Comparative Study of Image Segmentation Techniques and Object Matching using Segmentation

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***Abstract*—Several general-purpose algorithms and techniques have been developed for image segmentation. Since there is no general solution to the image segmentation problem, these techniques often have to be combined with domain knowledge in order to effectively solve an image segmentation problem for a problem domain. This paper presents a comparative study of the basic image segmentation techniques i.e. Edge-Based, K-Means Clustering, Thresholding and Region-Based techniques, using a number of test images. The objects extracted after image enhancement and image segmentation as compared to the objects desired, whether the region boundaries are closed or disconnected and the Mean Weighted Distance measure of the segmented objects with respect to the original image form the criteria to perform the comparative study. Image segmentation is further used for object matching between two images. Correlation between the objects being matched in the two images is used as a measure of similarity between the two objects. The first principal component axis, determined by Principal Component Analysis (PCA), of the objects being matched are aligned with the x-axis to take into account the different orientation of an object in different images.**

***Keywords:* Image Segmentation, Clustering, Thresholding, Edge Detection, Region Growing, Object Matching, PCA**

I. INTRODUCTION

Segmentation is one of the first steps in image analysis. It refers to the process of partitioning a digital image into multiple regions (sets of pixels). Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Applications of image segmentation range from filtering of noisy images, medical imaging, locating objects in satellite images (roads, forests, etc.), automatic traffic controlling systems, machine vision to problems of feature extraction and recognition. Many segmentation methods [1] [2] [3] have been proposed in the literature. The choice of a segmentation technique over another and the level of segmentation are decided by the particular characteristics of the problem being considered. Image segmentation could be further used for *object matching* between two images. An object of interest is specified in the first image by using the segmentation result of that image; then the specified object is matched in the second image by using the segmentation result of that image.

II. IMAGE SEGMENTATION TECHNIQUES

A. Clustering Methods

Clustering [2] [3] [4] is a process whereby a data set (pixels) is replaced by cluster; pixels may belong together because of the same color, texture etc. There are two natural algorithms for clustering: *divisive clustering* and *agglomerative clustering.* The difficulty in using either of the methods directly is that there are lots of pixels in an image. Also, the methods are not explicit about the objective function that is being optimized. An alternative approach is to write down an objective function and then build an algorithm. The K-means algorithm is an iterative technique that is used to partition an image into K clusters, where each pixel in the image is assigned to the cluster that minimizes the variance between the pixel and the cluster center and is based on pixel color, intensity, texture, and location, or a weighted combination of these factors. This algorithm is guaranteed to converge, but it may not return the optimal solution. The quality of the solution depends on the initial set of clusters and the value of K.

B. Thresholding Methods

Thresholding [1] [3] [6] [7] is the operation of converting a multilevel image into a binary image i.e., it assigns the value of 0 (background) or 1 (objects or foreground) to each pixel of an image based on a comparison with some threshold value T (intensity or color value). When T is constant, the approach is called global thresholding; otherwise, it is called local thresholding. Global thresholding methods can fail when the background illumination is uneven. Multiple thresholds are used to compensate for uneven illumination. Threshold selection is typically done interactively; however, it is possible to derive automatic threshold selection algorithms.

C. Edge-Detection Methods

Edge detection methods [1] [2] locate the pixels in the image that correspond to the edges of the objects seen in the image. The result is a binary image with the detected edge pixels. Common algorithms used are Sobel, Prewitt and Laplacian operators. These algorithms are suitable for images that are simple and noise-free; and will often produce missing edges, or extra edges on complex and noisy images.

D. Region-Based Methods

The goal of region-based [1] [3] [7] [8] [9] segmentation is to use image characteristics to map individual pixels in an input image to sets of pixels called regions that might correspond to an object or a meaningful part of one. The various techniques are: *Local techniques, Global techniques and Splitting and merging techniques*.

The effectiveness of region growing algorithms depends on the application area and the input image. If the image is sufficiently simple, simple local techniques can be effective. However, on difficult scenes, even the most sophisticated techniques may not produce a satisfactory segmentation. Over-stringent criteria create fragmentation; lenient ones overlook blurred boundaries and over-merge. Hybrid techniques using a mix of the methods above are also popular.

III. Verification Through Back-Projection for Object Recognition

A Distance Transform (DT) [1] is applied to a binary image and computes, for each background element (pixel that is set to 0), the distance to the closest object element (nonzero pixel). DT of a binary image at pixel (x, y) using Euclidean distance metric is defined as:

$$WDT(x, y) = \min \{((x - i)^2 + (y - i)^2)^{1/2}\}$$

where $(i,j) \in$ binary image. In the transformed image, each pixel (x, y) has a value proportional to its distance from its current position to the closest boundary point.

To confirm the presence of a segmented region / object in the original image, the segmented region boundary is transformed on the original image. The distance between the segmented region boundary (SB) with respect to the original image is computed as follows:

$$D = (1/n)\, [\Sigma(x,y) \in SB\, WDT(x,y)\,]$$

where n is the number of pixels in the segmented region boundary and WDT (x,y) is the value of pixel (x,y) in the weighted distance transform image of the original image.

If the segmented region boundary fits the scene perfectly, the total distance will be zero; however, the value will be more than zero because of approximations and occlusions. The small value of mean weighted distance measure confirms presence of the segmented region in the scene; lower the value, better is the result of that segmentation technique.

IV. Object Matching Using Segmentation

Image segmentation can be further used to recognize and/or locate specific objects in an image and for object matching between two images. The image is segmented into its constituent objects using an appropriate image segmentation technique. Then, the matching is performed for a particular object in one image with the segmented objects of the other image. It can be accomplished using several techniques, one of which is correlation. Correlation provides a direct measure of the similarity between two images. It is sensitive to the scaling or rotation of objects, thus, the first principal component axis (determined by Principal Component Analysis) of the objects being matched are aligned with the x-axis to take into account the different orientation of an object in different images.

Principal Component Analysis

Principal Components Analysis (PCA) [1] [11] [12] is one of the multivariate techniques for data analysis. It is a quantitatively rigorous method that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. Each principal component is a linear combination of the original variables. All the principal components are orthogonal to each other. The principal components can be used to align objects (regions or boundaries) with the eigenvectors of the objects.

V. Simulation Results

A. Image Segmentation Techniques

Four image segmentation techniques, namely, *Clustering, Edge Detection, Multiple Thresholding and Region-Based* segmentation techniques have been studied and implemented using a number of test images. The image segmentation results are shown in Fig. 1 and Fig. 2 of Set I. The regions smaller than a threshold were removed for better visualization. The boundaries of the segmented objects are superimposed on the original image to measure the Mean Weighted Distance measure with respect to the original image. The results are summarized in Table I and Table II of Set I. The lower is the value of Mean Weighted Distance measure, better is the result.

Edge-based methods trace the object boundaries using the detected edges, as there is often a contrast in intensity between the object and background. However, in complex images, the edges identified are often disconnected, while closed region boundaries are required to segment an object.

Segmentation of regions based on single threshold is very effective for images containing solid objects in a contrasting background; however, the robust segmentation is negatively effected in case of uneven illumination as seen in Fig. 2(d) and for the domains with slowly varying intensity (brightness).

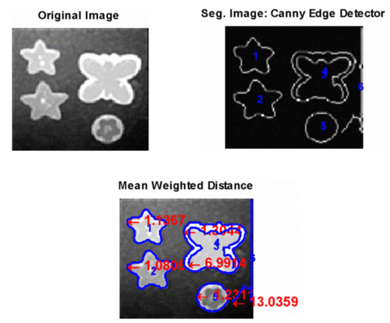
For multithresholding problems, the selected thresholds generally become less credible as the number of classes to be separated increases.

For clustering by k-means algorithm, the quality of the final solution depends largely on the initial set of clusters. However, the algorithm is extremely fast and is run several times to return the best clustering found.

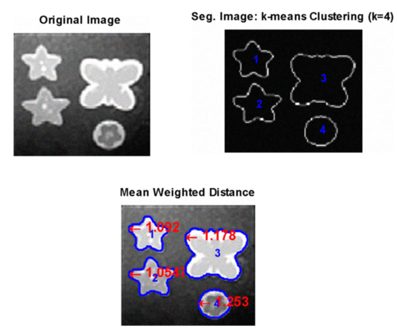
B. Object Matching using Segmentation

Image segmentation is used for object matching between two images. K-means Clustering algorithm is used for image segmentation. The image segmentation results and the principal component axes of the various objects extracted are shown in Fig. 3 and Fig. 4 of Set II. Correlation between the object desired and the object extracted (value greater than 0.8) is used as a measure of similarity between the two objects. Correlation results are summarized in Table III of Set II.

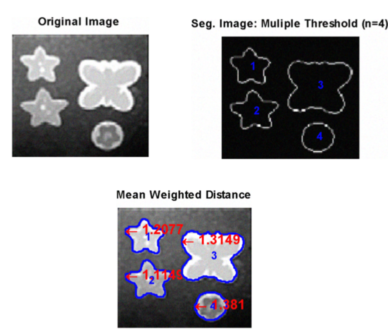
Set I: Image Segmentation Techniques



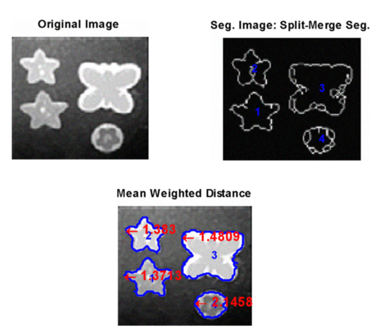
(a)



(b)



(c)



(d)

Fig. 1: (a) Edge Detection (b) K-means Clustering (c) Multiple Thresholding (d) Split-Merge Algo.

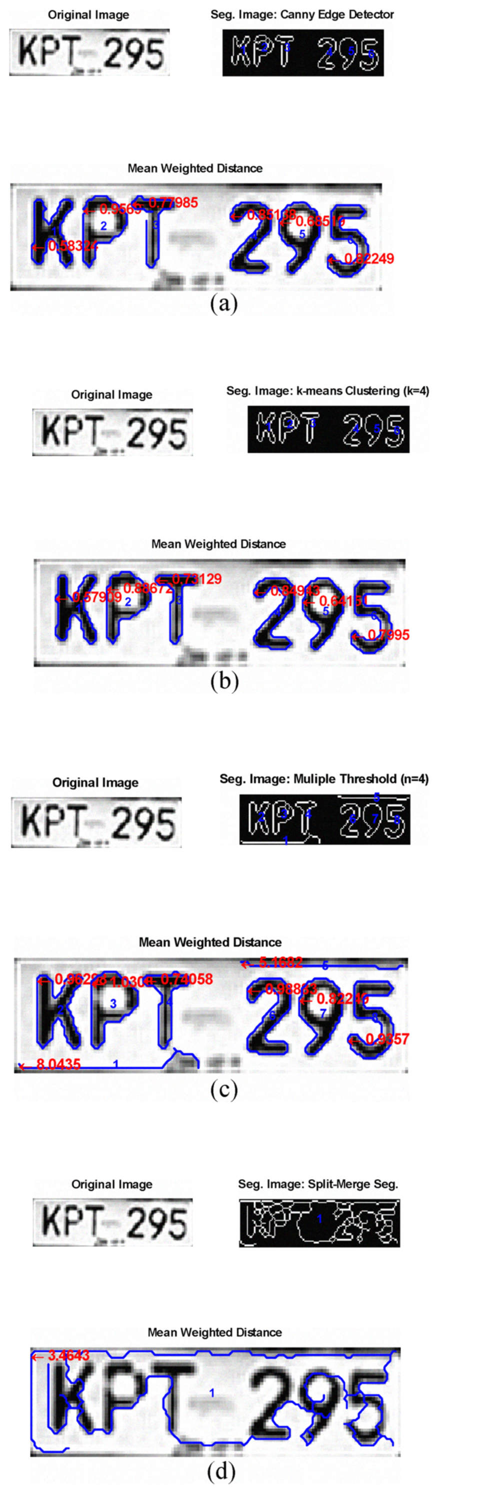


Fig. 2: (a) Edge Detection (b) K-means Clustering
(c) Multiple Thresholding (d) Split-Merge Algo.

SET II: OBJECT MATCHING USING SEGMENTATION

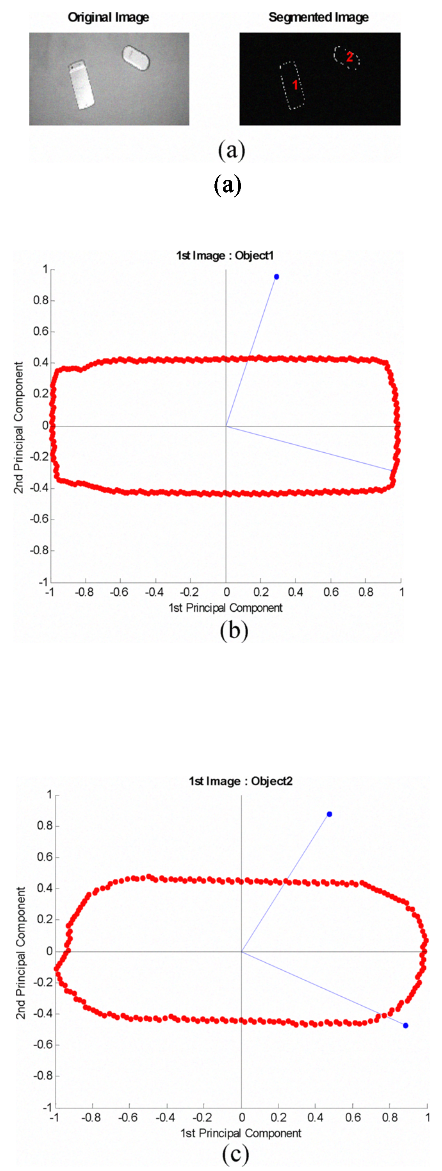
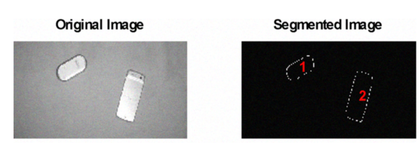
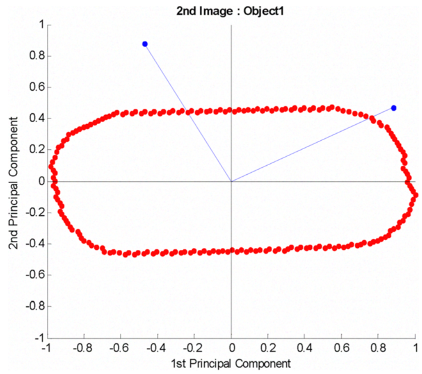


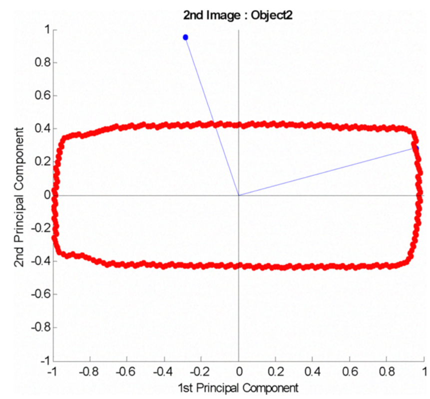
Fig. 3: (a) 1st Image (b) PCA of 1st Image: Object 1
(c) PCA of 1st Image: Object 2



(a)



(b)



(c)

Fig. 3: (a) 1[st] Image (b) PCA of 1[st] Image: Object 1
(c) PCA of 1st Image: Object 2

TABLE I: MEAN WEIGHTED DISTANCE FOR IMAGE SEGMENTATION TECHNIQUES

S. No.	Object	Mean Weighted Distance			
		Canny Edge Detector	*K-means Clustering (K=4)*	*Multiple Thresholding (n=4)*	*Split-Merge Algo. using Single Threshold*
		No. of Objects = 6	*No. of Objects = 4*	*No. of Objects = 4*	*No. of Objects = 4*
1		1.1367	1.092	1.2077	1.383
2		1.0809	1.0547	1.1149	1.3713
3		1.3044	1.178	1.3149	1.4809
4		1.2311	1.253	1.381	2.1458

Inference: Segmentation using K-means Clustering results in better Mean Weighted Distance measure than the other three techniques. All the techniques, except Split and Merge, resulted in clean object boundaries.

TABLE II: MEAN WEIGHTED DISTANCE FOR IMAGE SEGMENTATION TECHNIQUES

S. No.	Object	Mean Weighted Distance			
		Canny Edge Detector	*K-means Clustering (K=4)*	*Multiple Thresholding (n=4)*	*Split-Merge Algo. using Single Threshold*
		No. of Objects = 6	*No. of Objects = 6*	*No. of Objects = 8*	*No. of Objects = 1*
1	K	0.5832	0.5791	0.963	Fails to produce the desired result due to uneven illumination
2	P	0.9569	0.8867	1.0308	
3	T	0.7799	0.7313	0.7406	
4	2	0.8514	0.8494	0.9888	
5	9	0.6852	0.6415	0.8225	
6	5	0.8225	0.7995	0.9357	

Inference: Segmentation using K-means Clustering results in better Mean Weighted Distance measure than the other three techniques. All the techniques extracted desired objects with clean boundaries except for Split-Merge algorithm that failed due to uneven illumination as it's criteria is based on global single threshold.

TABLE III: RESULTS OF MATCHING OBJECTS FROM THE FIRST IMAGE IN THE SECOND IMAGE

S. No	Obj. from First Image	Obj. from Second Image	Corr. Coeff.	Displaceme-nt	Status
1	[1]	[1]	0.4934	Inf	Object 1 of the first image matched Object 2 of the second image.
	[1]	[2]	0.9533	[177.796 0.208]	
2	[2]	[1]	0.9649	[-168.182 0.162]	Object 2 of the first image matched Object 2 of the second image.

VI. CONCLUSION

Four image segmentation techniques, namely, *Clustering, Edge Detection, Multiple Thresholding and Region-Based* segmentation techniques have been studied and implemented using a number of test images. Segmentation using K-means Clustering algorithm has given better results for various types of images as compared to Edge-based and Region-based methods in terms of the objects extracted as compared to the desired objects and mean weighted distance measure of the extracted objects with respect to the original image. More improved and separated regions or objects can be obtained using the other higher-level segmentation techniques such as level set methods, graph partitioning methods, neural networks segmentation etc.

Image segmentation is further used for object matching between two images using a number of test images. K-means Clustering algorithm is used for image segmentation. Correlation between the object desired and the object extracted is used as a measure of similarity between the two objects. Value greater than 0.8 is considered as a good match between the two stationary objects. The first principal component axis of the objects being matched is aligned with the x-axis to take into account the different orientation of an object in different images. The approach used is able to detect the presence or absence of an object being matched from the first image in the second image.

VII. FUTURE WORK

While the present study performed the comparison between the image segmentation techniques as described earlier, more improved and separated regions or objects can be obtained using the other higher level segmentation techniques such as level set methods, graph partitioning methods, neural networks segmentation etc. and the results can be incorporated to further extend the comparative study. Region-based method can be tested with more sophisticated criteria such as multiple thresholds to improve the results as compared to when tested with single threshold.

Object matching between two images can be further extended for video segmentation thereby improving the coding efficiency and reducing the storage requirements.

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