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Image Segmentation Using Mamdani Rule Base

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Abstract - One of the biggest problems in computer vision systems, analyzing images having high uncertainty/vagueness degree, is the treatment of such uncertainty. This problem is even clearest in the segmentation process. Fuzzy set theory and fuzzy logic are ideally suited for dealing with such uncertainty. On the other hand image segmentation and subsequent extraction from a noise-affected background, with the help of various soft computing methods, are relatively new and quite popular due to various reasons. These methods include various Artificial Neural Network (ANN) models (primarily supervised in nature),providing an extraction solution working in unsupervised mode happens to be even more interesting problem. Literature suggests that effort in this respect appears to be quite rudimentary. In the present article, we propose a fuzzy rule guided novel technique that is functional devoid of any external intervention during execution. Experimental results suggest that this approach is an efficient one in comparison to different other techniques extensively addressed in literature. In order to justify the supremacy of performance of our proposed technique in respect of its competitors, we take recourse to effective metrics like Peak Signal to Noise Ratio (PSNR).

Index Terms - Fuzzy Rule Base, Image Extraction, Fuzzy Inference System (FIS), Membership Functions, Threshold methods, Soft Computing, Fuzzy Image Processing, Feature based modeling.

I. INTRODUCTION

In traditional computing methodology, the prime considerations are precision, certainty, and rigor. By contrast, the principal guidelines of soft computing revolve around the following: tolerance for imprecision, Uncertainty, partial truth and approximation. It will help to achieve tractability, robustness and low solution cost. Although fuzzy methods are not a solution to all problems, they are useful in situations in which the concepts (features, criteria, or rules) are vague. This is often the situation in computer vision. There is uncertainty in many aspects of image processing and computer vision [8]. Visual patterns are inherently ambiguous, image features are corrupted and distorted by the acquisition process, and object definitions are not always crisp. Moreover, knowledge about the objects in the scene can be described only in vague terms, and the outputs of low level processes provide vague, conflicting, or erroneous inputs to higher level algorithms.

In Fuzzy Image processing, fuzzy set theory [14] is applied to the task of image processing. Fuzzy Image Processing depends upon membership values of Fuzzy Logic [15]. All membership functions are in the form of a *triangular* function [17]. Fuzzy set theory and fuzzy logic are ideally suited for dealing with such uncertainty. The fuzzy approaches for image segmentation are divided into four approaches as outlined in [18]. The approaches are 'Segmentation via thresholding', 'Segmentation via clustering', 'Supervised Segmentation' and 'Rule-based Segmentation'.Medical image segmentation techniques typically require some form ofexpert human supervision to provide accurate and consistent identification of anatomic structures of interest[11].

In many medical image segmentation applications identifying and extracting the region of interest (ROI) accurately is an important step[19] .Naturally, the extraction of objects prevalent in image content from a noise affected background. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture [12]. Despite the fact that grey-level distributions, small objects, and object overlapping are some of the most complicated issues that create several challenging difficulties for multilevel threshold selection in images, a thresholding technique must be able to segment a digitized image into different objects with similar properties[5][13]. In this correspondence, we will present an extension of Otsu's approach.

Generally, two steps have to be considered in order to address any segmentation problem:

Step 1: To formalize the segmentation problem, a mathematical notion of homogeneity or similarity between image regions need to be considered.

Step 2: An efficient algorithm for partitioning or clustering has to be derived particularly to carry the earlier step out in a computationally efficient manner.

The problems of image segmentation become more uncertain and severe when it comes to dealing with noisy Images. A formal definition of segmentation of an image can be defined as, Segmentation of image I is a partition P of I into a set of M regions {Rm, m=1, 2…M} such that,

$$1.\bigcup_{m=1}^{M} R_m = I with R_m = \Phi \quad (1)$$

$$m \neq n, 1 \leq m, n \leq M$$

$$2.H\left(R_m\right) = true \forall m, 1 \leq m, n \leq m \quad (2)$$

$$3.H\left(R_m \cap R_n\right) = false \forall R_m and R_n$$

$$adjedent, 1 \leq m, n \leq M \quad (3)$$

Here H is the predicate of homogeneity. A region is homogeneous if all its pixels satisfy the homogeneity predicate defined over one or more pixel attributes such as intensity, texture or color. On the other hand, a region is connected if a connected path exists between any two pixels within the region. Here H is the predicate of homogeneity. A region is homogeneous if all its pixels satisfy the homogeneity predicate defined over one or more pixel attributes such as intensity, texture or color. On the other hand, a region is connected if a connected path exists between any two pixels within the region.

1. Region or boundary-based
2. Graph-based
3. Histogram-based
4. Pixel based
5. Area based
6. Physics based

In this work we consider the use of fuzzy set theoretic decision-making models and algorithms within the computer vision framework, particularly we consider problems in segmentation [9].

II. SURVEY

Fu et al. discussed segmentation from the viewpoint of cytology image processing [1]. The paper categorized various existing segmentation techniques into three classes:
i. Characteristic feature thresholding or clustering
ii. Edge detection and
iii. Region extraction.

The segmentation techniques were summarized and comments were provided on the pros and cons of each approach. The threshold selection schemes based on gray level histogram and local properties as well as based on structural, textural and syntactic techniques were described.

Haralick et al. classified image segmentation techniques into six major groups [2]:
i. Measurement space guided spatial clustering
ii. Single linkage region growing schemes
iii. Hybrid linkage region growing schemes
iv. Centroid linkage region growing schemes
v. Spatial clustering schemes and
vi. Split & merge schemes.

These techniques are compared on the problem of region merge error, blocky region boundary and memory usage. The hybrid linkage region growing schemes appear to be the best compromise between having smooth boundaries and few unwanted region merges. One of the drawbacks of feature space clustering is that the cluster analysis does not utilize any spatial information. The article also presented some spatial clustering approaches, which combine clustering in feature space with region growing or spatial linkage techniques.

Sahoo et al. surveyed segmentation algorithms based on thresholding and attempted to evaluate the performance of some thresholding techniques using uniformity and shape measures [3]. It categorized global thresholding techniques into two classes:
i. point-dependent techniques (gray level histogram based)
ii. region-dependent techniques (modified histogram or co-occurrence based).

Spirkovska et al. regarded image segmentation in a machine vision system as the bridge between a low-level vision subsystem including image processing operations (such as noise elimination, edge extraction etc.) to enhance the image quality on one hand and a high-level vision subsystem including object recognition and scene interpretation on the other [4].
i. pixel based segmentation
ii.area based segmentation
iii..edge based segmentation
iv.physics based segmentation.

Most gray level image segmentation techniques can be extended to color images, such as histogram thresholding, clustering, region growing, edge detection, fuzzy approaches and neural networks. Gray level segmentation methods can be directly applied to each component of a color space.

Power et. al. compared different color spaces (RGB, normalized RGB, HSI- hybrid color space) and supervised learning algorithms for segmenting fruit images [6]. Supervised algorithms include Maximum Likelihood, Decision Tree, K-Nearest Neighbor, Neural Networks, etc.

Hance et al. explored six unsupervised image segmentation approaches [7]:
i.Adaptive thresholding
ii. Fuzzy C-means (FCM)
iii.SCT/center split
iv.PCT (Principal Components
v.Transform) median cut
vi. Split and merge
Vii.Multi-resolution segmentation

Some algorithms resort to combination of unsupervised and supervised methods to segment color images.

III. FUZZY RULE-BASED ALGORITHMS FOR INTEGRATING EXPERT'S KNOWLEDGE

When performing image understanding, we need to represent properties and attributes of image regions and spatial relations among regions. Fuzzy rule- based systems are ideally suited for this purpose. For example, a usual rule in a rule-based scene understanding system could be:

IF brightness of a pixel is high AND the granularity within a 3x3 window, centered in the pixel, is medium, THEN the pixel belongs to….

Terms as brightness, high, granularity and medium are intrinsically vague. Fuzzy set theory provides a natural mechanism to represent such vagueness effectively. Flexibility and power provided by fuzzy set theory for knowledge representation makes fuzzy rule-based systems very attractive, when compared with traditional 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 sophisticated control strategies to solve this problem in traditional systems. In contrast, with fuzzy rule-based classifier systems, problems such as these are attacked by manipulating certainty factors and/or firing strengths to combine the rules. Going back to the segmentation problem, it is known that, in a segmented image, ideally each region should be homogeneous with respect to some characteristics or features such as gray level or texture, and adjacent regions should have

Significantly different characteristics or features. However, if the features used to determine homogeneity don't have sharp transitions at region boundaries, won't be easy to determine if a pixel should belong to a region or not, as when features are computed using, say, a local 3x3 or 5x5 - window. To alleviate this situation we can insert fuzzy set concepts into the segmentation process. In 1970, Prewitt already suggested that the results of image segmentation should be fuzzy subsets rather than crisp subsets of the image plane. In this sense, within a fuzzy segmentation, each pixel is assigned a membership value in each of the regions. If the memberships are taken into account while computing properties of regions, we often obtain more accurate estimates of region properties.

So, it can be deduced that determining appropriate membership functions is one of the fundamental issues to apply fizzy set theory within image segmentation and understanding. In computer vision applications, membership Fictions are not always subjective evaluations of vague concepts, but rather a means to model the uncertainty contained in the input information such as images and/or features extracted from images. Therefore, to get appropriate methods for membership function generations it is important that they formalize expert's knowledge and its uncertainty [10].

IV. MAMDANI RULE BASE

Thresholding [16] has been the most common way to segment a picture. To obtain the robustness of the thresholding method, we explored the combination of more than one thresholding algorithm based on the conjecture that they could be complementary to each other. The Combination of thresholding algorithms can be done at the feature level or at the decision level. At the feature level, we use, for example, some averaging operation on the maximum values obtained from individual algorithms; on

The decision level, we have fusion of the foreground-background decisions, for example, by taking the majority decision. Thus it will help us on creating membership envelops in the proposed system.

The algorithm for the Segmentation work is as follows:

Step 1. Read a Gray Scale image as input
Step 2. Identify the Region of Interests of the image by Constant thresholding values
Step 3. Extract the image information in terms of pixel attributes and threshold values for future use.
Step 4. Construct the different membership envelops of the input image.
Step 5. Generate fuzzy rules based on the numerical data obtained from the input image corrupted by noise. The fuzzy rule generation consists of five steps:
a. Discern Input and Output spaces into fuzzy regions

b. Generate fuzzy rules from the given data
c. Map the threshold values obtained from different methods in the corresponding fuzzy region
d. Create a combined fuzzy rule base Determine a mapping on the basis of this combined fuzzy rule base.
Step 6. Approximate the value obtained in **Step 5**
Step 7. Display the image constructed thus.

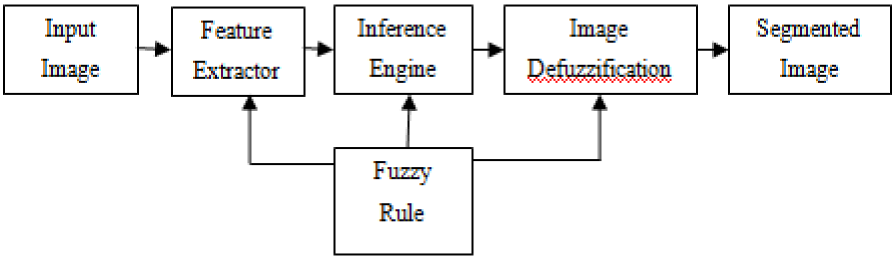

Fig.1: Schematic diagram of Fuzzy Image Processing

Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of Membership values, and, if necessary, image defuzzification as shown in Fig.1.

V. RESULTS AND ANALYSIS

The goal of this paper is to describe a linear system using a Mamdani rule base. Specifically, we are modeling the relationship among the images, its extracted counterpart and the fuzzy rule base system. The comparisons are listed in the TABLE I. We evaluated all possible to measure of how well the rule described the actual system behavior over the domain where its antecedent was true. In this paper, we take proper care about how well a Mamdani rule base can be put to model the system, using rules that have high correctness. The corrupted image, subsequent result obtained by well known methods and proposed.
fuzzy rule base method are depicted in Figure below.

Table 1 PSNR and MSE value of different medical image using Mamdani Rule

	Original Image PSNR	Filtered Image PSNR	Segmented Image PSNR	MSE Value of Segmented Image	Time Taken by FCM in Sec
Image 1	26.55dB	28.81dB	30.15dB	43.66	218.79
Image 2	27.80dB	29.40dB	30.52dB	42.77	175.13
Image 3	23.97dB	28.27dB	30.02dB	43.98	171.18
Image 4	25.41dB	28.54dB	30.15dB	42.22	187.94
Image 5	23.61dB	28.18dB	30.01dB	42.62	174.07
Image 6	23.27dB	27.98dB	29.91dB	44.32	195.10
Image 7	24.51dB	28.27dB	29.97dB	44.60	202.09
Image 8	26.15dB	28.79dB	30.20dB	44.44	188.28
Image 9	27.86dB	29.44dB	30.51dB	42.73	170.96
Image 10	25.74dB	28.64dB	30.14dB	44.68	189.03

Table 2 Compararision between psnr values of mamdani rules

S/NO	Theoritical psnr of mamdani	Simulated psnr of mamdani
Image 1	29.6435	30.15
Image2	29.3126	30.52
Image3	28.9962	30.02
Image 4	28.7134	30.15

VI. CONCLUSION

In this paper we implemented Mamdani Rule Base for medical images with Gaussian Noise.
The PSNR value or Original image is very less then Segmented Image which is shown in table 1.
It provides us a general method to combine measured numerical information. There is freedom in choosing the membership domain in the said design. In this paper, we take care about how well a mamdani rule base can be put to model the system rule that have high correctness. The main power of fuzzy image processing depend on the use of the middle step (modifying the membership values). On the other hand from table 2 we conclude that the simulated psnr of mamdani is better than the theoretical value of mamdani.

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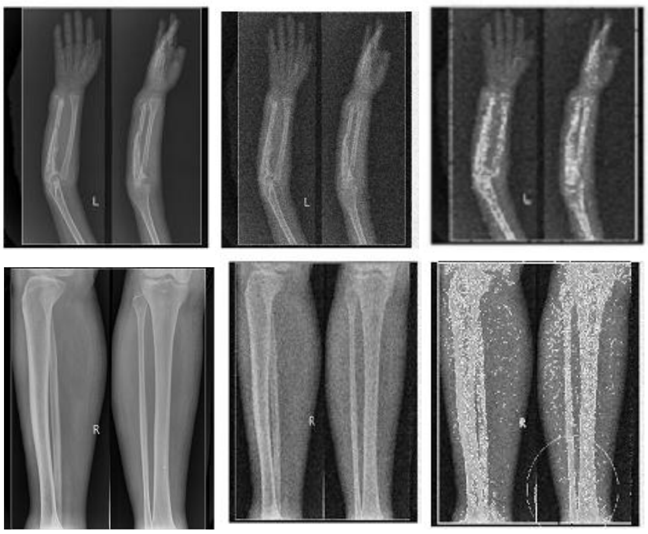
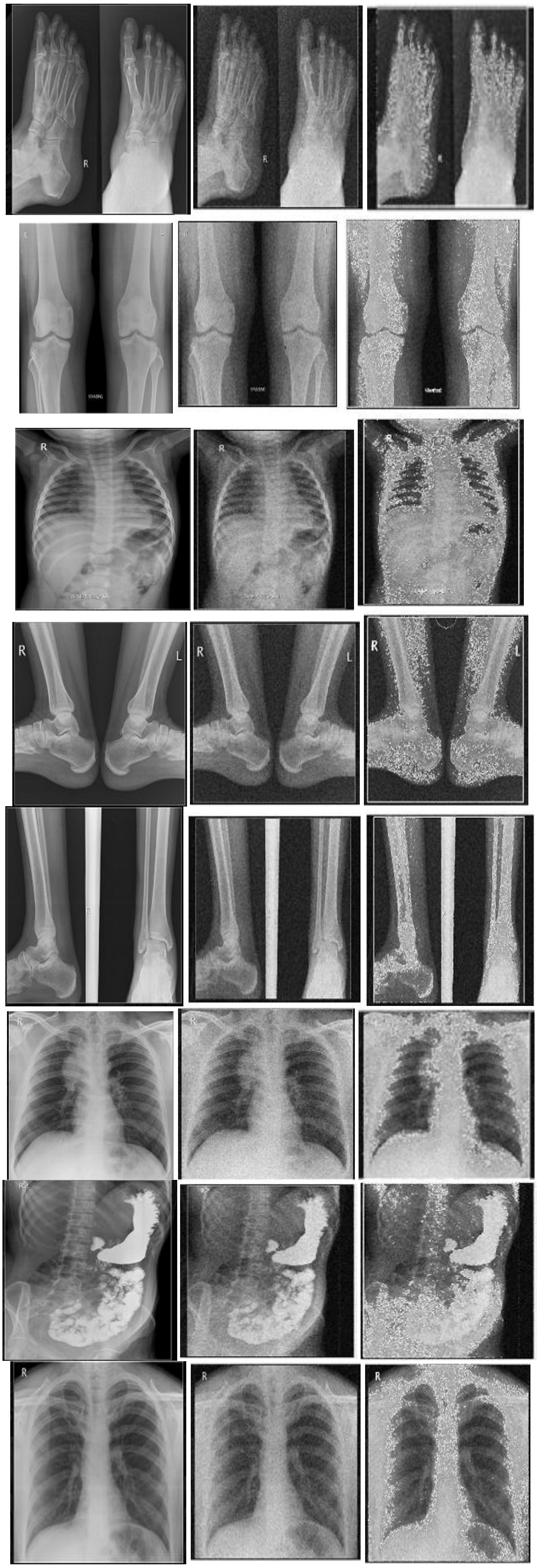
RESULTANT IMAGES

Original Noisy Segmented





Segmented Image using Mamdani rule