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A Survey on Pattern Recognition using Fuzzy Clustering Approaches

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***ABSTRACT**: The objective of the present paper is to describe a pattern recognition approach for image segmentation using fuzzy clustering. Soft computing techniques have found wide applications. One of the most important applications is edge detection for image segmentation. Clustering analysis is one of the major techniques in pattern recognition. These fuzzy clustering algorithms have been widely studied and applied in a variety of substantive areas. In this paper, we give a survey of methods based on fuzzy clustering and segmentation techniques. The main aim is to study the theory of edge detection for image segmentation using fuzzy approach based on the fuzzy logic clustering.*

***Keywords** – Soft computing, Pattern recognition, Clustering, image segmentation, Fuzzy threshold, Fuzzy clustering, Fuzzy edge detection.*

I. INTRODUCTION

Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and the results in much more accurate representations of the way systems behave in the real world.

Fuzzy sets were introduced in *1965* by *Zadeh* as a new way of representing vagueness in everyday life. This theory provides an approximate and yet effective means for describing the characteristics of a system that is too complex or ill-defined to admit precise mathematical analysis. Fuzzy approach is based on the premise that key elements in human thinking are not just numbers but can be approximated to tables off fuzzy sets, or, in other words, classes of objects in which the transition from membership to non membership is gradual rather than abrupt. Much of the logic behind human reasoning is not the traditional two-valued or even multi-valued logic, but logic with fuzzy truths, fuzzy connectives and fuzzy rules of inference. This logic plays a basic role in various aspects of the human thought process. The significance of fuzzy set theory in the realm of pattern recognition [1-5, 10, 19, and 23] is adequately justified in

∑ Representing linguistically phrased input features for processing.
∑ Providing an estimate of missing information in terms of membership values.
∑ Representing multiclass membership of ambiguous patterns and in generating rules and inferences in linguistic form.
∑ Extracting ill-defined images regions, primitives and properties and describing relations among them as fuzzy subsets.
∑

II. FUZZY APPROACHES

Three different soft computing approaches for image segmentation are most frequently used. These are (1) Fuzzy based approach [22] (2) Genetic Algorithm based approach [9] and (3) Neural Networks based approach [6]. This paper discuss details about fuzzy based approach

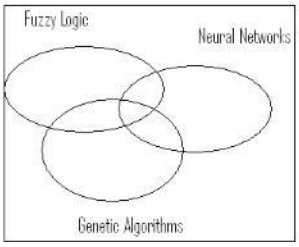

Fig 1: Soft Computing Approach

There are different possibilities for development of fuzzy logic based edge detections [22]. One method is defining a membership function indicating the degree of edginess in each neighborhood. This approach can only be regarded as a true fuzzy approach [35] if fuzzy concepts are additionally used to modify the membership values [14]. The membership function is determined heuristically. It is fast but the performance is limited.

$\mu Edge\ (g(x,y))=1-(1/1+(\sum N \| g(x,y)-g(i,j) \|)/\Delta)$

Using appropriate fuzzy if-then rules, one can develop general or specific edge detection in pre-defined neighborhoods [27]. Fig 2 shows the fuzzy rules for detection and neighborhood of a central pixel of the image.

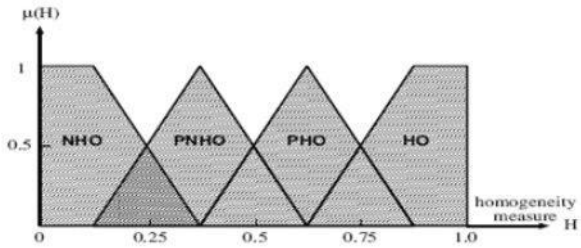

Fig2: The fuzzy sets used for homogeneity inference.

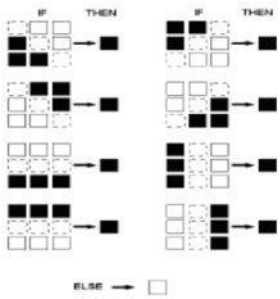

Fig3: Neighborhood of a central pixel
Fig 3 shows the membership function for homogeneity interference.

The image segmentation task consists of dividing the input image in a number of different objects called *image segments* or *clusters*, such that all the pixels from a segment have a common property called *similarity criterion*. Fuzzy systems can be broadly categorized into two families [12]. The first includes linguistic models based on collections of IF-THEN rules, whose antecedents and consequents utilize fuzzy values. It uses fuzzy reasoning and the system behaviors can be described in natural terms.

2.1 Methods based on fuzzy set theory

Zadeh introduced the concept of fuzzy sets in which imprecise knowledge[24-26] can be used to define an event. A fuzzy set A represented as

$A = \{\mu A(xi)/xi, i=1,2,\ldots\ldots,n\}$

Where $\mu A(xi)$ gives the degree of belonging of the element xi to the set A.

The relevance of fuzzy sets theory in pattern recognition problems has adequately been addressed that the concept of fuzzy sets can be used at the feature level in representing an input pattern as an array of membership values denoting the degree of possession of certain properties and in representing linguistically phrased input features; at the classification level in representing multi-class membership of an ambiguous pattern, and in providing an estimate of missing information in terms of membership values. In other words, fuzzy set theory may be incorporated in handling uncertainties in various stages of pattern recognition system.

While the application of fuzzy sets in cluster analysis and classifier design was in the process of development, an important effort in fuzzy image processing and pattern recognition was evolving more or less in parallel was based on the realization that many of the basic concepts in image analysis, e.g., the concept of an edge or a corner or a boundary or a relation between regions, do not lend themselves well to precise definition. A gray tone image tone possesses ambiguity within pixels due to the possible multi-valued levels of brightness in the image. This indeterminacy is due to inherent vagueness rather than randomness.

Incertitude in an image pattern may be explained in terms of 1.Grayness ambiguity means "indefiniteness" in deciding whether a pixel is white or black. 2. Spatial ambiguity means "indefiniteness" in the shape and geometry of a region within the image. 3. Both Grayness ambiguity and spatial ambiguity

We shall describe here a few method of fuzzy segmentation (based on gray level thresholding and pixel classification) and edge detection using global and/or local information of an image space.

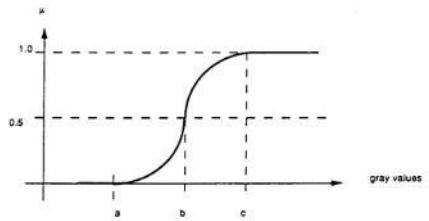

Fig4: S-type membership function

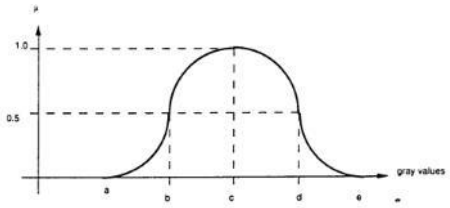

Fig5:∏-type membership function

In fuzzy clustering, an objective may belong to different clusters at the same at least to some extent, and the degree to which it belongs to a particular cluster is expressed in terms of fuzzy membership[5]. The membership functions of the different clusters (defined on the set of observed data points) are usually assumed to form a partition of unity.

III. PATTERN RECOGNITION AND IMAGE PROCESSING

Research on the application of fuzzy set theory to *supervised* pattern recognition was started in 1996 in the seminal node of Bellman et al. [1] where the two basic operations-abstraction and generalization – were proposed. Abstraction in fuzzy set theory means estimation of a membership function of a fuzzy class from the training samples. Having obtained the estimate, generalization is performed when this estimate is used to compute the values of the membership for unknown objects not contained in the training set. Consideration of linguistic features and fuzzy relations in representing a class has also been suggested by Zadeh. Subsequently, multi valued recognition system and fuzzy k-NN rule, among others, have been developed in the supervised framework.

3.1 Fuzzy logic in pattern image processing

Image pattern recognition represents an important computer vision domain, consisting of classification of the patterns of a given image, based on various similarity criterions. In this paper we consider the image regions as patterns.

Fuzzy set theory has been extensively used in clustering problems where the task is to provide class labels to input data (Partitioning of feature space) under *unsupervised* mode based on certain criterion. A seminal contribution to cluster analysis was Ruspini's concept [36] of a fuzzy partition. This was followed by the design of fuzzy *c*-means, fuzzy ISODATA, fuzzy DYNOC[28] and other possibility clustering algorithms. Although the task of feature selection plays an important role in designing a pattern recognition system, the research in this area using fuzzy set theory has not been significant, as compared to classification or clustering. Applications of fuzzy pattern recognition and image processing have been reported in various domains, like speech recognition, remotely sensed images, medical imagery, and atmospheric sciences.

A gray tone image possesses some ambiguity within the pixels due to inherent vagueness rather than randomness. The incertitude in an image pattern may be explained in terms of grayness ambiguity or spatial (geometrical) ambiguity refers to indefiniteness in shape and geometry (e.g., in defining centroid, sharp edge, perfect focusing). These aspects are handled under the area fuzzy image processing, that grew up almost in parallel with fuzzy pattern recognition. It is based on the very concept that the basic definitions of edge, boundary, region, and the relations between them, do not lend themselves to precise formulation. In fact, in 1970, PREWITT [17] first mentioned that gray image segments should be fuzzy subsets of an image.

When the input pattern is a gray tone image some processing tasks such as enhancement, filtering, noise reduction, segmentation, contour extraction and skeleton extraction are performed in the measurement space, in order to extract salient features from the image pattern. This is what is basically known as *image processing*. The ultimate aim is to make its understanding recognition and interpretation from the processed information available from the image pattern. Such a complete image recognition/interpretation system is called a *vision system* which may be viewed as consisting of three levels namely, low level, mid level and high level corresponding to M,F, and D with an extent of overlapping among them.

3.2 The Hierarchy of current segmentation evaluation methods

Many image segmentation methods have been proposed over the last several decades. As new segmentation methods have been proposed, a variety of evaluation methods have been used to compare new segmentation method to prior methods. These methods are fundamentally very different, and can be partitioned based on five distinct methodologies, as shown in below figure 6.

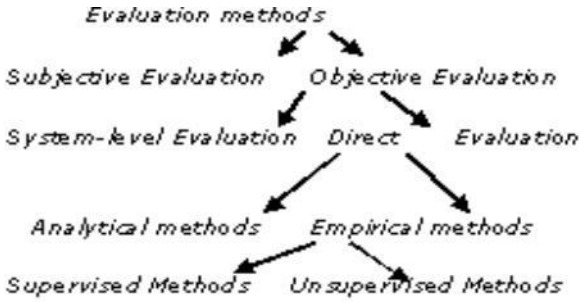

Fig 6: The hierarchy of segmentation evaluation methods.

Depending on whether a human evaluator examines the segmented image visually or not, these evaluation methods can be divided into two major categories: Subjective Evaluation and Objective Evaluation. In objective evaluation category, some methods examine the impact of a segmentation method on the larger system/application employing this method, while others study the segmentation method independently. Thus, we divide objective evaluation methods into System-level Evaluation and Direct Evaluation. The direct objective evaluation can be further divided into Analytical Methods and Empirical Methods, based on whether the methods itself, or the result that the method generated are being examined. Finally, the Methods and Supervised Methods, based on whether the method requires a ground-truth reference image or not.

Notice that these categories are not mutual exclusive. Evaluation methods might use techniques from multiple categories. For example [33, 34] use both supervised evaluation and system-level evaluation.

IV. PATTERN RECOGNITION BASED ON FUZZY CLUSTERING

Clustering can be considered the most important unsupervised learning problem; so, as every other problem of this kind, it deals with finding a structure in a collection of unlabeled data.
Clustering is defined as "the process of organizing objects into groups whose members are similar in some way". A Cluster is therefore a collection of objects which are "similar" between them and are "dissimilar" to the objects belonging to other clusters.

Image segmentation is one of the best known problems in computer vision. Graph based methods were earlier considered to be too insufficient in practice. Recent advances in technology and algorithm have negated this assumption. Histogram based methods are very effective while compared to other image segmentation methods because they typically require one phase through the pixels in the image and the peaks and valleys in the histogram are used as the measure. This process is repeated with smaller and smaller clusters until no more clusters are formed. This approach can be quickly adapted to multiple frames which is done in multiple fashion.

Segmentation can also be done based on spatial coherence[31]. This includes two steps: Dividing or Merging existing regions from the image and growing regions from seed points.

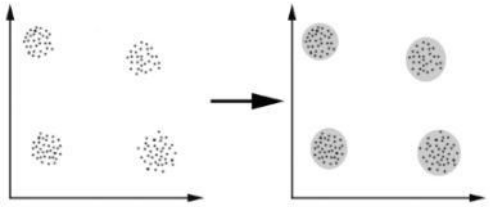

Fig 7: Sample example of Clustering 4.*1 Fuzzy clustering*

Clustering is an unsupervised learning task, where one needs to identify a finite set of categories known as clusters to classify pixels. Clustering use no training stages rather train themselves using available data. Clustering is mainly used when classes are known in advance. A similarity criteria is defined between pixels and then similar pixels are grouped together to form clusters. Segmentation process is also known as cluster analysis and is a widely studied area in statistics. The goal of clustering is to group data into clustering such that similarities among data members within the same cluster are maximal while similarities among data members from different clusters are minimal. In this context clustering algorithms are used from image segmentation in literature. Clustering algorithms are generally classified as hierarchical and partitioning clustering.
Some of the clustering algorithms are explained below.

4.2 Fuzzy C-means Algorithm

The fuzzy c-means (FCM) clustering algorithm has also been used in image segmentation. The fuzzy c-means algorithm uses an iterative optimization of an objective function based on a weighted similarity measures between the pixels in the image and each of the c-cluster centers. A local extreme of this objective function indicates an optimal clustering of the input data. The objective function that is minimized is given by

$$W_m(U, V) = \sum_{k=1}^{n} \sum_{i=1}^{C} (\mu_{ik})^m (d_{ik})^2$$

Where μik is the fuzzy membership value of the K^{th} pixel in the i^{th} cluster, d ik is any inner product induced norm metric, m controls the nature of clustering with hard clustering are m=1 and increasingly fuzzier clustering at higher values of m,V is the set of c-cluster centers and U is the fuzzy c-partition of the image. Trivedi and Bezdek proposed a fuzzy set theoretic images segmentation algorithm for aerial images. The method is based upon region growing principles using a pyramid data structure. The algorithm is hierarchical in nature.

4.3 Log-Based Clustering

Images can be clustered based on the retrieval system logs maintained by an information retrieval process[12]. This session keys are created and accessed for retrieval. Through this the session clusters are created. Each session cluster generates log-based document and similarity of image couple is retrieved. Log-based vector is created for each session vector based on the log –based documents[30]. Now, the session cluster is replaced with this vector. The unaccessed documents creates its own vectors based on the log- based clustering.

A hybrid matrix is generated with at least one individual document vector and one log-based clustered vector. At lease the hybrid matrix is closeted. This technique is difficult to perform in the case of multi dimensional images means that the multi dimensional images not supported in log based clustering. To overcome this hierarchical clustering is adopted.

4.4 Hierarchical Clustering

One of the well-known technologies in information retrieval is hierarchical clustering [1]. It is the process of integrating different images and building them as a cluster in the form of a tree and then developing step by step in order to form a small cluster.

The steps involved in this process are as follows: the images from various databases are divided into X-sorts. The classification will be calculated by modifying the cluster centers, sorts of the images and stored in the form of matrix m*m continuously which also includes dissimilarity values[37]. At first it calculates the similarities between the queried image and the retrieved image in the image database. Secondly, it identifies the similarities between two closest images and integrates them to form a cluster. Finally all the similarities are grouped to form a single cluster.

4.5 Retrieval Dictionary Based Clustering

A rough classification retrieval system is formed. This formed by calculating the distance between two learned patterns and these learned patterns are classified into different clusters followed by a retrieval stage. The main drawback addressed in this system is the determination of the distance.

To overcome this problem a retrieval system is developed by retrieval dictionary based clustering [13, 33]. This method has a retrieval dictionary generation unit that classifies learned patterns into plural clusters and creates a retrieval dictionary using the clusters. Here, the image is retrieved based on the distance between two spheres with different radius. Each radius is a similarity measure between central cluster and an input image. An image which is similar to the query image will be retrieved using retrieval dictionary.

4.6 Fuzzy K-Means clustering method

The k-means algorithms are an iterative technique that is used to partition an image into k-cluster. In statistics and machine learning, k-means clustering is a method of cluster analysis which can to portions n observation into k cluster with the nearest mean[20-21]. The basic algorithms is given below

- Pick k cluster center's either randomly or based on some heuristic.
- Assign each pixel in the image to the cluster that minimum the distance between the pixels cluster centre.
- Re-compute the cluster centre's by averaging all of the pixels in the cluster.
- Repeat last two steps until convergences are attained. The most common algorithm uses an iterative refinement technique; due to this ambiguity it is often called the k-means algorithms.

4.7 Fuzzy edge detection

Pal and King[15] used a non-symmetrical membership function G to get the fuzzy property plane from the intensity plane. The G is defined as

$$G(f(x,y)) = (1 + |f^* - f(x,y)|/F_d)^{-F_e}$$

Where f* is a reference level. Fc and Fd are the exponential and denominational fuzzifiers, respectively. If f*=fmax, the maximum gray level, then G approximates the standard S function of Zadeh and when f* is equal to some other level, 0<f*<fmax, it approximates the standard ∏ function of Zadeh shown in fig 4(b).

The G function under the above cases are denoted by Gs and Gx functions in conjunction with an intensification operator INT to intensify the contrast in the image. Finally, an inverse transformation is applied to get the enhanced spatial domain image[38]. Edges of this enhanced image can then be easily found with any spatial domain technique. Edge detection operators based on max and min operations are available in references [15,16] . In references [16] the entropy of a fuzzy set defined by an adaptive membership function, over a neighborhood of a pixel (x,y) is used as a measure of edginess at (x,y). The use of an adaptive membership function makes the detection algorithm robust. The framework of the algorithm is quite general and works with any measure of ambiguity (fuzziness).

V. FURTHER DISCUSSIONS

5.1 Different approaches of soft computing

We concentrated on the fuzzy approaches for the understanding of pattern image segmentation based on the Fuzzy logic, Genetic Algorithms and Neural Networks concepts[7][22]. This can be implemented further by the combination of all the above three approaches referred as hybrid system[12].

5.2 Evaluation methods of segmentation method

We examine the breadth of existing unsupervised methods that objectively evaluate image segmentation. It presents the full range of segmentation evaluation methodologies[28], and discuss the advantages and shortcoming of each type of evaluation, including subjective, supervised, system-level, and unsupervised evaluation among them.

5.3 Pattern recognition of fuzzy clustering

In this study, five different clustering algorithms were handled and performance of them for image segmentation was compared with each other. It has been aimed to find optimal
values for cluster centers with this silkworm intelligence-based algorithm. The number of cluster centers of test images used in the study is provided by literature. Although the algorithm is unsupervised clustering techniques [13], their performance are impressed with random assigned initial values of cluster centers and distribution on data so much.

VI. DEDICATED RESEARCH CENTERS

The success of fuzzy set has been mainly vindicated by the commercial popularity in Japan of Fuzzy logic and control systems, where both pattern recognition and image processing provide direct interaction and support. Some international centers of repute, devoted to research in soft computing, are Fuzzy Logic System Institute(FLSI), the RIKEN Brain Science Institute, Japan, and BISC, University of California at Brekely, USA. Recently a national facility, decided to both basic and applied soft computing research, has been set up at the Indian Statistical Institute, Kolkata under the patronage of the Department of Science and Technology, Government of India, because of the outstanding contribution of the members of the Machine Intelligence Unit since 1975. The Center has provision for formal collaboration with overseas university and institutes. The Kaieteur Institute for Knowledge Management is a research center mainly concentrates on the knowledge of pattern recognition.

VII. CONCLUSION

To summarize, a comprehensive survey highlighting different clustering techniques used for image segmentation based on fuzzy pattern recognition. Through clustering algorithms, image segmentation can be done in an effective way. Extensive research has been done in creating many different approaches and algorithms for image segmentation, but it is still difficult to assess whether one algorithm produces more accurate segmentations than another, whether it be for a particular image or set of images, or more generally, for a whole class of images. This is the basic work of my research and in future, we continue the research process of Segmentation more effective by using fuzzy clustering for the classification of prawn species detectors.

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