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Analysis of Image Segmentation Techniques: A Survey

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***Abstract*— This paper presents an overview of some well-known image segmentation techniques. The segmentation process divides a given image into different regions and objects. Image Segmentation has become popular due to its many vision applications. The main goal of this survey is to explore various algorithms of image segmentation. The short-comings of the survey on image segmentation algorithms have also been evaluated. The main focus of this paper is on the clustering based segmentation techniques. This paper concludes with certain limitations of available techniques and also the possible solutions for the same for future use.**

***Index Terms*— Segmentation, Thresholding, Clustering, Edge Detection, Image Processing.**

I. Introduction

Image Segmentation is a vital procedure of processing and understanding an image. It is the fundamental necessity of any computer based vision application on the grounds that individuals are mostly interested just in specific parts of the picture. Essentially it is characterized as the procedure of isolating the picture into distinctive parts of homogeneity. An image might be defined as a two-dimensional function, f(x, y), where x and y are the spatial coordinates, and the amplitude of at any pair of coordinates is known as the intensity of the image at specific point. When the intensity of f and the value of x, y are finite then the image is called digital image [1].

In this paper our main focus will be on Thresholding-based, Clustering-based and the Edge-based Methods. Segmentation methods can be classified into three main categories [2]:

- **Classical Methods** that include Thresholding, region growing, clustering, and edge detection approaches, etc.
- **Artificial Intelligence Techniques** that include Neural Network Based image segmentation techniques, like, Supervised-KNN, Unsupervised Hopfield ANN, etc.
- **Hybrid Techniques** that either crossover or fall into none of the first two categories. For example, Graph Cut.

II. Literature Review

There exists a large body of research from the last two decade. A lot of surveys have been done, with various classifications of image segmentation methods and the segmentation techniques themselves.

Patil et al. 2013 [3], "Overview of Colour Image Segmentation Techniques" classifies all the techniques into three major categories namely, Edge-based Segmentation Methods, Region-based Segmentation Methods and Cooperative Segmentation Methods. The author came to a conclusion that the Edge-based techniques cannot be implemented by themselves and are better in serving as a step in other image segmentation algorithms because they provide useful information about the region boundaries.

Rajeshwar et al. 2012 [2] "Image Segmentation Techniques" has done a very broad classification of various image segmentation techniques into six categories called Segmentation Based on Edge Detection, Thresholding Method, Region Based Segmentation Methods, Segmentation Based on PDE (Partial Differential Equation), Segmentation Based on Artificial Neural Networks, Segmentation Based on Clustering, and Multi-objective Image Segmentation, although being a comprehensive paper, it does not appear to show as to what algorithms are suitable for what type of images.

Basavaprasad et al. 2013 [4] "A comparative study on classification of image segmentation methods with a focus on graph based techniques" gives three major categories that consist of various sub-categories to withhold the various image segmentation techniques, as Pixel-based Segmentation Methods, Edge-based Segmentation Methods and Region-based Segmentation Methods. In the paper the author has rate the image segmentation techniques surveyed on the basis of Good, Bad and Normal.

While Yogamangalam et al. 2013 [5] "Segmentation Technique Comparision in Image Processing" has classified the same techniques into five categories viz., Region Based, Edge Based, Threshold, Feature Based Clustering, and Model Based Techniques in [5]. A completely different structure of classification of segmentation techniques has been given in [5] and it provides experimental results on the Lena image. It compares algorithms from different techniques and concludes that Thresholding is the simplest of all kind of segmentation techniques, it also states that the same technique is computationally fastest.

III. Proposed Work

In this paper, we will lay focus on three main types of segmentation methods, namely, Thresholding based, Clustering based and Edge based.

Under the thresholding-base segmentation method we have picked the basic Global Thresholding (iterative), Otsu's Method and Local Thresholding.

In the Clustering-based segmentation method we have laid focus on K-Means and Mean Shift clustering algorithms.

While in the Edge-based segmentation method, we touched the basics of the Canny, Sobel and Prewitt operators and their use.

We have implemented these algorithms in MATLAB and produced results on three types of images, a Leukemia cell image, a scan of a paper image and a green outdoor image.

Applying the above mentioned techniques, we have taken the outputs and presented them. We have measure the execution time for each segmentation technique and also rated the segmentation between good, bad and average.

IV. Segmentation Methods and Techniques

4.1 Thresholding

Threshold technique is one of the most used techniques in image segmentation. This technique can be expressed as [6]:

T=T[x , y, p(x, y), f(x, y)]

where:

T is the threshold value.

x, y are the coordinates of the threshold value point.

p(x, y) and f(x, y) are points in the gray level image pixels.

Thresholding in an image can be defined as:

$$g(x,y) = f(x) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \leq T \end{cases}$$

Some of the thresholding techniques are:

4.1.1 Basic Global Thresholding

In basic global thresholding, a single pixel is used for all the image pixel. . When the pixel values of the components and that of background are fairly consistent in their respective values over the entire image, global thresholding could be used. The iterative global thresholding flow chart is presented below:

Algorithm:

Step 1: Select an initial estimate for T.

Step 2: Segment the image using T. This will produce two groups of pixels. G1 consisting of all pixels with grey level values >T and G2 consisting of pixels with values <=T.

Step 3: Compute the average grey level values mean1 and mean2 for the pixels in regions G1 and G2.

Step 4: Compute a new threshold value T=(1/2)(mean1 +mean2)

Step 5: Repeat steps 2 through 4 until difference in T in successive iterations is smaller than a predefined parameter T0, i.e., if |T-Tnew| > ΔT, back to step 2, otherwise stop.[7]

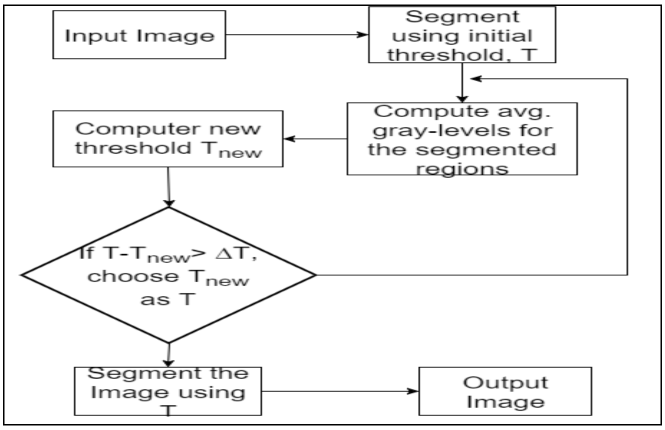


Fig. 1 Global Thresholding flow chart.

4.1.2 Otsu's Threshodling

This method was proposed by N. Otsu in 1975 and has been in fashion ever since [8]. It is aimed at reducing the within-class variance while maximizing the inter-class variance. The flow chart for Otsu;s thresholding is show here:

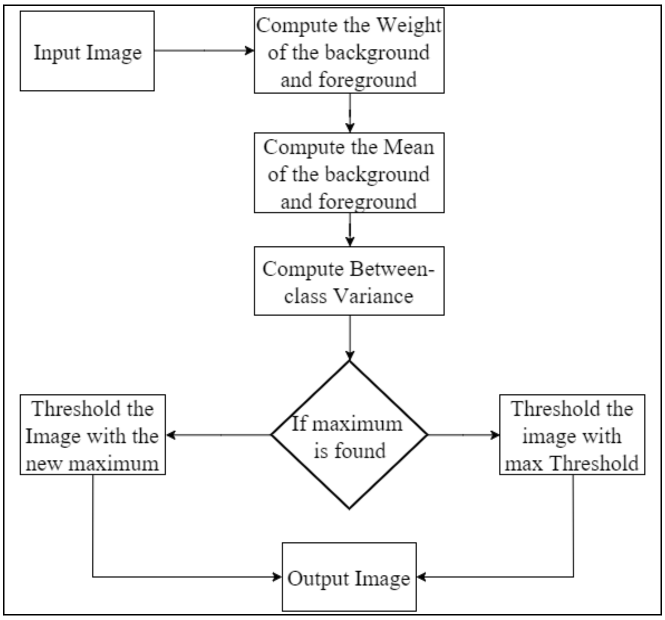


Fig. 2: Otsu's Thresholding flow chart.

Algorithm:

It more or less works in the same way as the Global Thresholding.

4.1.3 Local Thresholding

Local thresholding is an image thresholding techniques that segments an image on the basis of local threshold, i.e. it compares threshold for every pixel in an image. The main idea is that each pixel is compared to an average of the surrounding pixels. Specifically, an approximate average of the last $s \times s$ window of pixelscenteredaround each pixel is calculated while throughout the image which means, it considers neighbouring pixels on all sides in the region. If the value of the current pixel is *t* percent lower than the average then it is set to black, otherwise it is set to white [9]. The flow chart of local thresholding is given here:

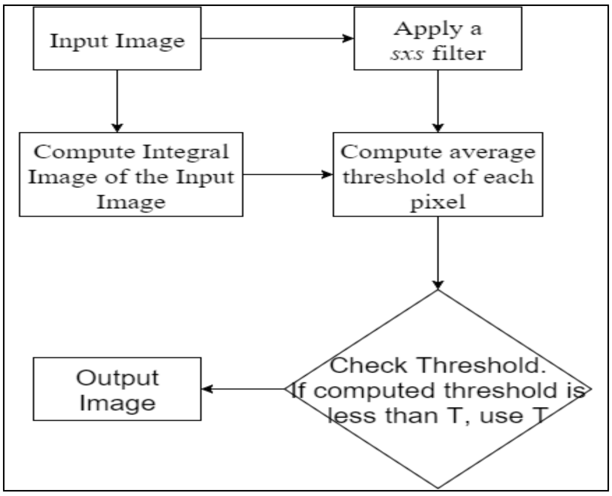


Fig.3 Local thresholding flow chart.

Algorithm:

procedure AdaptiveThreshold(in, out, w, h)

Step1: for i = 0 to w do

Step2: sum ← 0

Step3: for j = 0 to h do

Step4: sum ← sum + in [i, j]
Step5: if i = 0 then
Step6: intImg[i, j] ← sum
Step7: else
Step8: intImg[i, j] ← intImg[i−1, j] +sum
Step9: end if
Step10: end for
Step11: end for

4.2 Clustering-based Methods

Clustering method is a procedure in which a data set or say pixels are exchanged by cluster, pixels may belong together because of the same color, texture etc. There are two types of clustering that is hierarchical clustering and partional clustering [10].

Some of the clustering technique under implemntation are:

4.2.1 K-Means Clustering:

This is an iterative technique used to partition an image into lot of clusters in which there is option of k cluster centers; randomly each pixel in the image is assign to the every cluster. The cluster centers is again computed by taking mean of all the pixels in the center. The quality of explanation obtained from this method depends upon the initial set of clusters and the value of k. The flow chart of k-Means Clustering is given here:

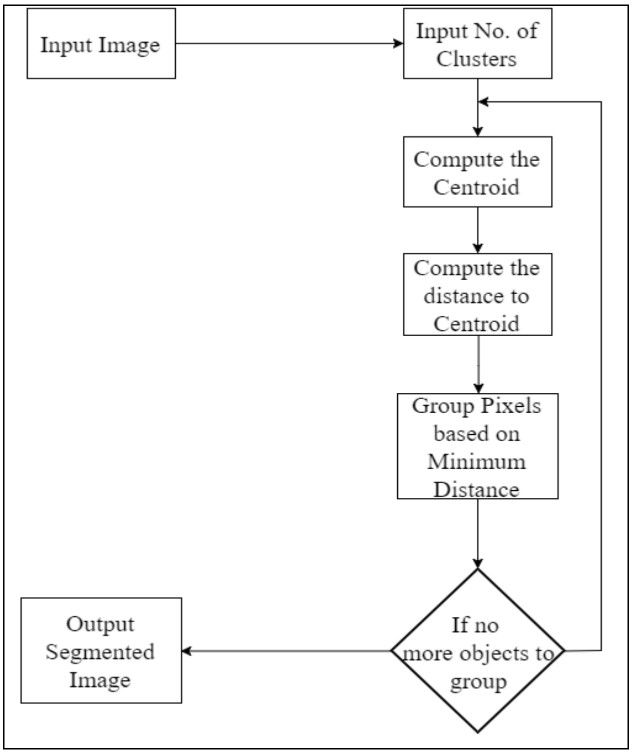


Fig. 4 K-Means Clustering flow chart.

Algorithm:
Step1: Input image 'leuk.jpg'
Step2: Give the number of cluster value as k. Here we chose the cluster value as 3.
Step3: Randomly choose the k cluster centers.
Step4: Calculate the mean or center of clusters.
Step4: Calculate the distance between each pixel to each cluster center.
Step5: If the distance is near to the center then move to that cluster
Step6: Otherwise move to next cluster.
Step7: Re-estimate the center.

4.2.2 Mean Shift Clustering:

This is an advanced technique for clustering based-method.It starts by taking a mean for each pixel, using which a *kernel desnity estimator* is built. This is shifted throughout the image. Typical kernel density estimators are Gaussian. By iteratively shifting the mean based on the kernel, all the pixels get drawn to a number of local points of convergence.

Algorithm:
Step1: For each i = 1…n run the mean shift procedure for xi and store the convergence point in zi..
Step2: Identify clusters {Cp….} p=1…m of convergence points by linking together all zi which are closer than 0,5 from each other in the joint domain.
Step3: For each i = 1…n assign Li = {p | zi ϵ Cp }.

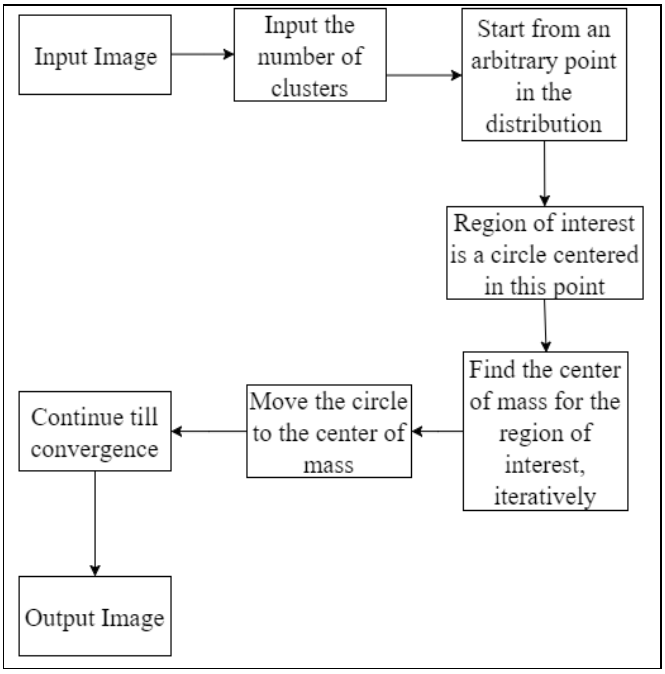


Fig. 5: Mean Shift flow chart.

4.3 Edge-based Methods

The variation in the image feature usually brightness of image gives rise to the edges. More objectively, the edges are the representation of discontinuities of image intensity function. There could be various reasons such as lightning condition, bject geometry, type of material, surface texture, etc as well as their mutual interaction and so on [11]. In edge based segmentation, gradient is known as the first derivative of an image f(a,b). The first derivative operator uses gradient method to find the edges by using the maximum and minimum value of the gradient. The gradient is a measure of change in a function.

The famous edge-based methods are:

4.3.1 Canny Edge Detection:

Canny edge operator is asecond order derivative operator for edge detection and is considered as superior edge detection operator among the available operators based on the experimental results as it determines strong and weak edges in the image. Image is first smoothed by using circular two-dimension Gaussian function, computing the gradient of the result and then using the gradient magnitude and direction to approximate edge strength and direction at every point. The gradient magnitude array so obtained consists of undesirable ridges around local maxima and are to be suppressed to get discrete orientations of the edge normal by the process of nonmaxima suppression. Then the technique of double thresholding is employed to reduce false fragments. Two thresholds are used to solve the purpose T1 and T2 where T2 ≈ 2T1 [11].

Algorithm:
Step1: Convolve image f(r, c) with a Gaussian function to get smooth image f ^ (r, c). f ^ (r, c)=f(r,c)*G(r,c,6)
Step2: Apply first difference gradient operator to compute edge strength then edge magnitude and direction are obtain as before.
Step3: Apply non-maximal or critical suppression to the gradient magnitude.
Step4: Apply threshold to the non-maximal suppression image.

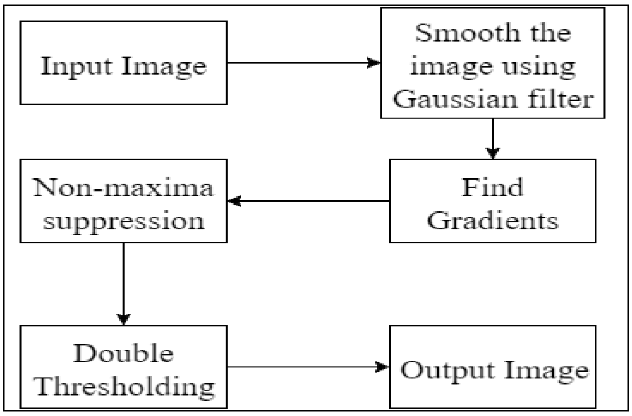


Fig 6: Canny Edge Detection flow chart

4.3.2 Sobel edge Detector:

This is widely used first derivative operator to find edges and is modification of Prewitt's operator, as will be discussed next. It changes the center coefficient by '2'. The Sobel operators are given as [12]:

-1	-2	-1
0	0	0
+1	+2	+1

G_x

-1	0	-1
-2	0	+2
-1	0	+1

G_y

Fig. 7: An example of Sobel Operator.

Algorithm [13]:
Step1: Apply mask Gx, Gy to the input image.
Step2: Apply Sobel edge detection algorithm and the gradient.
Step3: Masks manipulation of Gx, Gy separately on the input image.
Step4: Results combined to find the absolute magnitude of the gradient.

$$|G| = \sqrt{Gx^2 + Gy^2}$$

Step5: the absolute magnitude is the output edges.

4.3.3 Prewitt Edge Detector:

This operator uses 3 X 3 mask to find the edges. The mask used along x and y direction corresponding [12] they are:

-1	-1	-1
0	0	0
+1	+1	+1

G_x

-1	0	+1
-1	0	+1
-1	0	+1

G_y

Fig. 8: An example of Prewitt Operator.

Algorithm:
Prewitt Pretty much works in the same way as Sobel operator.

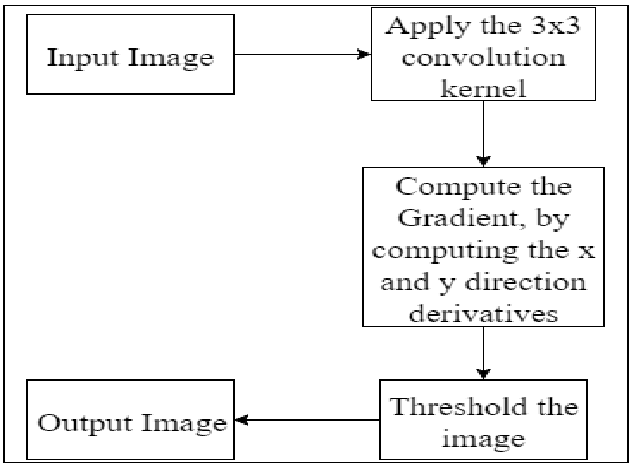
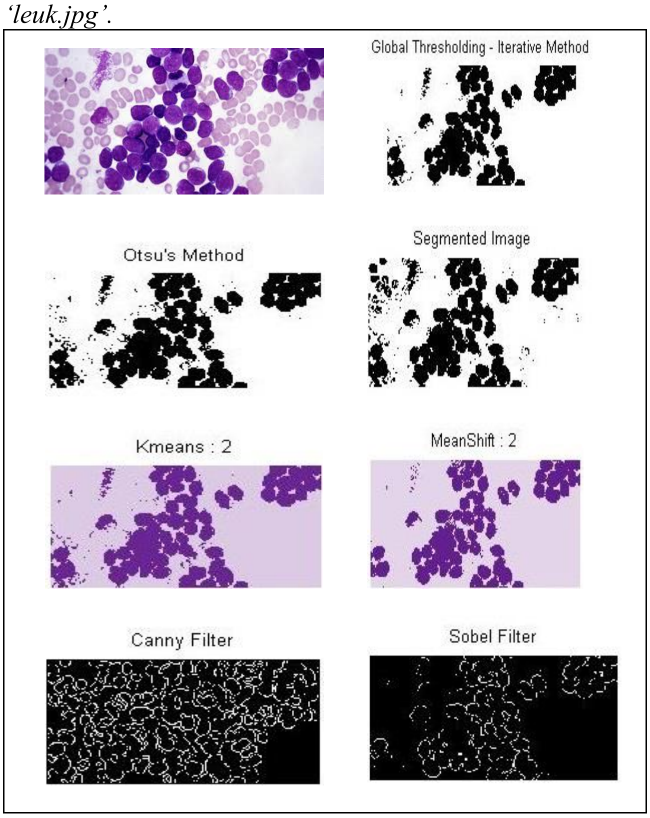


Fig. 9: Prewitt Edge Detection flow chart

In the next section we will show the algorithms of these image segmentation techniques.

V. RESULTS

The above mentioned algorithms were tested on various images. In here we present the results on the medical image *'leuk.jpg'*.



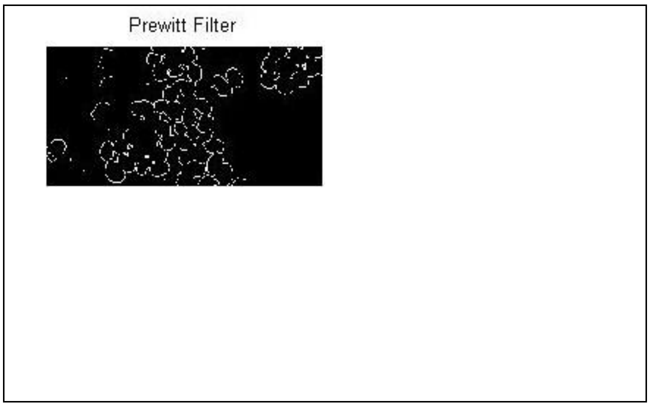


Fig. 10: From top-left to bottom: Original Leukemia Image; Globally thresholded image; Otsu's thresholded image; Locally Thresholded Image; Segmented Image from K-Means Clustering, with $k=2$; Segmented Image from Mean Shift Clustering, with $k=4$ and bandwidth $bw=0.3$; Canny Edge Detected Image; Sobel Edge Detected Image; Prewitt Edge Detected image.

The experimental results of the algorithms on the paper image *'paper.jpg'*:

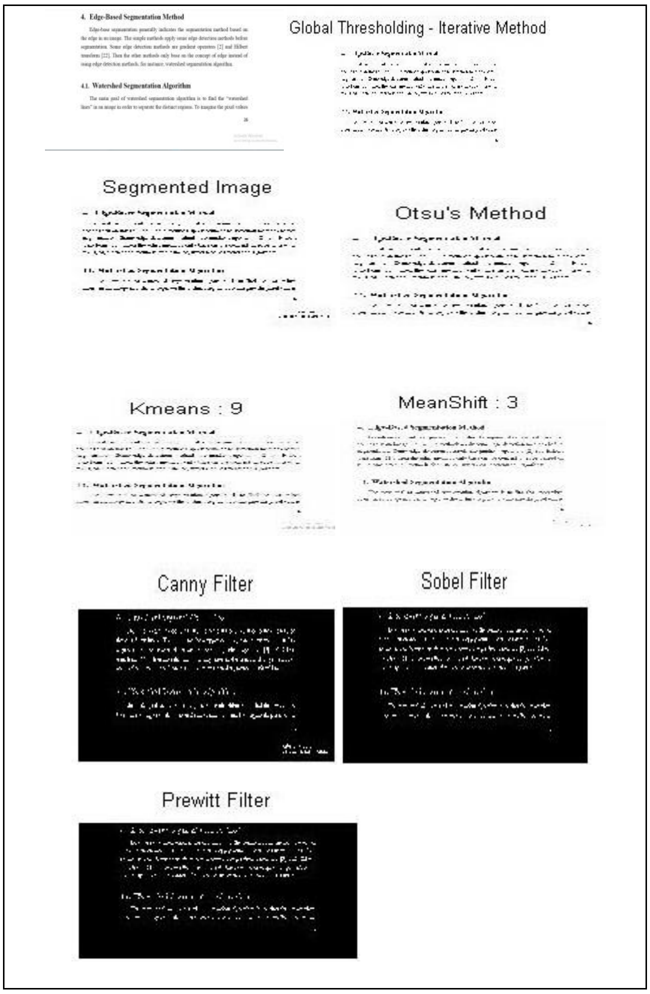


Fig. 11: From top-left to bottom: Original Paper Image; Globally Thresholded Image; Otsu's Thresholded Image; Locally Thresholded Image; K-Means Segmented Image, with k=9; Mean Shift segmented image, with $k=4$ and bandwidth $bw= 0.3$; Canny Edge Detected Image; Sobel Edge Detected Image; Prewitt Edge Detected Image.

The experimental results of the algorithms on the outdoor image 'outdoor.jpg':

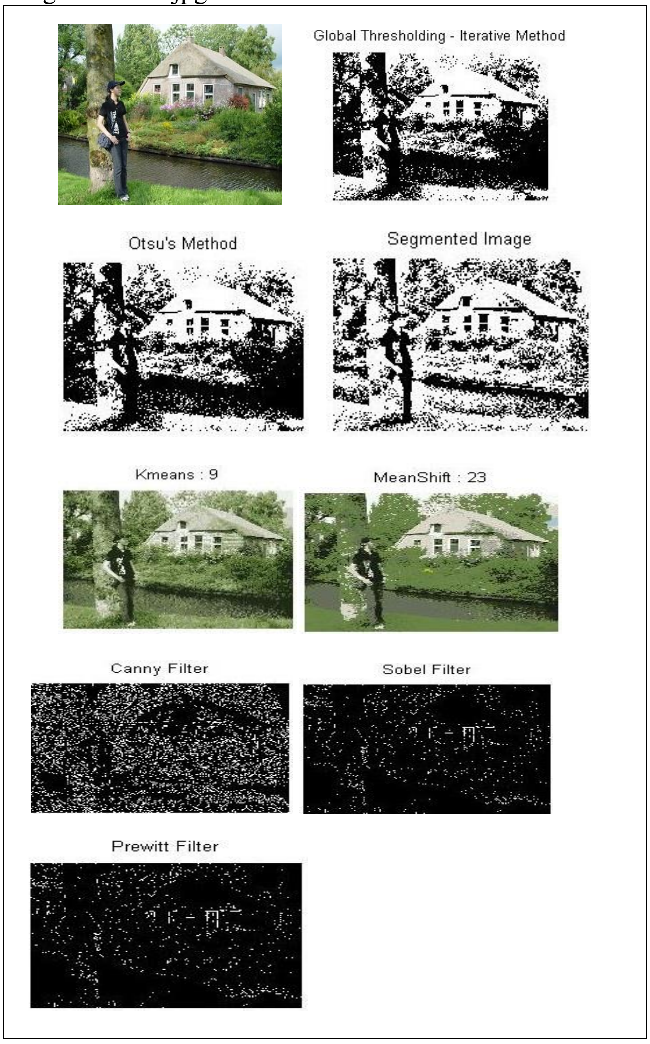


Fig. 12: From top-left to bottom: Original Outdoor Image; Globally Thresholded Image; Otsu's Thresholded Image; Locally Thresholded Image; K-Means Segmented Image, with k=9; Mean Shift segmented image, with $k=8$ and bandwidth $bw= 0.7$ Canny Edge Detected Image; Sobel Edge Detected Image; Prewitt Edge Detected Image.

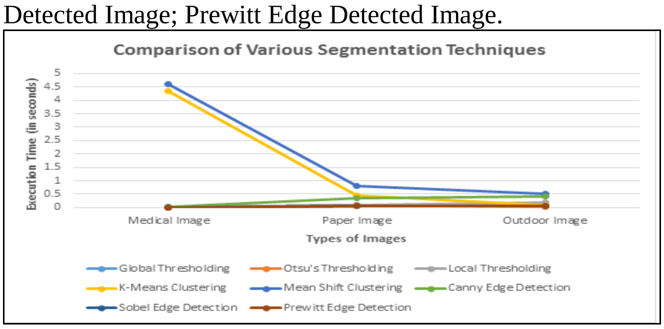


Fig. 13: Graph of various segmentation techniques' time.

Method	Technique	Medical Image (Execution time in seconds)	Paper Image (Execution time in seconds)	Outdoor Image (Execution time in seconds)
Thresh-olding	Global	0.010028	0.08322	0.063088
	Otsu's	0.010077	0.083592	0.02732
	Local	0.039294	0.087735	0.18045
Cluster-ing	K-Means	4.3637	16.9748	11.5059
	Mean shift	0.29009	0.42078	8.9856
Edge-based	Canny	0.034638	0.35395	0.40902
	Sobel	0.005281	0.056954	0.053207
	Prewitt	0.005143	0.06226	0.052044

Table 1: Execution Times of various segmentation techniques on each type of test image.

VI. CONCLUSION

On the basis of our experimental observations, we were able to come to the following conclusions:

i. Otsu's Thresholding performs closely well enough to Canny Edge Detection Technique on the Paper Image.
ii. Both Mean Shift and Local Thresholding perform really closely on the outdoor image.
iii. Mean Shift clustering outperforms its counterparts under the survey and particularly on the Medical Image and Outdoor Image, but lags behind on the mostly black and white Paper Image
iv. K-Means is computationally exhaustive, though provides suitable results given the correct number of clusters (though not ideal).
v. Edge Detection techniques can't be used independently, though they give useful information that can be used in some other step of image segmentation along with some other technique.

Thresholding is computationally inexhaustive, but does not take the spatial features of an image into account and even though it can be used independently it is more suitable as a step in some image processing application.

While clustering techniques work quite well, they are susceptible to noise and are highly dependent on the input parameters.

The second order edge operators (like Canny) give quite reliable results, while the first order edge operators give useful information which can be used as a step in some other edge detection technique. Also, it is quite clear that no single operator can be applied to all images and sometimes the edges obtained are not continuous.

Thus, it seems that as sound as each method may sounds theoretically, they have their limitations. The biggest one being, that no method can be applied to all kinds of images, universally.

VII. FUTURE WORK

A survey of new (advanced) image segmentation techniques can be done, while many methods like Artificial or Hybrid that could not be included in this survey can be worked upon.

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