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Thresholding Algorithms for Image Segmentation - Entropy Based Comparison

– Sudhansh Sharma*
Assistant Professor, School of Computer and Information Sciences, IGNOU
sudhansh@ignou.ac.in *https://orcid.org/0000-0002-6870-0885*

– Bhavya Sharma
B.tech (CSE), Inderprastha Engineering College, AKTU
sharma1.bhavya@gmail.com

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ABSTRACT

Purpose: Image segmentation relates to the process of labelling of pixels in any image. This concept of image segmentation is generally used to find the Region of Interest – ROI in images, thus it is used very frequently in the field of computer vision. Among the various techniques of image segmentation, Thresholding is quite common, this technique is quite simple and efficient. Thresholding can be done locally as well as globally, and this selection of suitable thresholding technique is a critical factor for image segmentation. The Otsu's method and K-means algorithm are commonly used techniques for thresholding, the Otsu's method works on Global thresholding and the K-means works on Local thresholding. But both methods i.e. Otsu's method and K-means algorithm, explores the criteria of minimizing the within-class variance, to yield better segmentation results. But among the two, which one is better? The work performed in this paper relates to the comparison of the Otsu's method and K-means algorithm, to find the better among the two.

Design/Methodology/approach: It is a case based study.

Findings: Both methods yield better segmentation results yet K -means imparts more satisfactory results rather than Otsu.

KEYWORDS Thresholding Algorithms | Otsu's Method | K-Mean | Image Segmentation | Image Entropy

INTRODUCTION

Image segmentation relates to the process of labelling of pixels in any image, this is achieved by splitting a multispectral and panchromatic image into a group of homogeneous pixels, On the basis of the Region of Interest-ROI, this process of image segmentation is a universal step for many advanced image processing and object recognition techniques. Hence the performance of any automated image analysis system is heavily based on this process of image segmentation, which can be performed either by recursive splitting of the whole image or by merger of the minute regions of image until a specified condition is achieved. Various algorithms have been proposed for image segmentation, like grey level histograms [1], multiscale-segmentation [2], Markov Random fields [3] and entropy [4], the performed work relates to the study of entropy for the Otsu's method[5] and K-means algorithm, which are commonly used techniques for thresholding.

***Corresponding Author** (Sudhansh Sharma)

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Image segmentation based on thresholding

Among the various techniques of image segmentation, Thresholding is quite common, this technique is quite simple and efficient. It can be applied as a basic step in different sophisticated image analysis tasks. Thresholding can be done locally as well as globally, and this selection of suitable thresholding technique is a critical factor for image segmentation. Thresholding relates to the selection of threshold, which can be determined by using either the parametric approaches or the nonparametric approaches. Some prior assumptions are required for finding the threshold values by the parametric method, but in the case of the nonparametric method, the optimality of threshold is dependent on some defined criteria. Information theory has been applied to define some of the thresholding criteria, and definition of the criteria, improves the performance and efficiency of the nonparametric methods. Relative Entropy concept has also been used in the literature as a thresholding technique, Pun [6] proposed the first method which was later enhanced by Kapur et al. [7], both worked on the objective function defined by them is a maximization problem, where the histogram is separated into independent classes so that its entropy is maximized. Further, Brink [8] extended this method by introducing spatial information to two dimensions(2-D) images. Later, an image segmentation algorithm for medical images, based on the mutual information maximization of the information channel between the histogram bins and the regions of the partitioned image was proposed by Rigau et al [9]. Demonstration of image segmentation of infrared images using 2-D maximum entropy method was given by Feng et al. [10]. Zhang [11] uses the same method to segment the underwater images that show the same performance. In addition, Manmatha [12] demonstrated that the maximum entropy technique has outperformed one of the classical translations, the proposed model used the large number of predicates to possibly increase performance even further, and it is found as a promising model for the task of automatic image annotation. Brink [13] contributed the research and proposed the maximum entropy method for the selection of threshold, with the inclusion of spatial information in the entropy measure, the results improve significantly. Since, entropy is identified as the most important parameter for image segmentation, and due to the simplicity of thresholding technique, it is widely used for image segmentation. The Otsu's Method and K-means method are famous thresholding methods for image segmentation, and both works on multilevel thresholding, and both *explores the criteria of minimizing the within-class variance, to yield better segmentation results. T*he performed work relates to the comparison of Otsu's Method and K-means method, on the basis of the entropy variation, to identify the better among the two.

Entropy :

Entropy is a statistical measure of randomness which helps to characterize texture of an image which can be calculated by following formula:

$$E = -\sum_{i=1}^{l} h_{count}(i) \log \log h_{count}(i) \qquad \ldots(1)$$

Where 'i' is number of intensity levels and $h_{count}(i)$ is histogram count of intensity 'i'.

The image which has high entropy, the difference between neighbour regions will be high. Similarly the lowest difference in image will be an image with greatest entropy.

In information theory, the quantification of average amount of information is performed on the basis of entropy, which reflects the information content of symbols independent of any particular probability model. This parameter i.e. entropy is widely used as a tool for image processing applications [14], because it quantifies the minimum descriptive complexity of a smooth region in any image. Image analysis takes the concept of entropy in the sense of information theory, because the entropy can provide a good level of information to describe a given image. We can compute the entropy of the distribution of grey levels and obtain an appropriate partition for the target image. This entropy approach has two main advantages i.e. easy to implement and it is based on the entropy of the texture of an image. Thus, Image entropy is the best parameter to judge image segmentation [15].

K-mean clustering

K-Means clustering algorithm belongs to the category of is an unsupervised learning algorithms, and it is used to segment the Region of interest-ROI, from the background. Thus clusters, or partitions the given data into K-clusters or parts, on the basis of K-centroids. It is used when you have un-labelled data (i.e. data without defined categories or groups). The goal of K-means is to determine certain groups on the basis of some kind of similarity in the data with the number of groups represented by the factor K [16].

The objective of K-Means clustering is to minimize the sum of squared distances between all points and the cluster centre. Suppose, we have initial K-means ={m1…mk), and we need to compute square Euclidian distance as $s_i = \|x_i - m_i\|^2$ $s_i = \|x_i - m_i\|^2$. Then the minimum distance cluster from the point is given by the equation

$$\arg \sum_{i}^{k} \sum_{x \in s_i} \|x_i - m_i\|^2 \qquad \ldots(2)$$

Steps in K-Means algorithm:

1. Choose the number of clusters K.
2. Select at random K points, the centroids (not necessarily from your dataset).
3. Assign each data point to the closest centroid, which forms K clusters.
4. Compute and place the new centroid of each cluster.
5. Reassign each data point to the new closest centroid. If any re assignment took place, go to step 4, otherwise, the model is ready.

Otsu's Method

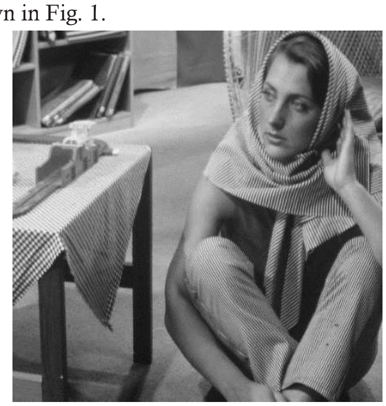
Image processing applications widely deploy Otsu's method to execute histogram based image thresholding or to transform a gray level image to a binary image [17]. The algorithm works on the principle that bi-modal histogram (for instance, foreground and background pixels) is embraced by the image under consideration, whose optimal threshold is evaluated for partitioning the aforementioned two classes (i.e. foreground and background pixels), such that the joint spread i.e. intra-class variance is negligible [18].

Otsu's Algorithm:

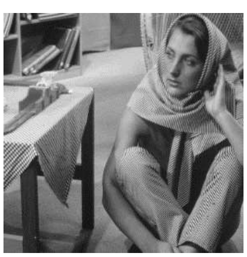
1. Figure out histogram and probabilities of each intensity level
2. Set up initial wi(0) and μi(0)
3. Rank through entire possible thresholds ranging from t=1 to maximum intensity
   i. Update wi and μi
   ii. Compute $s_b^2(t)$
4. Desired threshold corresponds to the maximum $s_b^2(t)$

Experiment & Results

To calculate the Entropy, the image should be distributed into regions with any type of selection. In our experiment, we have chosen different resolution (512x512, 256x256, 128x128, and 64x64) of the image i.e. Barbara.png,; as shown in Fig. 1.



512x512



256x256

128x128

64x64

Fig 1: experiment image Barbara.png with different resolution

We calculated the entropy for the original image with different resolutions (Fig.2), then the entropy is calculated for the various resolutions of the image, segmented by Otsu's method (Fig.3) & k-mean algorithm (with two mean has been used here with 10 iteration.), the variation in image entropy with variation in image size is shown in Fig 3 and Fig. 4 respectively.

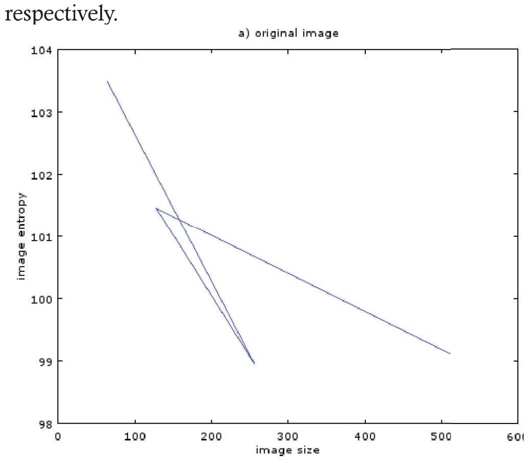


Fig 2: Entropy Variation in Original image for different resolution

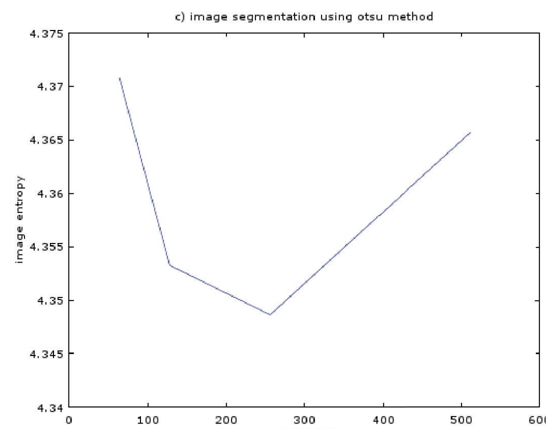


Fig. 3 Resolution wise Entropy Variation in image Segmented by Otsu's Method

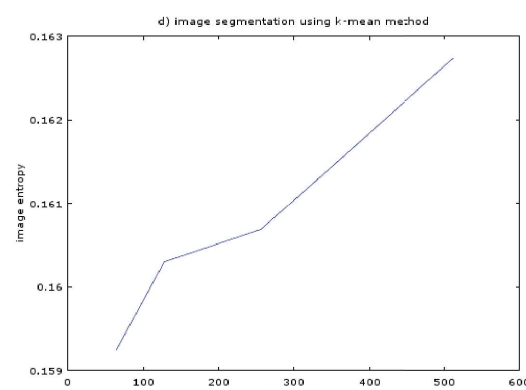


Fig 4: Resolution wise Entropy Variation in image Segmented by K-means Method

Conclusion

Comparing the resolution wise results shown in the Fig 2, Fig 3and Fig 4, we analysed that the entropy variation is quite inconsistent in the original image, but when the segmentation is performed this inconsistency is vanished. Further, it is observed that in comparison to K-means image segmentation, the entropy variation is quite high and non-linear when the image is segmented by the Otsu's method. By looking at Fig 4 we can identify that k-mean segmented image has lowest entropy value and the variation in entropy is more or less following the Linear pattern. Otsu method is similar to that of K means method in multilevel thresholding. Both are based on the criteria of minimizing the within-class variance. Furthermore, the Otsu method deploys global thresholding while the K –Means employs local thresholding. The Otsu method requires a gray level histogram which is not true for K means. Both methods yield better segmentation results yet K -means imparts more satisfactory results rather than Otsu.

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The Editorial Board had used the Urkund plagiarism [http://www.Urkund.com] tool to check the originality and further affixed the similarity index which is 0% in this case (See Annexure-I). Thus the reviewers and editors are of view to find it suitable to publish in this Volume-11, Issue-4, Oct-Dec, 2019

Annexure 1

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Urkund Analysis Result

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Sources included in the report:

Instances where selected sources appear: 0

Reviewers Comment

Reviewer's comment 1: Both Otsu's method and K-means algorithm being commonly used techniques for thresholding and both methods explores the criteria of minimising the within-class variance, to yield better segmentation result. The paper attempted to answer which technique is better.

Reviewer's Comment 2: The paper is well structured even though the paper is concrete in nature. It has touched the wider concepts of image segmentation. The graphs presented in the paper are making it more presentable as well as easily understandable.

Reviewer's Comment 3: The paper has taken a good number of the past studies to form the basis for the proposed study.

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EDITORIAL BOARD EXCERPT At the time of submission, the paper had 0% of plagiarism which is an accepted percentage as per the norms and standards of the journal for the publication. As per the editorial board's observations and blind reviewers' remarks the paper had some minor revisions which were communicated on timely basis to the authors (Sudhansh & Bhavya) all the corrections had been incorporated as and when directed and required to do so. The comments related to the manuscript are related to the theme "**Thresholding Algorithms for Image Segmentation**" both subject-wise and research-wise. The Image separation involves splitting an image into its component parts and extracting them accordingly. Image segmentation by thresholding is the simplest process which contains the basic statement that the objects and upbringings in an image have distinct gray-level deliveries. This assumption implies that the gray values cover two or more distinct peaks and there exists a threshold value separating them. Thresholding is a course in which a group of dawns is selected under some criteria, and then, pixels of an image are divided into a series of groups or classes according to some rule. By and large all the editorial and reviewer's comments had been incorporated in paper and the manuscript had been earmarked and decided under the "**Case Study Based Paper**" category.