Computer Vision IT524 Project Report

Course Instructor
Dr. Pankaj Kumar

Submitted By-
Rajat Kumar (201811024)
Harsh Desai (201811011)
Praveen Kumar Singh (201811021)

Image Segmentation: Using Region-Based, Edge Detection and Clustering Techniques

1. Abstract

In this project, we used three techniques Edge Detection Based, Region-Based and Clustering Based for Image Segmentation Problem. The dataset used for the project consists of 100 images with its ground truth and we have used 50 images from the dataset[1]. The ground truths and the segmented results are converted to binary images for evaluation of the result. The results of the three techniques have been compared using metrics: precision, recall, F1 Score and IoU score. We found the performance of Edge Detection Based and Region-Based techniques better than Clustering Based techniques based on these scores.

Keywords: Image segmentation, Region-based Segmentation, Edge Detection, Clustering, IoU Score, F1-Score

2. Introduction

In computer vision, Image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as image objects). Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, it is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics. 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 characteristic(s). Some of the practical applications of image segmentation are Medical imaging, Object Detection, Object Recognition, Video Surveillance, Face Recognition, etc.[2]

3. Methodology

A. Problem Description

To solve the Image segmentation task on the given dataset[1] using Edge Detection Based, Region-Based and Clustering Based Techniques and compare the results using metrics such as F1 score and IoU(Intersection Over Union) score.

B. Dataset Used

- The Dataset[1] used contains 100 images with their ground truth.
- 50 images were used from the dataset for the experiment.
- Sample Image with its ground truth:

Fig 1. Left is the original RGB image. Right one is Ground Truth.

C. Algorithms Used

a) Edge Detection Based Segmentation:

- For edge detection canny edge detector is used.
- Canny edge detector is composed of steps below:
    - Smooth the image with a Gaussian filter to reduce noise and unwanted details and textures.

$$g(m,n) = G_\sigma(m,n) * f(m,n)$$

$$G_\sigma = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{m^2+n^2}{2\sigma^2}\right)$$

    - Compute magnitude and orientation using sobel operator .

$$M(n,n) = \sqrt{g_m^2(m,n) + g_n^2(m,n)}$$

$$\theta(m,n) = tan^{-1}[g_n(m,n)/g_m(m,n)]$$

- Non-Maximum Suppression:
  - After getting gradient magnitude and direction, a full scan of image is done to remove any unwanted pixels which may not constitute the edge.
  - For this, at every pixel, pixel is checked if it is a local maximum in its neighborhood in the direction of the gradient.
  - The result you get is a binary image with "thin edges”.

b) Region-Based Segmentation

Two Techniques used for Region-Based Segmentation:

1.Region Growing

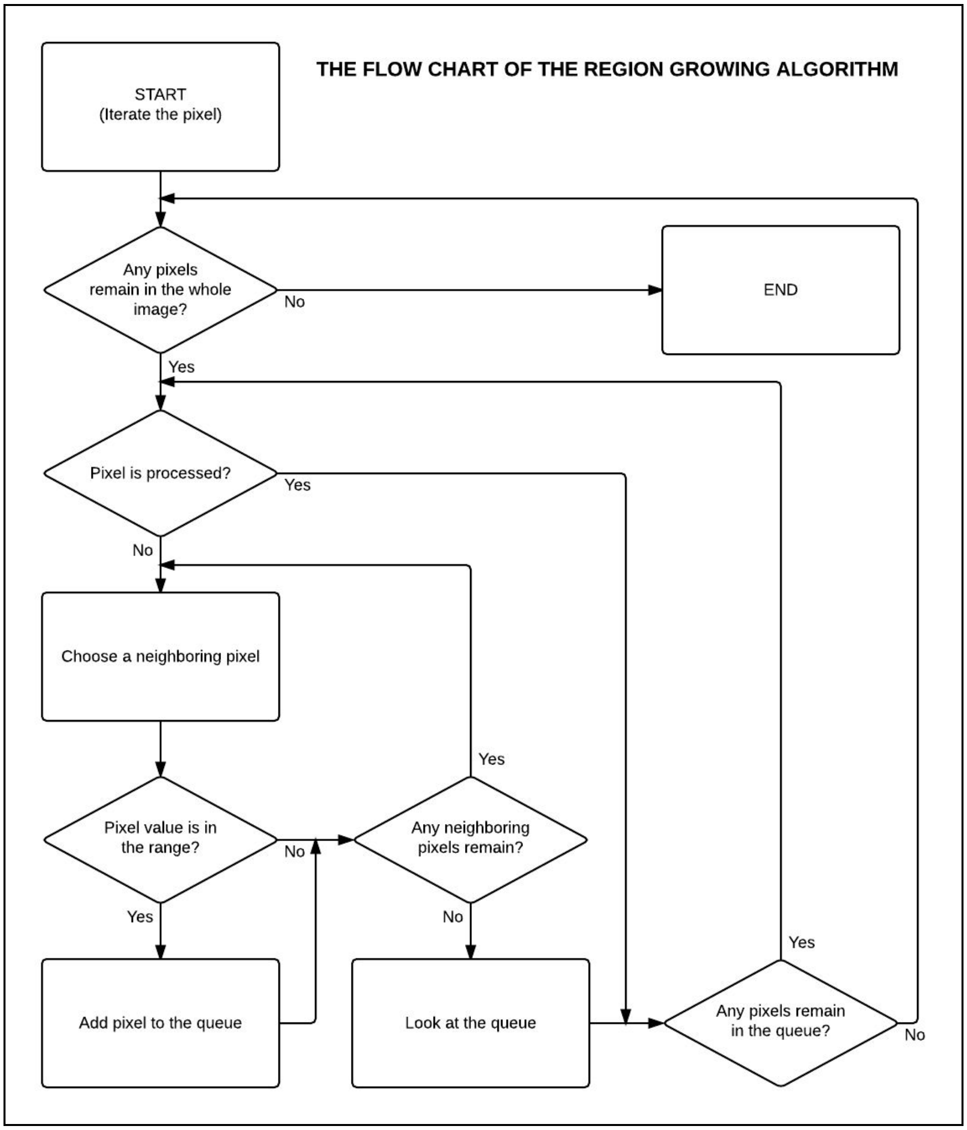
2.Region Split and Merge

b1) Region Growing Algorithm

- Region growing is a pixel-based image segmentation process.
- Goal is to map individual pixel to a set of pixels called regions based on the characteristics of the image.
- Algorithm starts with selecting the initial seed. Then it examines neighboring pixels of initial seed point and determines whether the pixel neighbors should be added to the region. The process is iterated on, in the same manner as general data clustering algorithms.
- Flowchart:

Fig.2 Region Growing Algorithm Flowchart

- Advantages:
  - Region growing methods can correctly separate the regions that have the same properties we define.
  - Region growing methods can provide the original images



which have clear edges with good segmentation results.

- The concept is simple. We only need a small number of seed points to represent the property we want, then grow the region.
- We can determine the seed points and the criteria we want to make.

    - We can choose the multiple criteria at the same time.
    - It performs well with respect to noise.
- Disadvantages:
    - The algorithm depends on the initial seed position.
    - This algorithm is also not invariant of number of seeds.
    - Threshold value plays a vital role, since if the threshold value is very small then the image would be undersegmented and if the threshold value is very large then the image would be oversegmented.
    - The result also depends on the chosen neighborhood pattern, whether 4-connected or 8-connected.

b2) Region Split and Merge

- In this technique, image is successively split into quadrants based on a homogeneity criterion and similar regions are merged to create the segmented result.
- The technique incorporates a quadtree data structure, meaning that there is a parent-child node relationship. The total region is a parent, and each of the four splits is a child.

- **Algorithm[6]**:
    - START: consider entire image as one region

      1. If region satisfies homogeneity criteria, leave it unmodified

      2. If not, split it into four quadrants and recursively apply 1 and 2 to each newly generated region and STOP when all

regions in the quadtree satisfy the homogeneity criterion.

3. If any two adjacent regions Ri , Rj can be merged into a homogeneous region, merge them.

- STOP: when no merging is possible any more.

c) Clustering Based Segmentation

Three techniques are used for segmentation:

c1) K-Means Clustering Algorithm

1. Specify the number of clusters K. (K = 2 here)
2. Initialize centroids by first shuffling the dataset and then randomly selecting K data points for the centroids without replacement.
3. Keep iterating until there is no change to the centroids. i.e assignment of data points to clusters isn't ever-changing.
   - ❖ Compute the sum of the squared distance between data points and all centroids.
   - ❖ Assign each data point to the nearest cluster (centroid).
   - ❖ Compute the centroids for the clusters by taking the average of the all data points that belong to each cluster [3].

c2) K-Medoids Clustering Algorithm

1. A medoid can be defined as the object of a cluster whose average dissimilarity to all the objects in the cluster is minimal, that is, it is the most centrally located point in the cluster.

2. In contrast to the k-means algorithm, k-medoids chooses data points as centers (medoids or exemplars) and can be used with arbitrary distances, while in k-means the centre of a cluster is not

necessarily one of the input data points (it is the average between the points in the cluster).

3. The PAM method (Partitioning around medoids) was proposed in 1987 [4] for the work with L1 norm and other distances. It is more robust to noise and outliers as compared to k-means because it minimizes a sum of pairwise dissimilarities instead of a sum of squared Euclidean distances.

c3) Fuzzy C-Means Clustering Algorithm [5]

The FCM aims to minimize an objective function:

$$\underset{C}{\arg\min} \sum_{i=1}^{n} \sum_{j=1}^{c} w_{ij}^{m} \left\| \mathbf{x}_i - \mathbf{c}_j \right\|^2,$$

where:

$$w_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\left\| \mathbf{x}_i - \mathbf{c}_j \right\|}{\left\| \mathbf{x}_i - \mathbf{c}_k \right\|} \right)^{\frac{2}{m-1}}}.$$

Fig 3. Cost Function

$$c_k = \frac{\sum_x w_k(x)^m x}{\sum_x w_k(x)^m},$$

Fig 4. Cluster Updation

1. Fuzzy clustering (also referred to as soft clustering or soft k-means) is a form of clustering in which each data point can belong to more

than one cluster.

2. The fuzzy c-means algorithm is very similar to the k-means
3. Algorithm:

    a. Choose a number of clusters.

    b. Assign coefficients randomly to each data point for being in the clusters.

    c. Repeat until the algorithm has converged (that is, the coefficients' change between two iterations is no more than eps, the given sensitivity threshold) :

    d. Compute the centroid for each cluster (shown below).

    e. For each data point, compute its coefficients of being in the clusters.

4. Evaluation Metrics

1. Precision
2. Recall
3. F1 Score = Harmonic Mean of Precision and Recall
4. IoU Score = Intersection over Union =TP /(TP + FN + FP)
5. 00 = TN, 01 = FP, 10 = FN, 11 = TP (ground_truth, result)

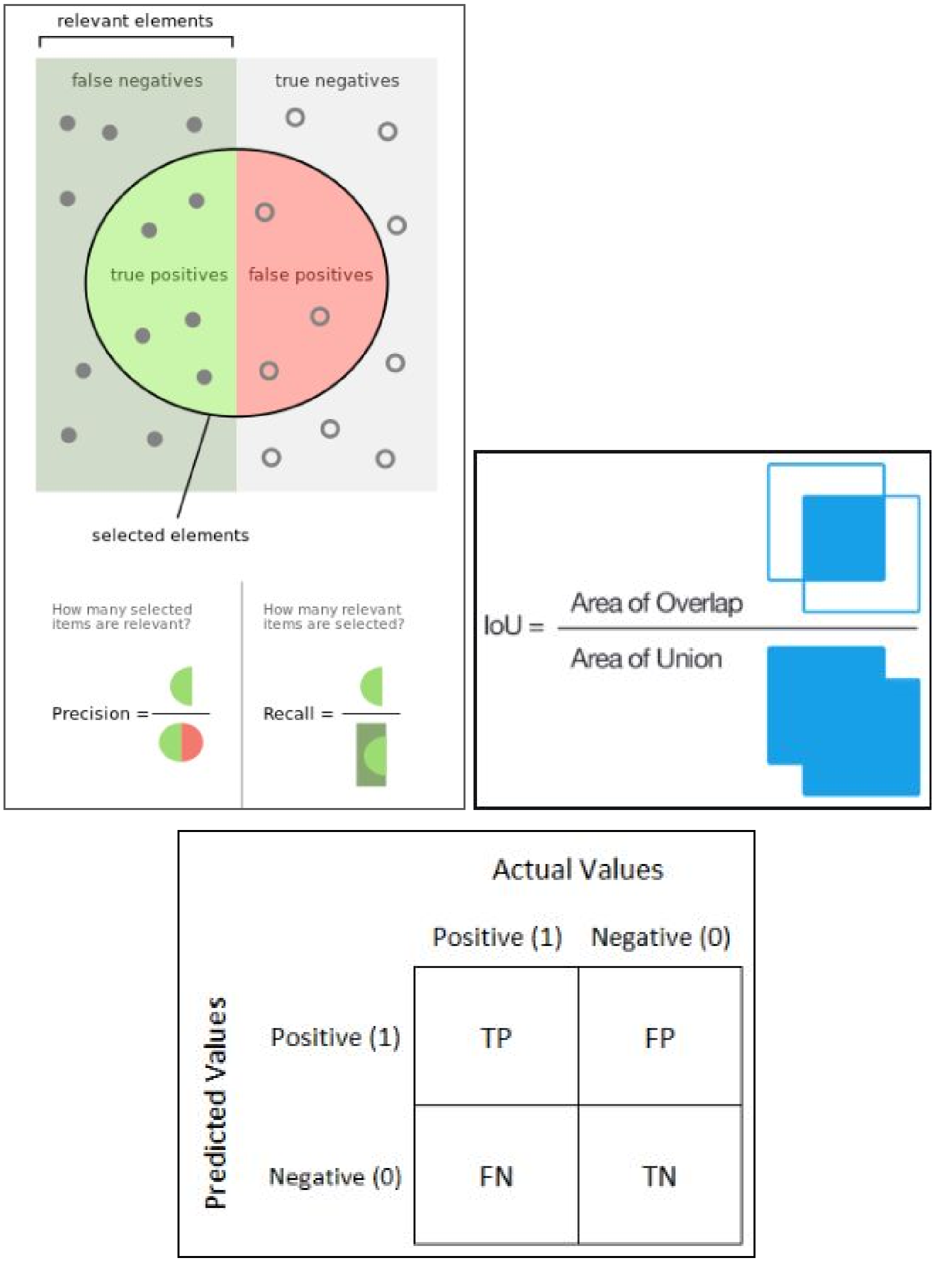


Fig 5. Confusion Matrix and Intersection Over Union

(References: https://creativecommons.org/licenses/by-sa/4.0/
https://www.pyimagesearch.com/2016/11/07/intersection-over-union-iou-for-object-detection/

5. Results

a) Edge Detection Based Segmentation

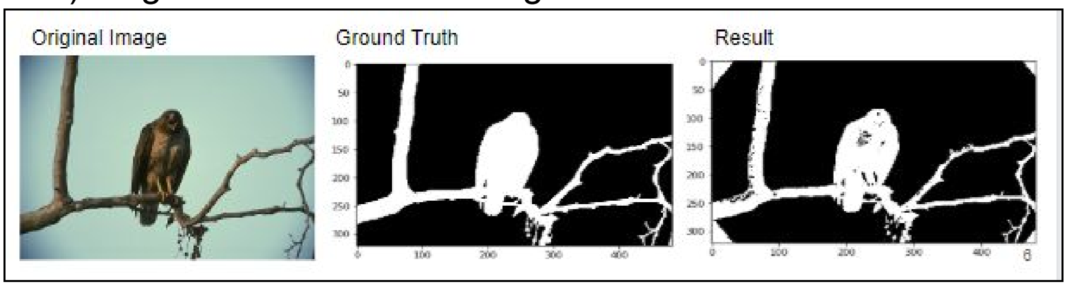


Fig 6.

b) Region Based Segmentation

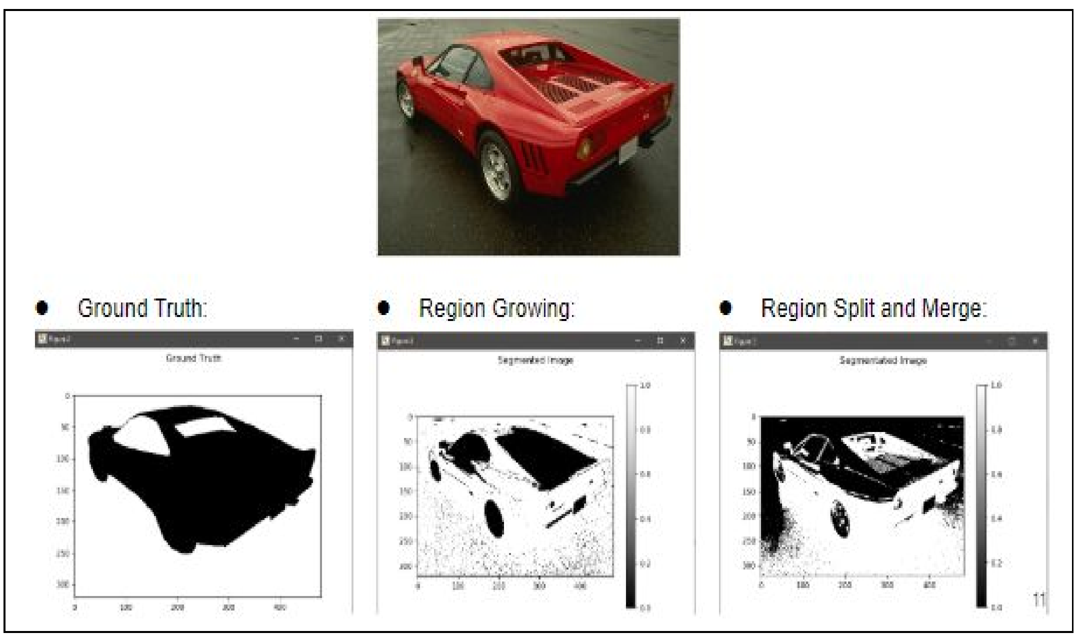


Fig. 7

c) Clustering Based Segmentation

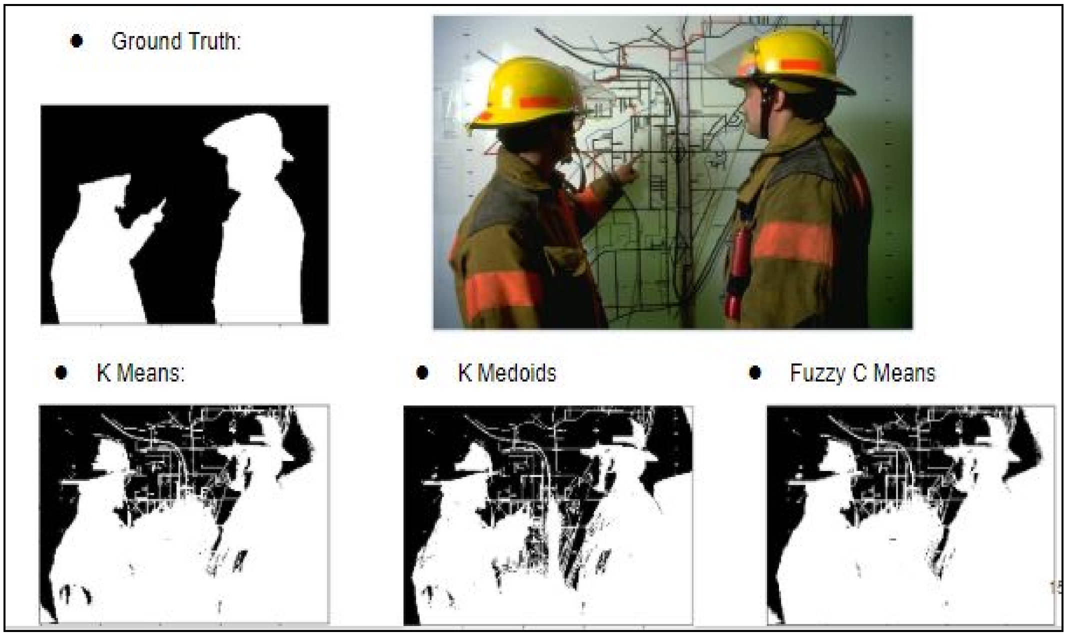


Fig 8

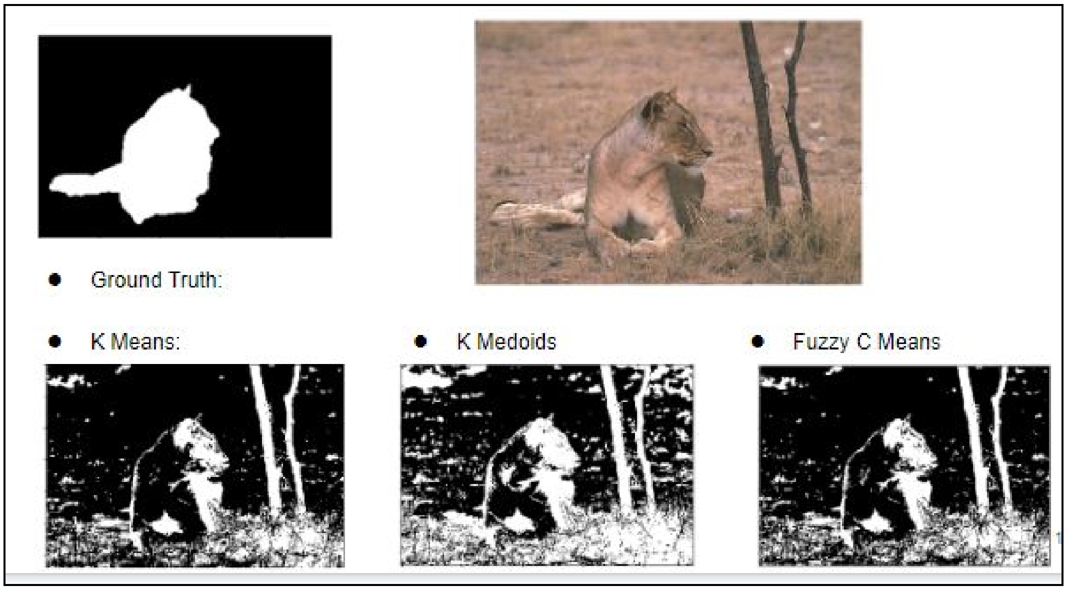


Fig 9

● Results (Average over 50 images)

Algorithms	Region S & M	Region Growing	Edge Based	K-Means	K-Medoids	Fuzzy C-Means
Precision	**0.82**	0.77	0.67	0.78	0.70	0.67
Recall	0.64	0.69	**0.80**	0.49	0.24	0.51
F1 Score	**0.70**	0.65	**0.70**	0.52	0.33	0.52
IoU Score	0.56	0.55	**0.57**	0.39	0.22	0.38

● Precision histograms of respective techniques

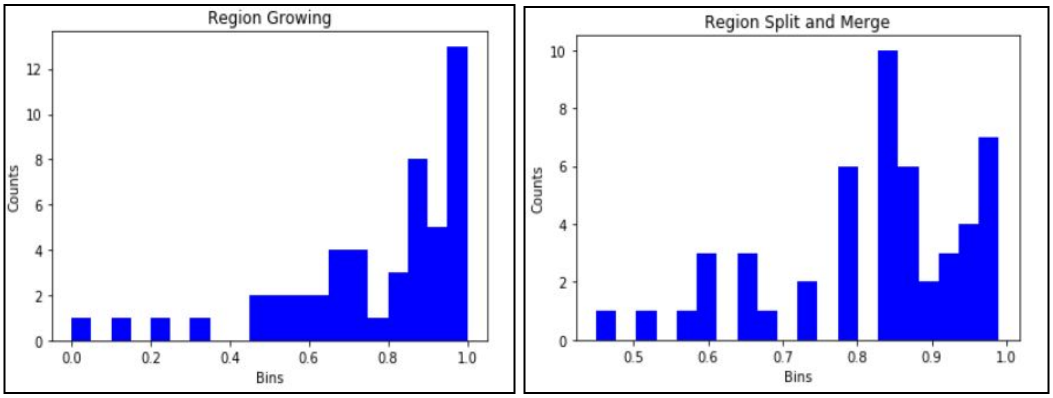


Fig 10

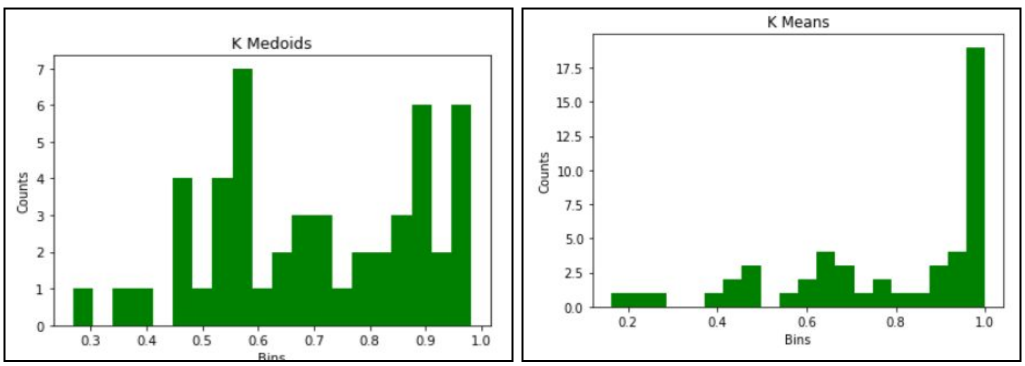


Fig 11

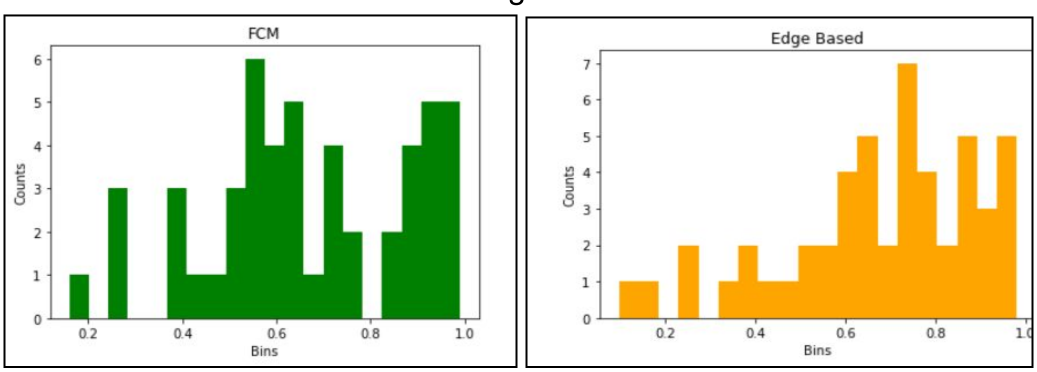


Fig 12

- **Recall histograms of respective techniques**

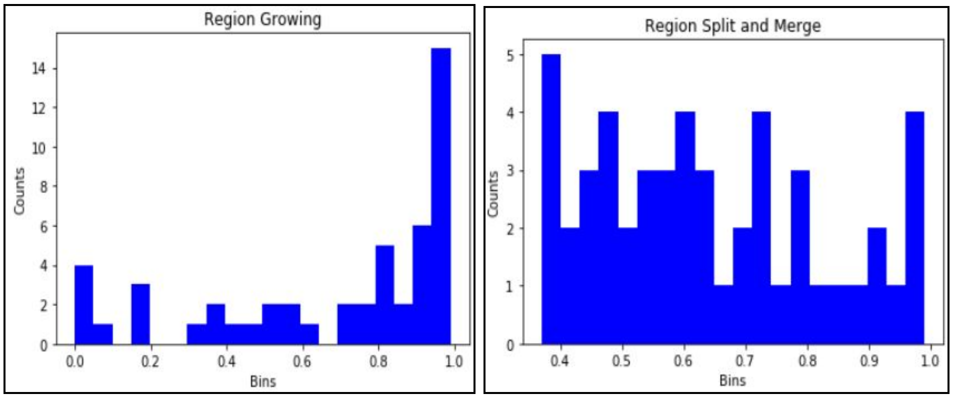


Fig 13

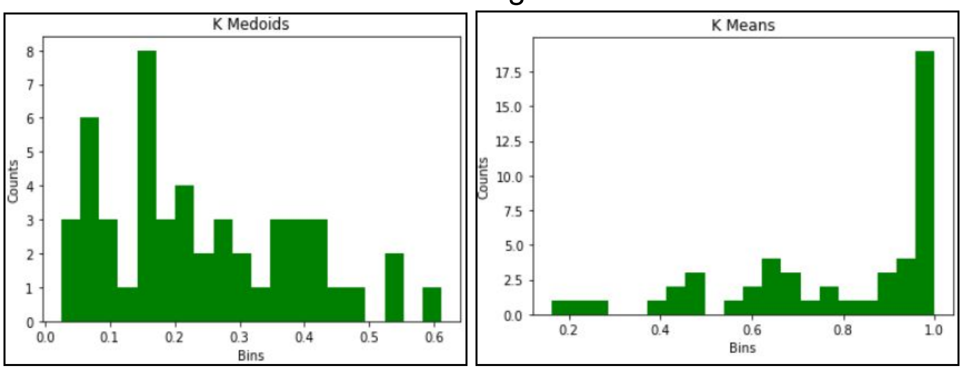


Fig 14

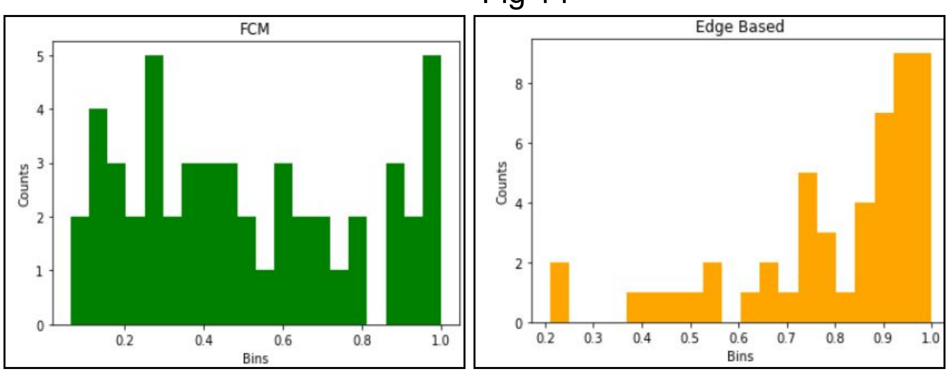


Fig 15

- **F1 Scores**

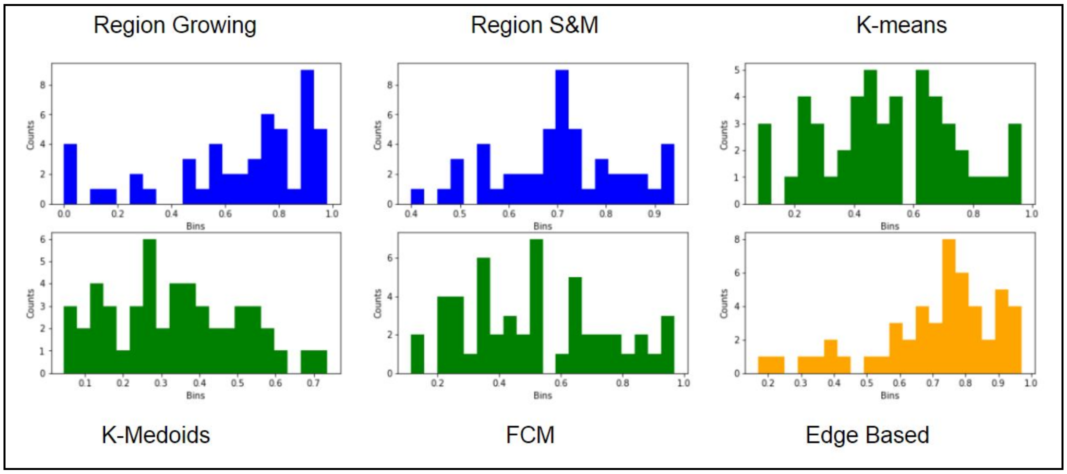


Fig 16

- **IoU Scores**

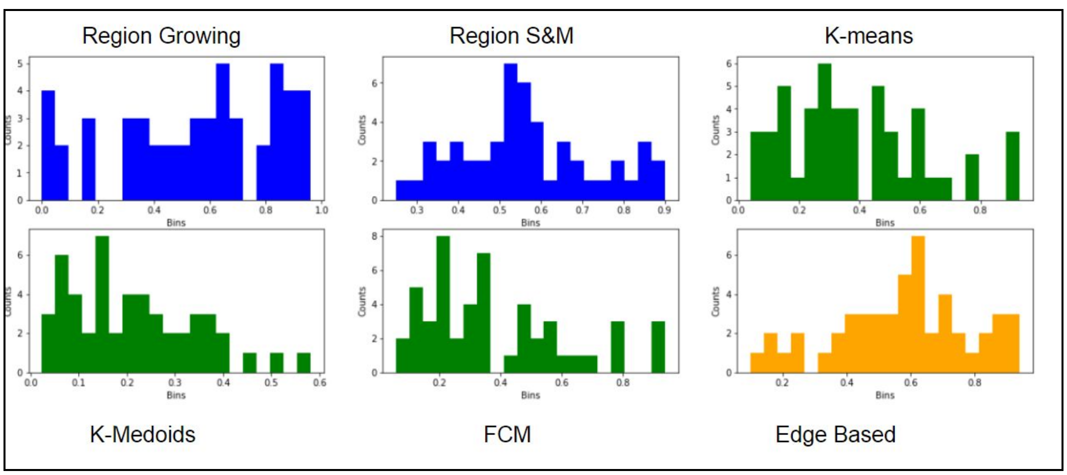


Fig 17

6. Conclusion

- Region Split and Merge and Canny Edge Detection Based Segmentation techniques gives better results among all other techniques.

- Region growing algorithm depends on initial seed position and threshold value.
- In Clustering techniques, Fuzzy C-Means gives average accuracy of 64% which is better than that of K-Means (58%) and K-Medoids (21.45%)
- Metrics like Precision and Recall use pixel by pixel comparison of ground truth and segmented image. Other metrics can be used which compare regions having different weights may prove better.
- For binary image segmentation, Edge based and Region based are better as having F1 scores as 70% and also IoU scores as 0.57.

7. References

[1] Hui Li, Jianfei Cai, Thi Nhat Anh Nguyen, Jianmin Zheng. A BENCHMARK FOR SEMANTIC IMAGE SEGMENTATION. IEEE ICME 2013.

[2]https://en.wikipedia.org/wiki/Image_segmentation

[3]https://towardsdatascience.com/understanding-k-means-clustering-in-machine-learning-6a6e67336aa1

[4] Kaufman, L. and Rousseeuw, P.J. (1987), Clustering by means of Medoids, in Statistical Data Analysis Based on the L1–Norm and Related Methods, edited by Y. Dodge, North-Holland, 405–416.

[5] M. C. J. Christ and R. M. S. Parvathi, "Fuzzy c-means algorithm for medical image segmentation," 2011 3rd International Conference on Electronics Computer Technology, Kanyakumari, 2011, pp. 33-36.

[6]https://www.ece.uvic.ca/~aalbu/computer%20vision%202010/L16.%20S

egmentation-region-based.pdf

[7] GitHub Link : https://github.com/rajatgupta1234/CV_IT524_Project