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DESIGN AND IMPLEMENTATION OF AN EMBEDDED COLOR BASED CITRUS CLASSIFICATION SYSTEM

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ABSTRACT

The need for fruit classification is latest trend in today' s world. In this paper, we propose the design and implementation of Embedded color based citrus classification system. The input image is converted to separate R, G and B component and applied to Gaussian filter for filtering of high frequency edges. The adaptive threshold and binarization techniques are applied to smoothen and convert to the limited range of representation to increase the visibility. The mean filter is applied as post processing filter to remove remaining noise. Finally the pixel classification block is used to classify the rotten part by using blue color as reference and considering average of red and green as test feature. The system is implemented on Spartan 6 LX45 FPGA board. It is observed that the proposed system is better compared to existing system.

Keywords: *Pixel Classification, Gaussian, Citrus, Mean Filter, Adaptive Threshold etc.,*

I. INTRODUCTION

There are many citrus industries spread across the world. Citrus is the yellowish-orange coloured fruit like lemon, orange, mandarin, tangelo etc. Citrus fruits are produced in large quantity all over the world. According to UNCTAD, there were 140 citrus producing countries like India, Brazil, China, US, Mexico, Spain, Iran, Italy etc. in 2004. The annual worldwide citrus production is over 70 million tons out of which more than half are oranges. About 70% of the citrus production is done in the Northern Hemisphere. China plays a major role in orange juice producer. About one-third of citrus fruit goes for processing –more than 80% of the citrus fruit is used for orange juice production. For juice production there arises need to use good quality fruits. After harvesting if the citrus fruit is not processed within time then it may cause heavy loss. Hence post harvest treatment to classify fruit into good or rotten becomes necessary. In citrus industries there are many stages like washing, sorting, rasping, brushing, filling etc. Out of these the sorting stage is most important and time consuming one. This is carried out manually by humans but the manual grading includes visual inspection which is time consuming and it may detoriate the quality of fruit while handling. Also, there is increase in the labour cost. Considering all the facts it becomes necessary to have automatic system for citrus classification. This can be done using computer vision system with image processing technique.

The classification of fruit can be done based on different features like flabbiness, shape, size, intensity, defects [1]. To estimate the features, color intensity distribution, outer profile of fruit, numbers of pixels covering the image are considered. Color and features are of prime importance, hence the fusion of both color and features has been done [2] for fruit recognition for which the RGB image is converted to HSV and the statistical features are derived from the H and S components whereas V component corresponds to brightness. The classification is also done by GLCM texture features and BPNN in Matlab 7.0 [3]. An integrating system for grading fruit based on weight, color and size using ARM7 has been proposed [4]. For automatic grading of apples which includes segmentation of defected skin is done by using different global thresholding techniques [5]. In the existing paper [6] FPGA implementation of citrus fruit classification is done using image processing by considering ripeness levels of fruit and the classification of bananas [7] into different levels is proposed. This is done by using artificial neural networks considering the fruit appearance which includes development of spots for which the color and texture features are considered. Shelf-life estimation [8] of perishable fruits stored in cold area is proposed where fruit color extraction is done by k-mean clustering method and dimension analysis is done in terms of size and figure. An algorithm implemented in Visual Basic-6 programming is proposed in [9] to sort the lemon depending on its color and size. Along with color , volume evaluation is done by using calibration process. Different soft computing techniques are proposed [10] to classify different fruits depending on type of fruit like apple, orange, date etc. Different techniques like neural networks, Fuzzy logic, Bayesian networks etc are used. From all the mentioned methods it can be seen that color plays an important role in classification of fruit. Hence, considering the color of fruit, it can be classified as either good or rotten. The fruit classified as good can be used for further processing whereas the fruit classified as rotten can be discarded.

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II. PROPOSED TECHNIQUE

The proposed technique for classification of citrus fruit consists of following algorithm.

1. The input image in RGB format is separated into individual Red, Green and Blue components.
2. The separated images are applied with 3x3 Gaussian filter to remove detail and noise.
3. The filtered image is applied to adaptive thresholding block.
4. Binarization is performed to separate foreground and background pixels.
5. Then 3x3 mean filter is applied to preserve the edges.
6. Finally, pixel classification is performed to count the number of pixels belonging to each group and the classification of citrus fruit is done.

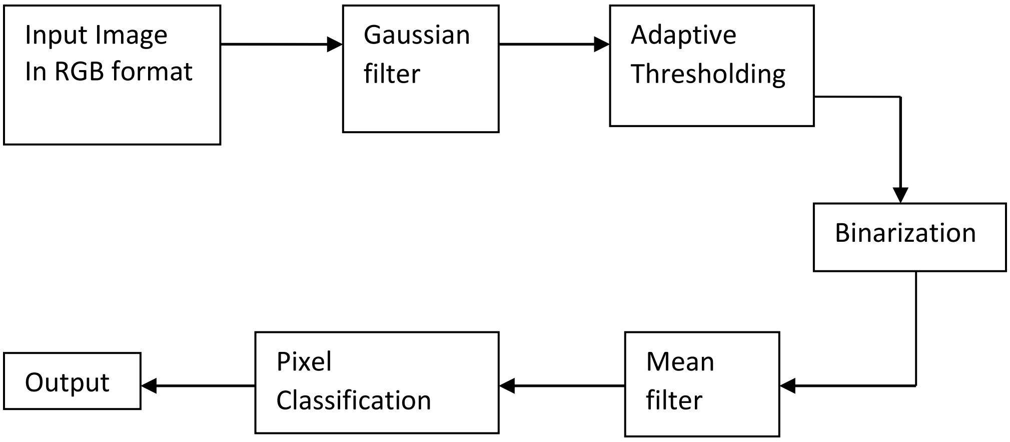

Fig.1 Block diagram for proposed citrus classification system

The block diagram of proposed citrus classification system is as shown in Fig. 1. The system consists of Gaussian filter, Threshold, Binarization, Mean filter and pixel classification.

1. Input image: The input image of RGB format with 24-bit pixel depth is considered and is separated into three components Red, Green, Blue.

2. Gaussian filter: The three separated image components are applied to Gaussian filter. Here, 3x3 Gaussian mask is used to remove the noise. In order to perform convolution between 3x3 Gaussian mask and input image, moving window architecture is used to scan the 3x3 input matrix from the input image.

The Gaussian filter equation is:

$$\text{Gaussian filter} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \frac{1}{16} \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Where, the first matrix inputs a, b, c, d, e, f, g, h, i indicates the input pixel values from the image whereas the second matrix is the Gaussian mask.

3. Adaptive Thresholding: It includes finding the threshold value for the image obtained in order to separate the foreground and background pixels. The threshold value is obtained by finding the average of squares of all pixels.

$$\text{Adaptive thresholding} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(xi*xi)}{8*m*n}$$

Where,

'm' indicates the number of rows in the image

'n' indicates the number of columns in the image

'xi' is the input pixel value in the image and the value 8 is the sensitivity factor.

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4. Binarization: It is used to obtain the binary image i.e. the pixel values are either 0 or 1 (255) where 0 indicates black color and 1 indicates white. Binarization is used to obtain the region of interest from the image. According to the threshold value obtained the pixels are classified as black or white.

5. Mean filter: Mean filter is used to smooth the image and preserve the edges. Here, 3x3 mean filter is used.

$$\text{Mean filter}=\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Where, the first matrix inputs a,b,c,d,e,f,g,h,i indicates the input pixel values from the image whereas the second matrix is the mask for mean filter.

6. Pixel classification: It consists of three counters and a maximum finder block. Each counter is applied with color component i.e. one counter is used to count the number of red pixels, one counter is used to count the number of green pixels and other counter is used is used to count the number of blue pixels in an image.

It also includes maximum finder block. The maximum finder block computes the maximum of either red or green and outputs whichever the maximum of both color components is.

$$\text{Maximum Finder} = \frac{\max(Red, Green)}{2}$$

The output of maximum finder is given to comparator block. The comparator block compares the number of blue component pixels with those of maximum of red or green pixels. If the blue component pixels are more than maximum of red or green pixels then the fruit may be considered as rotten else it may be considered as good fruit.

III. RESULTS AND DISCUSSIONS

The proposed technique was designed using software Xilinx 14.5. The language used was VHDL and block diagram was designed in system generator and implemented on Spartan 6 FPGA board. The system was tested for different citrus fruit images and the hardware utilization was reported. Table 1 shows the hardware resource utilization for existing and proposed method. It is observed that the slice registers, slice LUT's, Block RAM's and DSP slices are better in proposed method compared to existing method, Since our method is based on multiplier less architecture compared to 64x64 multiplier used in existing method.

Table 1. Hardware resource utilization comparison between existing and proposed system

Device Utilization	Existing System [6]		Proposed System	
Selected Device	Spartan-6 (XC6SLX150T)		Spartan-6 (XC6SLX45)	
	Used	Available	Used	Available
Slice registers	735	184307	32	54576
Slice LUTs	4550	92152	46	27288
Occupied slices	1714	23038	1601	6822
Block RAMs	28	268	0	6408
DSP48A1 slices	64	180	3	58

The results of fruit classified as good fruit as shown in Fig 2, where 2(a) is the input image for good fruit , 2 (b) is input in gray level image, 2(c) shows the Gaussian filter output for given input where noise present in input image is removed, 2(d) shows its thresholding and binarization, 2(e) shows mean filter output and finally the fruit is classified as good fruit and can be used for further processes. The results of fruit classified as rotten fruit is as shown in Fig 3, where 3(a) is the input image for fruit, 3(b) shows input in gray level image, 3(c) is the Gaussian filter output for given input, 3(d) shows the thresholding and binarization, 3(e) shows mean filter output and finally the fruit is classified as rotten fruit and hence the fruit cannot be used further.

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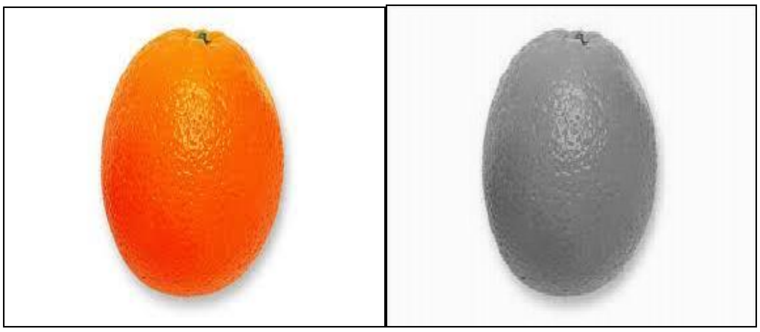
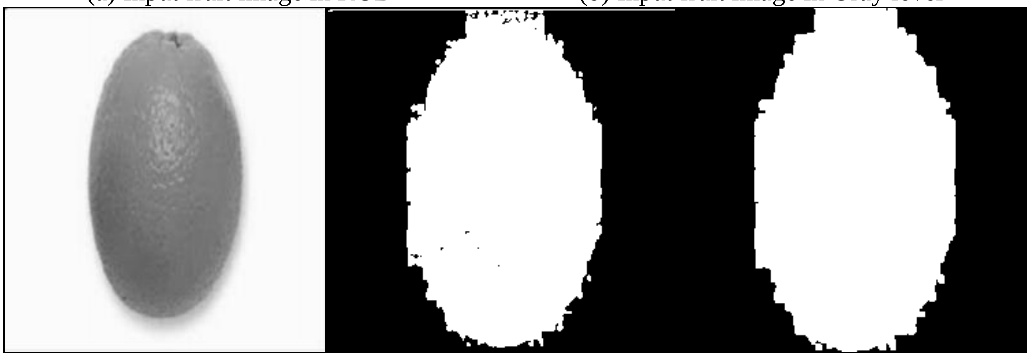


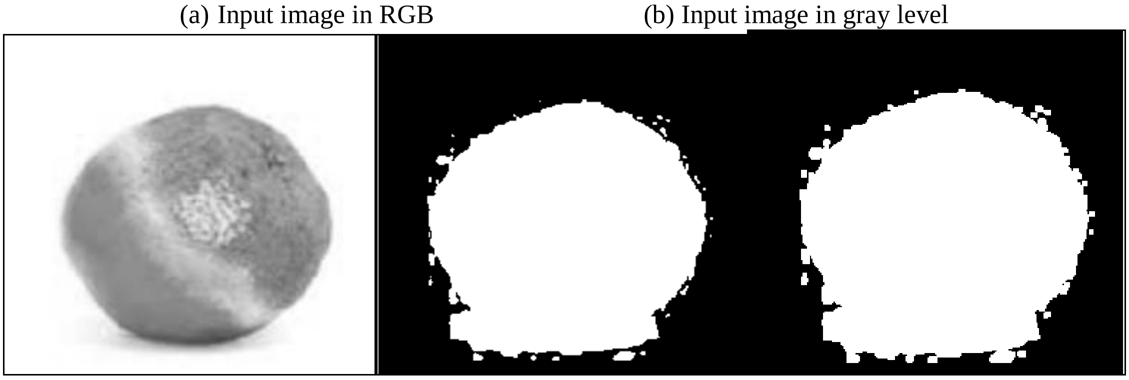
(a) Input fruit image in RGB (b) Input fruit image in Gray level



(c) Gaussian filter output (d) Thresholding and binarization output (e) Mean filter output

Fig.2 Fruit image classified as good fruit

(a) Input image in RGB (b) Input image in gray level



(c) Gaussian filter output (d) Thresholding and binarization output (e) Mean filter output

Fig.3 Fruit image classified as rotten fruit

IV.CONCLUSIONS

In this paper, efficient hardware architecture for accurate classification of citrus fruit was proposed. The citrus fruit image is preprocessed, feature extracted and classified for proper matching. It can be seen that the proposed system uses less area as compared to the existing system and also it provides the accurate classification of citrus fruit for different citrus images. In Future, the system can be extended for classification based on volume and size of fruit.

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