University of Girona

Spain

Scene Segmentation and Interpretation

Lab 1 - Image Segmentation

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1 Introduction

Image segmentation is an important process in computer vision that is used for several operations as edge detection, classification, 3D reconstruction, etc. The main goal of image segmentation is to cluster pixels into regions. This clustering image pixels into image regions in turns convert the image into a representation that is more meaningful and easier to analyze. 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 characteristics. Image segmentation has broad range of applicability in different fields of science and engineering. In this lab work, we implement the region growing algorithm which is one of the basic process of partitioning a digital image and then analyze the design and implementation of it. Finally, we compare the region growing algorithm with other image segmentation algorithms. We describe also about the organization and development phase of the lab work.

2 Problem Statement

The task is to implement region growing on given set of grey-level and color images. Segmentation is done sequentially, each time examining neighboring pixels of a region, that starts growing from "seed" points. Those neighbours that are satisfying criteria of similarity are added to the region, leaving their own neighbours in the queue for further examination. Neighborhood is defined as 8- neighborhood or 4-neighbourhood, depending on connection type. By this way, region growing satisfies another principle of region-based segmentation - connectivity. In each case, the segmentation results should strongly be determined by a tuning parameter which defines aggregation criteria threshold. At the end we compare our clustering result with Fuzzy C-Means (FCM) clustering algorithm.

3 Algorithm Analysis

Region growing is a pixel-based image segmentation process. Region growing works with a goal to map individual pixel to a set of pixels, based on the characteristics of the image. This set of pixels are called regions which can be an object or anything meaningful. The approach to region growing algorithm starts with selecting the initial seed. Then it examines neighboring pixels of initial seed points and determines whether the pixel neighbours should be added to the region. The process is iterated on, in the same manner as general data clustering algorithms. A general discussion of the region growing algorithm is described below.

- Choose a starting single pixel or seed. Give the seed a region
- Check the neighboring pixels considering neighborhood connectivity and add them to the queue if they have not been processed before
- Add the pixels to the region if they are like the seed pixel

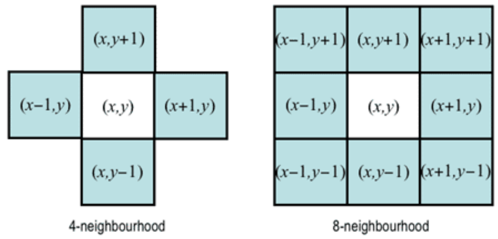

Figure 1: 4 point and 8 point connectivity pixel neighbourhood

- Change the seed position from the queue following right-hand rule and considering neighboring connectivity
- The step 2 continues for each new seed until there is no new pixel to become seed
- The region R_i and R_j are different in the sense of predicate P

We start the iteration from the top-left corner of the image and look at its 8 neighbours. For each neighbours, we check the following condition:

$$|f(x,y) - \mu_{R_i}| < \Delta$$

where $f(x,y)$ represents the current pixel intensity at (x,y) , μ_{R_i} represents the mean value of the pixels in the same region and Δ represents the threshold value that is taken from the user.

If the previous condition is met then we add the current neighbor to the queue. Then, we need to calculate the new μ_{R_i} value. After checking all the neighbours of the current pixel, we mark it as a processed pixel. We check our queue sequentially for each pixel value in the queue and we continue it until the queue is empty. It means that we reach at the border for the current region. After that we increase the region counter and continue to traverse the image matrix until there are no further processed pixels.

Example for 4 point connectivity

Assume that we have initial R_counter = 1, P_queue = {}, $\mu_{R_i} = 0$ values and an image matrix as follows:

$$M_{image} = \begin{bmatrix} 202 & 201 & 202 & 102 & 104 \\ 200 & 201 & 205 & 102 & 101 \\ 204 & 102 & 106 & 101 & 102 \\ 103 & 101 & 103 & 54 & 50 \\ 12 & 13 & 11 & 52 & 53 \end{bmatrix}$$

Let, our initial seed is the first pixel of this image. So, we start from the top-left corner of the image matrix to iterate. First, we look at the pixel (1, 1) whether it is processed before or not. Since it is the initial seed, it is not processed before. Then we set the new μ_{R_i} value taking account the current pixel and look at its neigbors (1, 2), (2, 1). For each neighbor, if the condition ($|f(x, y) - \mu_{R_i}| < \triangle$) is satisfied then we put the related neighbor pixel value to the queue. After traversing all it's neighbour pixels we set the current pixel as processed pixel.

$$M_{region} = \begin{bmatrix} [C]1 & -1 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\mu_{R_i} = 0, R_{counter} = 1, P_{queue} = \{Pixel_{(1,2)}, Pixel_{(2,1)}\}$$

$$M_{region} = \begin{bmatrix} 1 & [C]1 & -1 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\mu_{R_i} = 0, R_{counter} = 2, P_{queue} = \{Pixel_{(1,3)}, Pixel_{(2,2)}\}$$

Then we traverse the queue. For each element in the queue, we apply the same procedure as above. We look at the first pixel (1, 2) in the queue.

After traversing the whole image pixels we get the label image. This is the label matrix for our example.

$$M_{region} = \begin{bmatrix} 1 & 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 2 & 2 \\ 1 & 1 & 2 & 2 & 2 \\ 2 & 2 & 2 & 4 & 4 \\ 3 & 3 & 3 & 4 & 4 \end{bmatrix}$$

Segmented matrix for our example. It has 4 regions. We put 4 different intensity values to show the segmented matrix.

$$M_{\mu_{mean}} = \begin{bmatrix} 202 & 202 & 202 & 102 & 102 \\ 202 & 202 & 202 & 102 & 102 \\ 202 & 102 & 102 & 102 & 102 \\ 102 & 102 & 102 & 52 & 52 \\ 12 & 12 & 12 & 52 & 52 \end{bmatrix}$$

Similar approach is used for 8-point connectivity neighborhood, except this time in addition to 4 neighbours, skew direction neighbours are also considered. Recursive implementation has some disadvantages due to the maximum number of recursive calls allowed.

Therefore, the algorithm has been implemented in a sequential way and the segmentation labeling was performed over gray level and color images.

The flow chart of our region growing algorithm is shown below in Fig. 2

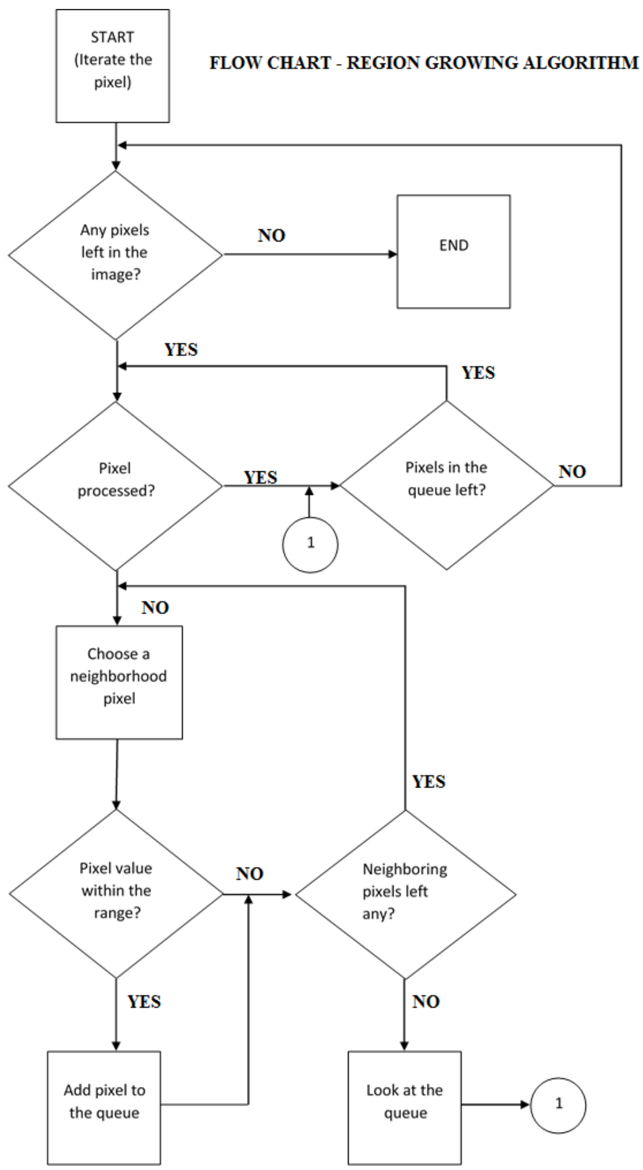

Figure 2: Flowchart - Region Growing Algorithm

Segmentation of color images

For segmentating RGB color space image's we must follow some extra steps.

- RGB color space images have 3 layers. At first we will extract the 3 different layers

- For each layer, compute the mean value of each pixel and then using the Euclidean distance formula, compute the mean value for the image.
- The Euclidean distance between two points $P = (x, y, z)$ and $Q = (a, b, c)$ in space is defined as

$$d(P,Q) = \sqrt{(x-a)^2 + (y-b)^2 + (z-c)^2}$$

- Perform Region growing algorithm over the image matrix to get the label image
- Convert the label matrix to a RGB image using *label2rgb(L)* function

Fuzzy C-Means clustering methods

The FCM algorithm is one of the most widely used fuzzy clustering algorithms. The FCM algorithm attempts to partition a finite collection of elements $X =$, , ..., into a collection of c fuzzy clusters with respect to some given criterion. Given, a finite set of data, the algorithm returns a list of c cluster centers V, such that

$$V = v_i, i = 1, 2, \ldots\ldots, c$$

And a partition matrix U such that

$$U = u_{i,j}, i = 1, 2, \ldots\ldots, c, j = 1, 2, \ldots\ldots., n$$

where $u_{i,j}$ is a numerical value in $[0, 1]$ that tells the degree to which the element x_j belongs to the i^{th} cluster.[4]

4 Design and Implementation

In this section, we discuss about the design and the implementation phase of the lab work. The algorithm was implemented in a sequential way because of the maximum number of recursive calls. We approached to our design and implementation phase by following few step.

4.1 Segmentation using Region Growing Algorithm

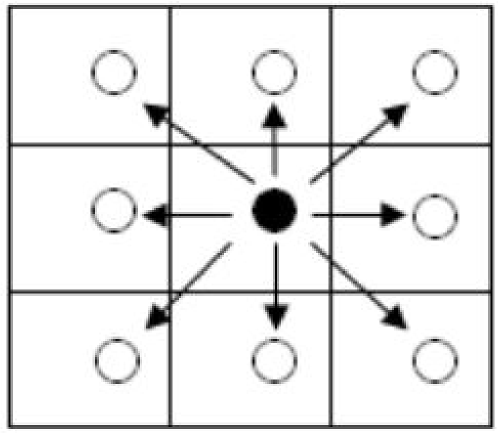

Figure 3: The 8 surrounding neighbours growth

First, we start in a seed. We find the 8 - connectivity neighbours of the seed and put it in a queue. We will check the first neighbor in the queue and compute the criteria wanted (choice between several criteria presented in the part of the algorithm analysis). If the neighbor respects the criteria, it will belong to the queue and we will update the statistical parameters. If not, we will ignore this neighbor and marked like view. We will check the queue until this one will be empty. When the queue is empty, we search a new seed, which is the first pixel on the image that it is not labelled and start a new region.

4.2 Improvements

Very often the region growing algorithm generates too many segments (over-segmentation). Region growing algorithm has some disadvantages as it is prone to salt and pepper noise. It is possible to limit several segments by different additional pre-processing and post-processing procedures. Good example for pre-processing is the median filtering before image segmentation. This filtering procedure significantly decreases the number of regions in segmented image. To overcome this constraint of Region growing, we applied 9×9 median filter. This filter reduced the salt and pepper noise and produced better result with accuracy.

4.3 Comparing our results with Fuzzy C-Means clustering algorithm

To evaluate the performance of our Region growing algorithm we compared our result with the clustering result of Fuzzy C-Means clustering algorithm. Fuzzy C-Means clustering algorithm is a clustering algorithm that divides data into homogeneous classes to keep similar data in the same region and dissimilar data into different classes.

5 Experimental Results

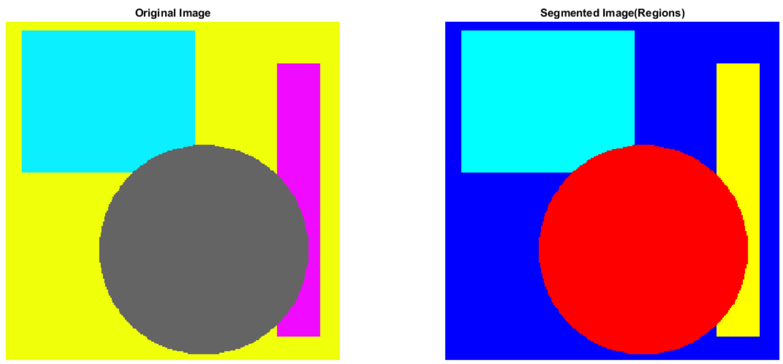

Figure 4: Threshold = 80, 4 segments

After running the algorithm, we get four images. First one represents the original image, and the second image was created by *label2rgb(L)* function and converted a label matrix, L, into the RGB color image for the purpose of visualizing the labeled regions. Third one represents the filtered image after applying 9×9 median filter, and fourth image shows the segmented regions result after filtering.

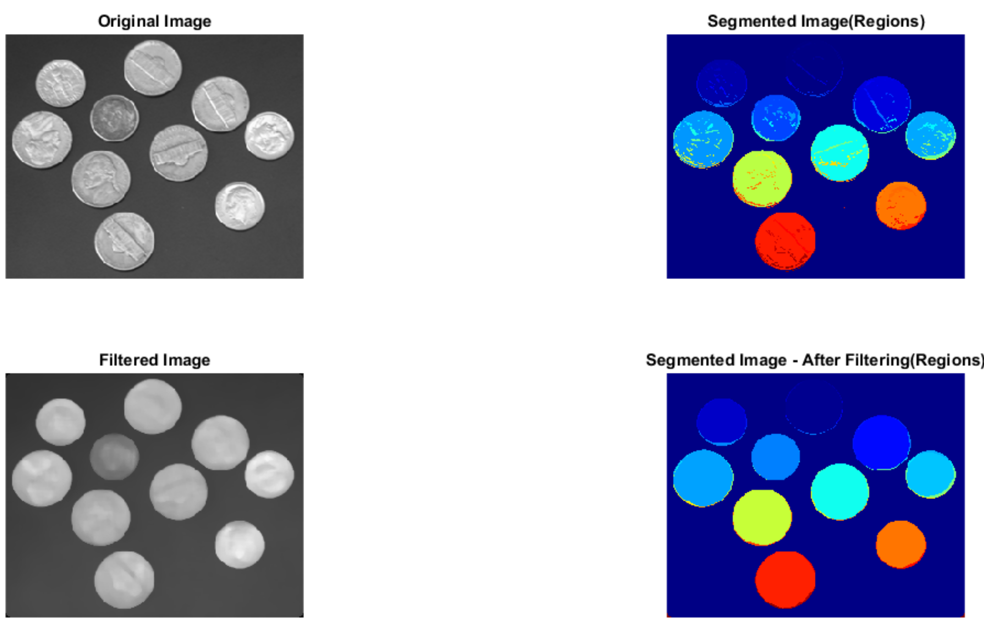

Figure 5: Median Filter with 9x9 kernel with threshold =30, 844 segments, after filtering: 382 segments

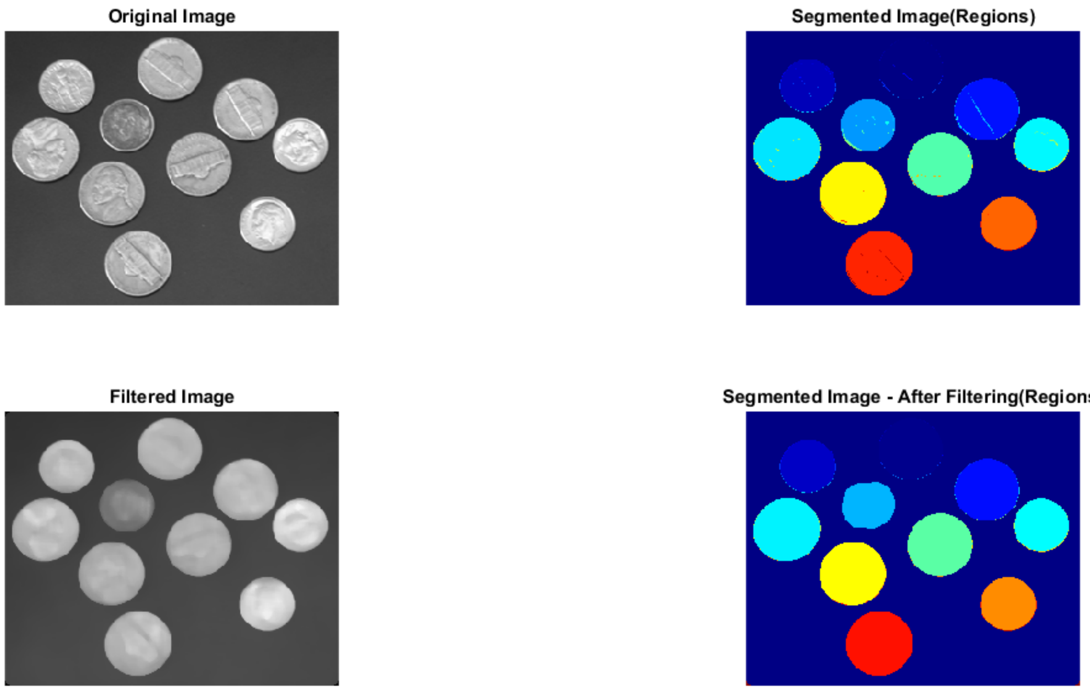

Figure 6: Median Filter with 9x9 kernel with threshold =50, 314 segments, after filtering: 246 segments

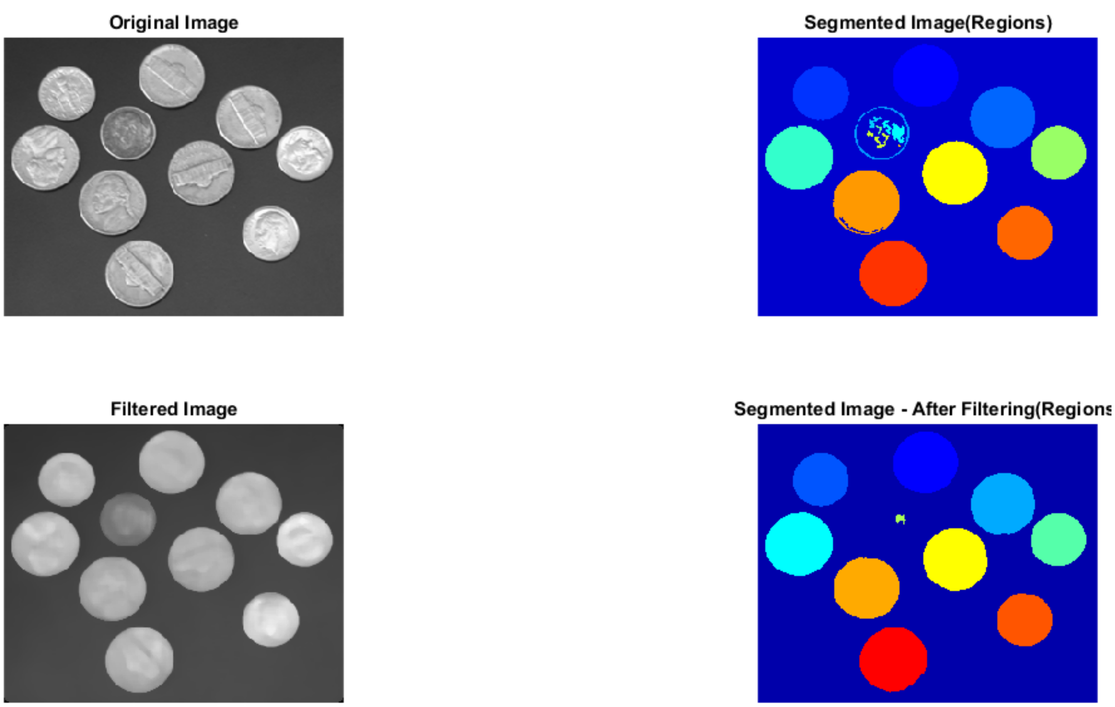

Figure 7: Median Filter with 9x9 kernel with threshold =80, 17 segments, after filtering: 11 segments

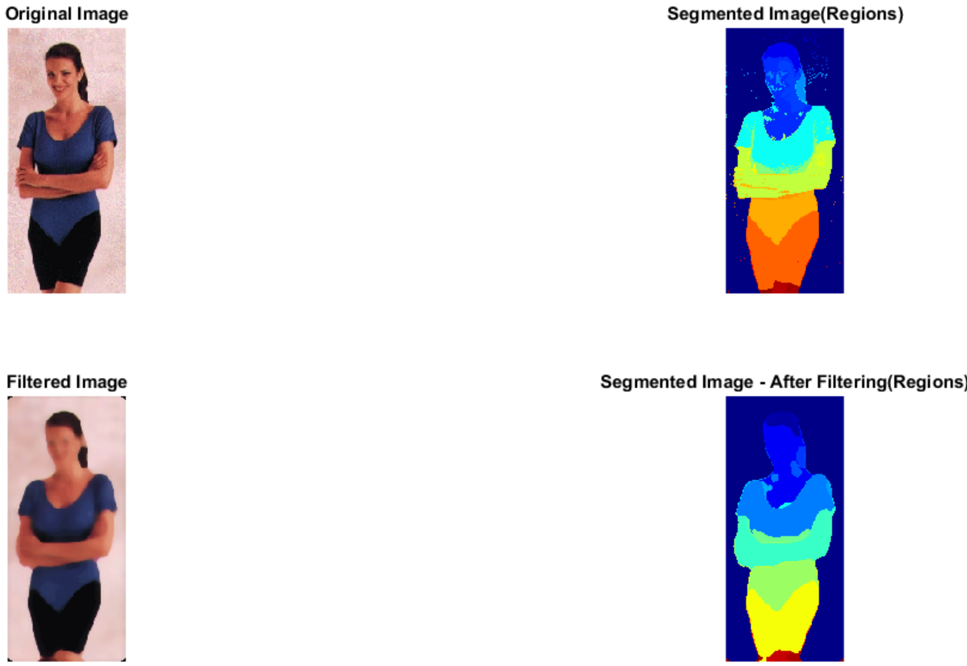

Figure 8: Median Filter with 9x9 kernel with threshold =50, 534 segments, after filtering: 256 segments

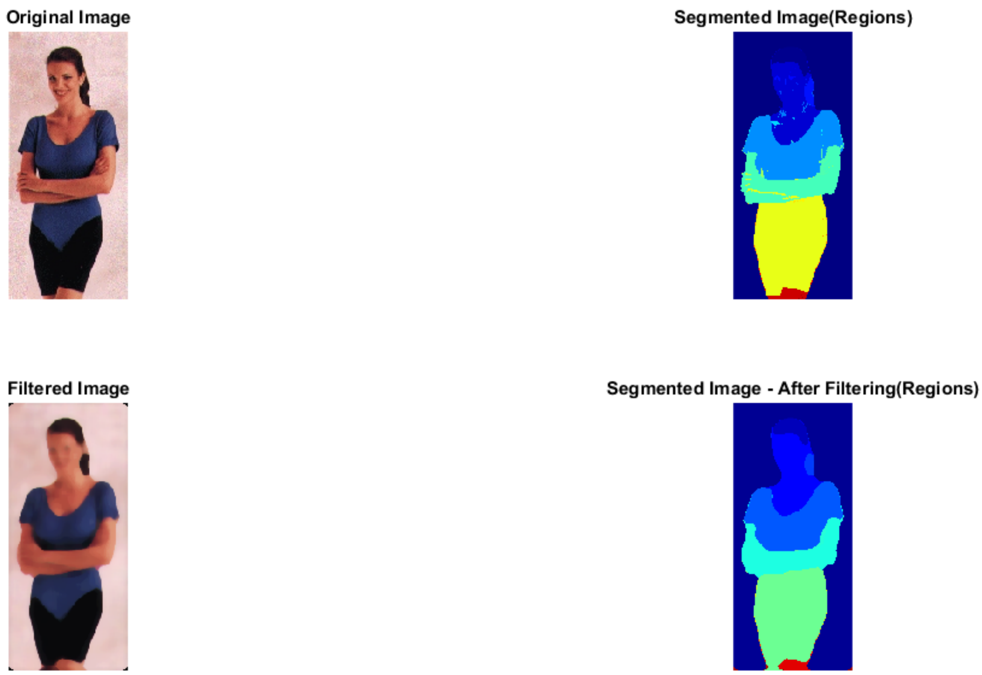

Figure 9: Median Filter with 9x9 kernel with threshold =80, 178 segments, after filtering: 104 segments

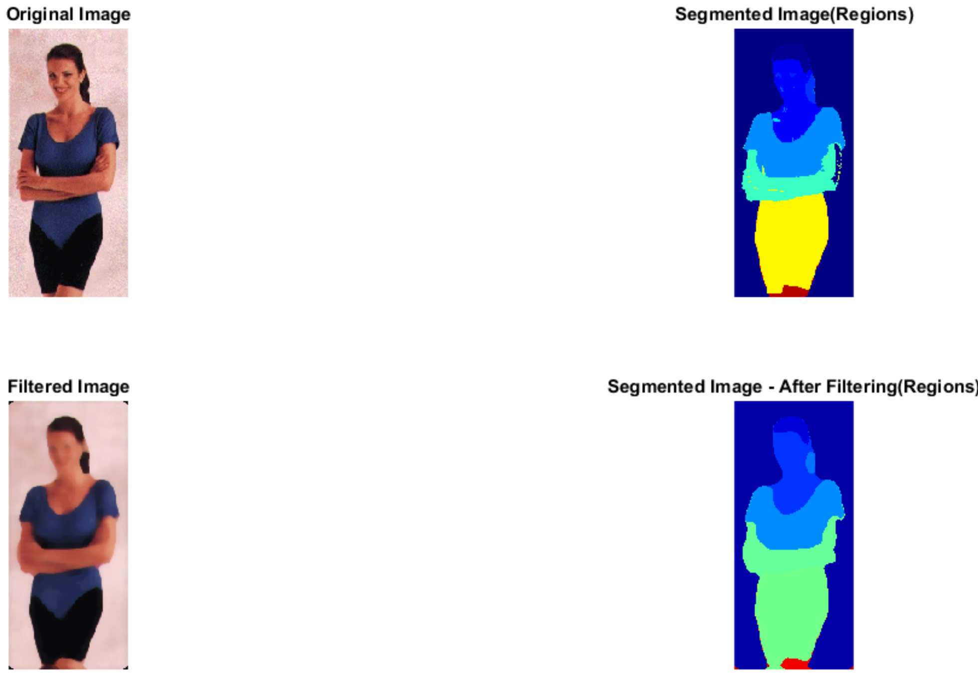

Figure 10: Median Filter with 9x9 kernel with threshold =90, 123 segments, after filtering: 77 segments

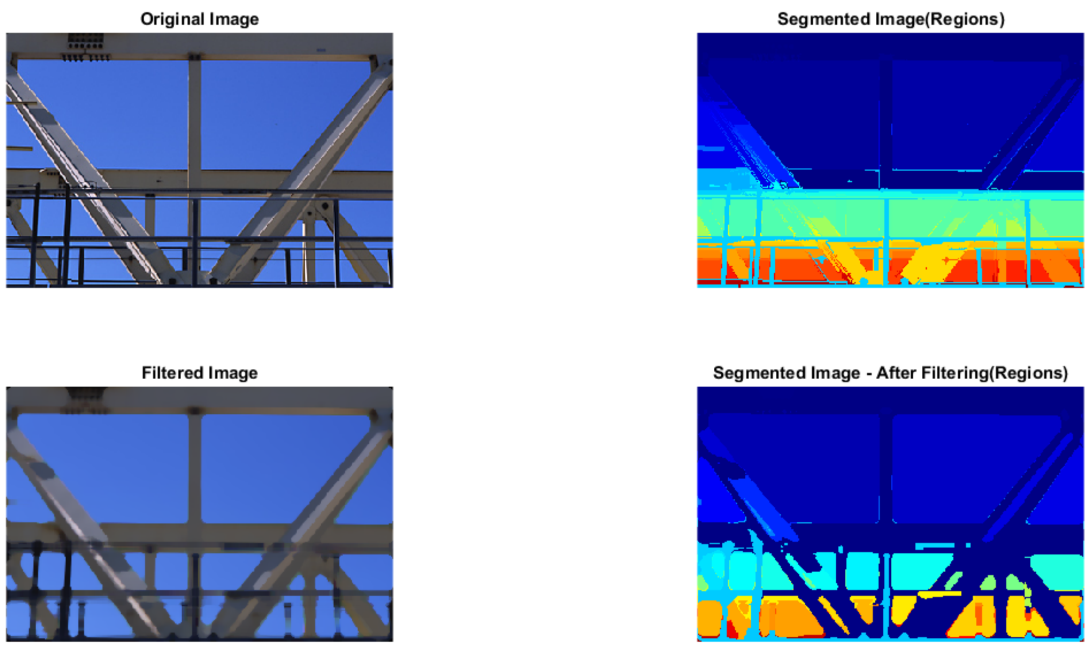

Figure 11: Median Filter with 9x9 kernel with threshold =50, 1406 segments, after filtering: 354 segments

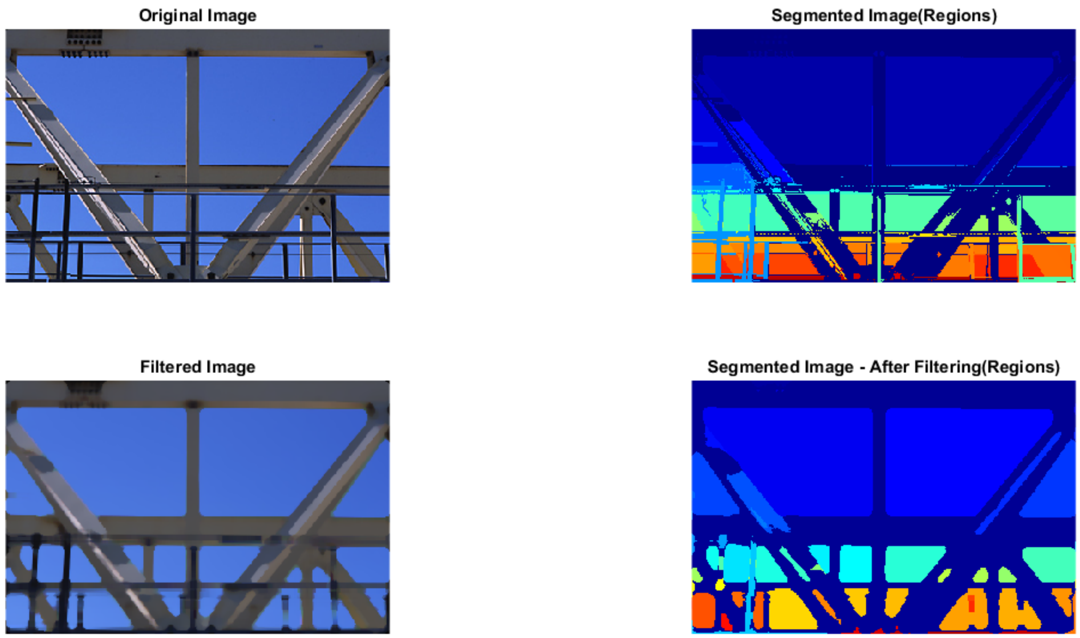

Figure 12: Median Filter with 9x9 kernel with threshold =80, 751 segments, after filtering: 74 segments

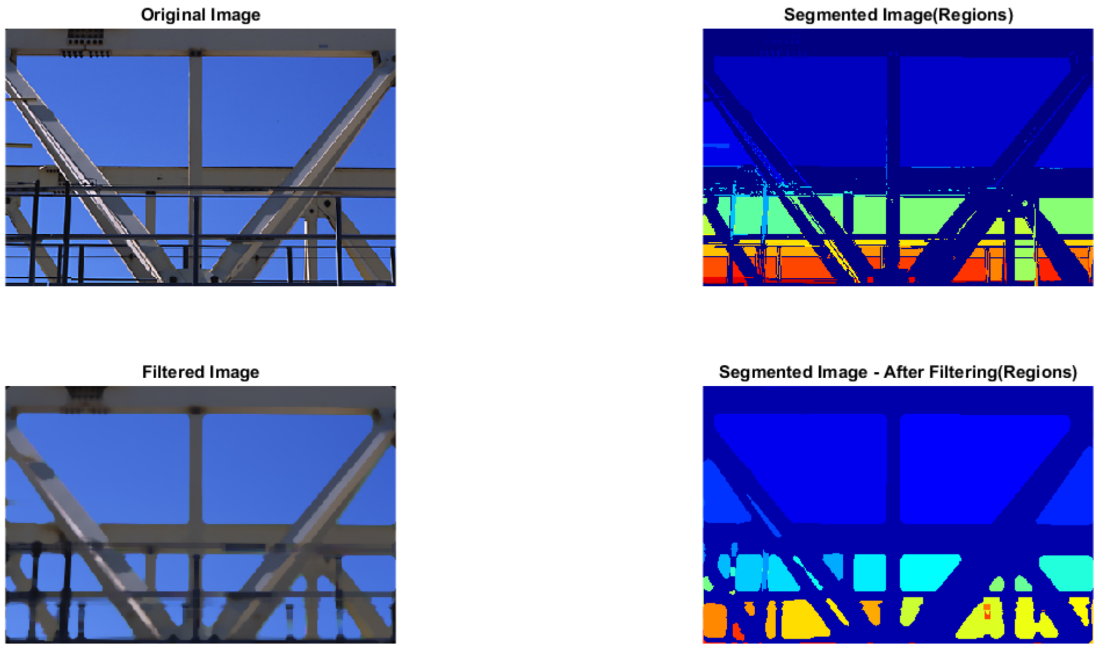

Figure 13: Median Filter with 9x9 kernel with threshold =100, 506 segments, after filtering: 57 segments

The comparison between our result and the clustering result from FCM algorithm

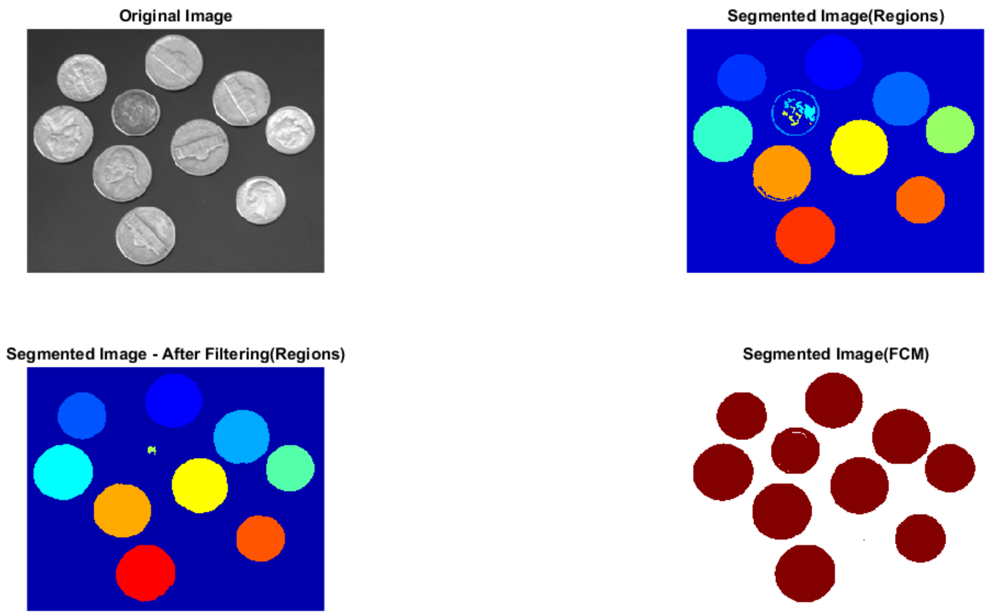

Figure 14: Comparison between the region growing algorithm(threshold = 80) and FCM (clusters =2)

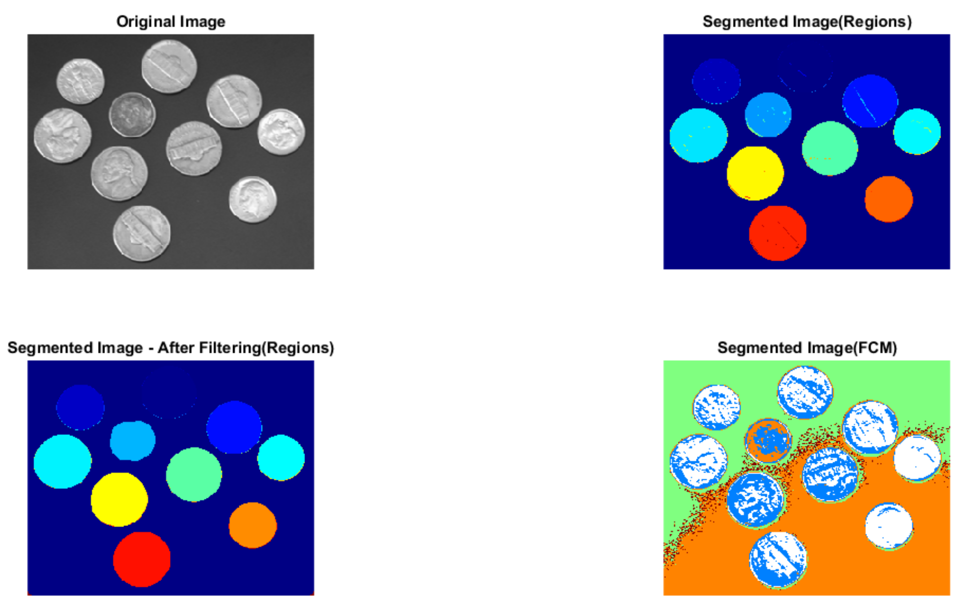

Figure 15: Comparison between the region growing algorithm(threshold = 50) and FCM (clusters =5)

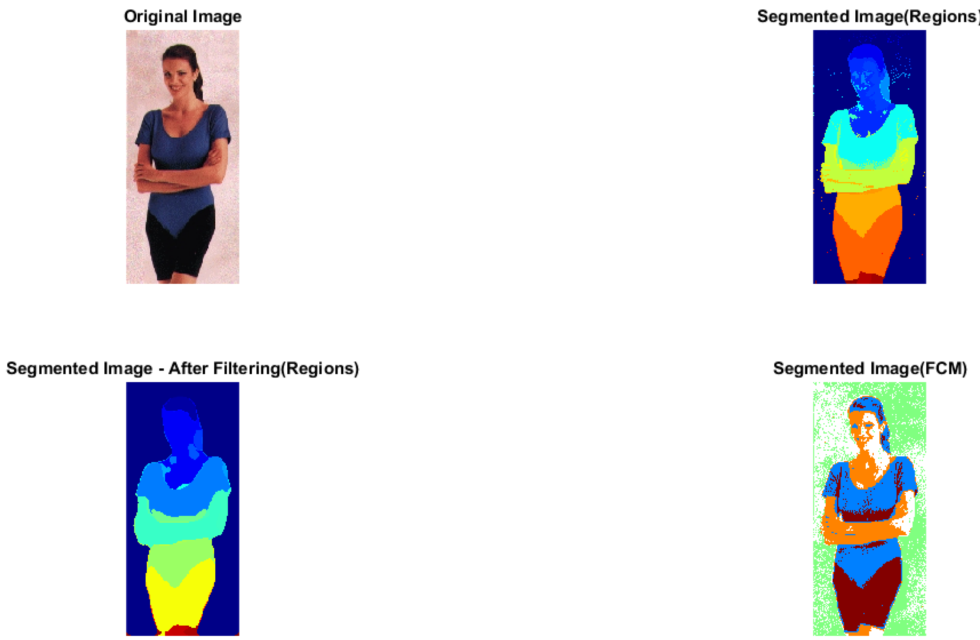

Figure 16: Comparison between the region growing algorithm(threshold = 50) and FCM (clusters =5)

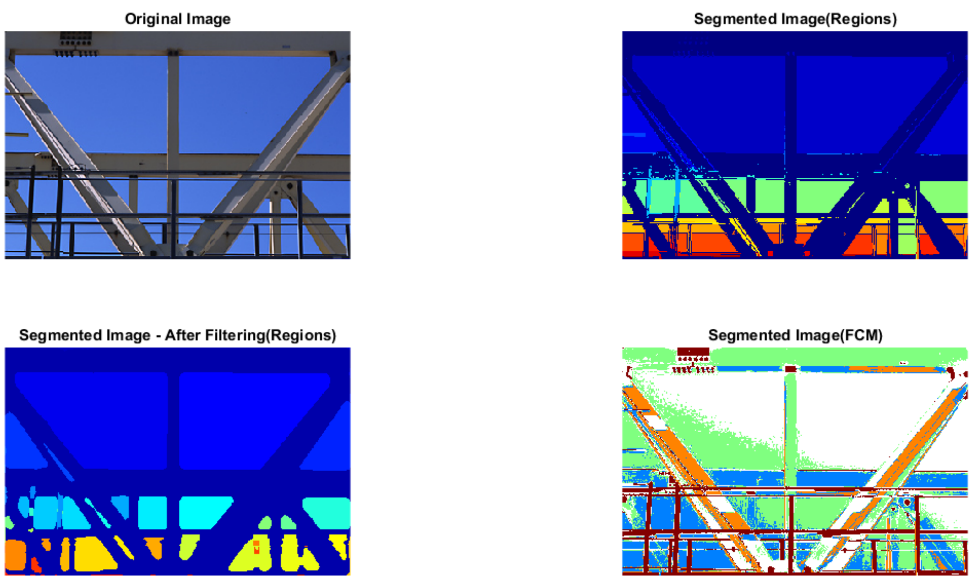

Figure 17: Comparison between the region growing algorithm(threshold = 100) and FCM (clusters =5)

5.1 Comparison Results

Image	coins	color	woman	gantrycrane
Threshold = 30	10.266	7.49	2.951	9.52
Threshold = 50	10.18	7.41	2.92	8.78
Threshold = 80	10.733	7.39	2.67	10.78
Threshold = 100	13.48	7.27	2.41	12.93

Table 1: Computational time for region based growing algorithm

Image	coins	color	woman	gantrycrane
Cluster = 2	1.99	3.50	0.763	2.44
Cluster = 3	2.13	3.52	1.11	5.47
Cluster = 4	2.21	2.799	1.66	9.25
Cluster = 5	2.25	3.51	4.51	9.50

Table 2: Computational time for FCM algorithm

Table 1 and Table 2 shows the computation time for both the methods. In case of region growing algorithm, the computation time does not vary much for different threshold values. The computation time for Fuzzy C means method has greater variation as the number of clusters increases.

Comparative study of these methods using some standard parameters such as: spatial information, region continuity, speed, computation complexity, automaticity, noise resistance, multiple object detection and accuracy is done. Table 3 presents analysis of both the methods.

Parameter	Region Growing Algorithm	Fuzzy C-Means Method
Spatial Information	Considered	Considered
Region Continuity	Good	Good
Speed	Slow	Moderate
Computation Complexity	Rapid	Moderate
Automaticity	Semiauto	Automatic
Noise Resistance	Less	Moderate
Multiple Object Detection	Fair	Fair
Accuracy	Fine	Moderate

Table 3: Region Growing vs FCM

6 Brief discussion regarding the algorithms

While we were working on the region growing algorithm we noticed some advantages and disadvantages of this algorithm

Region Growing Algorithm

- **Advantages**
  1. Region growing methods can correctly separate the regions that have the same properties we define
  2. Region growing methods can provide the original images which have clear edges with good segmentation results
  3. The concept is simple. We only need a small number of seed points to represent the property we want, then grow the region
  4. We can determine the seed points and the criteria we want to make. We can choose the multiple criteria at the same time
  5. It performs well with respect to noise

- **Disadvantages**
  1. The algorithm depends on the initial seed position
  2. This algorithm is also not invariant of number of seeds
  3. 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
  4. The result also depends on the chosen neighborhood pattern, whether 4-connected or 8-connected

We overcame some noise problems easily by using some mask to filter the holes or outliers. Therefore, the problem of noise actually did not exist. After all, it was obvious that the most serious problem of region growing was the power and time complexity.

Further Improvement scope

The region merging procedure as post processing procedure can be used to avoid over-segmentation or remove small highlights from objects. This procedure locates all regions smaller than a given area, analyses their 4- connected neighborhood or 8- connected neighborhood and merges each region with most similar region from its neighborhood

Fuzzy C-Means Method

- **Advantages**
  1. FCM is better than K-means.
  2. FCM is unsupervised and converge very well.
- **Disadvantages**
  1. Sensitive to noise.
  2. Computationally expensive.
  3. Determination of fuzzy membership is not easy.

7 Organization and development

In this section, we have presented the management process we followed to organize and develop a deliverable as required by the lab work. To accomplish the assigned task, we planned to organize our lab work. We arranged and synchronized our management process considering several criteria such as

1. Studying and analyzing the problem
2. Defining the approach
3. Coding the Region growing algorithm
4. Testing and comparing with FCM
5. Report writing

We had studied and analyzed the problem before the first lab and we implemented the region growing algorithm over gray level images in our first lab. Before the second lab, we had implemented the region growing algorithm over RGB color images. on the second lab day, we compared our result with the results from FCM (Fuzzy C-Means) clustering algorithm.

8 Conclusion

In summary, region growing algorithm is a good algorithm in terms of region continuity. But still it has some drawbacks as the algorithm depends on the initial seed position and also if the threshold value is very small then the image would be under segmented and if the threshold value is very large then the image would be over segmented. We can introduce Active region method to overcome some of the problems. We compared our result with FCM

(Fuzzy C-Means) clustering algorithm. Our algorithm gave fast result comparing to FCM while FCM provided more accurate clustering results. Result of image segmentation method is dependent on many factors such as intensity, texture, image content. Hence neither the single segmentation is applicable to all type of images nor do all the segmentation methods perform well for one particular image.

REFERENCES

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3. http://reference.wolfram.com/applications/fuzzylogic/Manual/12.html