A COMPARATIVE STUDY ON DIVERSE FUZZY LOGIC TECHNIQUES IN SEGMENTING THE COLOR IMAGES

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ABSTRACT

During the past several decades, there are tremendous development in the field of Image Segmentation. Due to the extreme thirst in enhancing the quality of the image segmentation process, numerous segmentation techniques have been evolved. Segmentation in color images is quite difficult due to the uncertainties that exist in the boundary. Fuzzy logic is an ideal concept which is well suited in such cases. It is an approach of computation which is based on the degrees of truth rather than the Boolean logic through which the modern computer works. Fuzzy techniques are highly popular due to its rapid extension of fuzzy set theory and are mainly based on the binary valued membership. Thus the Fuzzy techniques applied in image processing can efficiently manage the ambiguities present in the images. Hence this comparative analysis mainly exemplifies the working methodologies of different collection of Fuzzy logic techniques in image segmentation and this in turn helps the image processing researchers to innovate more advanced techniques in Fuzzy concept and solves the problem in hand.

Keywords: Segmentation, Fuzzy Logics, Fuzzy Set Theory, Clustering, Uncertainty, Membership Function.

INTRODUCTION

Image segmentation plays a significant role in image analysis and computer vision. The main aspire of image segmentation is partitioning of an image into a set of disjoint regions with uniform and homogeneous salient features such as intensity, color, one etc. The image segmentation approaches can be categorized into four types such as threshold, edge detection, clustering, and region extraction. In image processing, two major terms usually exposed very close to each other are clustering and segmentation. When examining the color information of the image, such as trying to separate regions or ranges of color components having same characteristics, the process is called color clustering. The process of mapping those clusters onto the spatial domain and physically separated regions in the image is called segmentation. In color images, the boundaries between objects are blurred and distorted due to the imaging acquisition process. Furthermore, object definitions are not always crusty and knowledge about the objects in a scene may be vague. Fuzzy set theory and Fuzzy logic are ideally suited to deal with such uncertainties. Fuzzy logic is defined as a form of many valued logics which deal with reasoning that is approximate rather than fixed and exact. Fuzzy logic variables may have a truth value that lies in between 0 and 1. Fuzzy logic is used to handle those ambiguous situations where we have the values which can be completely true or completely false. In such situations there may be no specific value hence we need to take some range of values between 0 and 1. As uncertainty increases complexity also increases thus uncertainty may be defined to be directly proportional to the complexity. Thus to overcome complexity assumptions, simplifications etc are taken, these are collectively referred to as Fuzziness. The fuzziness is similar to other Engineering theories.

Classical logic only permits propositions having a value of truth or falsity. There are certain situations where people are asked to identify a color of an object. The value may result in either one of the spectrum they are truth spectrum or false spectrum. The final results or an overview can be obtained based on the above analyzed spectrum.

Both degrees of truth and probabilities range between 0 and 1 and hence may seem similar at first. Consider an example, an individual X, the short person may be one whose height is below 4'30". For other individual Y, the short person may be one whose height is less than or equal to 3'50". This "short" is called as linguistic descriptor.

The term "short" informs the same meaning to the individuals X and Y, however they both do not provide a unique definition. The term "short" would be conveyed effectively, only when a computer compares the given height value with the reassigned value of "short".

There is some difference between fuzzy logic and probability. If the fuzzy logic is considered, truth degrees are used as a mathematical model of the vagueness phenomenon while in the case of probability, it is a mathematical model of ignorance. For example probability of obtaining a head on tossing a coin is 0.5. This example gives a clear idea on the concepts of probability. The fuzzy logic can also be defined as those systems which accept imprecise data and vague statements such as low, medium, high and provides decisions. The decisions which are obtained are said to be as the outcome of the fuzzy logic systems.

1. Different Fuzzy Logic Techniques

The below section describes on few different methods of Fuzzy Techniques in Image Segmentation. The Salient features and methodology of each process are described in brief.

1.1 Fast Multilevel Fuzzy Edge Detection Technique

This Fast Multilevel Technique [1] was specially used for the detection of fast and accurate edge detection of blurry images efficiently. It enhances the contrast of images through the process of Fast Multilevel Fuzzy Enhancement algorithm with the implementation of simple transformation function based on two image thresholds. After that, the edges are extracted using the two stage edge detection operator that identifies the edge candidates based on the local characteristic of the image. The initial stage is fuzzy rule based in which memberships are assigned to pixels, classification of the pixels that have only one high membership and estimation of the initial conditions for the next stage.

The second stage is the fuzzy c-means algorithm which organizes the undetermined pixels. Hence the Preliminary segmentation of the human brain MR images [2] [14] exposes the two-stage fuzzy system could determine white matter, gray matter, cerebrospinal fluid and HIV+lesion in an efficient and accurate manner. Hence there exists some two-stage system combining two techniques and dealing with different problem, so it indicates that different fuzzy segmentation techniques should be followed. The Systematic work flow of the fuzzy enhancement algorithm is as follows,

- Load the image as an input to algorithm
- Set the 16 types of fuzzy templates
- Apply fuzzy templates prescribed
- Detect the maximum edge using derivate detection
- Finally apply the edge detection technique

1.2 Modified Fuzzy C-Means Technique

This Modified Fuzzy C-Means (MFCM) method mainly does the job of clustering the featured vectors into several classes with every class corresponding to one region in a segmented image. The MFCM algorithm [4] [11] is applied to the Hue component of the original image represented in HSI color space. The idea is to replace the vector X used in the image segmentation method based on the pixel value and the FCM algorithm by a matrix (n x n) and the F containing the same number of lines n, in accordance with 4 columns. These columns contain 4 statistical features extracted from the sliding window centered on every pixel. Hence, this algorithm scans the image using a sliding window, from top to bottom and left to right in an efficient manner. A feature vector is extracted from each block subsequently. However, the selection of the best attributes is fully based on the characterization degree.

The Modified Fuzzy C-Means technique for image segmentation using FCM algorithm combined with the statistical features can be summarized by the following steps,

- Input an N x M image
- Randomly initialize the centers of the class vectors
- Calculate the matrix F of size (n X 4) containing statistical characteristics extracted from the image
- Above step should be continued until the iteration t=1
- Calculate the membership matrix (Ut) of the element Uik using the below mentioned equation (1),

$$U_{ik} = \frac{1}{\sum_{j=1}^{c} \frac{|F_k - v_i|}{|F_k - v_j|}^{\frac{2}{m-1}}}$$

where U_{ik} is the member function, c be the clusters formed, m is referred as the fuzzy factor, v_i anf v_j be the number of samples taken, and F_k be the centroid of the samples.

- Estimate the matrix composed of four columns using the below equation (2) and then increment the iteration t

$$V_i = \frac{\sum_{k=1}^{n} U_{ik}^{m} F_k}{\sum_{k=1}^{n} U_{ik}^{m}}$$

- Stop the process as it reaches the positive threshold value

The Entire workflow of this technique is given in the following steps,

- Presentation of the Image should be in original color.
- The Hue should be computed with the following equation (3),

$$Hue = \arctan\left(\frac{\sqrt{3}(G-B)}{(R-G)+(R-B)}\right)$$

- Statistical features of the above stated algorithm should be processed.

Final Segmentation result is determined.

1.3 Fuzzy Min-Max Clustering Technique

This technique [3] is mainly implemented for the purpose of segmenting adaptive color images. It uses the concept of HSV color space and is highly compatible with the vision psychology of human eyes, in which it comprises Hue, Saturation and Intensity. These three things are relatively independent to each other. It is far better than the RGB transformation, since there exists a high correlation with each other. Henceforth HSV color space can efficiently overcome the difficulties in the discrimination of the highlights, shadows and shading of the color images. HSV color model has the following merits, as basically Hue is mostly invariant to the above stated difficulties, and also it decouples the intensity component extracted from the color images efficiently.

Fuzzy Min-Max clustering algorithm [3] on image histogram produces saturation and intensity plane. This algorithm mainly enhances the saturation and intensity planes for color image segmentation since these are the two quantities that may vary and hue value remains same also, non-removable singularity is one of hue's drawbacks this may create discontinuities and spurious modes in the representation of colors. The systematic process followed in the Fuzzy Min-Max Technique is given below.

Initially the concept of fuzzy set [6] was defined with the process of extracting the imprecise knowledge that can be used to express an event. A fuzzy set A is represented as in the given equation (4).

$$A = \{\mu_A(x_i)/x_i, i = 1,2, \dots \dots, n\}$$

μ_A (xi) gives the degree of belonging the element x1 in the set A. The relevance of fuzzy set theory in pattern recognition problems has adequately been addressed in the literature. A fuzzy set theory that allows dealing with uncertainty and ambiguity has found considerable applications in image segmentation. The overall integration of fuzzy logic along with neural network has emerged as a promising field of research in recent years. This has lead to the development of a new branch called Neuro-fuzzy computing.

The algorithm tries to search a hyper box for the same class at the time of training sample which can expand to include the input. If no suitable hyper box is found to accommodate the applied training sample, a new hyper box is formed and added to the neural network. After expansion, overlap test find out the overlap between expanded hyper boxes with all other class hyper boxes. When the overlap occurs between hyper boxes representing the same class, the overlap is not removed. But when the overlap occurs between hyper boxes that represents the different classes, the overlap is eliminated using contraction process. Hence this process only eliminates the overlap between those portions of the hyper boxes from separate classes that are having full membership. The membership function for the hyper box is given in the below equation (5),

$$b_{j(A_h)} = \frac{1}{2n}\sum_{i=1}^{n}\begin{bmatrix} \max\left(0,1-\max\left(0,\gamma\min\left(1,a_{hi}-w_{ji}\right)\right)\right) \\ +\max\left(0,1-\max\left(0,\gamma\min\left(1,v_{ij}-w_{hi}\right)\right)\right) \end{bmatrix}$$

where,

$$A_h = (a_{h1}, a_{h2}, \dots a_{hn}) \in I^n \text{ is } h^{th} \text{ input pattern}$$

$$V_j(v_{j1}, v_{j2}, \dots v_{jn}) \text{ is mid point for } B_j$$

$$\gamma \text{ be the sensitivity parameter.}$$

Thus the membership function for each hyper box fuzzy set must describe a degree to which the pattern fits within a hyper box.

1.4 Fuzzy C-Means Technique

The most important part of this segmentation [5] method is extension of feature space. Extension of feature space [13] is based on simple concept, that neighboring pixels have roughly same values of lightness and chroma. But in real images, noise is corrupting the image data or image usually consists of textured segments.

Basic Segmentation methods based on fuzzy c-means clustering are working as follows,

- Convert image into feature space of clustering method (usually is used RGB color space, but IHS, HLS, L*u*v* or L*a*b* color spaces are used too).
- Run fuzzy c-means method on converted image.
- Use some defuzzification rule or rules to classify each pixel to segment. Simple defuzzification rule is based on maximal membership grade of pixel to cluster.

This feature spaces in combination with clustering methods have one big drawback. In clustering process information about pixels is not involved in neighborhood, which results in poor segmentation results, because of noise or texture in images.

1.5 Optimized Fuzzy Logic Technique

This Optimized Fuzzy Logic algorithm [10] assigns pixels to each category by using fuzzy memberships. The algorithm is an iterative optimization that minimizes the cost function defined as follows,

The following equations (6), (7), (8) represent the membership function of pixel xj in the cluster, vi is the cluster center, and m is a constant.

$$J_Q = \sum_{i=1}^{c}\sum_{l1}^{q^2} h_l u_{il}^m \|x_l - v_i\|^2$$

$$u_{il} = \frac{\|x_l - v_i\|^{-2/(m-1)}}{\sum_{j=1}^{c}\|x_l - v_j\|^{-2(m-1)}}$$

$$v_i = \frac{\sum_{l=1}^{q^2} h_l u_{il}^m x_l}{\sum_{l=1}^{q^2} h_l u_{il}^m}$$

where uil represents the membership function of the pixel x1, v1 be the cluster center, and m is referred as the constant parameter. The cost function is minimized when pixel appears to be close to the centroid of their clusters which are then assigned to high membership values, and pixels with data far from the centroid areassigned to low membership values. The membership function illustrates the probability that a pixel belongs to a specific cluster. In the FCM algorithm [7], the probability is highly dependent solely on the distance between the pixel and each individual cluster center in the feature domain. Starting from an initial guess for each cluster center, the FCM transfers to a solution for vi in which it represents the local minimum or a saddle point of the cost function. Convergence can be mainly detected by contrasting the changes in the membership function or the cluster center at two successive iteration steps.

The clustering technique consists of two-pass process at each iteration. The first pass is similar to that in standard FCM [17] to evaluate the membership function in the spectral domain. Next in the second pass, the membership information of each pixel is correspondingly mapped to the spatial domain, and the spatial function is computed from that. The FCM iteration proceeds with the new membership that is incorporated with the spatial function. The iteration ends when the maximum difference between two cluster centers at two successive iterations is less than a threshold. After the convergence process, defuzzification is applied to assign each pixel to a specific cluster for which the membership is maximal.

1.6 Intuitionist Fuzzy C-Means Technique

Intuitionist fuzzy c-means function [9] [12] contains two terms of modified objective function of conventional FCM using Intuitionist fuzzy set and Intuitionistic Fuzzy Entropy (IFE). IFCM [16] greatly minimizes the objective function. The term IFE is introduced to maximize the good points in the class. The main aspire is to minimize the entropy of the histogram of an image. At each iteration, the cluster center and membership matrix are updated and the algorithm stops when the updated membership and the previous membership detects the user defined values.

1.7 Fast quantized Fuzzy C-Means Technique

In recent days, processing an image without preprocessing and regularization is pointless. In bilateral filtering procedure [8],which is an anisotropic approach based on both spatial and photometric considerations. Formally, the filtered image is obtained by estimating the following equations (9), (10), (11).

$$x_i' = \frac{\sum_{j\in N_i} w(i,j)x_j}{\sum_{j\in N_j} w(i,j)}$$

$$w_s(i,j) = exp\left(-\frac{d_s^2(i,j)}{2\sigma_s^2}\right)$$

$$w_c(i,j) = \exp\left(-\frac{d_c^2(x_i, x_j)}{2\sigma_c^2}\right)$$

wherw w(i,j) is said to be as the weights applied to every pixel xj, in the image, ws (i,j) is referred as the spatial weights and wc (i,j) is said to be as the color weights of the processed image.

Hence, the above processed image segmentation objective functions are computationally intractable with the color images processing. Although the introduction of a bilateral filtering process before clustering improves the effectiveness of segmentation, it still lack enough robustness and neighborhood importance should be taken into account in the clustering algorithm. To this aim, instead of considering the entire image, to normalize the partition matrix, based on the neighborhood of eachpixel. The advantage of this proposition [8] is to get rid of the selection of the crucial balance parameter α in the methods. This parameter guarantees a balance between robustness to noise and effectiveness of preserving details. Hence it is hard to set and have considerable impact on the performances. However, due to quantization, the elements of the partition matrix do not have spatial relationships. However, in order to keep the algorithm fast, regularization method cannot be done in each updating step, so that smoothing process can be proceeded when the local optimum has been reached.

1.8 Fuzzy Rule-based Technique

This Fuzzy Rule based algorithm [8] is specifically developed for the integration of expert's knowledge. At the time of performing image analysis, the representation of the properties and attributes of image regions and spatial relations among other regions are highly specified. Fuzzy rule- based systems are ideally suited for the above mentioned purpose. Usually Rule is based on the understanding purpose in the terms of brightness, high granularity and also the medium should be intrinsically vague. Fuzzy set theory provides a natural mechanism to represent such vagueness effectively.

The Fuzzy set theory mainly presents Flexibility and power for knowledge representation in which it makes the fuzzy rule-based systems [12] very attractive, when compared with conventional rule-based systems. Furthermore, rule based approaches must address the problem of conflict resolution when the preconditions for several (partially) conflicting rules are simultaneously satisfied. There are many sophisticated control strategies to solve this problem in traditional systems. In contrast to the above fuzzy rule-based classifier systems, some problems are harassed by manipulating certainty factors and also firing strengths to combine the rules.

However, it is highly stated that sharpness of the image is affected at the boundary regions if the features of the gray scale image are not so highly determined. To alleviate this situation, fuzzy set concepts [15] into the segmentation process is embedded. In the applications of computer vision, membership functions are not always subjective evaluations of vague concepts, but rather than a means to model the uncertainty contained in the input information such as images or features extracted from segmented images. Therefore, to get appropriate methods for membership function generations, it is highly mandatory that they formalize expert's knowledge and its uncertainty feature. Furthermore, Fuzzy Morphological Structural Elements (FRISE) are established to be used in image segmentation based on pixel classification, with the aim of reducing uncertainty problems, pixel misclassification, and also in providing accurate boundaries among different regions.

2. Comparison of Fuzzy Logic Methods

This section exemplifies the comparison of the previously described different Fuzzy logic methods based on their highlights. The main thought of this work is not to examine which is the best Fuzzy logic technique but to differentiate the methods based on its behavioral performance and its Salient features in which it helps the users to select the appropriate Fuzzy logics for efficient segmentation of the images. In Table 1, we summarized the previously denoted Fuzzy logic methods in relate to its highlighting features which are as follows.

Conclusion

This paper presents a clear overview of several segmentation techniques using the concept of Fuzzy logic segmentation techniques like Fast Multilevel fuzzy Edge detection technique, Fuzzy C Means algorithm, Intuitionistic Fuzzy C Means algorithm, Modified Fuzzy C Means algorithm, Fuzzy rule based algorithm, Fuzzy Min Max clustering algorithm, Optimized Fuzzy logic technique, and Fast Quantized Fuzzy C Means technique have been compared and carefully examined in the comparative analysis, extends a great support during the segmentation process. It is clearly proven that segmentation using Fuzzy logic results in acceleration

Segmentation Approaches	Fuzzy Techniques used	Salient Features
Enhanced Image Segmentation Approach	Fast Multilevel Fuzzy Edge Detection algorithm	-Effectively segments the Magnetic Resonance Imaging (MRI) brain images with spatial information. -Reduced time consumption.
Color Image Segmentation Approach	Fuzzy C Means (FCM) algorithm	-Good segmentation results in case of images with large homogeneous segments. -Efficient Noise filtration.
Noisy Digital Image Segmentation Approach	Intuitionistic Fuzzy C Means (IFCM)	-In absence of noise, FCM generates finest results and in presence of noise IFCM comes up with the best segmentation results. -Highly minimizes the entropy of the histogram of images.
Color Image Segmentation Approach	Modified Fuzzy C Means (MFCM) Algorithm	-The color feature Hue is proved to be more efficient than RGB color in terms of clarity. -More effective in detecting homogeneous regions.
Human Automated Image Segmentation Approach	Fuzzy rule based algorithm	-Produces very high degree of variability, accuracy, and brightness in vagueness treatment. -Higher degree of variability. -Expresses accurate brightness and detection.
Adaptive color Image Segmentation	Fuzzy min-max clustering algorithm	-Efficiently segments the unknown color images and also highly robust to noisy images. -Effective in segmenting unknown color images without prior information.
MRI Brain Image Segmentation Approach	Optimized Fuzzy logic technique	-It segments the MRI brain tumor images accurately with spatial information. -Less sensitive to noisy images. -Avoids spurious blobs in homogeneous regions.
Color Image Segmentation Approach	Fast Quantized Fuzzy C Means (QFCM)	-The most highflying feature is the Faster convergence in each iteration. -Highly robust in spatial regularization. -Highly efficient in both accuracy and the computational time. -Performs goodness-of-fit in high extend.

Table 1. Comparative Analysis of Different Fuzzy Logic Techniques

convergence, clustering with robustness and reduced computational time. Fuzzy segmentation has good and efficient capability of handling noisy images possessing higher degree of variability. Fuzzy segmentation techniques help in acquiring improved result by assimilating spatial information into the member function. Imprecise data can be dealt in a proficient manner with the help of Fuzzy Logic. Fuzzy segmentation helps in extracting the complete edge map from the color image without much difficulty. These comparative studies assist the future researchers with great impulses.

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