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Novel Algorithm for Threshold Selection in Pattern Recognition Applications

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***Abstract*— In this article, threshold selection is done on the basis of different entropy measures on both gray scale and color images. Comparative study of the Shannon and non-Shannon entropies (Renyi, Havrda-Charvat, Kapur and Vajda) is done to obtain an appropriate threshold value for the purpose of image segmentation. It is observed through the simulation experiments performed on images, that the position of the smallest minima obtained in the entropy versus gray-level plot is different for each entropy measure. The threshold values obtained from these plots is therefore dependent on the particular definition of the entropy chosen, which in turn affects the segmentation results. Quantitative evaluation of the quality of the enhanced images is also an important issue. Several measures have been proposed in the literature for this purpose [23]. In this article, we propose and investigate the use of different entropy measures for quantitative evaluation of the quality of enhanced images. Simulation results of quantitative evaluation of the quality of the enhanced images using different entropy measures are also presented.**

Keywords—image segmentation,thresholding.

I. INTRODUCTION

Image segmentation entails the division or separation of the image into regions of similar attributes and is a vital step in a series of processes aimed towards understanding a given image [1]-[10]. The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics [11]. 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. Adjacent regions are significantly different with respect to the same characteristics.

The main areas of the digital image processing methods are:

- Make changes in the pictorial information like enhancement of degraded images and this also include restoration of these type of image for final human interpretation.
- Processing of image segmentation and description to automatic machine interpretation.

Image partitioning is depends on abrupt changes in gray level values. Edges of the image are detect and linked using the principal areas of interest for example edges are the basic representation of shape outline, only difference with the colors or texture. These edges are basically used for segmentation purpose of scene understanding.

II. ENTROPY BASED APPROACH

(i) First of all, the co-occurrence matrix C_{m_1,m_2} [5] of the image to be segmented is computed for each color channel.
(ii) The probability distribution $p_{m_1,m_2} = C_{m_1,m_2} / MN$ is then calculated from its co-occurrence matrix C_{m_1,m_2} .
(iii) The entropy function for each entropy definitions, as defined below, are then calculated for each $t \in [0,1,2,....,L-2]$ for a given image to be segmented using the probability distribution p_{m_1,m_2} .

1). DIFFERENT ENTROPY MEASURES:-

1) SHANNON ENTROPY:

Shannon's entropy measure provides an absolute limit on the best possible lossless compression of a signal under certain constraints [3]. It is defined as:

$$H_s\left(p_{m_1,m_2}\right) = -\sum_{m_1}\sum_{m_2} p_{m_1,m_2} \log p_{m_1,m_2} , \quad (1)$$

where p_{m_1,m_2} is the probability distribution associated with the 2-D random variable. In this major project thesis, we have computed the values of p_{m_1,m_2} from the entries of the gray level co-occurrence matrix (C_{m_1,m_2}) [5], [6] of the given image as given by the relation $p_{m_1,m_2} = C_{m_1,m_2} / (MN)$ where M ,

N represents the image dimensions along x and y directions respectively. The entropy function for the purpose of the calculation of threshold for image segmentation is then computed from the expression given as:

$$Entropy(t) = -\sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1} p_{m_1,m_2}\log p_{m_1,m_2} - \sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t} p_{m_1,m_2}\log p_{m_1,m_2} \quad (2)$$

where, L represents the maximum number of gray level present in a particular image and $m_1, m_2 \in [0,1,2,....,L-1]$ and $t \in [0,1,2,....,L-2]$.

2) KAPUR ENTROPY:

Kapur's entropy $H_k\left(p_{m_1,m_2}\right)$ of order α and type β defined as [3], [8]:

$$H_k\left(p_{m_1,m_2}\right) = \left(\frac{\sum_{m_1}\sum_{m_2} p_{m_1,m_2}^{\alpha+\beta-1}}{\sum_{m_1}\sum_{m_2} p_{m_1,m_2}^{\beta}} - 1\right)(2^{1-\alpha}-1)^{-1}, \quad (3)$$

and the corresponding entropy function is given by

$$Entropy(t) = \sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1}\left(\frac{p_{m_1,m_2}^{\alpha+\beta-1}}{p^{\beta}_{m_1,m_2}} - 1\right)(2^{1-\alpha}-1)^{-1} + \sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t}\left(\frac{p_{m_1,m_2}^{\alpha+\beta-1}}{p^{\beta}_{m_1,m_2}} - 1\right)(2^{1-\alpha}-1)^{-1} \quad (4)$$

3) VAJDA ENTROPY:

Vajda entropy measure $H_v\left(p_{m_1,m_2}\right)$ is a special case of Kapur's entropy where β=1 is taken. It provides the advantage of faster calculations over Kapur's entropy measure and is defined as [3]:

$$H_v\left(p_{m_1,m_2}\right) = \left(\frac{\sum_{m_1}\sum_{m_2} p_{m_1,m_2}^{\alpha}}{\sum_{m_1}\sum_{m_2} p_{m_1,m_2}} - 1\right)(2^{1-\alpha}-1)^{-1}, \quad (5)$$

and the corresponding entropy function is given by

$$Entropy(t) = \left(\frac{\sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1} p_{m_1,m_2}^{\alpha}}{\sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1} p_{m_1,m_2}} - 1\right)(2^{1-\alpha}-1)^{-1} + \left(\frac{\sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t} p_{m_1,m_2}^{\alpha}}{\sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t} p_{m_1,m_2}} - 1\right)(2^{1-\alpha}-1)^{-1} \quad (6)$$

4) RENYI ENTROPY:

The Renyi entropy $H_r(p_{m_1,m_2})$ which is a generalization of Shannon entropy is one of a family of functional for quantifying the diversity, uncertainty or randomness of a system. It is defined as [3], [10];

$$H_r(p_{m_1,m_2}) = \frac{\log\left(\sum\sum\left(p_{m_1,m_2}\right)^{\alpha}\right)}{1-\alpha}, \alpha \neq 1, \alpha > 0 \quad (7)$$

And the corresponding entropy function is given by

$$Entropy(t) = -\sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1}\frac{\log\left(\sum\sum\left(p_{m_1,m_2}\right)^{\alpha}\right)}{1-\alpha} - \sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t}\frac{\log\left(\sum\sum\left(p_{m_1,m_2}\right)^{\alpha}\right)}{1-\alpha} \quad (8)$$

5) HAVRDA-CHARVAT ENTROPY:

The Havrda–Charvat entropy $H_{hc}(p_{m_1,m_2})$ of degree introduced by Havrda and Charvat and later on modified by Daróczy is often used in statistical physics and is defined as follows [3]:

$$H_{hc}(p_{m_1,m_2}) = \frac{\sum\sum p_{m_1,m_2}^{\alpha} - 1}{2^{1-\alpha}-1} \quad (9)$$

and the corresponding entropy function is given by

$$Entropy(t) = \frac{1}{2^{1-\alpha}-1}\left(\sum_{m_1=0}^{t}\sum_{m_2=t+1}^{L-1} p_{m_1,m_2}^{\alpha} - 1\right) + \frac{1}{2^{1-\alpha}-1}\left(\sum_{m_1=t+1}^{L-1}\sum_{m_2=0}^{t} p_{m_1,m_2}^{\alpha} - 1\right) \quad (10)$$

The above mentioned entropy functions given in (2),(4),(6),(8) and (10) are calculated for each $t \in [0,1,2,....,L-2]$ for a given image to be segmented using the probability distribution p_{m_1,m_2} which in turn is calculated from its gray and color component level co-occurrence matrix C_{m_1,m_2} .The numbers of minima points are determined from the entropy function versus gray level and color component level (t) plot. The gray level and color component level corresponding to the smallest minima may be taken as a threshold for image segmentation problems.

III.EXPERIMENTAL RESULTS

For the experimental sake various test images are investigated for the application of above discussed entropy based techniques for image segmentation. Via experimentation, the retrieved results are further compared on behalf on mean opinion score. In the subsequent part of article experimental results are aligned in a sequential manner. Table 1 gives the entropy plot for various gray levels for threshold determination. Table 2 delineates the threshold values selected for individual color plane using above discussed algorithm. While Table 3 depicts the experimental outcome for various entropy functions and Table 4 gives the comparison of experimental outcomes using opinion based scoring techniques.

TABLE 1. Entropy versus individual RGB components level plot for different entropy measures

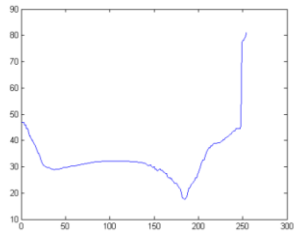
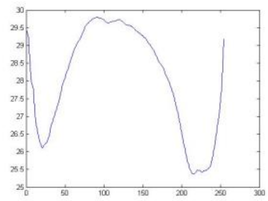
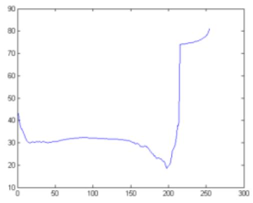
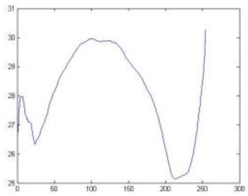
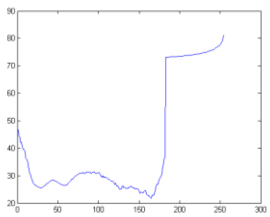
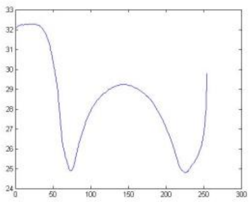
R plane		
G plane		
B plane		

TABLE 2. Threshold parameters of entropy versus individual RGB component level plot for figure 1(a) image

Entropy	**R**	**G**	**B**
Shannon Entropy	71	57	157
Kapur Entropy	183	197	164
Vajda Entropy	184	197	27
Renyi Entropy	182	193	165

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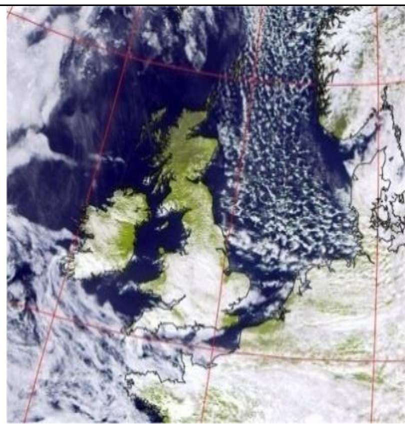
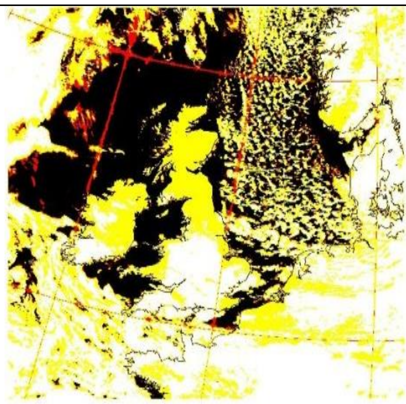
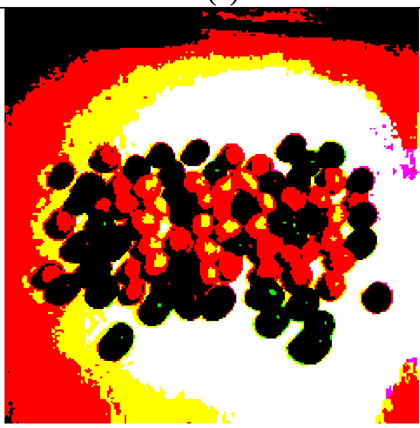
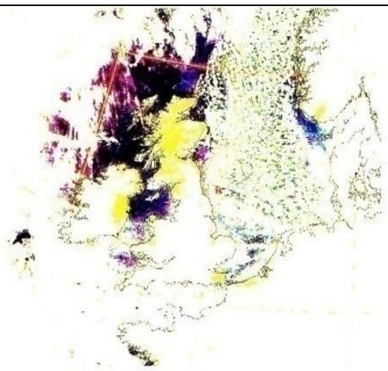
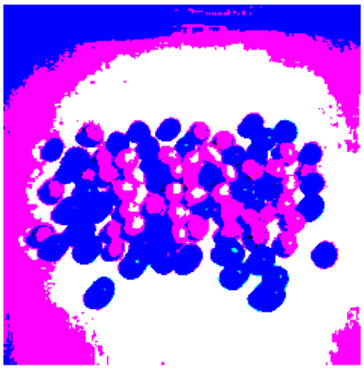
Table 3: Segmentation result for different entropy functions.

Original Image	 (a)	 (b)
Shannon Entropy Segmented Image	 (c)	 (d)
Kapur entropy Segmented Image	 (e)	 (f)
Vajda entropy Segmented Image		

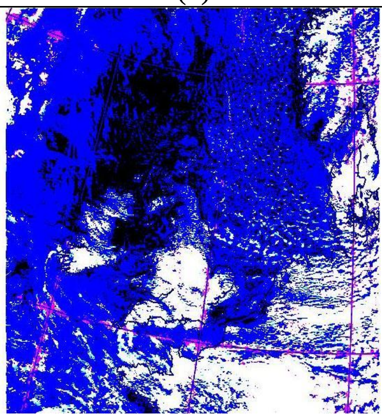
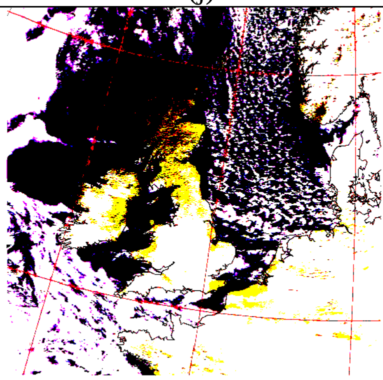
	(g)	 (h)
Renyi entropy segmented image	 (i)	 (j)
Havrda-charvat entropy segmented image	 (k)	 (l)

Fig.1 Segmentation results for different entropy measures (a) Original jelly bean image (b) Original Satcom image (c) Shannon entropy segmented image for jelly bean image(d) Shannon entropy segmented image for Satcom image (e)Kapur entropy segmented image for jelly bean image(f) Kapur entropy segmented image for Satcom image (g) Vajda entropy segmented image for jelly bean image (h) Vajda entropy segmented image for Satcom image (i) Renyi entropy segmented image for jelly bean image (j) Renyi entropy segmented image for Satcom image(k)Havrda-charvat entropy segmented image for jelly bean image (l)Havrda-charvat entropy segmented image for Satcom image.

TABLE 4: Entropy values of figure and original image

ENTROPY	HISTOGRAM EQUALIZATION			ORIGINAL		
	R	G	B	R	G	B
Shannon	10.1830	10.2133	10.1969	9.7700	9.6664	9.3922
Havrda-Charvat	6.6885	6.6962	6.6936	6.5573	6.5294	6.4583
Renyi	10.0429	10.0802	10.0674	9.4471	9.3292	9.0401
Kapur	6.2969	6.4415	6.4752	4.4215	4.5348	4.6783
Vajda	6.5728	6.5566	6.5448	6.3074	6.3169	6.0538

IV. CONCLUSION

In this paper, we have investigated the issue of threshold selection in image segmentation problem, and quantitative evaluation of the quality of the enhanced images using different entropy measures. Appropriate threshold selection is a difficult task in image segmentation problems. Several entropy measures for threshold selection purpose in gray and color image segmentation problems are studied. Threshold selection is done on the basis of different entropy measures on both gray scale and color images. Comparative study of the Shannon and non-Shannon entropies (Renyi, Havrda-Charvat, Kapur and Vajda) is done to obtain an appropriate threshold value for the purpose of image segmentation. Quantitative evaluation of the quality of the enhanced images is also an important issue and we have investigated the use of different entropy measures for quantitative evaluation of the quality of enhanced images.

We can conclude the following vital points related to above two issues:-

a. Havrda-Charvat entropy based image segmentation technique is better for gray images than any other entropy measures.
b. The values of the parameters α, β appearing in the definitions of the Kapur and Vajda entropy affect the threshold changes only slightly.
c. Segmentation results obtained using Havrda-Charvat entropy measures are better than other entropy measures in the sense of preservation of colors in different segments.
d. For the method of image enhancement of [25], with different transform, the image having lowest value of R plane entropy is better in quality than others.

In the histogram equalization enhancement technique, increment in the entropy values indicates the enhancement with respect to original image.

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