

# Medical Imaging Analysis: 3D Breast Ultrasound segmentation

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## Abstract

*This particular project work is about segmenting 3D breast ultrasound images to get the best result. The segmented results are compared with provided ground truth to tune the parameters to obtain better segmented result. Necessary pre and post-processing steps have to be carried out to obtain more accuracy and more efficiency. At the end, the results are evaluated using quantitative and qualitative methods.*

## 1. INTRODUCTION

Image segmentation is one of the active research areas in computer vision which deals with analyzing an image by partitioning it on specific visual characteristic basis. Segmentation is a crucial tool to identify these regions as objects and subsequently classify or label them as anatomical structures on corresponding physiological properties. Thus, it became a vital part in medical science. Segmentation is used for several reasons, as an example, to identify a lesion from the surrounding tissues. Since, for different image modalities, the segmented result differs in intensity, shape, etc., there is no single approach to solve the problem of segmentation for different image modalities. This made segmentation a challenge in the field of medical imaging.

Fundamentally, segmentation result affects all the subsequent processes of image analysis such as object representation and description, feature measurement, and even the following higher level tasks such as object classification. Hence, image segmentation is the one of the most essential and crucial processes for facilitating the delineation, characterization, and visualization of regions of interest in any medical image.

There are several methods to segment an image. A common problem shared by many of the methods is that automated methods for partitioning structures within a dataset may not correspond to the object or

structures that a human expert would identify. Often, the dataset is over segmented into many small pieces that have to be aggregated into whole structures using expert, human intervention. Another common error is to under segment a dataset, which requires later subdivision of mixed or connected objects into separate pieces. The result is that automated segmentation methods are often mixed with graphic user interfaces to allow clinicians and researchers to explore, manipulate, and edit the results created by computer segmentation algorithms.

This project work includes segmenting 3D Breast Ultrasound images. The ground truth for the training images have been provided. The first task comprises generating segmented images and check the accuracy of the segmentation by comparing the result with its corresponding ground truth. All the methods that have been implemented over the images are described below. We used several methods from the two main segmentation components, Region growing algorithm and Level set segmentation. The results are also shown in the implementation part.

## 2. Ground-truth generation

Segmentation evaluation can be categorized into two groups: supervised and unsupervised evaluation, depending on whether the method utilizes a priori knowledge. In this project work, we were only concerned about supervised evaluation which is widely used in medical image research. It computes the difference between the ground truth and a segmentation result using a given evaluation metric.

### 2.1. Methods for ground truth estimation

**2.1.1. Voting policy.** In this method the ground truth is computed based on multiple references where segmentation is considered as a labeling problem. The most intuitive way of solving such problems is to use a voting

policy (or label voting). The winner threshold value is then used to determine the classification of each pixel.

**2.1.2. Variation Based Method.** The second approach minimizes the average variation between the ground truth and manual results.

**2.1.3. Maximal a posteriori probability based method.** The third method is based on statistical theory. The probabilistic formulation estimates the ground truth as a process of finding an optimal partition of the image domain. It maximizes the posteriori probability based on a set of manual results. In other word, the ground truth should be the segmentation that makes all the manual results most probable.

### 3. Segmentation

Generally, image segmentation approaches can be divided into two broad categories, based on two properties of image.

**Detecting Discontinuities:** This process checks for abrupt changes in intensity in an image. Edge detection algorithms are the ones which perform this operation, as an example, Canny edge detection algorithm.

**Detecting Similarities:** In this approach an image is partitioned into regions that are similar according to a set of predefined criterion ; this includes image segmentation algorithms like thresholding, region growing, region splitting and merging.

#### 3.1. Region Growing

The Region growing algorithm is one of the methods to do regional segmentation. The procedure is based on a pixel that is named **seed**; This seed point will start growing to grow a region that adds all the vicinity pixels that meet the criteria of homogeneity; for each of these new pixels, their neighbors are also checked in an spiral form and if fall in the condition, included in the region. This process continues until there is no more pixels that share the same trait as the seed.

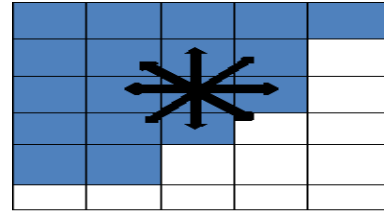


Figure 1: Region Growing algorithm.

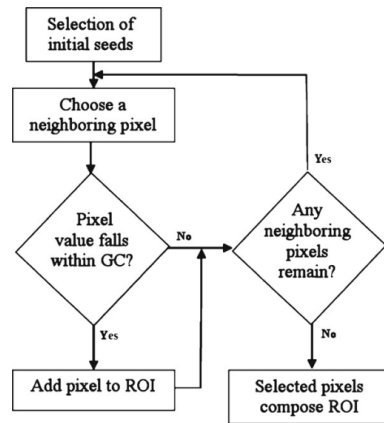


Figure 2: Flow chart for Region Growing algorithm [1]

Region growing algorithms follows several criteria to decide whether a pixel should be included in the region or not, the type connectivity used to determine neighbors, and the strategy used to visit neighboring pixels. Several implementations of region growing are available in ITK. We implemented some of them over our dataset, they are explained below.

**3.1.1. Connected Threshold.** Connected threshold method evaluates intensity value inside a specific interval. This interval is manually provided by the user. The lower and upper threshold values are also needed to be specified. The region-growing algorithm includes those pixels whose intensities are inside the interval.

$$I(X) \in [lowerupper]$$

The initialization of this algorithm requires the user to provide a seed point. It is convenient to select this point to be placed in a typical region of the anatomical structure to be segmented.

The pipeline we used to implement this algorithm is shown below:

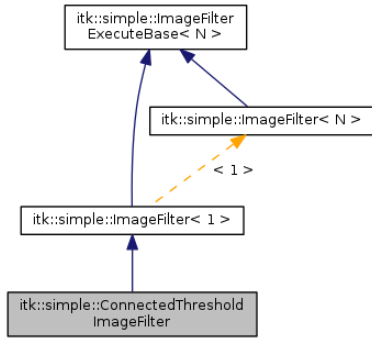


Figure 3: Pipeline for Connected Threshold. [2]

**3.1.2. Isolated Connected.** In this filter, two seed points and a lower threshold value are provided by the user. The filter will grow a region connected to the first seed and not connected to the second one. In order to do this, the filter finds an intensity value that could be used as upper threshold for the first seed. A binary search is used to find the value that separates both seeds. The pipeline is similar with *itk::connectedthreshold filter*. The pipeline for this segmentation algorithm is shown below:

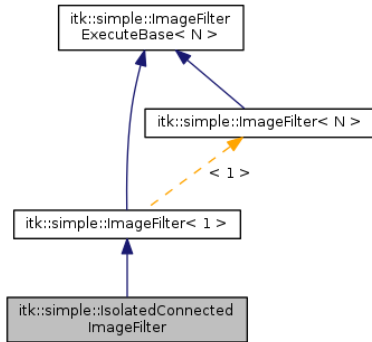


Figure 4: Pipeline for Isolated Connected Threshold Filter. [3]

**3.1.3. Confidence Connected.** The criterion used by the *ITKConfidenceConnectedImageFilter* is based on simple statistics of the current region. First, the algorithm computes the mean and standard deviation of intensity values for all the pixels currently included in the region. A user-provided factor (*multiplier factor, f*) is used to multiply the standard deviation and define a range around the mean. Neighbor pixels, whose intensity values fall inside the range are accepted and included in the region.

$$I(X) \in [m - f\sigma, m + f\sigma]$$

When no more neighbor pixels are found that satisfy the criterion, the algorithm is considered to have finished its first iteration. At that point, the mean and standard deviation of the intensity levels are recomputed using all the pixels currently included in the region. This mean and standard deviation defines a new intensity range that is used to visit current region neighbors and evaluate whether their intensity falls inside the range.

This iterative process is repeated until no more pixels are added or the maximum number of iterations is reached. The number of iteration is typically determined based on the homogeneity of the image intensity representing the anatomical structure to be segmented. The initialization of the algorithm requires the user to provide a seed point and size of the initial neighborhood around the seed is defined.

The pipeline we used to implement this algorithm is given below:

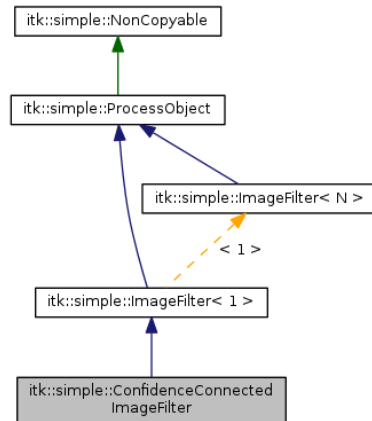


Figure 5: Pipeline for Isolated Connected Threshold Filter. [4]

### 3.2. Level-set segmentation

Level set is a method to model a deformable shapes. In this approach, the segmentation problem reduces in finding curves to enclose regions of interest. The level set method can be used to efficiently address the problem of curve. The main idea is to represent the evolving contour using a signed function, where its zero level corresponds to the actual contour. According to the motion equation of the contour, one can easily derive a similar flow for the implicit surface that when

applied to the zero-level will reflect the propagation of the contour. The level set method encodes numerous advantages: it is implicit, parameter free, provides a direct way to estimate the geometric properties of the evolving structure, can change the topology and is intrinsic.

The advantages of level set segmentation are: their stable evolution of the propagating interface, ability to deal with automatic topological changes and potential for robust and automatic image segmentation.

**3.2.1. Threshold Segmentation Level Set Image Filter.** This algorithm is an extension of the threshold connected component segmentation to the level set framework. The goal of this algorithm is to define a range of intensity values that classify the tissue type of interest. It comprises two approaches:

- **Threshold segmentation method:** This method is used to control the diffusion coefficient of curve within the threshold set.
- **Fast Marching method:** The Fast Marching Image Filter requires the user to provide a seed point from which the level set will be generated. The user can actually pass not only one seed point but a set of them. Note the the Fast Marching Image Filter is used here only as a helper in the determination of an initial Level Set.

We also applied Mean filter with this algorithm. The pipeline we used is shown below:

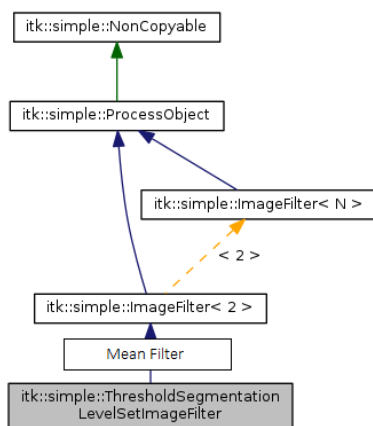


Figure 6: Pipeline for Threshold Segmentation Level Set Image Filter.

## 4. Evaluation

This section illustrates how we evaluated our segmentation results to chose the better algorithm. In medical image analysis the common approach is to compare the segmentation result with the ground truth given by experts. Generally, For evaluating segmentation methods, three factors need to be considered for both recognition and delineation: *precision*(reproducibility), *accuracy* (agreement with truth, validity), and *efficiency*. Although precision, accuracy, and efficiency are interdependent, it is difficult to improve one factor without affecting others. Segmentation methods must be compared based on all three factors. The weight given to each factor depends on application. For this project work, we considered 4 measurements, Dice coefficient, Jaccard Index, True-Positive rate and False-Positive rate. In the following section they are discussed briefly.

### 4.1. Dice Index

Dice Index is also known as Dice Similarity Coefficient (DICE) is a similarity measure over the ground truth. Let the ground truth image is A and the algorithm image is B, then the Dice Similarity Coefficient index is given by:

$$Dice = \frac{2|AB|}{A+B} = \frac{TP}{2TP+FP+FN} \quad (1)$$

TP stands for true positive, and FP for false positive. Normally dice coefficient ranges between 0 and 1. Coefficients above .85 is assumed to be good registration. Small values of coefficient indicates high degree of over lap between images.

### 4.2. Sensitivity

Sensitivity or true positive rate (TPR) relates to the test's ability to identify a condition correctly. Consider the example of a medical test used to identify a disease. Sensitivity of the test is the proportion of people known to have the disease, who test positive for it.Using confusion matrix this can be expressed as:

$$sensitivity = \frac{Truepositives}{Truepositives + Falsenegatives} \quad (2)$$

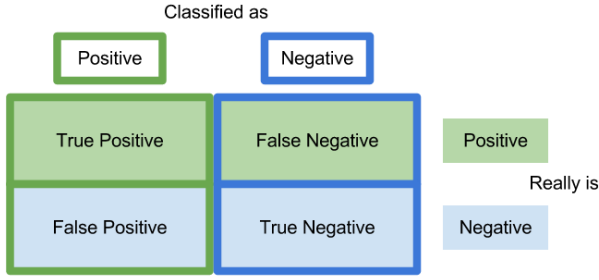


Figure 7: Confusion matrix

It measures probability of positive test given the patient is ill. A high value of sensitivity is preferred. A test with 100% sensitivity will recognize all patients with the disease by testing positive.

### 4.3. Specificity

Specificity or True Negative Rate relates to the test's ability to exclude a condition correctly. Consider the example of a medical test for diagnosing a disease. Specificity of a test is the proportion of healthy patients known not to have the disease, who will test negative for it. Using the confusion matrix this can also be written as:

$$Specificity = \frac{Truenegative}{Truenegative + Falsepositives} \quad (3)$$

In other words, It measures the probability of negative tests given that the patient is well. A test with 100% specificity will identify healthy patients correctly, and reads negative on all of them.

### 4.4. Precision

Precision is the probability that a (randomly selected) retrieved patient is truly ill given that the test result gives positive. Mathematically it is expressed as

$$Precision = \frac{Truepositive}{Truepositive + Falsepositives} \quad (4)$$

### 4.5. Hausdorff distance

[13] The Hausdorff distance finds the largest distance between the boundary points.

Let  $GT = \{gt_1, gt_2, \dots, gt_n\}$  and

$SR = \{sr_1, sr_2, \dots, sr_n\}$

denote the set of points belonging to contour GT and contour SR, respectively. The distance from  $gt_i$  to

its closest point (DCP) in SR is given by

$$d(gt_i, SR) = \min_j \|sr_j - gt_i\| \quad (5)$$

The Hausdorff distance is the maximum of the distance to the closest points between the two curves

$$HD(GT, SR) = \max\{\max_i d(gt_i, SR), \max_j d(sr_j, GT)\} \quad (6)$$

This metric generally computes the distance between the ground truth and the segmentation result curves in pixels. The minimum this distance is the more segmentation result resembles the ground truth.

## 4.6. Implementation and Result

We used both the MevisLab and *itk* to implement this algorithms. After evaluating all our results, we chose to use the Threshold Segment Level Set Image Filter for the final challenge. For level set algorithms, we added more functionalities by adding *Gaussian Smoothing*, *Mean Filter*, *Median Filter* to the pipeline. But for all cases, the results were almost the same. So, we kept *Mean Filter* as a pre-processing filter for our final segmentation algorithm as it gave a little bit good result. Our output for the training images is shown below:

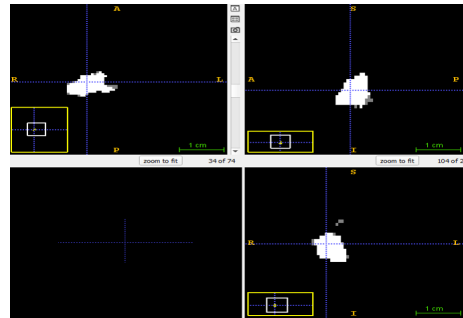


Figure 8: For *t0200254601ml.dcm* DICOM image

Table 1: Evaluation of the Segmentation algorithm

Image Name	Dice Coefficient
t0200254601ml.dcm	0.84
t0200403301al.dcm	0.68
t0200403301lr.dcm	0.52

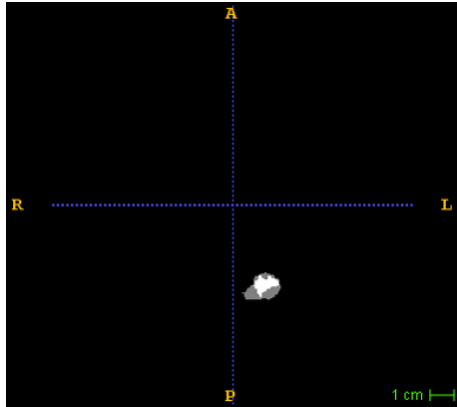


Figure 9: For *t0200403301al.dcm* DICOM image

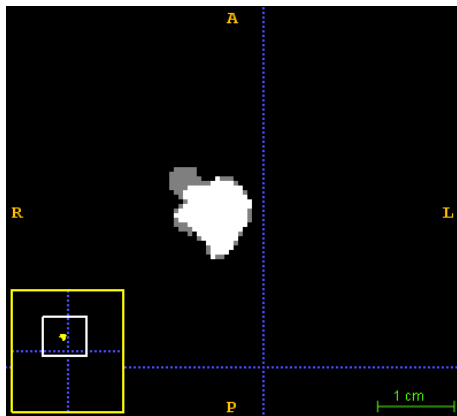


Figure 10: For *t0200403301lr.dcm* DICOM image

The Dice Similarity Coefficient for these 4 training images are :

On the challenge day, DSC for our algorithm was around 6.3. Over all, our algorithm was performing well.

## 5. Conclusion

In this project, we worked on segmentation of 3D Breast Ultrasound images. Then to evaluate the result of segmentation we used a ground truth and different evaluation matrices.

After implementing few segmentation algorithms, we found that some of the segmentation methods available are not suitable for medical images. The ones that are appropriate have their own advantages and disadvantages. From the available segmentation methods the thresholding level set based segmentation has been implemented.

Threshold segmentation level set image filter gave use good result. Still this filter needs some pre-processing to provide some good results. But the main advantage of this filter is that it is fast.

This project work helped us to understand different categories of segmentation techniques including their evaluation methods. Moreover, the real competition made us more competitive to implement it efficiently.

## References

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