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Sequential Hybridization of Genetic Algorithm and Fuzzy Logic for Enhanced Edge Detection of Banan

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Abstract : Edges are the basic feature that highlights object boundaries in an image. Extraction of the exact edges in an image is a critical phase in image processing technique as it is easily prone to external factors like noise, lighting system and so on. There are numerous methods existing for edge detection, but still these methods are not effective on certain real images that are used for specific application. Banana fruit quality analysis is one of the distinct applications in image processing technique. Achieving enhanced and accurate edges of banana image is still being a challenging task due to the problems such as discontinuity in edges, noises, and change in pixel location, double edges, and false edges and missing exact edge regions. In this paper, to avoid these problems, a sequential hybrid method using genetic algorithm and fuzzy logic is proposed. Gradient of the image is calculated directly over the RGB image. Genetic algorithm, a heuristic optimization method, is used to enhance the quality of gradient image. Sequentially fuzzy logic, a soft computing method is used to classify the edge and non-edge pixels in the enhanced image. Finally the proposed method is successful to identify a definite, continuous and clear edge region of banana fruit. Performance of the proposed method has been evaluated and compared using goodness measures such as entropy and kappa method. These methods quantitatively proved that the proposed method shows better result when compared to other existing edge detection methods.

Keywords : Entropy, fuzzy logic, genetic algorithm, goodness measures, image edge detection, kappa statistics.

1. INTRODUCTION

Object identification and feature extraction are the vital tasks in image processing as they determine the accuracy of applications. Image segmentation phase forms the base for these tasks. Selection of an appropriate segmentation method is important as they are application specific in characteristics. Application of image processing in fruit quality analysis has now become an integral part in agricultural research sector [1]. Banana is a major fruit crop for consumption and is demanded all through the year. Due to its importance in market, automated system for quality analysis is a prerequisite for traders and consumers [2]. Image processing helps to develop a complete automated system for banana fruit quality analysis. This vital task can be achieved with higher accuracy by selecting an appropriate image segmentation method [3].

Image segmentation plays an important role to segregate banana from the background image. There are two basic classifications of image segmentation as region based and edge based segmentation methods [4]. Region based segmentation methods are based on the similarity measures of pixels in which the intensity values are related. Methods such as region growing and region split and merge are belonging to this method [5]. Edge based methods

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are based on the discontinuity property of pixels in which the pixel values are not related. Methods like point, line and edge detection methods belong to this method. These methods are traditional, classical and are based on either first order derivative or second order derivatives for identifying the edge regions. It includes methods like sobel, robert and prewitt method of first order derivatives and LoG, zero cross and canny methods of second order derivatives for edge detection. Susan, Edison, Rothwell, Nalwa, Iverson, Bergholm are some of the other familiar edge methods which have been widely used. Recently techniques like particle swarm optimization, ant colony optimization and bacterial foraging technique are applied to identify edges. Though several algorithms are available, yet more new algorithms are required to identify exact edge regions.

Edge detection methods are useful to identify the boundary of banana region in an image. Existing edge detection methods suffer from a major drawback to provide enhanced and accurate edges of banana image. Major problems faced in edge detection include discontinuity in edges, noise which also has unexpected change in pixel values like edge, double edges, false edges and missing exact edge regions in an image. To avoid these disadvantages, a suitable edge detection method has been proposed using the sequential hybridization of soft computing techniques namely genetic algorithm and fuzzy logic.

In contrast to conventional hard computing technique, soft computing is suitable for data which are not crisp, definite and certain. It inherits the reasoning and learning ability of human mind and is inspired from the characteristics of biological system. Fuzzy logic, neural network and genetic algorithm are the main soft computing techniques used to solve problems in machine learning and artificial intelligence. These methods are useful for situation which requires learning, training, classification, inference, prediction and optimization. These methods are not competitive in nature but rather they are complementary as each method has its own methodologies and design model. Neural network is adaptive in nature and is used to solve problems using self-learning algorithms. Genetic algorithm is an evolutionary computing technique used to search for an optimal solution for a problem from the available search space [6]. Fuzzy logic is used to solve problem related to fuzzy sets using if-then rules. Performing hybridization among soft computing methods paves way for a successive effect.

In this paper, genetic algorithm and fuzzy logic have been hybridized in a sequential manner to achieve an efficient edge detection method which is capable to produce an enhanced and continuous edge without any discontinuity issues. Performance of the proposed hybrid method was compared with other existing method using quantitative analysis measures such as entropy and kappa due to the absence of appropriate ground truth image or golden standard image.

2. EXISTING CLASSICAL EDGE DETECTION METHODS

Major task of edge detection methods is to identify the boundary of an image and to extract the required region of interest in an image. Edge regions are found by marking edge regions based on the image pixel properties like unexpected change in pixel value. Two broad categories of edge detection methods are gradient based and laplacian based methods. Gradient based methods derive edge regions by calculating the first order derivatives and Laplacian based methods derive edge regions by calculating the second order derivatives. These edge detection methods cannot be manipulated directly in the RGB color space. Hence, these images are converted into grayscale color space which is suitable for performing manipulations in an image as in Fig. 1.

Gradient based method calculates the maximum and minimum value derived from the first order derivatives in an image. Robert's edge detection is an earliest, simplest and fastest first order derivative based method used to derive the difference between the pixels in the neighborhood. It uses 2-D gradient measurement to highlight the edge point regions in an image. This method has no resistance towards noise as in Fig. 2a [7]. Prewitt operator is better than the roberts as it applies 3×3 mask over an image in horizontal and vertical direction to identify the edges as in Fig. 2b. Sobel operator uses the same concept of mask to identify the edge regions but is capable to suppress the noise to a great extent as in Fig 2c. Major drawback of these gradient methods is their frequent influence towards noise.

Laplacian based method calculates edge region using second order derivatives [8]. Laplacian of gauss (LoG) method identifies the edges by calculating the rapid change in intensity value as in Fig. 3a and it uses the concept of gaussian smoothing to identify edges. Marr Hildreth edge detection is a popular method before the release of canny edge method. This method is based on gradient operator and uses the laplacian operator to calculate the second order derivatives. Zero crossing method calculates the edge region by finding the zeros in the second order derivatives as in Fig. 3b. Canny's edge detection is a standard method with special features of hysteresis and noise suppression. It identifies even the small change in intensity values and highlights even the thin and weak edges as in Fig. 3c [9]. But the major pitfall in this method is the identification of false edges.

3. PROPOSED METHODOLOGY

Feature extraction is an essential task in banana fruit quality analysis to obtain fruit quality characteristics such as size, shape, color, texture and appearance. Image segmentation is used to extract banana fruit region and also assists to identify different quality characteristics of banana fruit. Edge based segmentation is suitable to identify edges of banana fruit but the existing methods suffers from a disadvantage of discontinuity of edges, influence of noise and improper detection of boundaries in an image. Proposed method based on sequential hybrid system of genetic algorithm and fuzzy logic has been developed to have continuous, definite and clear edges. The proposed algorithm is developed using Matlab and the steps involved are depicted in Fig. 4.

3.1. Calculating Color gradient

Input image in RGB color space is used to calculate the color gradient [10]. Color gradient method calculates the gradient value in each color components (red, green and blue components) of an image using vector space and then combines them together to calculate the gradient for the entire image [11]. Calculating the 2-D gradient for each component of an image $f(x, y)$ is done using the formula,

$$\nabla f \equiv \text{grad}(f) = ||g_x| + |g_y| \quad (1)$$

where, 'f' is an individual component of an image and 'x' and 'y' are the coordinate values of 'f', 'g_x' and 'g_y' are the gradient value in 'x' and 'y' direction. This method has higher ability to produce a gradient image with low contrast than the scalar space based gradient calculation [12].

3.2. Enhancement of pixel values by Genetic Algorithm

The next step is to enhance the image for smoothing to reduce the noise level. Genetic algorithm (GA), a heuristic approach of optimization, is applied over the gradient image to enhance the image. It is an evolutionary computing technique for a directed random search to reach an optimal solution. This method of optimization is considered over the traditional methods for enhancement as it definitely reaches optimal solution and it's evaluation over the pixel value is done using the fitness function rather than functions based on derivatives [13]. The other reasons are its flexibility, adaptability, understandability and requirement of less mathematical knowledge.

The steps involved in this phase of genetic algorithm for enhancement are as follows :

Step 1: Get Initial pixel value (x_0) from gradient image.

Step 2: Set population size.

Step 3: Set number of iterations.

Step 4: Generate initial population randomly.

Step 5: Decode Initial population in binary form to decimal value.

Step 6: Evaluate the initial population by fitness function,

$$((x^2 - 4)^2/8) - 1 \quad (2)$$

Step 7: If converged terminate the process and move to step 13, else proceed.

Step 8: Select two parents by Random selection technique to generate next generation [14].

Step 9: Mate two parents by shuffle crossover technique to generate new desired offspring.

Step 10: Mutate by reversing technique to avoid local minima errors and to recover from loss of genetic information.

Step 11: Move to step 6.

Step 12: Evaluate the newly generated offspring population.

Step 13: Replace new pixel value (x_1) in x_0.

Similarly, this genetic algorithmic step is iterated over entire pixel values in an image and finally, a new optimized pixel values are replaced to get an enhanced output image as in Fig. 5.

3.3. Identification of edge regions by Fuzzy Logic

Fuzzy logic is an extension of Boolean or conventional logic used to analyze data which are partially true [15]. The value of fuzzy logic lies within the range of 0 to 1 in contrast to Boolean logic where the value is either 0 or 1. So, fuzzy is considered as a simplified technique of conventional method. The main advantage of this method is its flexibility in bringing together the detailed information of the system. This method is useful to identify the exact edge regions in an image as it has higher ability to manage vagueness and ambiguity information in an image. Mamdani Fuzzy Inference System is implemented to extract the edge regions in an image. It performs the mapping operation of input to output using fuzzification and defuzzification process [16].

Fuzzification is a process in which the crisp set of input is converted into fuzzy set and are represented using a membership function. Defuzzification is a process in which the output in fuzzy set is converted back into a crisp set. So, using fuzzy logic the edges regions are identified exactly and provide an exact edge map of the image. The output of enhanced color gradient image using genetic algorithm is taken as input for fuzzy logic.

Steps involved in the phase of fuzzy logic for identifying the edges are described below:

Step 1: Consider GA applied output as input (I) for fuzzification.

Step 2: Set Gaussian membership function for Input variable (I) as in Fig. 6.

Step 3: Set Triangular membership function for output variable (O) as in Fig. 7.

Step 4: Set a Fuzzy rule to differentiate edge and non-edge pixel regions.

Step 5: Evaluate Fuzzy rule and identify itsconsequences.

Step 6: Combine the Consequents to get a final output.

Step 7: Defuzzify the fuzzy result into crisp values using centroid method.

Step 8: Enhanced edge image is achieved as in Fig. 8

4. PERFORMANCE EVALUATION

The hybrid algorithm based on genetic algorithm and fuzzy logic has been implemented over 10 banana fruit images and its efficacy was compared with existing methods such as sobel, LoG, canny and susan (Fig 9).

Banana images taken are of real time images and do not have ground truth or golden standard or standard reference images for performing standard evaluations like ROC (Receiver Operating Characteristics) analysis and precision and recall analysis [17]. Hence, performance of the proposed method was evaluated using goodness measures such as kappa and entropy. Kappa method measures the accuracy between two images using the relative grading technique [18]. It performs pixel-to-pixel comparison between two images to measure the performance of proposed method. This kappa is calculated using

$$\text{Kappa} = (0 - K)/(1 - K) \quad (3)$$

where ‘O’ is the observed pixels in segmented image and ‘K’ is the majority image formed by calculating the probability of having pixel by chance. The value of kappa is normalized to range from 0 to 1. Higher value of kappa denotes that performance of segmentation method is better. In this method a majority image is formed by combining the edge detectors of existing methods to determine the probability of having a pixel by chance. A pixel is formed as an edge pixel in a majority image, if the pixel is claimed as edge pixel in most of these edge detectors.

Entropy method is used to measure the randomness of useful information from an image [19]. Though there are different entropy methods for measuring the randomness, Shannon entropy was best suited for measuring the information content in an image. Shannon entropy was calculated using,

$$\text{Entropy} = \sum_{i=1}^{n} e_i \log e_i \tag{4}$$

where '*e*' represents the pixels frequency and '*i*' represents the pixel intensity value [19].

Fig. 10 shows the output of sobel (S), LoG (L), canny (C), susan (U), majority image and proposed hybrid method (P). From comparison it was inferred that there were no discontinuities of edges in the boundary of banana region in proposed method. Further, the proposed algorithm was also able to identify dark spots, dots or scratch in the banana area.

Performance of different edge detection techniques along with proposed hybrid method were compared as per the relative kappa value measure (Table 1). Primarily, kappa value is calculated by analyzing the proposed method (P) and majority image obtained from edge methods like sobel, LoG, canny and susan method (M1). This kappa value is represented as KM1P.

Secondly, to confirm the efficiency of proposed method a majority image was formed by combining LoG, canny and susan without considering sobel method (M2). This majority image is compared with sobel method to note the performance efficiency of sobel method. This kappa value is represented as KM2S. M2 is also compared with proposed method to note the efficiency when sobel method is not considered in forming the majority image. This kappa value is considered as KM2P. Similarly this concept of comparison was applied for different edge methods. A majority image formed from sobel, canny and susan without considering LoG method (M3), majority image formed from sobel, LoG and susan without considering canny method (M4) and majority image formed from sobel, LoG and canny without considering susan method (M5) are considered for comparison. Kappa (L, M3) is referred as KM3L, kappa (P, M3) is referred as KM3P, kappa (C, M4) is referred as KM4C, kappa (P, M4) is referred as KM4P, kappa (U, M5) is referred as KM5U and kappa (P, M5) is referred as KM5P.

Kappa values of proposed method (KM1P, KM2P, KM3P, KM4P and KM5U) and different existing methods (KM2S, KM3L, KM4C and KM5U) for ten different banana images were calculated and statistically analysed. Analysis of variance (ANOVA) with Tukey's HSD multiple range tests was used to compare the significance of datasets of different kappa values. The software used for statistical analysis was IRRISTAT version 92 developed by International Rice Research Institute Biometrics unit, Philippines.

The results of kappa values of proposed method and different existing methods are shown in Fig. 11. The proposed method when compared with different majority images formed from any combination of edge methods had more kappa values (0.6777 – 0.8047 in KM1P; 0.6580 – 0.8031 in KM4P; 0.6037 – 0.8069 in KM3P; 0.5337 – 0.6890 in KM2P; and 0.4126 – 0.6271 in KM5P) whereas the existing methods had relatively lower kappa values (0.5158 – 0.6846 in KM4C; 0.4606 – 0.6377 in KM3L; 0.3918 – 0.5767in KM2S; and 0.2781 – 0.4814 in KM5U). The average kappa values of proposed method and existing methods are shown in Fig. 12. Statistical analysis of variance revealed that there was significant differences among kappa values of proposed method and existing methods (F = 132.1; df = 8, 198; P d" 0.0001). Kappa was significantly higher (0.5133 - 0.7432) in proposed method when compared with different majority images formed from any combination of edge methods. Kappa of the existing methods was significantly lower (0.4099 – 0.6199). Results clearly demonstrated that the performance of the proposed method is better when compared with the existing methods as the kappa value is greater for the proposed method.

Entropy values of the existing edge detection methods and proposed method for the same ten different banana images are also calculated (Table 2) and are depicted in Fig. 13. These values are also statistically analyzed as per ANOVA. The proposed method had lesser entropy values (0.5350 – 0.7502) whereas the existing methods had relatively higher entropy values (1.1162 – 1.7027 in canny; 0.7872 – 1.2644 in sobel; 0.6567 – 0.8805 in LoG; and 0.5647 – 0.7976 in susan method). The average entropy values of the proposed method and existing methods are shown in Fig. 14. ANOVA revealed that there was significant differences among entropy values of proposed method and existing methods (F = 184.3; df = 4, 48; P d" 0.0001). Entropy was significantly higher in Canny method (1.3998) followed by Sobel (0.9660), LoG (0.7363) and Susan method (0.6981). Entropy of the proposed method was significantly lower (0.6543). Entropy with higher value indicates more randomness with less information content and entropy with lower value indicates less randomness with more information [19]. Results clearly indicate that the performance of proposed method is better when compared with existing methods as the entropy value is lesser for proposed method. The results of kappa and entropy quantitatively proved that proposed method could be a better edge detection output than the existing methods.

5. CONCLUSION

Sequential hybrid system using genetic algorithm and fuzzy logic has been proposed in this paper to identify the accurate edge information from an image. Real time images of banana are taken to analyze the accuracy of the proposed method. Banana data set is considered as it is commonly consumed fruit crop in market and it necessities farmers and traders to automate the quality analysis system to satisfy consumers demand to provide qualitative fruits in the market. Identifying accurate edges of noise infected images is made possible using the proposed hybrid system. Statistical evaluation of the proposed method has been done using kappa for measure of accuracy and entropy for measure of randomness. It was noted that the proposed method showed a higher accuracy when compared with other existing methods like sobel, LoG, canny and susan method.

Table 1. Comparison of Kappa values for the existing edge detection methods along with thep roposed hybrid method

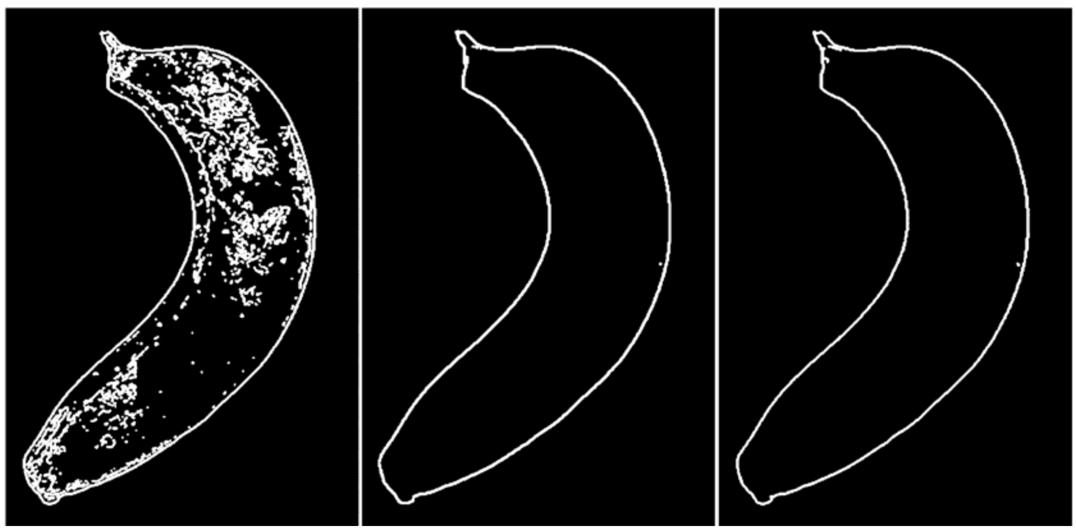
Data Set	*KM1P*	*KM2S/KM2P*	*KM3L/KM3P*	*KM4C/KM4P*	*KM5U/KM5P*
1	0.7644	0.3918/ 0.5337	0.6377/ 0.7641	0.6846/ 0.7730	0.4763/ 0.5130
2	0.7739	0.4314/ 0.5953	0.5159/ 0.7626	0.5162/ 0.7791	0.3915/ 0.5878
3	0.6777	0.4897/ 0.6272	0.4942/ 0.6191	0.6451/ 0.6580	0.4187/ 0.4367
4	0.7239	0.5541/ 0.6647	0.4727/ 0.6328	0.6667/ 0.6771	0.4054/ 0.4126
5	0.7489	0.5767/ 0.6890	0.4606/ 0.6288	0.6675/ 0.7284	0.4250/ 0.4388
6	0.7101	0.5340/ 0.6524	0.5172/ 0.6118	0.6470/ 0.6902	0.4616/ 0.4842
7	0.6825	0.5045/ 0.6237	0.5412/ 0.6037	0.6636/ 0.6808	0.4814/ 0.5019
8	0.8047	0.4767/ 0.5750	0.5380/ 0.8069	0.5214/ 0.8031	0.3305/ 0.5622
9	0.7677	0.5706/ 0.6315	0.5674/ 0.7648	0.5920/ 0.7638	0.4311/ 0.6271
10	0.7790	0.4344/ 0.5795	0.5315/ 0.7832	0.5158/ 0.7902	0.2781/ 0.5688

Table 2.Comparison of Entropy values of existing edge methods and the proposed hybrid method

Data Set	*Sobel*	*LoG*	*Canny*	*Susan*	*Proposed method*
1	1.2644	0.8805	1.7027	0.7946	0.7641
2	0.8950	0.6880	1.1162	0.5647	0.5350
3	0.9707	0.7625	1.4616	0.7164	0.6667
4	0.9148	0.6817	1.3226	0.6478	0.5902
5	0.8926	0.6567	1.4093	0.6417	0.6074
6	0.8960	0.7020	1.3156	0.6998	0.6581
7	0.7872	0.6930	1.3501	0.7031	0.6601
8	0.9845	0.6908	1.3570	0.6989	0.6414
9	1.0696	0.8434	1.4583	0.7976	0.7502
10	0.9856	0.7653	1.5049	0.7172	0.6706

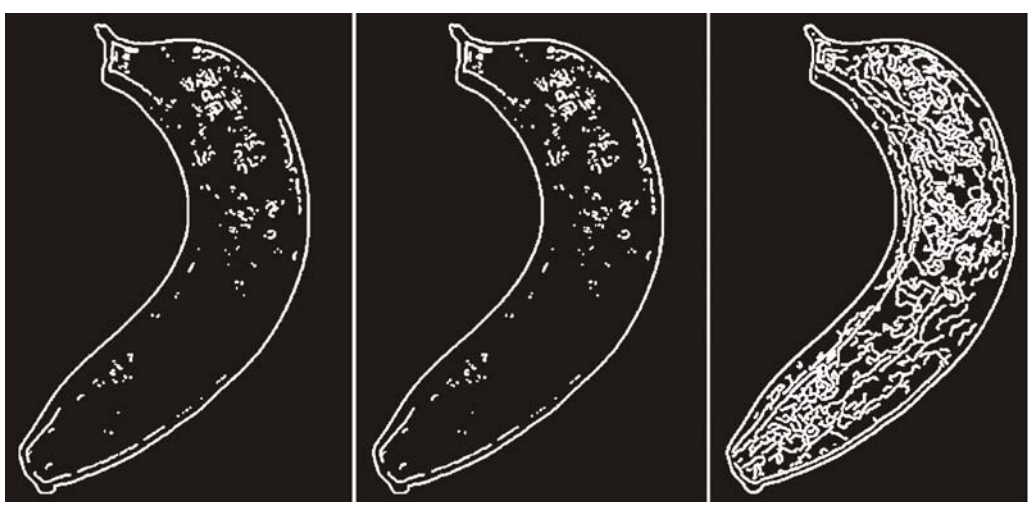
(*a*) (*b*)

Fig. 1. (*a*) Input RGB image (*b*) Converted Gray scale image.



(*a*) (*b*) (*c*)

Fig. 2. Output of input image of Figure. 1 in (*a*) Roberts method, (*b*) Prewitt method, (*c*) Sobel method.



(*a*) (*b*) (*c*)

Fig. 3. Output of input image of Figure. 1 in (*a*) LoG method (*b*) zero – cross method (*c*) canny method.

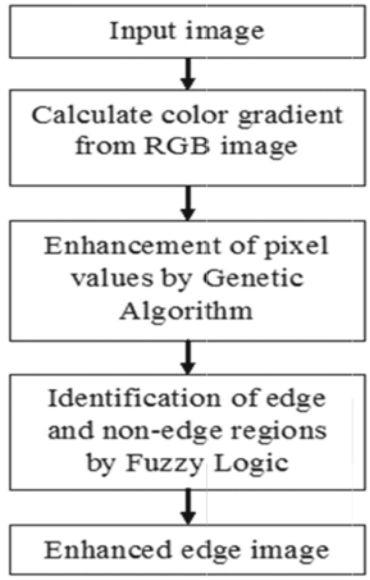
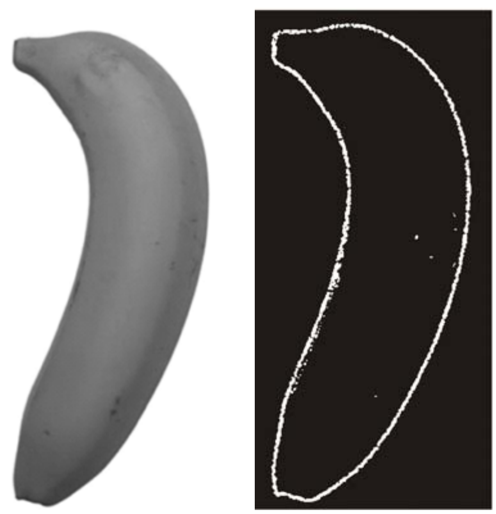


Fig. 4. Steps involved in the proposed algorithm



(*a*) (*b*)

Fig. 5. (*a*) Input image (*b*) Genetic Algorithm applied output image.

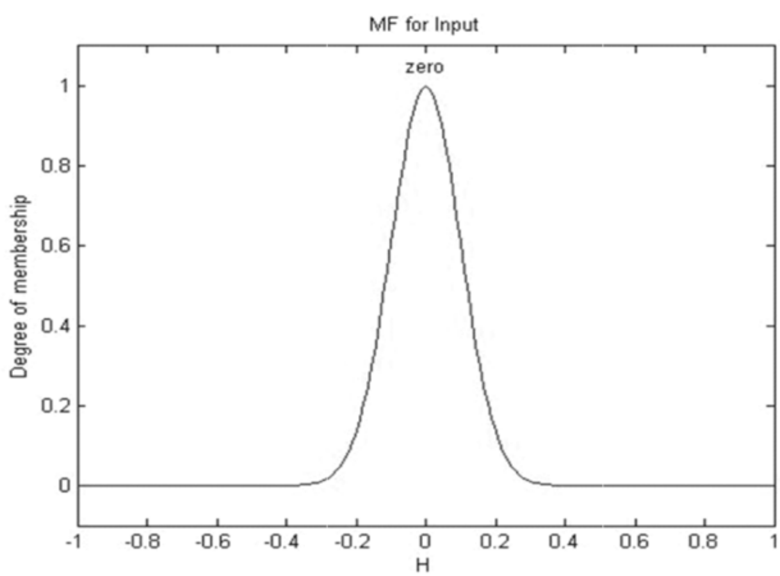


Fig. 6. Membership functions for the input variable.

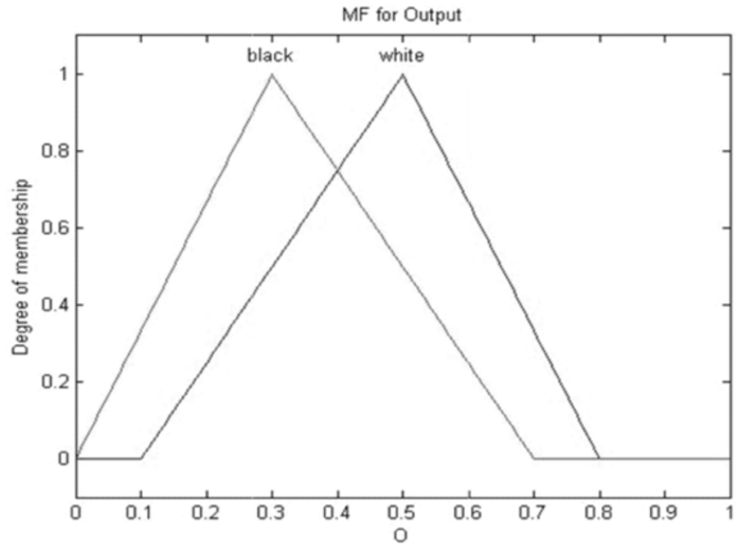
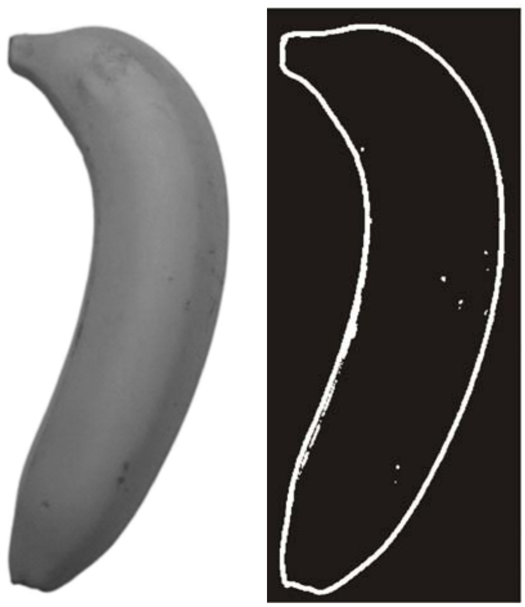
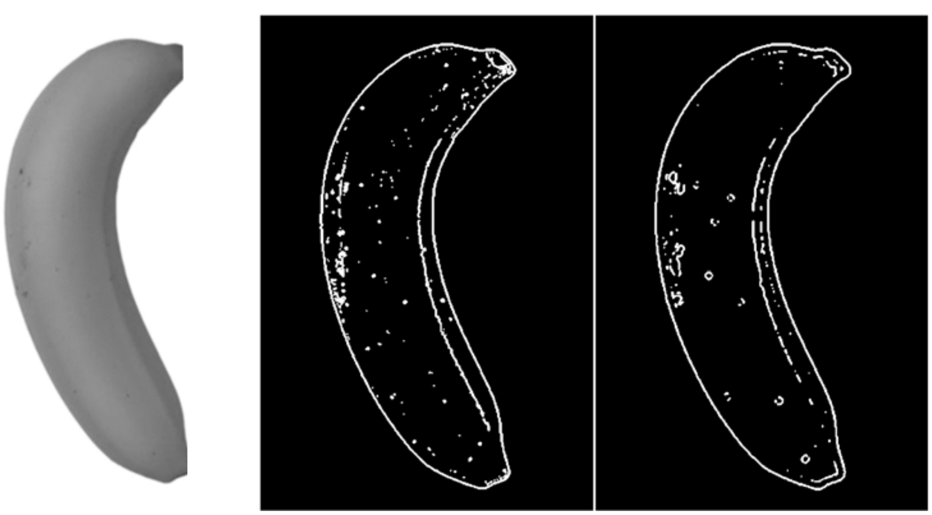


Fig. 7. Membership functions for the output variable.

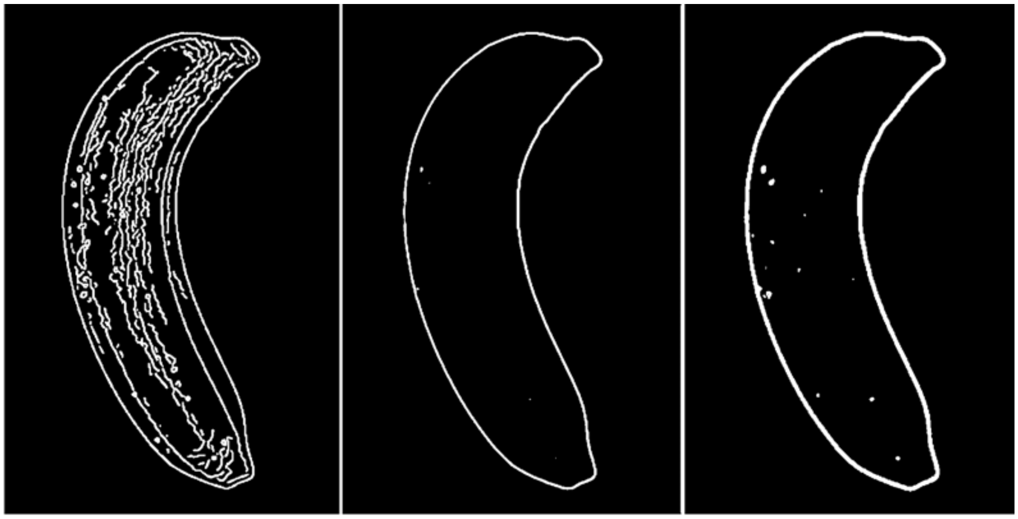


(*a*) (*b*)

Fig. 8. (*a*) Input image (*b*) Output of Fuzzy logic applied over Figure 5b.

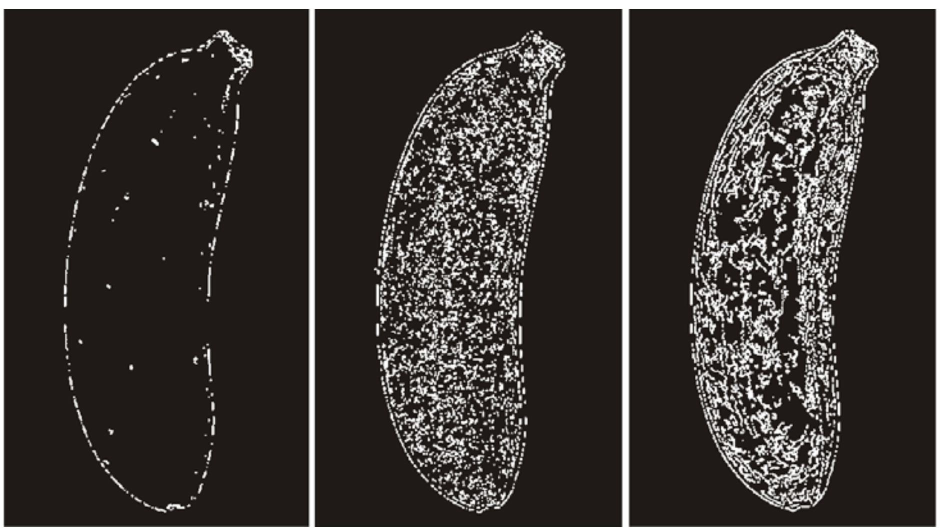


(*a*) (*b*) (*c*)

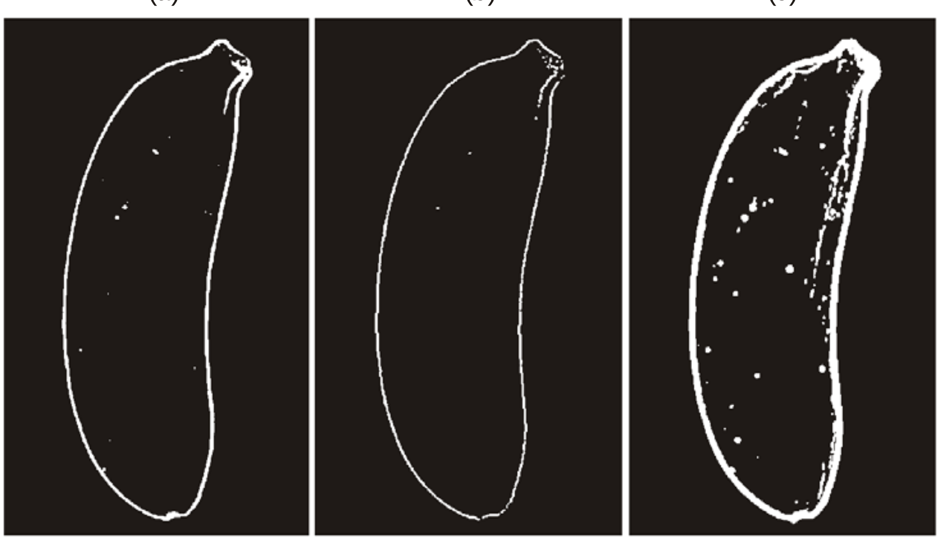


(*d*) (*e*) (*f*)

Fig. 9. (*a*) Input image, Output of (*b*) Sobel, (*c*) LoG, (*d*) Canny, (*e*) Susan and (*f*) Hybrid proposed method.



(*a*) (*b*) (*c*)



(*d*) (*e*) (*f*)

Fig. 10. Output of (*a*) Sobel, (*b*) LoG, (*c*) Canny, (*d*) Susan and (*e*) Majority image and (*f*) Hybrid proposed method.

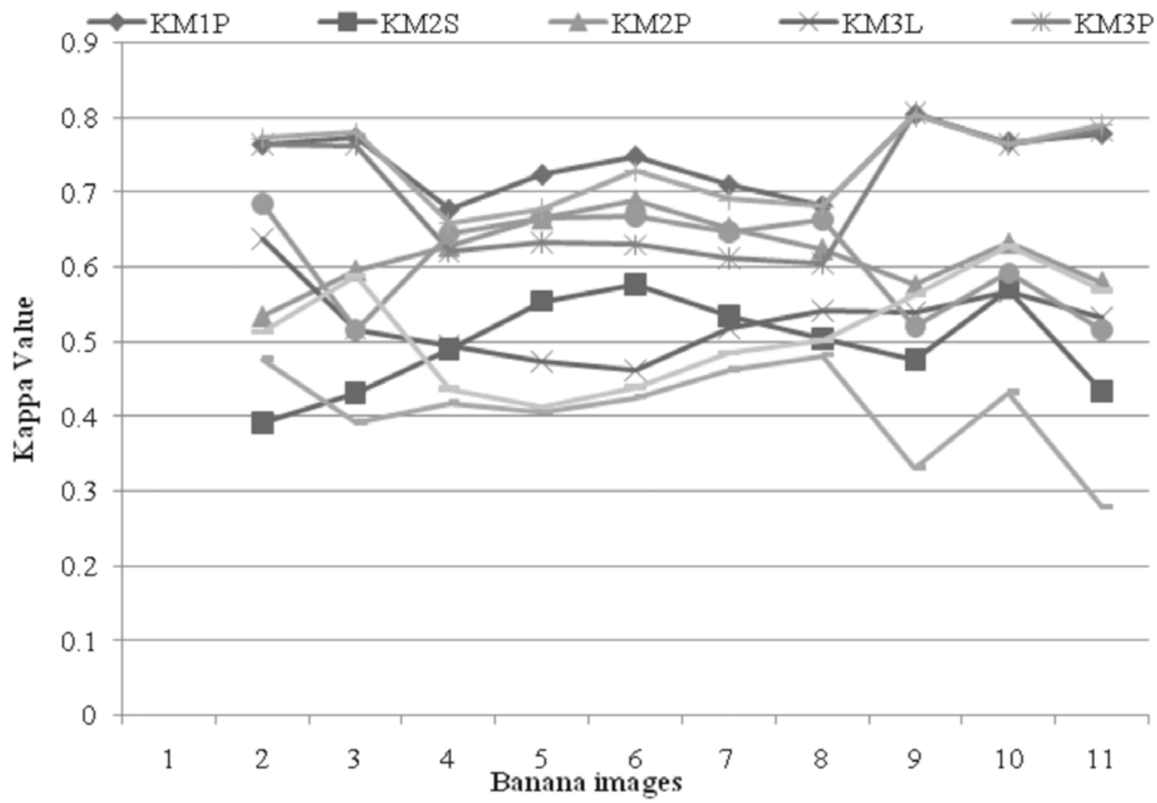
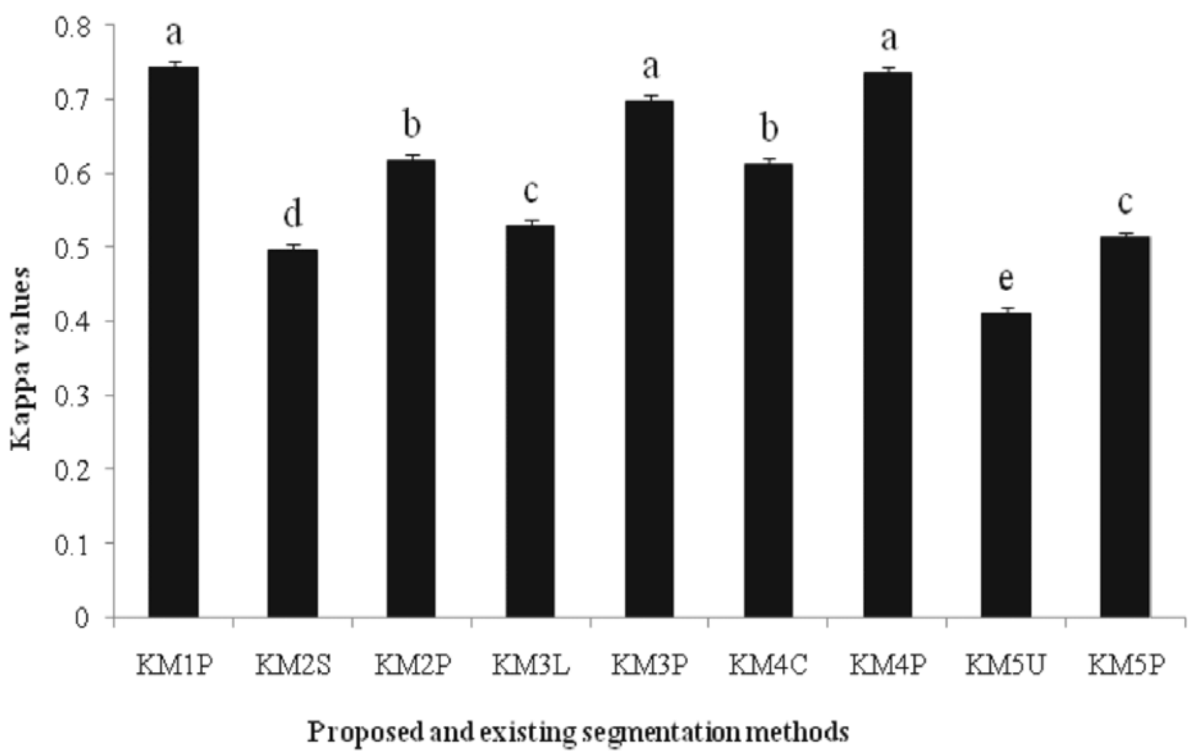


Fig. 11. Distribution Pattern of kappa values of existing edge methods and proposed edge method.



Fi g. 12. Comparing the kappa values by ANOVA. Bars followed by the same letter do not differ significantly according to Tukey's HSD multiple range test (P<0.05).

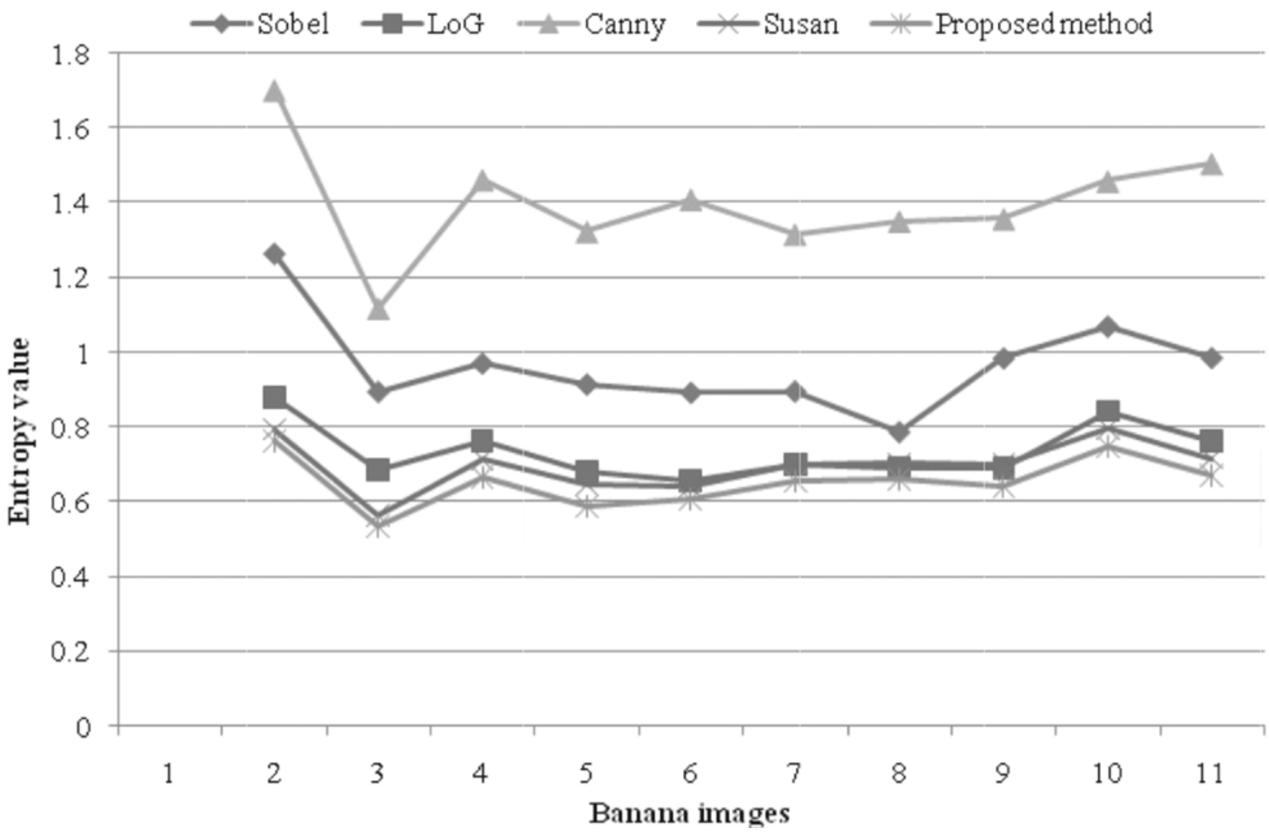


Fig. 13. Distribution pattern of entropy values of existing edge methods and proposed edge method.

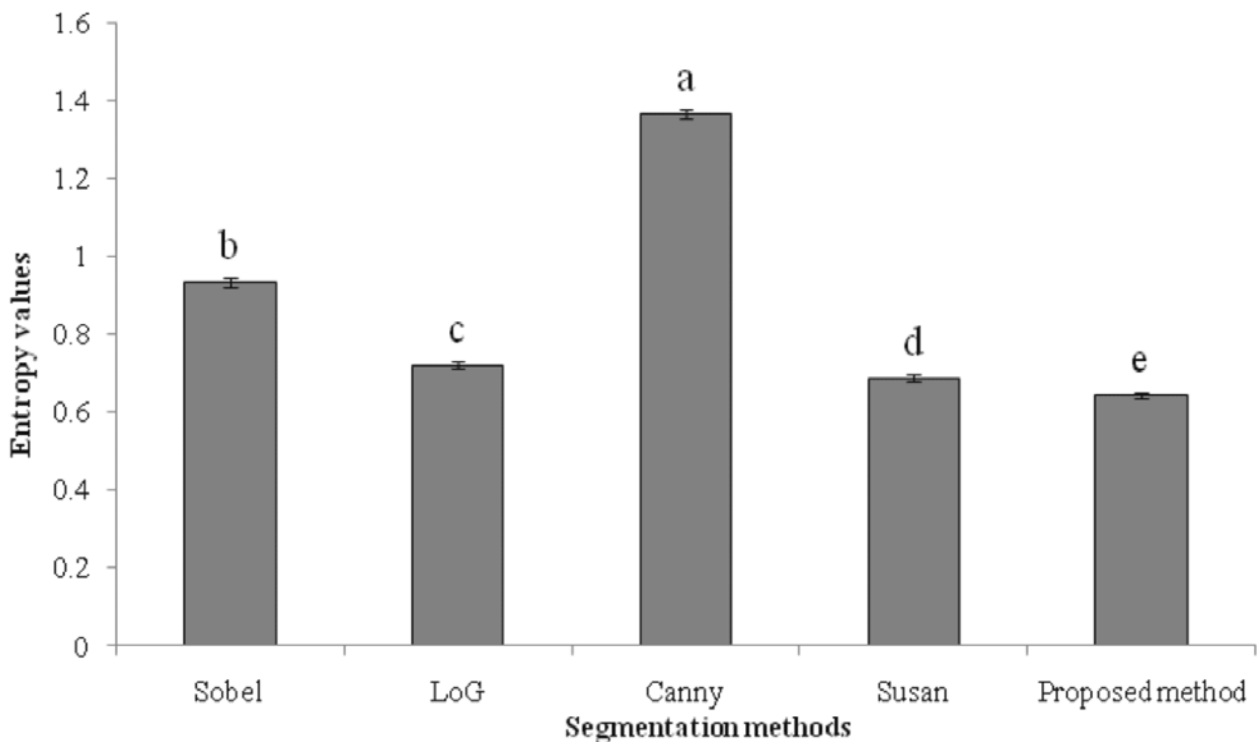


Fig. 14. Comparing the entropy values by anova. Bars followed by the same letter do not differ significantly according to tukey's hsd multiple range test ($p < 0.05$).

6. REFERENCES

1. D. Surya Prabha and J. Satheesh Kumar, “Assessment of banana fruit maturity by image processing technique”, *J. Food Sci. Tech*., vol 22, pp.1316-1327, 2013.
2. T. Brosnan and D.W. Sun, “Improving quality inspection of food products by computer vision - a review”, *J. Food Eng*., vol 61, pp. 3-16, 2004.
3. D. Surya Prabha and J. Satheesh Kumar, “A study on Image Processing Methods for Fruit Classification”, In *Proc. IPC & IPEeL ACT & CIIT CENT & CSPE* , Chennai, Tamil Nadu, India, pp. 403-406, 2012.
4. D. Surya Prabha and J. Satheesh Kumar, “Three dimensional object detection and classification methods: a study”, *Int. J. Engg. Res. Sci. Tech*., vol 2, pp. 33-42, 2013.
5. D. Surya Prabha and J. Satheesh Kumar, “Performance Evaluation of Image Segmentation using Objective Methods”, *Indian J. Sci. Technol.,* vol 9, pp. 1-8, 2016.
6. A.P. Engelbrecht, *Computational Intelligence: An Introduction*, John Wiley & Son: England, 2007.
7. N.R. Pal and S.K. Pal, “A review on image segmentation techniques”, *Pattern Recognit.,* vol 26, pp.1277-1294, 1993.
8. R. Stehling, M. Nascimento and A. Falcao, “A compact and efficient image retrieval approach based on border/interior pixel classification”, In Proc of the International Conference on Information and Knowledge Management, McLean, USA, pp. 102-109, 2002.
9. S. Yazdani, R. Yusof, A. Karimian, M. Pashna and A. Hematian, “Image segmentation methods and applications in MRI brain images”, *IETE Tech. Rev.,* vol 32, pp. 413-427, 2015.
10. D. Surya Prabha and J. Satheesh Kumar, “Hybrid Segmentation of Peel Abnormalities in Banana Fruit”, In *IJCA* Proc of the International Conference on Research Trends in Computer Technologies, Coimbatore, Tamil Nadu, India, pp.38-42, 2013.
11. C.R. Gonzalez and R.E. Woods. *Digital image processing,* Dorling Kindersley Pvt Lt Publications: India, 2011.
12. C.R. Gonzalez, R.E.Woods and S.L. Eddins, *Digital image processing using MATLAB*, Tata McGraw-Hill Publications: India, 2010.
13. S.F. Azadeh, S. Ghaderi, Tarverdian and M. Saberi, “Integration of artificial neural networks and genetic algorithm to predict electrical energy consumption”, *Appl Math Comput*., vol 186, pp 1731-1741, 2007.
14. J.H. Mathews and K.D. Fink, *Numerical methods using MATLAB*, Prentice-Hall Pvt. Ltd: India, 2005.
15. S. Rajasekaran and G.A. Vijayalakshmi Pai, *Neural Networks, Fuzzy Logic, and Genetic Algorithms- Synthesis and Applications*, PHI Learning Pvt Ltd: India, 2012.
16. S.N. Sivanandam and S.N. Deepa, *Principles of Soft Computing*, Wiley India Pvt. Ltd: India, 2014.
17. B. Avcýbas Sankur and K. Sayood, “Statistical evaluation of image quality measures”, *J. Electron. Imaging.,* vol. 11, pp. 206-223, 2002.
18. H. Zhang, J.E. Fritts and S.A. Goldman, “Image segmentation evaluation: A survey of unsupervised methods”, *Comp. Vision Image Understanding.,* vol. 110, pp. 260-280, 2008.
19. J.S. Cardoso and L. Corte-Real, “Toward a Generic Evaluation of Image Segmentation”, *IEEE Trans Image Processing.,* vol 14, pp. 1773-1782, 2005.