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A novel thresholding technique for digital image segmentation *

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Abstract Segmentation of region of interest is one among the main image processing step that has been carried on for any image analysis. A novel thresholding technique for segmenting an input image is proposed in this paper. As the first step RGB image is acquired. Taking into account only the green component image, we convert the image into a logical image and obtain the rank of the resultant image. Using this value as a threshold value we segment the given RGB image. A black and white segmented image is the output image that is generated using this proposed thresholding methodology. 112 sample images of apples, oranges, bananas and leaves are used for testing the accuracy rate of segmentation. A comparison between the famous Otsus thresholding technique and the proposed technique is done and it is found that the accuracy rate of segmentation of the test images using the proposed method is greater than or equal to the output images obtained using Otsus histogram thresholding technique.

Key words RGB, logical image, segment, thresholding, rank, Otsus thresholding.

2010 Mathematics Subject Classification 62H35, 62M40, 65D18, 68U10, 94A08.

1 Introduction

Image segmentation technique is the primary step involved in image analysis. Image segmentation techniques help in dividing image into parts till the required region of interest from the acquired input image is obtained. Thresholding is one among the various techniques available for segmenting an image from its original acquired image. It is also the simplest image segmentation technique. Based on a value, called the threshold value, a gray-scale image is converted into a binary image. The main key is to select an appropriate threshold value. Several techniques like the maximum entropy technique, Otsu's technique, maximum variance technique, and $k-$ means clustering can also be used for segmenting an image. The proposed technique which we elucidate in this paper introduces a new thresholding technique which helps in segmenting the foreground image from its background.
The rest of the paper is organized as follows. Section 1 contains the introduction of this research paper, while the section 2 lists the relevant works related to segmentation techniques. Section 3 explains the

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architecture and essential steps of the proposed segmentation technique, Section 4 explains the results obtained by implementing the proposed algorithm using the MATLAB software, it also discusses about the features and advantages of the proposed algorithm, and finally section 5 concludes with suggestions for future enhancement of this research work.

2 Related Works

Zhang [1] proposed a survey paper on the topic on evaluation techniques for image segmentation. An improved median-based Otsu image thresholding algorithm is proposed by Yang et al. [2]. Pham and Lee [3]. discussed about an image segmentation approach for fruit defect detection using $k-$means clustering and graph-based algorithm. An image segmentation method using Gaussian mixture model was proposed by Farnoosh and Zarpak [4]. Image thresholding by histogram segmentation using discriminant analysis is proposed by Arifin and Asano [5]. Seenivasagam and Arumugadevi [6] did a survey on Image Segmentation Techniques using Conventional and Soft Computing Techniques for Color Images.

3 Methodology

Among the two basic types of image segmentation techniques– the local and the global segmentation, we develop a technique for local segmentation that uses stochastic segmentation concept. Thresholding techniques divide an image into two categories with respect to their intensity level. Foreground images can be extracted from its background using these techniques. Thresholdings are of three types: global thresholding, variable thresholding and multiple thresholding. Our proposed technique uses the global thresholding concept. Based on the constant threshold value T, the image is segmented. Suppose if $\text{image}\,(m,n)$is the original image and $\text{Outimage}\,(m,n)$is the output image after segmentation, then the output image is obtained using

$$\text{Outimage}\,(m,n) = \begin{cases} 1, & \text{if image}\,(m,n) > T, \\ 0, & \text{if image}\,(m,n) \leq T. \end{cases} \tag{3.1}$$

where Outimage is the segmented image, T is the threshold value and ‘image’ is the input RGB image.

3.1 Samples used

For experimentation a total of 112 images of apples, oranges, bananas and leaves are taken. Out of these 112 images 34 are apple images, 26 are banana images, 25 are orange images and 27 are leaf images.

3.2 Image acquisition

RBG colour images can be acquired with the help of a Digital camera using an illumination chamber. For this research work image dataset is collected from secondary sources. All images used for this research work are of different sizes with different background.

3.3 Proposed method

This proposed algorithm is coded and executed using MATLAB 2017 software. As the first step the acquired colour image in RGB colour space is acquired and loaded in the workspace. Taking into account only the Green component image space, remaining work is carried on. The following flowchart depicts the proposed algorithm:

3.4 Proposed algorithm

Following is the proposed algorithm that is coded and tested for segmentation accuracy.

Algorithm :

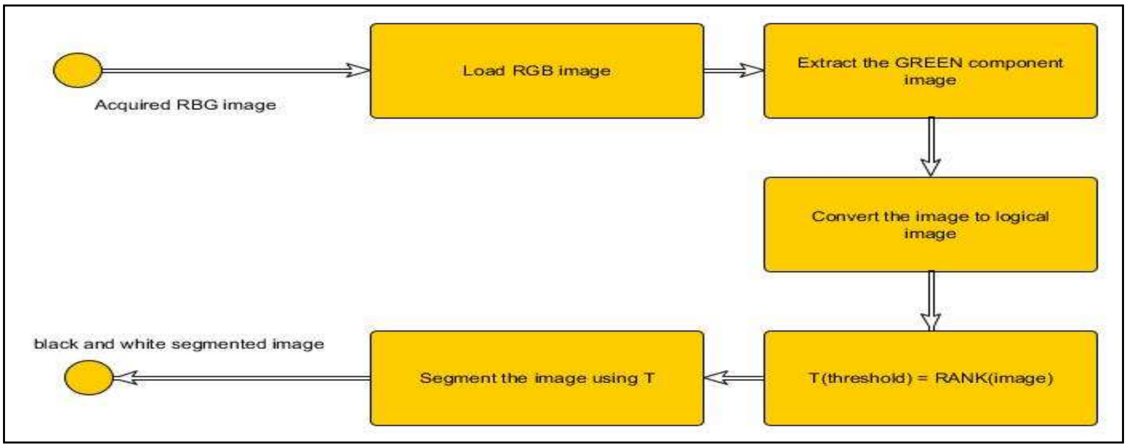
Step 1: Acquire the RBG image.

Step 2: Resize the image to 255 x 255.

Step 3: Take the green component image as input $(\text{image}\,(m,n)\,, m = 1.255, n = 1.255)\,.$

Step 4: Convert the above image to a logical image $(\text{image}\,(m,n))\,.$

Step 5: Calculate the threshold value as $\text{Th}r\text{eshold}\,T = \text{rank}\,(\text{image}\,(m,n))\,.$ Step 6: Segment the image using the calculated threshold value and generate a black and white image $\text{Outimage}\,(m,n)\,,$ using (3.1).



3.5 Rank of a matrix

The proposed threshold value is obtained by using the rank of the image matrix. The rank of A, an image matrix is the largest order of any non-zero minor in A. The order of a minor is the side-length of the square sub-matrix of which, it is the determinant. A single non-zero minor witnesses its order for the rank of the matrix, which can be useful to prove that certain operations do not lower the rank of a matrix. A non-vanishing $p-$ minor (i.e., $p \times p$ submatrix with non-zero determinant) shows that the rows and columns of that submatrix are linearly independent, and thus those rows and columns of the full matrix are linearly independent, so the row and column ranks are at least as large as the determinantal rank .The equivalence of determinantal rank and column rank is strengthening the statement that if, the span of n vectors has dimension p, then p of those vectors span the space. The equivalence implies that a subset of the rows and a subset of the columns simultaneously define an invertible submatrix. Let us assume that A be an $m \times n$ matrix and k an integer with $0 < k \leq m$, and $k \leq n$. A $k \times k$ minor of A, also called minor determinant of order k of A or, if , $(n-k)^{\text{th}}$ minor determinant of A, with the word determinant often omitted and the word "order" sometimes replaced by degree , is the determinant of a $k \times k$ matrix obtained from A by deleting $m-k$ rows and $n-k$ columns. Sometimes the term is used to refer to the $k \times k$ matrix obtained from A as above by deleting $m-k$ rows and $n-k$ columns , but this matrix should be referred to as a (square) submatrix of A, leaving the term "minor" to the determinant of this matrix. For matrix A there are a total of minors of size $k \times k$. Minor of order zero is defined to be 1. For a square matrix, 0^{th} minor is just the determinant of the matrix.

3.6 Otsu's technique

Comparison between Otsu's technique and the proposed technique is done. Converting a greyscale image to monochrome is a common image processing task. Otsu's technique is named after its inventor Nobuyuki Otsu (see, [7,8]). Otsu's thresholding technique iterates through all possible threshold values. It calculates a measure of spread for the pixel levels on each side of the threshold. The aim of the algorithm is to find the threshold value where the sum of the foreground and the background spreads was at its minimum. So, for each potential threshold T:

1. in the proposed technique the T value separates the pixels into two clusters,
2. the mean value of each cluster is found,
3. the difference between the means is squared, and
4. the number of pixels is multiplied one cluster times the number in the other.

4 Experimental results and discussion

Results obtained after executing the algorithm are represented below in the tables and figures. In the Fig. 1, fifteen images out of the 112 images that are tested using the proposed algorithm are used for discussion and are shown as below

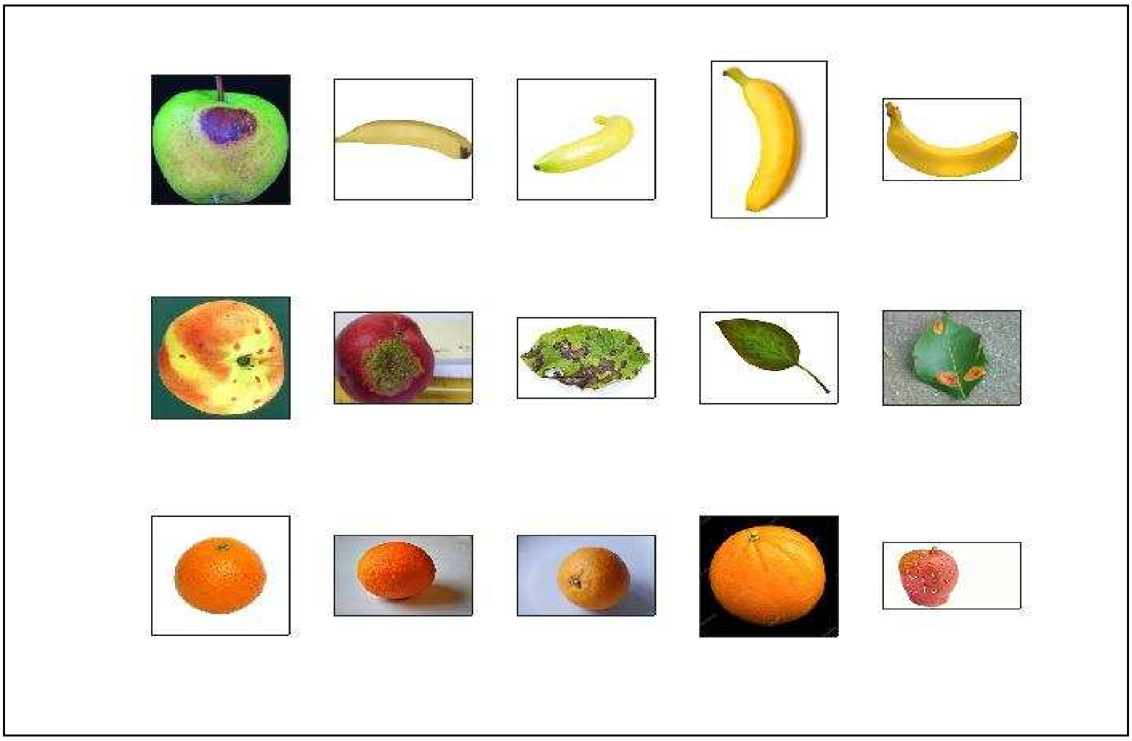


Fig. 1: Test samples taken for testing the proposed methodology.

In the Figs. 2 (Fig.2(a)), 3 (Fig.2(b)), 4 (Fig.2(c)), 5 (Fig.2(d)) and 6 (Fig.2(e)) the first column contains the input image to be segmented. The second column has the corresponding segmented output image obtained using Otsu's technique and third column has the segmented images obtained as output using our proposed technique.

If we visually inspect the output obtained by implementing the Otsu and our proposed technique, we see that the outputs obtained by using both the techniques are the same. Also for some images the segmented image obtained by using the proposed technique shows good results than the Otsu's technique. In the Figs. 2 (Fig.2(a)) and 3 (Fig.2(b)) the image output list generated by the proposed technique produces banana images (third column) that are segmented well when compared to those produced by applying the Otsu's technique (second column). Even in the Fig. 5 (Fig.2(d)) segmentation of the second orange image is well pronounced using the proposed technique.

The Table 1 (Fig. 7) tabulates the statistical measures used to assess the quality of the segmented images that were obtained as output by applying the Otsu's technique and the proposed technique.

Standard deviation of the image is found in order to show how much variation or dispersion exists from the mean pixel value given by (4.2). A low standard deviation indicates that the pixel values tend to be very close to the mean, whereas a high standard deviation indicates that the pixel values are spread out over a large range of values. This is calculated using (4.1).

$$\text{Standard Deviation} = \sigma = \frac{\sqrt{\sum (\text{image}\,(i,j) - \mu)^2}}{m \times n}, \text{ where, } i = 1, \ldots, m, \; j = 1, \ldots, n. \tag{4.1}$$

$$\text{Mean} = \mu = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} \text{image}\,(m,n)\,. \tag{4.2}$$

MSE (Mean Square Error), is computed by averaging the squared intensity of the original input image and the output image pixels as follows:

$$\text{MSE} = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (e\,(i,j) * e\,(i,j)) \tag{4.3}$$

where m is the number of rows and n is the number of columns in the image matrix and $e\,(i,j)$ is the error difference between the original and the proposed output image.
The Peak Signal to Noise Ratio (PSNR), which is a mathematical measure of image quality, is calculated based on the pixel difference between the two images.

$$\text{PSNR} = 10 \log_{10} \frac{s^2}{\text{MSE}} \tag{4.4}$$

where $s = 255$ for an 8 bit image.
Table 2 (Fig. 8) shows the threshold values obtained by using the Otsu's and the proposed techniques for all the 15 test samples. Fig. 9 depicts their corresponding difference in the form of bars in the bar chart. The coefficient of correlation for the image $(i, j)$is calculated from the relation

$$\text{Correlation} = \sum_{i=1}^{m} \sum_{j=1}^{n} \text{image}\,(i,j)\, \frac{(i-\mu)\,(j-\mu)}{\sigma^2} \tag{4.5}$$

where m is the number of rows and n is the number of columns in the image matrix. The correlation helps in measuring the joint probability occurrence of the specified pairs of pixels. It is also a quality assessment measure that can be used to find the quality correlation between the two segmented images. It can be observed from the Fig. 10, that the output segmented images obtained by using the Otsu's and our proposed techniques have a correlation above 0.50 and some images like, for example, Banana2, Banana3, and Banana4 have their values of the correlation coefficients less than 0.50, which indicates a poor degree of correlation. This is because the segmented images generated by both the techniques varied a lot, since the banana images segmented by the proposed technique are more accurate than the banana images segmented by using the Otsu's technique. This can be visualized by observing the Fig.2 (Fig.2(a)) and Fig.3 (Fig.2(b)) carefully.

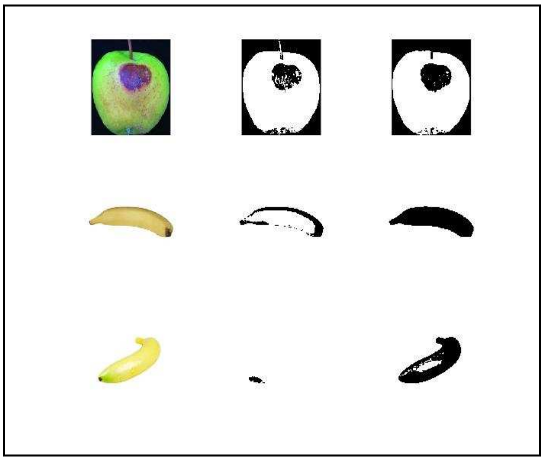


Fig. 2: Fig. 2(a)

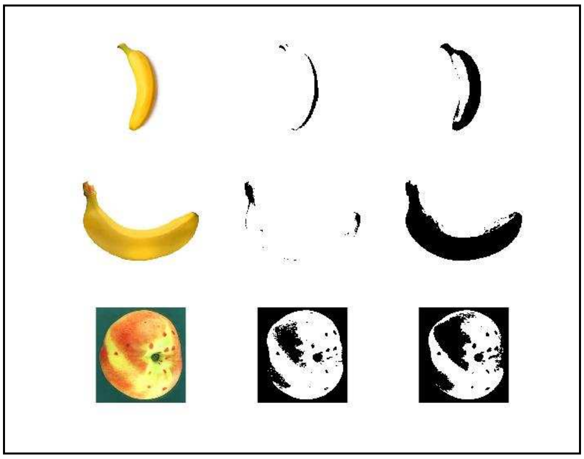


Fig. 3: Fig. 2(b)

5 Conclusion

A novel thresholding technique is proposed in this paper for segmenting a color image and to produce a black and white image as output. This segmentation technique can be used to segment and extract features of images for classification related problems. This technique can be extended to generate a

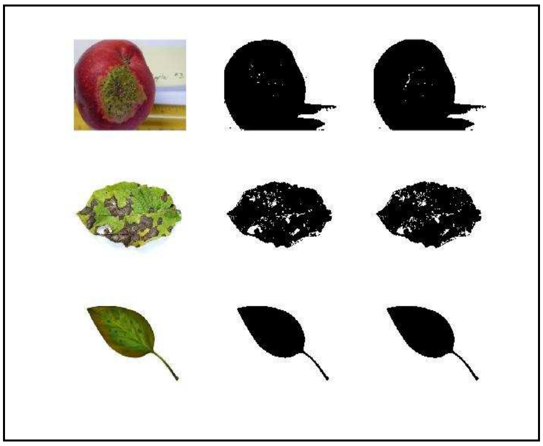


Fig. 4: Fig. 2(c)

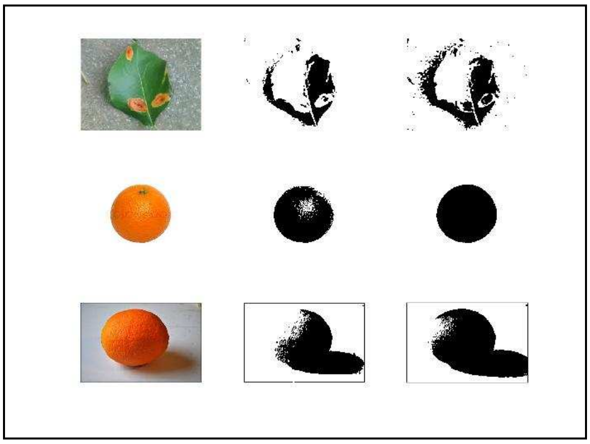


Fig. 5: Fig. 2(d)

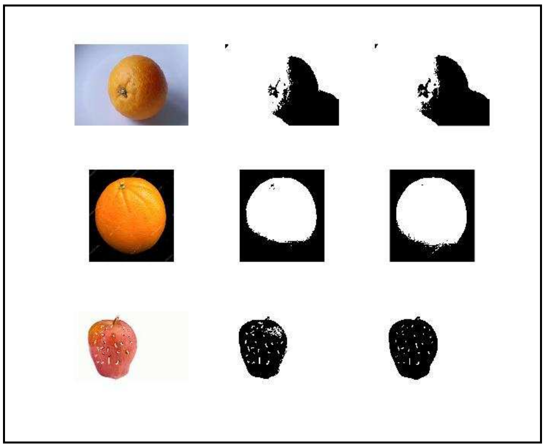


Fig. 6: Fig. 2(e)

segmented colour image instead of generating a black and white image. Accuracy rate of segmentation is more than 90% using this proposed technique. Also no segmentation algorithm produces 100% accuracy rate in segmenting an image. Based on a value called the threshold value, a gray-scale image is converted into a binary image in most of the surveyed methods, but our proposed technique takes only the green component image space alone for segmenting the foreground from its background.

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Fig. 7: **Table 1:** Statistics and quality measures.

STATISTICS / QUALITY MEASURES								
	OTSU'S				PROPOSED			
SAMPLES	MEAN	STD.DEV.	RMSE	PSNR	MEAN	STD.DEV.	RMSE	PSNR
Apple 1	0.619	0.486	0.038	143.588	0.608	0.488	0.026	147.451
Banana1	0.938	0.242	0.055	139.881	0.821	0.383	0.171	128.484
Banana2	0.993	0.084	0.006	162.275	0.849	0.358	0.150	129.796
Banana3	0.954	0.210	0.035	144.415	0.795	0.404	0.194	127.216
Banana4	0.979	0.144	0.009	157.900	0.681	0.466	0.306	122.655
Apple 2	0.516	0.500	0.029	146.282	0.424	0.494	0.116	132.369
Apple 3	0.346	0.476	0.008	158.772	0.345	0.475	0.002	175.599
Leaf 1	0.517	0.500	0.298	122.941	0.512	0.500	0.302	122.784
Leaf 2	0.763	0.425	0.022	148.975	0.762	0.426	0.023	148.459
Leaf 3	0.829	0.377	0.057	139.541	0.778	0.416	0.035	144.411
Orange 1	0.711	0.453	0.041	142.793	0.673	0.469	0.079	136.181
Orange 2	0.682	0.466	0.130	131.210	0.566	0.496	0.014	153.288
Orange 3	0.691	0.462	0.011	156.054	0.667	0.471	0.022	148.927
Orange 4	0.468	0.499	0.188	127.528	0.490	0.500	0.210	126.425
Apple 4	0.733	0.443	0.032	145.390	0.715	0.452	0.049	140.929

Fig. 8: **Table 2:** Threshold values obtained for the same set of images using Otsu's and proposed methodology.

	Threshold values		
SAMPLES	Otsu's	Proposed	Correlation
Apple 1	102	212	0.93
Banana1	183	115	0.55
Banana2	180	153	0.20
Banana3	152	152	0.43
Banana4	140	187	0.22
Apple 2	153	235	0.83
Apple 3	128	201	0.98
Leaf 1	173	202	0.97
Leaf 2	158	196	1.00
Leaf 3	112	247	0.80
Orange 1	158	139	0.91
Orange 2	113	184	0.79
Orange 3	135	178	0.95
Orange 4	103	168	0.95
Apple 4	169	172	0.95

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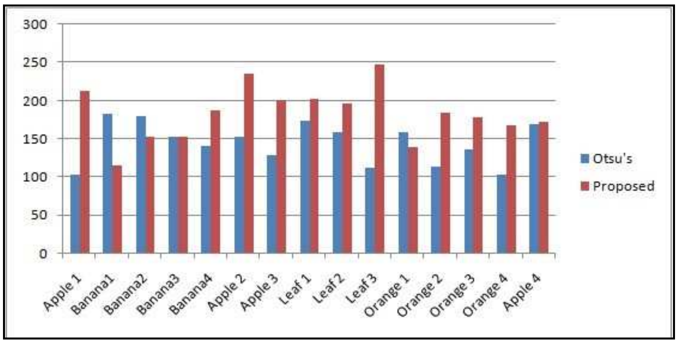

Fig. 9: Bar chart representing threshold values using Otsu's and proposed technique

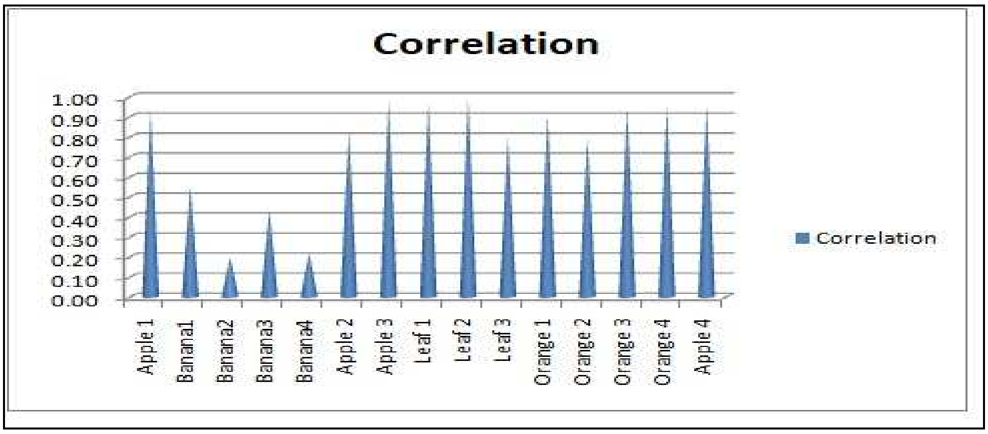

Fig. 10: Bar chart representing the correlation between images generated using Otsu's and proposed technique