International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)
Volume-3 Number-3 Issue-11 September-2013

Comparative Study on Image Segmentation Algorithms

G. Evelin Suji[1] , Y.V.S. Lakshmi[2] , G. Wiselin Jiji[3]

Abstract

Segmentation divides the image into different regions or meaningful parts. Segmentation algorithm groups a set of pixels with same characteristics such as colour, intensity, texture, disparity and motion and extracts the features of images. The accuracy of the extracted feature decides the accuracy of the algorithm. A number of image segmentation algorithms have been proposed but, the selection of a suitable algorithm is application dependent. This paper reports a comparative study of different segmentation algorithms.

Keywords

Algorithm, Analysis, Colour Image, Feature, Segmentation

1. Introduction

An image is a two dimensional function that represents characteristics such as colour, brightness of a scene. Analog image is characterized by a physical magnitude, varying continuously in space. Analog image f(x, y) is continuous with respect to X and Y-coordinate values and also in amplitude [1, 2]. Digital image is a matrix of integers. Each matrix element is called 'pixel'. A pixel represents intensity or brightness at that point.

A digital image f(x, y) contains M rows and N columns and represented as

$$f(x,y)=\begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & \dots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix}$$

G. Evelin Suji, Electrical and Electronics Engineering, B S F Institute of Technology, Bangalore, India.
Y.V.S. Lakshmi, Manager- IPR, C-DOT, Bangalore, India.
G. Wiselin Jiji, Computer Science and Engineering, Dr. SivanthiAditanar College of Engineering, Tiruchendur- 15, India.

In MATLAB, a digital image is represented as

$$f(x,y)=\begin{bmatrix} f(1,1) & f(1,2) & \dots & f(1,N) \\ f(2,1) & f(2,2) & \dots & f(2,N) \\ \vdots & \vdots & & \vdots \\ f(M,1) & f(M,2) & \dots & f(M,N) \end{bmatrix}$$

where $f(1,1) = f(0,0)$

The Four basic types of digital images are: (i) Binary Image (ii) Gray scale Image (iii) RGB or True Colour Image and (iv) Indexed or multi Spectral Image. In binary image, each pixel can be represented as either black or white. Hence, it requires only 1 bit per pixel. Gray Scale image is a shade of gray between black and white. Each pixel corresponds to the amount of light intensity and is represented by a byte or word. For an 8-bit image, black is represented by 0 and white by 255. Each pixel in a gray scale image represents one shade of gray level by an integer value between 0 and 255. RGB or True colour image is also called 24-bit colour image. It has three values per pixel. Each pixel contains the vector of colour components. The common colour space used are RGB (Red, Green, Blue), HSV (Hue, Saturation, Value), and CMYK (Cyan, Magenta, Yellow, Black). Colour images consists of three separate image representations called colour planes, with pixel values in each plane corresponding to the intensity of the colour at a specific point [1]. The 24-bit colour image is represented by

$$f(x,y)=\begin{bmatrix} f_R(x,y) \\ f_G(x,y) \\ f_B(x,y) \end{bmatrix}=\begin{bmatrix} r_o \\ g_o \\ b_o \end{bmatrix}$$

An RGB colour image is an M x N x 3 array of colour pixels. It may be viewed as a stack of three gray scale images that, when fed into the red, green, and blue inputs of colour monitor, produce a colour image on the screen [3]. Multispectral images have more than 16 million colours, which cannot be distinguished by our eyes. These are the images acquired for remote-sensing application. The information available in the multispectral image is

represented by mapping the different spectral bands to RGB components.

The main objectives of image segmentation are: (i) to recognize the objects of interest from other objects or background and partition into groups of pixels which are homogeneous with respect to certain criterion (ii) to divide an image into regions for further analysis and (iii) to prefer a change of representation of an image for faster analysis [4]. The segmentation procedure should stop when the object of interest have to be separated. The problem of image segmentation is due to image texture.

2. Classification of Gray Scale Image Segmentation

Image segmentation algorithms are based on the characters of gray level pixels such as discontinuity around edges and similarity in the region. Segmentation algorithms are classified as: (i) Edge based segmentation (ii) Region Based Segmentation (iii) Theory based segmentation. The algorithms are implemented to produce maximum reliability and better result.

Edge based segmentation is implemented to detect boundaries and discontinuities in an image. This technique avoids a bias of size of the segmented object. The edge is determined by the extreme of the first order derivative or a zero crossing in the second order derivative [5]. Edge detection is usually done with linear gradients operators such as Prewitt kernel, Robert Kernel, Sobel Kernel, Laplacian of Gaussian and Canny Edge detecting techniques. These operators work well with sharp edges and less noise [1, 2, 3, 4]. Edge based segmentation does not work well with ill-defined edges or with too many edges and less immune to noise [4, 8].

Region based segmentation technique partitions an image into regions that contains connected pixels with similar properties based on a set of predefined criteria. In this approach, the image features are compared without any object boundaries and later a preliminary segmentation is performed. To get a better result, feature computation and segmentation is repeated. Thresholding, region growing, region splitting, region merging and level set approaches falls under this category [4, 5].

Theory based segmentation algorithm are derived from the fields of knowledge such as Fuzzy mathematics, artificial intelligence, genetic algorithm and Neural network [4]. The segmentation algorithms mentioned so far, utilize the information gathered from local neighbourhood operators. In theory based segmentation approach, specific knowledge about the geometrical shape of the object is required, which can be compared with the information gathered from neighbourhood operators. The comparative study of different segmentation technique is given in Table1.

3. Classification of Colour Image Segmentation

Colour images provide more information than the gray scale images. It is represented as multidimensional vector. Hence, the gray image segmentation techniques cannot be implemented to colour images directly. In colour image segmentation technique, preserving the human perceivable colour boundary is very important. Colour image segmentation finds its applications as (i) to detect skin cancer (ii) to classify different types of plants in aerial images (iii) to identify defective fruits from normal fruits in a conveyor mechanism (iv)to identify the vegetation area from other areas (v) in computer vision and Satellite acquired images (vi) in multimedia application [1]. Like gray scale image segmentation, colour image segmentation is also classified as: (i) Edge based segmentation (ii) Region Based Segmentation (iii) Theory based segmentation.

3.1 Edge Based segmentation

An edge in a colour image is defined by the discontinuity in a three dimensional colour space. Edge can be detected by defining a metric distance in colour space and then identify the discontinuity in the distance. Edge can also be detected by enforcing some uniformity constraints on the edges in the basic colour components. Edge detection can be performed by gradient detection method, differential coefficient technique, and Laplacian of Gaussian and Canny operator. The Canny operator is the most effective technique among the operators [8].

3.2 Region based segmentation

Region based segmentation algorithm are based on the similarity of the pixels within the region. The basic formulation involved in region based segmentation is as follows [3]

Let X represents the image region. Segmentation algorithm partitions X into n sub regions, X1, X2, …, Xn, such that

(i) $\bigcup_{i=1}^{n} Xi = X$

(ii) Xi is a connected region, i = 1,2,..,n

(iii) $Xi \cap Xj = \Phi$ for all i and j, $i \neq j$

(iv) P(Xi) = TRUE for i = 1,2,...,n

(v) $P(Xi \cup Xj)$ = FALSE for any adjacent regions Xi and Xj

Here P(Xi) is a predicate defined over the point in set Xi and Φ is the null set.

Condition (i) indicates that every pixel must be in a region and the segmentation must be complete. Condition (ii) requires a connected point in some predefined sense. Condition (iii) indicates that the region must be disjoint. Condition (iv) indicates that the pixel in a segmented region must satisfy some defined properties. Condition (v) indicates that the adjacent regions Xi and Xj are different in the sense of predicate P. The different region based segmentation is Thresholding, region growing, splitting and merging.

3.3 Theory based segmentation

Theory based segmentation technique assumes that the individual region in a given image follow a repetitive form of geometrical structure [18]. Fuzzy Logic, Neural network and Watershed algorithms fall under this category.

Fuzzy set theory and Fuzzy logic have been applied to overcome the uncertainty and ambiguity manifested in images. In last decade, Fuzzy operators, mathematics and inference rules are used in colour image segmentation [8, 9, 10, 11, 12, 13, 14]. Neural network segmentation processes small areas of an image using an artificial neural network or set of neural networks. Once the processing is done, the decision making algorithm marks the areas of an image accordingly to the category recognized by the neural network [18]. The edge of the image is extracted by using dynamic equations to detect the state of every neuron towards minimum energy defined by neural network [8, 15, 16]. Neural networks have been applied successfully for face detection [1]. Watershed transformation is a powerful tool for image segmentation. Watershed algorithm uses mathematical morphological theory for image segmentation. In this approach, the image is considered as a topographic surface. Watershed algorithm represents every object of an image as a separate part and has a tag at least in each object or seed point [17, 18].

4. Comparative Study of Image Segmentation Techniques

Table 1: Image Segmentation Techniques

Segmentation Technique	Description	Merits	Demerits
Robert Operator	Determine the differences between adjacent pixels. Uses first order derivative and 2X2 mask	• Edges are more accurate • Oldest operator and easy to implement • Can be used in hardware implementation where simplicity and speed are dominant factor	• Highly sensitive to noise • Robert kernels are too small to reliably find edges in the presence of noise • It has limited functionality.
Prewitt Operator	Uses 3X3 masks, the operation is based on central difference and orientation. Mask differentiation in one direction and averages in the other direction	• Simpler to find edge orientation • Masks have longer support • Simpler to implement	• Less vulnerable to noise compared to Robert. • Results of orientation is less accurate • Produces noisier result
Sobel Operator	Operation relay on central differences. Uses weight of 2 in the center coefficient and gives greater weight to	• Produces both derivative and smoothing effect • Noise suppression is better	• Vulnerable to high frequency noise effect

	the central pixel while averaging	than Prewitt	
Laplacian of Gaussian	Uses second derivative operator Image is smoothened by convolution method and then the Laplacian operator is used	• Noise effect can be minimized • It can be used in real time algorithm for blob detection.	• Generate closed contours, which are not realistic. • Inherent reduction in overall image contrast
Canny operator	Works in multistage process. Image is smoothed by Gaussian convolution then 2D first derivative operator is applied	• Less sensitive to noise. • Produces cleanest edge map. • Improved feature detection.	• Setting a generic threshold that works well on all kinds of images is a difficult task
Region Splitting/ Merging	Common approach is to compare and group pixels with its neighbors. Takes spatial information into consideration and look for uniformity within a sub region based on a suitable property like intensity, color, texture etc.	• Useful for visualizing problem and implementing a solution. • Separate the region based on the property defined by the user. • Algorithm is simple and works well with noisy environment. • Borders of region found by this technique are perfectly thin and connected	• Selection of seed point is user dependent. • Selection of wrong seed points can lead to wrong segmentation result. • Algorithm is highly iterative and requires high computational time
Thresholding	Regions in an image can be identified based on intensity level. Histogram thresholding and slicing techniques are used to identify the regions of gray levels	• Useful for establishing boundaries in images that contain solid objects on contrast background • It does not require prior information of the image. • It has less computational complexity and less time consuming.	• Cannot be applied to multi-channel images. • There may be a possibility of overlapping between gray levels of the object and background. • Sensitive to noise and intensity in homogeneities. • Cannot work well for an image having no sharp peaks or with broad and flat valleys.
Level-Set	Initial curve has to be placed near symmetrically with respect to the object boundary	• Useful in solving problems involving moving interfaces, singularities and geodesics. • Stable and equations are not stiff. • Easy to compute three dimensional problems.	• The result is good only if the initial curves specified are placed near symmetrically with respect to the object boundary.
Fuzzy based	Fuzzy set theory and logic have been applied to handle the uncertainty manifested in images.	• Can represent the relationship between the input pattern data and clusters more naturally. • Feature selection algorithm provides better accuracy and suitable for noisy images. • Can be used to detect the automatic changes in the images.	• Iteration is longer and complex. • Computational complexity is intensive. • Determination of fuzzy membership in not a trivial job.
Neural Network based	The image is mapped into a neural network where each neuron represents a pixel. The edges are extracted by dynamic equations	• Provides better result for face detection. • Fast computational capability. • Can utilize the parallel nature of neural network. • Ability to interact among any processing unit.	• Knowledge of any kind of segmentation is required. • Training time is long. • Overtraining may occur in due process and should be avoided. • Results of segmentation has the influence of initialization

		• Insensitive to noise	
Watershed Transformation	Image is considered as a topographic surface. The gray-level of the image represents the altitude. The region with a constant gray level constitutes the flat zone of an image.	• Works well if each local minima corresponds to an object of interest. • Can extract nearly uniform (blob like) objects from the background.	• Over segmentation • Sensitive to noise • Poor performance in low contrast boundaries • Poor detection of thin edges.

5. Conclusion and Future Work

Image segmentation is an essential step in analyzing problems and pictorial pattern recognition. Segmentation of nontrivial images is one of the most difficult tasks in image processing. The accuracy of the segmentation algorithm determines the success or failure of the analysis procedure. Thus finding an appropriate segmentation algorithm is very important. Segmentation Algorithm can be applied to medical images and remote sensing images to find any abnormalities present, volume and the area of the affected regions if any. In this paper, we classify and discuss the various segmentation algorithms. Most of the Gray scale image segmentation techniques can be applied on color images. Finally, the choice of one segmentation algorithm over the other is based on the application and the characteristics of the problem being considered.

References

[1] S. Jayaraman, S.Esakkirajan, T. Veerakumar, Digital Image Processing, Tata McGraw Hill Education Private Limited.
[2] Vipula Singh, Digital Image Processing with MATLAB and LabVIEW, Reed Elsevier India Private Limited.
[3] R.C Gonzalez, R.E Woods and S.L Eddins, Digital Image Processing Using MATLAB, Pearson, Fifth Impression,2009.
[4] G.Evelin Suji, Y.V.S. Lakshmi, G. Wiselin Jiji, Image Segmentation Algorithms on MR Brain Images, IJCA, Vol 67, 18-20,2013.
[5] Krishna Kant Singh, Akansha Singh, A study of Image Segmentation Algorithms For Different Types of Images, International Journal of Computer Science, vol 7, 2010.
[6] H.D. Cheng, X.H.Jiang, Y.Sun, J. Wang, Color Image Segmentation:advances and prospects, Pattern Recognition, Vol 34(12),2259-281, 2001.
[7] Ravikanth Malladi, James A. Sethian and Baba C. Vemuri, Shape modeling with front propagation: a level set approach, IEEE Transactons on Pattern analysis and machine intelligence, vol 17,1995.
[8] Sameena Banu, The comparative study on color Image segmentation Algorithm, IJERA, vol 2, pp 1277-1281,2012.
[9] S.K. Pal et al., A review on Image segmentation techniques, Pattern Recognition, 29, 1277,1294, 1993.
[10] J. M. Keller, and C. L. Carpenter, Image Segmentation in the presence of Uncertainty, International Journal of Intelligent Systems, Vol. SMC-15, 193-208, 1990.
[11] S. K. Pal and R. A. King, On Edge Detection of X-ray Images Using Fuzzy Sets, IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol. PAMI-5, No.1, 69-77, 1983.
[12] I. Bloch, Fuzzy Connectivity and Mathematical Morphology, Pattern Recognition letters, Vol. 14, 483-488, 1993.
[13] T. L. Huntsberger, C. L. Jacobs and R. L. Canon, Iterative Fuzzy Image Segemntation, Pattern Recognition, Vol. 18, No. 2, 131-138, 1985.
[14] A. Borji, M. Hamidi and A.M.E. Moghadam, CLPSO-based Fuzzy color Image Segmentation, Proceedings of North American Fuzzy Information Processing Society,2007.
[15] Zhenghao Shi, Lifeng He, Application of neural Networks in Medical Image Processing, Proceedings of the second International Symposium on Networking and Network Security. ISBN 978-952-5726-09-1, 2010, 023-026.
[16] K. Suzuki et al, Neural Edge Enhancement from Noisy Images, IEEE Trans. Pattern Ana. Mach.Intell. 25, 2003, 1582-1596.
[17] L. shafarenko, M. Petrou, J. Kittler, Automatic watershed segmentation of randomly textured color images, IEEE Trans. On Image Processing, Vol 6, 1530-44,1997.
[18] Biplab Banerjee, Tanusree Bhattacharjee, Nirmalya Chowdhary, Color Image Segmentation Technique using "Natural Grouping" of Pixels, IJIP, Vol 4, 320-328.

G. Evelin Suji is working as a Lecturer in B.S.F. (Border Security Force) Institute of Technology, Bangalore. Her area of interest is medical imaging. She has published 6 research articles in International journals and 3conferences.

Dr. Y.V.S. Lakshmi is working as Manager- IPR in C-DOT, Bangalore. Her area of interest includes Image processing, Nano technology, system reliability, telecommunication etc. She has published more than 20 papers in international journals and also presented more than 20 conference papers.

Dr. G.Wiselin Jiji is working as the Professor and Head of the Department of Computer Science & Engineering in Dr.Sivanthi Aditanar College of Engineering. Her area of interest is Medical Imaging, Cognitive Science & Data Mining. She has published research articles in 40 Papers in Referred international journals. She has received Career Award for Young Teachers from AICTE, New Delhi. In addition, she has received 6 more awards in National & 2 state awards.