The illumination chamber is constructed from black Perspex glass. The interior of the chamber is covered with black paper to reduce reflection and glare effects. A CMOS camera is fixed at the top of the illumination chamber. Two light emitting diodes (LED) are glues against each walls of the chamber as shown in Fig. 1. The sample (grape)is placed on the sample holder which is directly below the CCD camera. The GUI is use to control the operation of the camera which is developed using Borland C++ Builder.

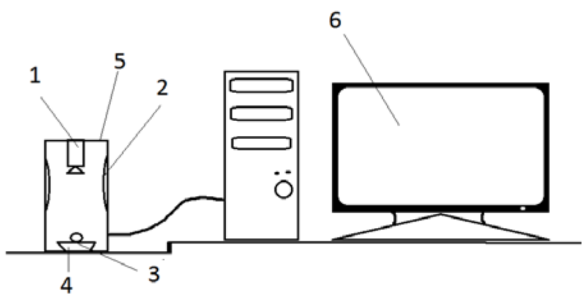

Fig.1 The Machine vision system

Table 1 lists the components used in the machine vision system. The numbers in the table corresponds to the numbers in Figure 1.

2.3 Digital Image Analysis

We define the Quality of the grapes by the texture of the surface of the grape. If the surface texture of the skin is smooth then it is considered as good grape. On the other hand if the skin is rough with lots of wrinkles then the grape is considered bad.

Table 1: List of components of machine vision system

No.	Components	Description
1	CMOS Camera	Digital camera models LU100C with a resolution of 1280 x 1024.
2	LED (White)	2 LED on each three sides of the camber
3	Sample	Grapes
4	Sample holder	Small round plate to place the grape.
5	Illumination chamber	Made from black Perspex glass.
6	Computer	Consist of the GUI

The analysis of the image was done by MATLAB version 7.7.0. Before working on the texture of the skin, we apply an algorithm to automatically remove the background image, thus masking out the grape.Figure 2 shows the proposed algorithm used to mask out the grape from the raw image. Canny Edge with a threshold value of 0.001 is used to create the outline of the mask. The mask is used in each of the channels (Red channel, Blue channel and Green channel) separately. These masked channel images is then combined to get the masked RGB image.

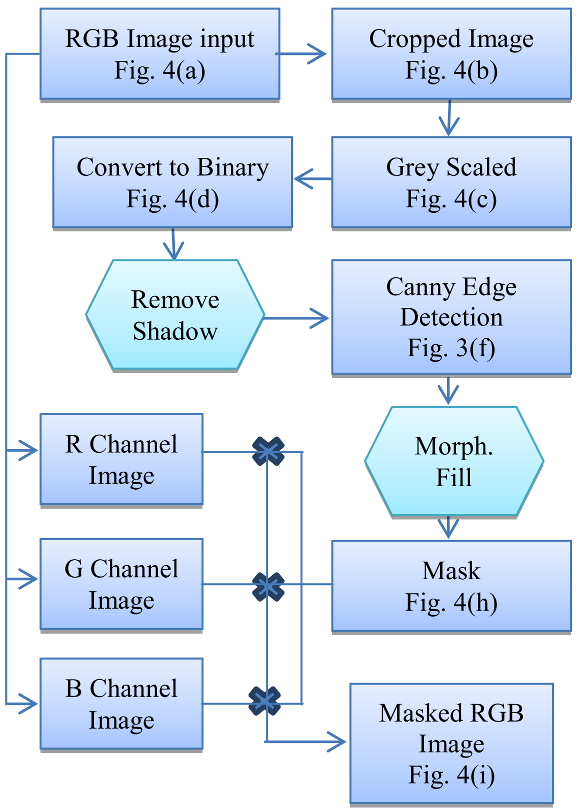

Fig.2Block diagram of fruit Segmentation Process

2.3.1 Canny Edge Detection

Canny edge detection is a multi-stage algorithm which is the ideal and most broadly used algorithm for edge detection. Canny edge detection is robust compared to otheredge detection methods such as Roberts and Sobel. Figure 3 illustrates the multistage mechanism of the canny edge detection.

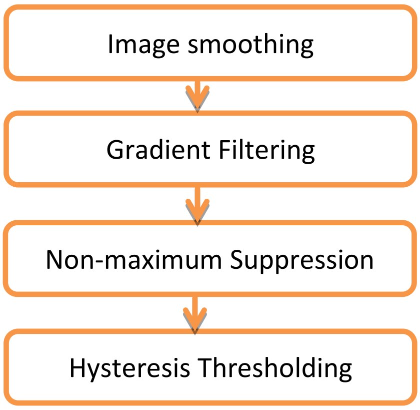

Fig.3 Block Diagram of Canny Edge Detection

Image smoothing is done to remove noise beforeedge detection. In this case second orders Gaussian function is used to smooth the image. The function isdescribed by the following equation:

$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \qquad (1)$$

The gradient vector is:

$$\nabla \boldsymbol{G} = \left[\frac{\partial G}{\partial x}, \frac{\partial G}{\partial y}\right]^T \qquad (2)$$

The smoothing degree is controlled by the parameter σ.

The gradient filter is done by applying first order finite difference which can be described as:

$$E^x_{i,j} = \frac{1}{2}(I'_{i,j+1} - I'_{i,j} + I'_{i+1,j+1} - I'_{i+1,j} \qquad (3)$$
$$E^y_{i,j} = \frac{1}{2}(I'_{i,j} - I'_{i+1,j} + I'_{i,j+1} - I'_{i+1,j+1} \qquad (4)$$

The gradient amplitude is defined as:

$$M_{i,j} = \sqrt{(E^x_{i,j})^2 + (E^y_{i,j})^2} \qquad (5)$$

The gradient direction is defined as:

$$\theta_{i,j} = \tan^{-1}\left|\frac{E^y_{i,j}}{E^x_{i,j}}\right| \qquad (6)$$

Non-Maximum Suppression process the gradient value ($M_{i,j}$) of object pixel and compares it with two adjacent pixels along the gradient direction. Two thresholds, High and Low, are used to obtain the outline of the grape.Low threshold is used to connect thediscontinuous part of the outline determined by the high threshold [7].

The detection accuracy of the grape using canny edge can be defined by the following equation:

$$D = \frac{D_o - D_1}{D_o} X\, 100\% \qquad (7)$$

Where,

D = Percentage detection accuracy
D_1 = Total number of grapes undetected
D_o = Total number of grape sample

Figure 4 (Appendix) shows the pre-processing segment of the image analysis. It shows the steps in which the grape was masked out from the original raw data. Removing the background is a very advantageous operation for extracting information from the image and analysing the surface texture by edge detection technique. This proposed algorithm also removes the stem and concentrates mainly on the grape.

2.3.2 Feature Extraction

For every sample of grape three features were extracted. The first two features were taken from the histogram of the image in fig 4(j). These were the maximum value of the histogram and the bin number where the maximum value occurs. The histogram shows a distribution of pixel with bins value ranging from 2 to 200 bins in gray scale. Canny edge algorithm is used to evaluate the surface texture of the grape. Calculating the edge intensity of the surface can give the roughness or the amount of wrinkles present on the grape. This was the third feature that was extracted from the image.

2.4 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a type of dimensional reduction analysis. It is a simple method that can effectively reduce redundant information by embedding objects distributed in high dimensional space into lower dimensional space [8]. The benefits of this reduction include simpler representation of data, reduction in memory and faster classification. Feature extracted from the raw image of grapes were reduce to lower dimensional space by using Principal Component Analysis.

3 Experimental Results

The performance of the system detecting the grape was measured using 30 images. The experiment shows that 1 out of 30 images, the grape was undetected giving an accuracy rate of 96.67%.

To enhance the performance, the detection technique was tested on 30 red grapes and 30 green grapes. Table 3 shows the result of automatic grape detection and its accuracy rate

Table 3: Percentage accuracy of grape detection

	Number of Detection		
	Correct	Error	Percentage
Black Grape	29	1	96.67%
Red Grape	28	2	93.33%
Green Grape	30	0	100.00%

After determining the detection accuracy rate of the system black grapes were used as a sample to evaluate the grape quality over time. The features were extracted and plotted in a scattered diagram.Figure 5 shows the PCA result on the analysis of the black grape at different days (Day1, Day3, Day5, Day7 and Day12). The first two components allow us to present 83.65% of the information in the database. Samples are grouped in 5 cluster representing the 5 different days. From the figure it can be clearly observed that there is a distinguishable pattern from day 1 to day 12. Classifying these clusters into groups can assist in the evaluation on the grape quality; day1 being good to day 12 being poor quality.

4 Conclusion

In this paper we proposed a simple and efficient algorithm to evaluate the quality of grapes using non-destructive machine vision system. The result shows the canny edge detection technique to be an effective and accurate detection method. PCA analysis is efficient in classifying grapes with the different storage time in its respective cluster. Real time detection and evaluation of fruit quality can improve the productivity of the food industries.

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APPENDIX

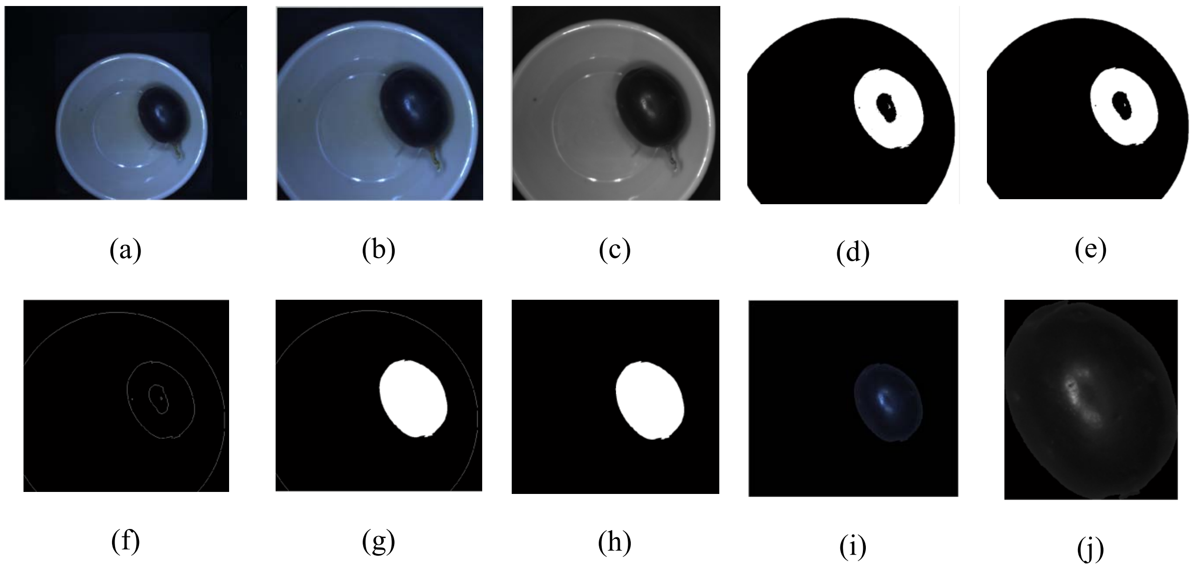

Fig.4(a) Original image, (b) Cropped image, (c) Grey-scaled image, (d) Binary image (e) Binary image after morphological operation, (f) Edge detection of binary image, (g) Mask image with edge, (h) Mask image, (i) masked grape, (j) Masked grape without the zero rows and zero columns

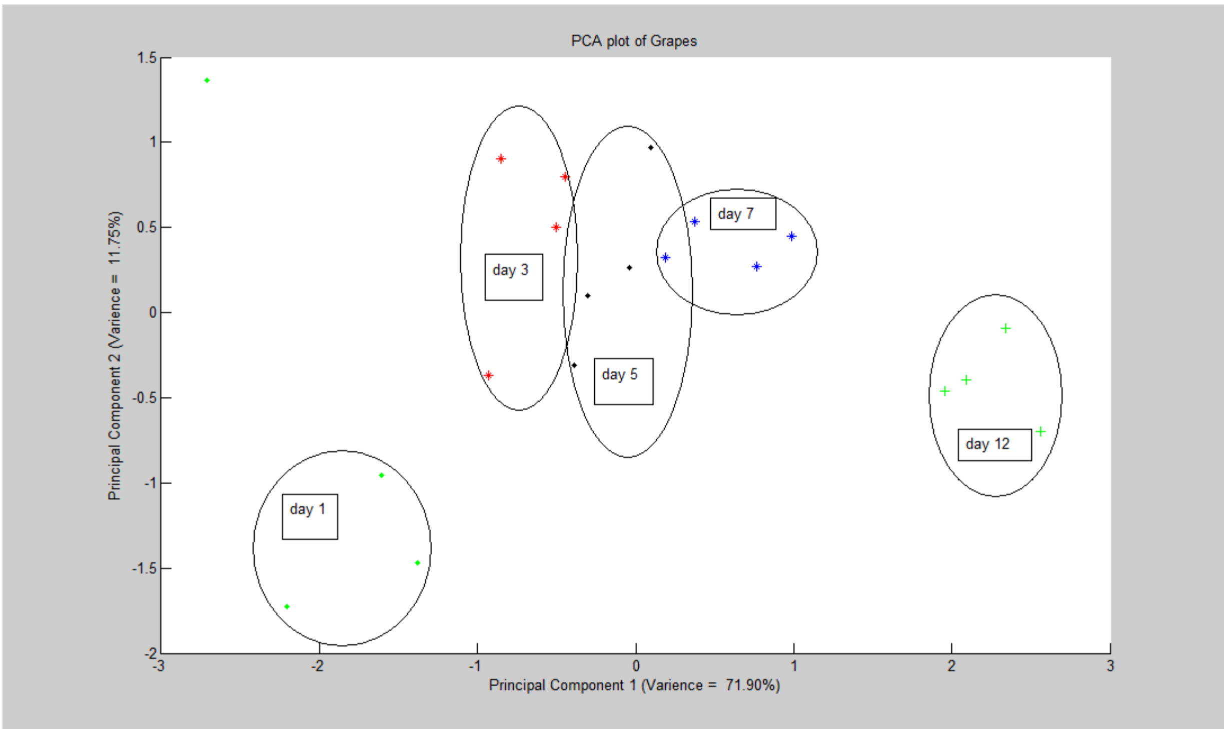

Fig.5PCA plot for Black grapes at day 1, day 3, day 5, day 7 and day12