Medical Imaging
Lab 3 : Segmentation

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April 9, 2017

1 Introduction

This lab work is an exercise on segmentation of the given data set of images. Ground truth form 3 experts was provided for each of the patients. The main goal of this lab experiment was to first combine the ground truth form the 3 experts into one, then test the provided segmentation algorithm and, lastly, implement a segmentation algorithm of choice while evaluating the algorithms at each step. All the work carried was divided into various steps that will be explained in the following with clear results.

2 Ground - Truth generation

The goal of this was to perform fusion of ground truth images from 3 experts by using any method of choice. After looking at major voting scheme method and the provided STAPLE algorithm, STAPLE algorithm was implemented to achieve this task. The provided implementation works on binary images and provides a single image with weights for each expert, and, the sensitivity, p, and the specificity, q, values for each expert. p and q are computed based on a confusion matrix for the final output image. A single ground truth can be selected from the obtained image by choosing different values of weight. The following images show the results obtained for a couple of images.

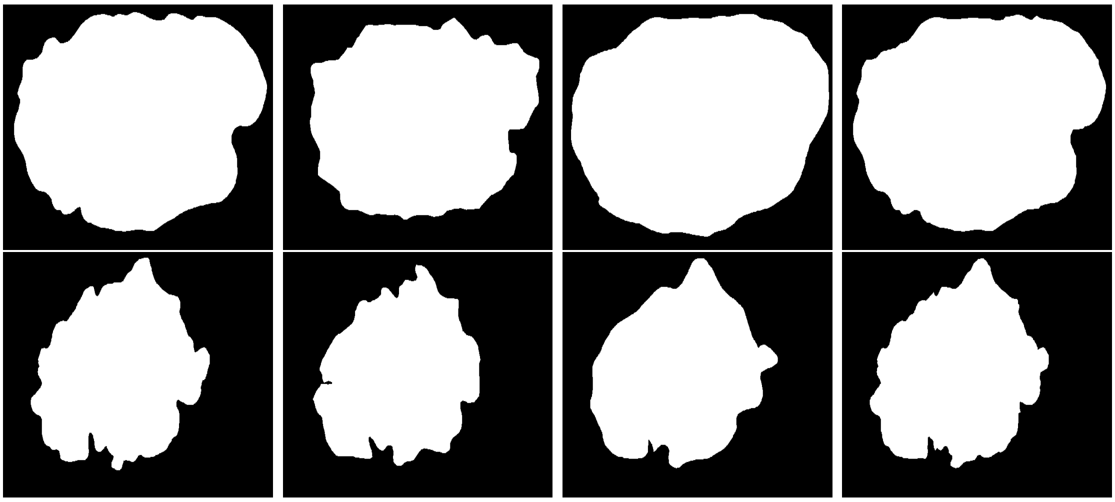

Figure 1: Each row from left: ground truth images from expert1, expert2, expert3 and fusion for $D134$ and $D503$ respectively.

3 Segmentation

3.1 PDF-Based Segmentation

The PDF-Based Segmentation technique was evaluated under this section. This technique works mainly on adaptive thresholding of the image. Firstly, the histogram of the image is plotted as a curve. Smoothing is applied over the curve to smooth the gradients of the image. The threshold for segmentation is computed using the local minima from the histogram curve. By looking at the provided code, one can note that the local minima are first obtained and the minimum values greater than a certain value are only considered for the selection of threshold. The vector containing the local minima is sorted in ascending order. The first minimum value in the sorted matrix is considered as the threshold for the image. Also, a default case is considered when no local minima can be located. The results and comparisons are clearly explained under the next section.

3.2 Level-Set Segmentation

The level-set algorithm was tested under this section. This algorithm also follows the principle of PDEs and surface curves. The basic idea is to represent the curves or surfaces as the zero level set of a higher dimensional hyper-surface. research suggests that this technique not only provides more accurate numerical implementations but also handles topological changes easily.

The boundary of the object in a two dimensional image would provide a three dimensional level-set function. With the curve as the boundary, the whole surface can be divided into an internal region and an external region of the curve. As, the code is not very well commented, the code for this particular method could not be understood easily. But on the whole, it can be understood that the program iterates over the level-set function based on a fixed number of iterations for the internal and external regions. Bias Field estimation has been used to generate the level-set surface. The curve generation could be compared with that of the snake algorithm, where the programs follows the boundaries of an object with a given speed until we obtain a closed surface. Also, the numerical solution of a level-set function requires sophisticated techniques. lastly, it can be noted that this method has high accuracy, while, involving higher computational cost. The results are further discussed in detail under the next section.

3.3 Fuzzy C-means Clustering

The Fuzzy C-means clustering is discussed under this section. This algorithm generates a pre-defined number of clusters based on similarities between certain features or parameters. A set of centroids, based on the given number of clusters, are generated all over the image. The generated centroid is compared with all the other pixels from the image and then added to that particular label if a given condition for similarity is satisfied. There are variations of this algorithm where, similarity can be checked only locally instead of globally, thus, reducing computational cost, or even limiting the size of each cluster, thus, increasing the accuracy. This method allows a given data point to be classified into more than one cluster. This algorithm also provides good results, that is explained under the next section. The provided implementation for this method uses the existing MATLAB function fcm, that executes fuzzy C-means clustering when provided with the necessary parameters. The provided code generates only 2 clusters i.e, either the lesion or not the lesion

4 Evaluation

This section discusses about the segmentation results by comparing them based on a few parameters, that can broadly be classified into $Dice's\ Coefficient\ Confusion\ Matrix\ Statistics$ and $hausdorff\ Distance$. The provided code compares all the images i.e, obtained segmentation results by using the above mentioned segmentation techniques, with the Ground-Truth images provided by each of the experts and also the computed fusion images. The comparison parameters can be described as follows: (Conventions: TP - True positive; FP - False positive; TN - True negative; FN - False negative)

- **Dice′s Coefficient** : This parameter describes the similarity between two images by the following formula;

$$DSC = \frac{2TP}{2TP + FP + FN}$$

- **Statistics** : The statistics of confusion matrix provide various information such as:
  - **Sensitivity** of a segmented image describes how much region is correctly located and can be given as follows:

    $$sensitivity = \frac{TP}{TP + FN}$$

  - **Specificity** of a segmented image describes how much region, not part of the lesion, has been correctly located and can be given as follows:

    $$specificity = \frac{TN}{TN + FP}$$

  - **precision** describes the accuracy (positive prediction value) of the algorithm and can be given as follows:

    $$precision = \frac{TP}{TP + FP}$$

  - **Negativepredictedvalue** is the complement of precision.
- **Housdorff Distance** : Gives the greatest of all the distances from a point in one set to the closest point in the other set i.e, center of segmented and the non-lesion area for our case.

The *main.m* file for evaluation, when executed, compares all the segmented images with each of the ground truth images on the basis of the above mentioned parameters. The following table provides a comparison of all the segmentation techniques for each of the fused (combined from all the three experts) ground truth images, based on the above mentioned parameters.

	D134			D322			D503		
Parameters	F	L	P	F	L	P	F	L	P
Dice Coeff	0.90	0.85	0.95	0.92	0.96	0.88	0.93	0.90	0.78
Sensitivity	0.82	0.74	0.93	0.86	0.95	0.79	0.88	0.83	0.64
Specificity	0.99	1.00	0.96	0.99	0.99	0.99	0.99	0.99	1.0
precision	0.99	1.00	0.97	0.99	0.98	0.99	0.99	0.99	1.0
NPV	0.76	0.69	0.90	0.96	0.98	0.94	0.94	0.92	0.83
Hausdorff	47.8	53.3	32.8	26.9	12.2	28.3	42.0	69.6	72.12

Table 1: Table showing the results compared with the Fused ground truth images

	D978			E976			G351		
Parameters	F	L	P	F	L	P	F	L	P
Dice Coeff	0.95	0.95	0.96	0.89	0.95	0.88	0.97	0.98	0.98
Sensitivity	0.96	0.92	0.98	0.81	0.93	0.80	0.97	0.96	0.96
Specificity	0.91	0.98	0.92	0.99	0.99	0.99	0.97	0.99	0.99
precision	0.94	0.99	0.95	0.98	0.98	0.99	0.97	0.99	0.99
NPV	0.94	0.89	0.97	0.93	0.97	0.93	0.97	0.96	0.96
Hausdorff	171.4	38.9	35.2	139.4	19.23	139.8	187.8	16.3	13.4

Table 2: Table showing the results compared with the Fused ground truth images F:Fuzzy C-means; L:Level-Set; P:PDF Based

By looking at the tables and comparing the results, it can be noted that, on the whole, level-set algorithm performs better than the other algorithms, in terms of *precision*. The precision value for level-set algorithm averages to 0.988 for the six images, which is slightly higher than 0.981, the value for PDF, that is the next best algorithm.

Also, if we look at the negative predictive value, we may note that level-set algorithm outruns the other algorithms here also as the average value 0.901 is lower than 0.916, the value for Fuzzy C-means, that is the next best algorithm in terms of NPV.

Since, these are one of the most important parameters for comparison, we can generalize that level-set algorithm can provide the most accurate results although it is quite slow for computation. But, if we have time constraints, the other two methods can be preferred over level-set, as they both provide almost similar results and take almost similar execution time.

Also, specificity can be an important parameter, when we want to consider the case where the prediction says negative even though the patient is positive, over the case where the prediction says positive even though the patient is negative. Even while comparing this parameter, one can conclude that level-set algorithm is better over the others. Hence, on a broader view, it can be argued that level-set is the best algorithm in terms of accuracy. But, the results for all the segmentation techniques are quite similar and the choice of segmentation technique would vary from situation to situation.

5 Own segmentation

5.1 Methodology

Our algorithm is mainly based on thresholding. Applying thresholding in rgb image causes much noise. Firstly the images are converted from rgb to hsv colorspace and taken the channel of saturation. Single threshold is not efficient for all the images, so ostu thresholding which is an adaptive thresholding is applied to convert the images into binary. Then the holes in the extracted area are filled to complete the foreground.

There are many regions and noise in the resultant images. What we want to segment is the most salient one which is the largest area in the image. So the binary images are divided into regions. The pixels in the largest region are reset to value one in a new image full of value zero. Thus the resultant images are showing the segmented object in white(foreground).

5.2 Results

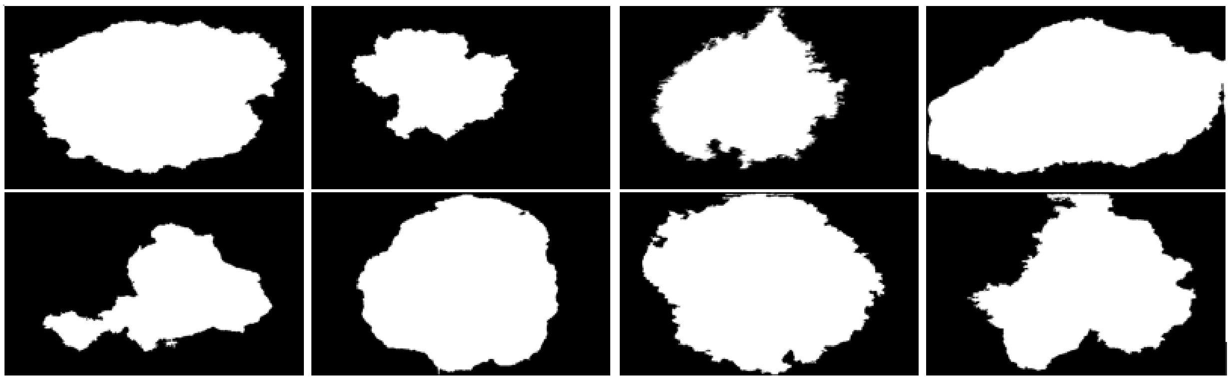

Figure 2: Segmented images of own algorithm. From left to right: D134, D322, D503, D978, E976, G351, H551, H568

Parameters	D134	D322	D503	D978	E976	G351	H551
Dice Coeff	0.91	0.95	0.95	0.97	0.95	0.98	0.96
Sensitivity	0.83	0.91	0.92	0.97	0.93	0.98	0.96
Specificity	1.0	0.99	0.99	0.94	0.99	0.99	0.95
precision	1.0	0.99	0.99	0.96	0.98	0.99	0.96
NPV	0.77	0.97	0.96	0.95	0.97	0.98	0.95
Hausdorff	37.9	27.58	34.9	24.11	20.39	15.6	28.6

Table 3: Table showing the results compared with the Fused ground truth images for our own segmentation technique

By looking at the above table, one can note that our segmentation lagorithm performs on par with other algorithms. The *precision* parameter averages to about 0.981 which is almost same as the average *precision* value for PDF based segmentation technique. By also comparing the other parameters, one can conclude that the results obtained by our implemented segmentation algorithm are satisfactory and the parameter values are almost the same when compared to the other segmentation techniques.

6 Conclusion

Firstly, the combined ground truth images were generated. All the provided segmentation techniques were applied on all the images and the results were compared with all the ground truth images and the results were clearly explained. Lastly, a segmentation technique of our own was implemented and the results were compared with the other provided methods.