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Fuzzy Art Based Image Segmentation and Statistical Analysis

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***Abstract*—Measurement of visual quality is of fundamental importance for numerous image applications, where the goal of quality analysis is to automatically assess the quality of images or in agreement with human quality judgments. Over the years, many researchers have taken different approaches to analyze their respective domains. It is important to evaluate the performance of clustering algorithms in a comparative setting and analyze the strengths and weaknesses. In this paper, we present results of an extensive statistical analysis of Fuzzy ART based segmented image by varying the parameters of it. Image segmentation plays a fundamental role in image analysis. It is used to extract the certain features from the image that aid in the identification of objects. Segmentation algorithms used in the Engineering Science areas such as biometric, remote sensing, color science, Image processing and etc.**

***Keywords*—Image Segmentation, Fuzzy ART, Statistical measures**

I. INTRODUCTION

A. Statistical Analysis

Statistical analysis methods analyze the spatial distribution of gray values, by computing local features at each point in the image, and deriving a set of statistics from the distributions of the local features [1]. The reason behind this is the fact that the spatial distribution of gray values is one of the defining qualities of texture. Depending on the number of pixels defining the local feature, statistical methods can be further classified into first order (one pixel), second-order (two pixels) and higher-order (three or more pixels) statistics [1]. The basic difference is that first-order statistics estimate properties (e.g. average and variance) of individual pixel values, ignoring the spatial interaction between image pixels, whereas second- and higher order statistics estimate properties of two or more pixel values occurring at specific locations relative to each other [2].

Statistical approaches yield characterizations of textures as fine, coarse etc. Thus one measure of texture is based on the primitive size, which could be the average area of these primitives of relatively constant gray level. The average could be taken over some set of primitives to measure its texture or the average could be about any pixel in the image. If the average is taken within a primitive centered at each pixel in the image, the result can be used to produce a texture image in which a large gray level at a pixel indicates, for example, that the average primitive size is large in a region around that pixel The average shape measure of these primitives, such as P2/A, where P is the perimeter and A is the area of the primitive could also be used as texture measure.

B. Image Segmentation

Image Segmentation is the process of partitioning an image into disjoint and homogeneous regions. This task can be equivalently achieved by finding the boundaries between the regions; these two strategies have been proven to be equivalent indeed. The desirable characteristics that good image segmentation should exhibit have been clearly stated by Haralick and Shapiroin [3] with reference to gray-level images. Regions of image segmentation should be uniform and homogeneous with respect to some characteristics such as gray tone or texture. “Region interiors should be simple and without many small holes. Adjacent regions of segmentation should have significantly different values with respect to the characteristic on which they are uniform. Boundaries of each segment should be simple, not rugged, and must be spatially accurate". Image segmentation algorithms generally are based on two basic properties of intensity values: discontinuity and similarity. In the first category, the approach is to partition and image based on an abrupt changes in intensity, such as edges in an image. The principal approaches in the second category are based on partitioning an image into regions that are similar according to a set of predefined criteria. Thresholding, region growing, and region splitting and merging are examples in this category. Fuzzy image segmentation techniques are much more adopt at processing such uncertainty than classical techniques and in this context; fuzzy ART algorithms are the most popular and extensively used image segmentation techniques.

C. Fuzzy Art Algorithm

The fuzzy-ART neural network [4] is a clustering self organizing neural network for analog input patterns. Figure 1. represents the architecture of a fuzzy-ART network. The network is composed of an attention subsystem and an orienting or vigilance subsystem. The attention subsystem is composed of two layers. Layer F1 is the input layer. Input patterns b = (b1; b2; . . . ; bN) composed of N Fuzzy values are presented to the system. F2 is the category layer. The system categorizes each input pattern as belonging to one of the [y1; y2; . . . ; yM] categories. The system stores a weight matrix of analog values that represents the categories learned by the system. Each category yj is represented by the weight vector zj composed of N analog values.

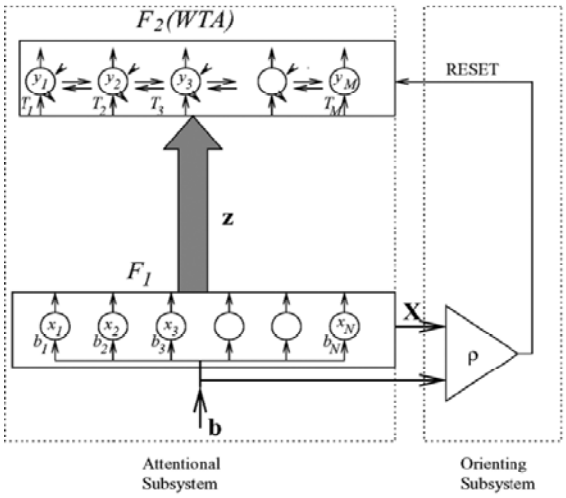


Fig 1. Topological structure of the fuzzy-ART architecture

The number of nodes in the output layer is decided dynamically. Every node in the output layer has a corresponding prototype vector. The network dynamics are governed by two sub-systems: an attention sub-system and an orienting subsystem. The attention subsystem proposes a winning neuron (or category) and the orienting subsystem decides whether to accept it or not. The network is said to be in a resonant state when the orienting system accepts a winning category (i.e. when the winning prototype vector matches the current input pattern close enough.).

II. Statistical Measures

Fuzzy ART Segmented images can be analyzed by describing the segmented image using following statistical measures [5].

A. Mean

$$m=\sum_{i=0}^{L-1} z_i \; p(z_i) \quad \text{(1)}$$

n^{th} moment about mean is given by

$$\mu_n=\sum_{i=1}^{L-1} (z_i - m)^n p(z_i) \quad \text{(2)}$$

B. Standard Deviation

$$\sigma = \sqrt{\mu_2(z)} = \sqrt{\sigma^2} \quad \text{(3)}$$

C. Smoothness

$$R=L-1/(1+\sigma^2) \quad \text{(4)}$$

D. Third moment - Skew ness

$$\mu_3=\sum_{i=1}^{L-1} (z_i - m)^3 p(z_i) \quad \text{(5)}$$

E. Uniformity

$$U=\sum_{i=0}^{L-1} p^2(z_i)\mu_X \quad \text{(6)}$$

F. Entropy

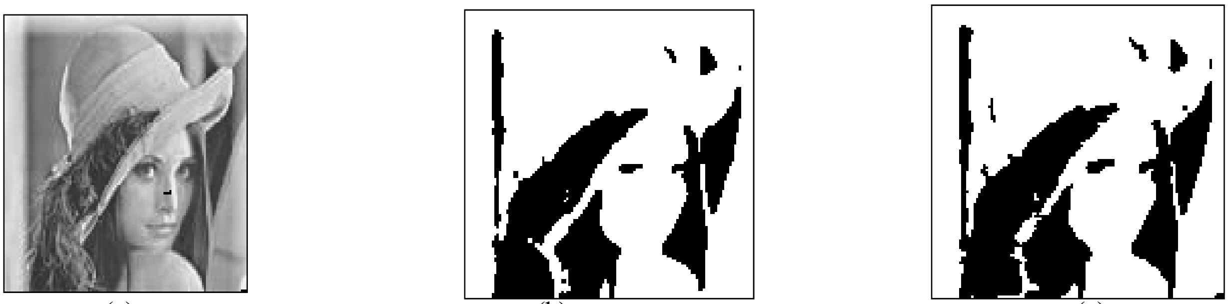
$$e = -\sum_{i=0}^{L-1} p(z_i)\log_2 p(z_i) \quad \text{(7)}$$

Where z_i is a random variable indicating intensity, p (z) is the histogram of the intensity levels in a region, L is the number of possible intensity levels and m is the mean intensity.

III. Experimental Results

Fuzzified image given as an input to the Fuzzy ART algorithm. The output of Fuzzy ART algorithm is defuzzified and then filtered using gray thresh to get segmented image. Fuzzy ART algorithm performance is observed by considering different vigilance parameter, ρ values for Lenna image of size 128x128 pixels shown in Figure 1. Statistical measures of

Fuzzy ART Segmented Image for different values of vigilance parameter, ρ shown in Table 1.



(a) (b) (c)

Fig 2. (a) Original Image (b) Segmented Image for vigilance parameter, ρ=0.75 (c) Segmented Image for vigilance parameter, ρ= 0.65

TABLE I
STATISTICAL ANALYSIS OF ORIGINAL AND SEGMENTED IMAGE

Image Type	Rho (Vp)	Mean	Standard deviation	Smooth	Skew	Uniformity	Randomness
Original		146.9883	50.857	0.0383	-0.548	0.006	7.4842
Fuzzy ART	0.50	179.786	117.16	0.1743	-21.23	0.5778	0.8847
Fuzzy ART	0.65	178.7366	104.75	0.1733	-21.48	0.5807	0.8802
Fuzzy ART	0.75	179.9039	116.23	0.172	-21.77	0.5845	0.8745
Fuzzy ART	0.95	184.168	114.21	0.1671	-22.74	0.5988	0.8524

Table I shows statistical measures of the input image, Fuzzy ART segmented image for different vigilance parameter values. The vigilance parameter, ρ= 0.65 provides 3 nodes, ρ =0.75 provides 1 node and ρ =0.5 provides only 4 clusters.

IV. CONCLUSION

In this paper we have presented a fuzzy ART based image segmentation. However, the goodness of a segmented grayscale image depends on so many factors such as homogeneity, spatial compactness, continuity, Correspondence with psycho-visual perception, etc., that a single measure is unlikely to capture all of them in a meaningful way. Finally analyzed the statistical measures of Fuzzy ART segmented image for different vigilance parameter values. There are 6 principal statistical measures used in segmented image analysis to describe the mean, SD, smoothness, skew, uniformity and randomness.

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