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Comparative Analysis and Evaluation of Image Segmentation Algorithms

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Abstract - With the rapid developments of higher resolution imaging systems, larger image data are produced. To process the increasing image data with conventional methods, the processing time increases tremendously. Image segmentation is emerging as a solution for computer vision and image processing. With the help of several image processing algorithms efficiency of segmentation can be improved, and it is widely used in medical imaging (i.e. find tumor in MRI), robotic vision (i.e. vision-based navigation), and face recognition. New faster image processing techniques are needed with their complete database including algorithms detail, their shortcoming with expected solution and implementation, to keep up with the ever increasing image data size. The focus of our study is Watershed and Clustering algorithm with their modified version to get better result. Watershed and K-means algorithm are each considered for their speed, complexity, and utility. Implementation of each algorithm is then discussed. Finally, the experimental results of each algorithm are presented and discussed with quantitative and qualitative comparison.

Keywords – Watershed, Clustering, Segmentation.

I. INTRODUCTION

Segmentation refers to the operation of partitioning an image into component parts or into separate objects. The goal of segmentation is to simplify 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 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. Image segmentation is an important and perhaps, the most difficult task in image processing. All subsequent interpretation tasks, such as object recognition and classification, rely heavily on the quality of the segmentation process. There are many applications where images require precise Segmentation.

In general, image noise should be eliminated first through image preprocessing. And there after some specifically-given work (such as region extraction and image marking) is done after the main operation of image segmentation for the sake of getting better visual effect. Clustering is one of the widely used image segmentation techniques which classify patterns in such a way that samples of the same group are more similar to one another than samples belonging to different groups. There has been considerable interest recently in the use of fuzzy clustering methods, which retain more information from the original image than hard clustering methods like K-mean clustering. In this paper we have compared and evaluated both clustering technique as well as improved watershed algorithm for the image segmentation. Fuzzy C-means algorithm, k-mean and watershed algorithm proved better in certain application. Each algorithm has its own area of application which is discussed and results shown in tabular form. Several metrics are introduced based on which we can compare the different algorithm.

II. CLUSTERING

The goal of a clustering analysis is to divide a given set of data or objects into a cluster, which represents subsets or group. The partition should have two properties:

- Homogeneity inside clusters: the data, which belongs to one cluster, should be as similar as Possible.
- Heterogeneity between the clusters: the data, which belongs to different clusters, should be as different as possible.

FUZZY C- MEANS C CLUSTERING

The theory of fuzzy sets has immediately found its potential application in the fields of pattern recognition and image processing. The fuzzy c-means algorithm generalizes a hard clustering algorithm called the c-means algorithm, The (hard) c-means algorithm aims to identify compact, well-separated cluster.

The membership functions do not reflect the actual data distribution in the input and the output spaces. They may not be suitable for fuzzy pattern recognition. To build membership functions from the data available, a clustering technique may be used to partition the data, and then produce membership functions from the resulting clustering.

In fuzzy clustering, each point has a degree of belonging to clusters, as in fuzzy logic, rather than belonging completely to just one cluster. Thus, points on the edge of a cluster may be in the cluster to a lesser degree than points in the center of cluster. For each point x we have a coefficient giving the degree of being in the kth cluster $u_k(x)$. Usually, the sum of those coefficients for any given x is defined to be 1:

$$\forall x \left(\sum_{k=1}^{\text{num. clusters}} u_k(x) = 1 \right).$$

With fuzzy c-means, the centroid of a cluster is the mean of all points, weighted by their degree of belonging to the cluster:

$$\text{center}_k = \frac{\sum_x u_k(x)^m x}{\sum_x u_k(x)^m}.$$

The degree of belonging is related to the inverse of the distance to the cluster center:

$$u_k(x) = \frac{1}{d(\text{center}_k, x)},$$

then the coefficients are normalized and fuzzyfied with a real parameter $m > 1$ so that their sum is 1. So

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$$u_k(x) = \frac{1}{\sum_j \left(\frac{d(\text{center}_k, x)}{d(\text{center}_j, x)} \right)^{2/(m-1)}}.$$

For *m* equal to 2, this is equivalent to normalising the coefficient linearly to make their sum 1. When *m* is close to 1, then cluster center closest to the point is given much more weight than the others.

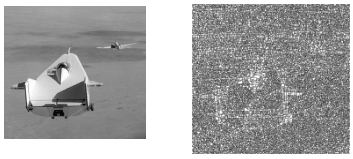
K- MEANS CLUSTERING

K-Means Clustering algorithm clusters the image data set into k subsets of pixels; each subset has a center value which is the average of all pixels in the subset, thus k subsets resulted in k centers total. A pixel is grouped into a subset by first calculating the distances between the pixel and each center, and then the pixel is grouped into the subset that has the closest center. After one pass through the image, error is calculated, and the clustering process is stopped when the error converged to a value; error is the sum of the squared distances between all pixels in a subset and the subset's center.

III. WATERSHED SEGMENTATION

Watershed segmentation is a morphological based method of image segmentation. An image may be interpreted as topographic surface where the gray-levels of the image (or gradient image) represent altitudes if the gradient image is used. Direct application of watershed algorithm on images creates problem of over segmentation that can be visualized in following image-

a b



(a): Test images, (b): watershed transform of (a)

Improvement over watershed segmentation can be done in following ways:

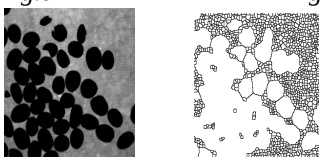
1) Distance transform
2) Gradient method
3) Marker controlled

By using above stated method we can improve the segmentation efficiency. distance transform calculates the measure of the separation of points in the image. In our experiment we used Euclidean distance tocalculate distance transform and then watershed algorithm applied.

Results of watershed segmentation with distance transform:

Fig.a *Fig.b*

Fig.c *Fig.d*



Examples of watershed segmentation; (a&c): Test images, (b): watershed transform of (a), (d): watershed transform of (c)

Test images and grey images

I) Image- 'd.jpg' (single object)

II) Image- 'Multiple object.jpg' (multiple object)

III) Image- 'Liftingbody.png'

Fig.5.1: single object , multiple object and lifting body

Quantitative results:

Quality metrics for given test images different segmentation algorithms

Types	Energy	entropy	contrast	Execution time(sec)
watershed	0.7319	0.4684	0.0972	167.786700
K-mean	0.2966	1.5669	0.471	47.246
Fuzzy c-mean	0.4560	0.9976	1.2051	28.698528

The quality of segmentation depends on several factors of images like contrast between background, foreground and number of distinct object or overlapped object and application area etc.Image segmentation is most practical approach among virtually all automated image recognition systems. Feature extraction and recognition have numerous applications on telecommunication, weather forecasting, environment exploration and medical diagnosis. The focus of study is on watershed and clustering algorithm, which includes implementation, performance analysis and comparison among those algorithms.

QUALITATIVE RESULTS

1) The watershed algorithm is applied over several images .While implementation the problem of over segmentation is seen and modifications are done in order to improve the results and to reduce the extent of over segmentation.
2) K-means algorithm is applied over several images and as the number of clusters increases the accuracy will increases.
3) Fuzzy c-mean clustering is considered and it results in better accuracy than above two.
4) For performance evaluation, Quantitative measures as gray level energy, entropy, Execution time, and contrast are calculated.
5) Based on the result of segmentation across several images qualitative evaluations can be done.

CONCLUSION

The watershed algorithm is more suitable for images having distinct object with non-overlapping boundary and mostly used for medical images. Segmentation by Clustering algorithms gives better results and has wide range of applications. K-means algorithm is less time consuming and results will be better as we go on increasing the number of clusters but the convergence rate is little lower then fuzzy c-mean.

The result o FCM algorithm show the better convergence rate in comparison with other traditional clustering approaches.FCM algorithm can be implemented to several kind of image like image with multiple object, overlapping object,3-D and 2D image with better accuracy and visualization both. It can be used to locate object as in case of tumors, for crowd analysis, for boundary detection, or analysis of aerial images.

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