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Comparison of segmentation using fast marching and geodesic active contours methods for bone

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Comparison of segmentation using fast marching and geodesic active contours methods for bone

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Abstract. Image processing is important in diagnosing diseases or damages of human organs. One of the important stages of image processing is segmentation process. Segmentation is a separation process of the image into regions of certain similar characteristics. It is used to simplify the image to make an analysis easier. The case raised in this study is image segmentation of bones. Bone's image segmentation is a way to get bone dimensions, which is needed in order to make prosthesis that is used to treat broken or cracked bones. Segmentation methods chosen in this study are fast marching and geodesic active contours. This study uses ITK (Insight Segmentation and Registration Toolkit) software. The success of the segmentation was then determined by calculating its accuracy, sensitivity, and specificity. Based on the results, the Active Contours method has slightly higher accuracy and sensitivity values than the fast marching method. As for the value of specificity, fast marching has produced three image results that have higher specificity values compared to those of geodesic active contour's. The result also indicates that both methods have succeeded in performing bone's image segmentation. Overall, geodesic active contours method is quite better than fast marching in segmenting bone images.

1. Introduction

Image processing plays an important role in diagnosing diseases or damages of the human organs. One of the important stages of image processing is segmentation process. Medical image segmentation is used to simplify image by separating an image into regions of certain similar characteristics so that it is easier to analyze [1]. The case raised in this study is the image segmentation of bones. Bone's image segmentation is a way to get bone dimension, which is needed for making prosthesis to treat broken or cracked bones. Bone images are used in this study as the input for the segmentation process.

Image segmentation is generally based on two types of approaches, discontinuity and similarity [2]. The similarity approach separates image into regions that are similar in accordance with a set of pre-defined criteria. The discontinuity approach separates an image based on sudden changes intensity, such as edges in an image. The method that is used in this study is based on edges detection technique: Level Set method. Edge detection is an operation of detecting edges that confine two homogenous image regions which have different levels of brightness [3]. The aim is to improve the appearance of the boundary line of a particular object in the image. Level Set method can be used to track the evolution of contours and surfaces [4]. This method is chosen because it can do segmentation by forming deformable curves so that this method can be suitable for all geometric shapes. Two of several methods from level set segmentation used in this study is fast marching and geodesic active contours. Therefore, the aim is to compare segmentation results from both of the methods to analyze how successful these methods are in segmenting bone images. And after that, a better method will be known.

2. Methods

This study uses ITK (Insight Segmentation and Registration Toolkit) software with DICOM file as the input. DICOM data is segmented, using Fast Marching and Geodesic Active Contours method that is available in ITK's library, by inserting parameters required by the ITK. After the image segmentation result is obtained, the accuracy, sensitivity, and specificity values are calculated. The result will be compared with the original image using ROC (Receiver Operating Characteristics) measurement [5].

2.1. Fast marching method

Fast marching (FM) is a method that performs a propagation spread from a starting point to all possible directions [6]. Every time the propagation happens, this algorithm always calculates and stores the values of the distance of a point to the starting point. The illustration is shown on figure 1 below.

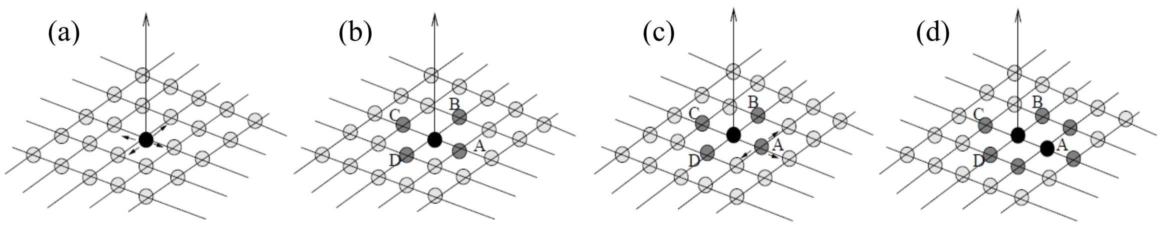


Figure 1. The illustration for overall process of fast marching method [7].

In figure 1(a), there is a black sphere, which marks the point of the initial value where *u*'s value is known, and the gray spheres show the still-unknown *u*'s value. When the FM algorithm starts the propagation from the origin point, it will calculate a possible new value in each of the four nearest neighbors (dark gray spheres A, B, C, and D), as seen on figure 1(b). The same rule also applies for the next steps. As seen on figure 1(c), consider sphere A has the smallest value. After that, three new possible values will be obtained in each of the three closest neighbors, as seen on Figure 1(d).

There are some parameters needed as the input for ITK. For the FM method, there is a *seed index* which must be specified by a user, stating the position of the starting point where the contour propagation process will begin. Then, there are σ as the smoothing factor value for the segmentation result's curve, α as an elasticity constant value of the segmentation result's curve, β as a flexibility constant value of the segmentation result's curve, *threshold* as scale to determine the grey level of the segmented sections, and the *stopping value* as a value to determine a time limit for the propagation spreads.

2.2. Geodesic active contours method

Active contours (AC) method produces a flexible curve that can adapt dynamically to the edges of the desired object [8]. Users should determine the initial contour estimation that almost matches the shape of the object feature, as seen in figure 2 below. Furthermore, the initial contour will be extracted toward the features in the image due to the influence of the internal energy that produces the image. The energy function used in the AC method consists of two components, which are the internal energy and the external energy. The energy minimization function can generally be expressed as in the following equation:

$$E^*_{snake} = \int_0^1 E_{snake}(v(s))ds = \int_0^1 \{E_{\text{int}}(v(s)) + E_{image}(v(s)) + E_{con}(v(s))\}ds \qquad (1)$$

where E_{int} is the internal energy of the curve, E_{image} is the energy of the image, and the E_{con} is external energy. Internal energy makes compact curve (elastic force). While external energy tends to make the curve moves toward the object boundary.

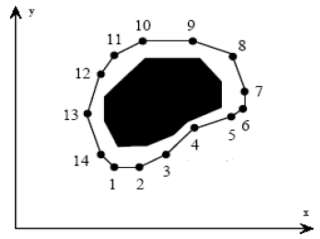


Figure 2. Illustration of geodesic active contours segmentation method, curve formed by point 1 to 14 is the initial contour [8].

There are some parameters needed as the input for ITK. For AC method, seed index, *σ, α,* and *β* parameters which show the same functions as those in the FM method. The different parameters are distance which declares the spread's distance and *propagation scaling* that states the scale of the segmentation's curve.

2.3. Receiver operating characteristics (ROC)

ROC (Receiver Operating Characteristics) is a measurement used for the evaluation of medical tests [9]. In figure 3, there is a TP (True Positive) component, showing the truth value between the result and the original images. TN (True Negative) shows a truth value between the result and the background. FP (False Positive) shows the inaccuracy value between the result and the original image. FN (False Negative) shows the inaccuracy value between the result and the background [5]. Those values are calculated based on the number of pixels covering the components.

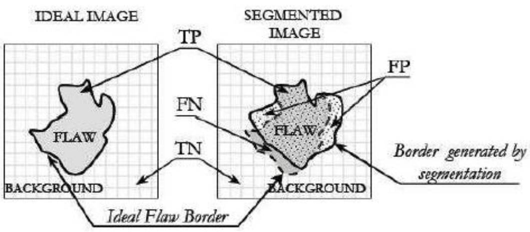


Figure 3. Illustration of regional division of TP, TN, FN, and FP on the original image and segmentation's image [9].

The calculation of accuracy, sensitivity, and specificity shown on these equations:

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FP+FN)} \tag{2}$$

$$Sensitivity = \frac{TP}{P} = \frac{TP}{(TP+FN)} \tag{3}$$

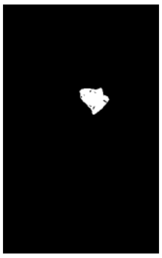
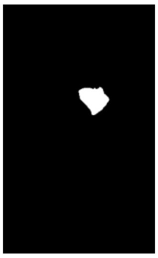
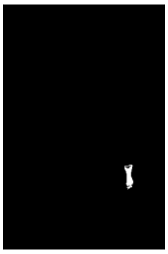
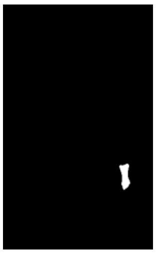
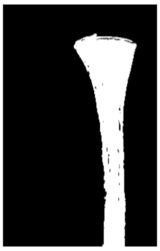
$$Specificity = \frac{TN}{N} = \frac{TN}{(FP+TN)} \tag{4}$$

3. Result and discussion

Comparison of image segmentation based on the image results of both methods can be seen in table 1 below. Visually, it appears that the image segmentation results using the fast marching still have some hollows in them. For the edges, it does not look too much different from the image segmentation results using the Active Contours method. But it appears that there are some parts that are not filled on the results of the image.

The values of the accuracy, sensitivity, and specificity are shown in table 2 below. In this study, the accuracy values for the results with the AC method (from image 1 to 5) are 0.9932, 0.9984, 0.9993, 0.9903, and 0.9865. The accuracy values for the results using the FM method are 0.9878, 0.9968, 0.9984, 0.9714, and 0.9802. It shows that both of methods have succeeded in segmenting an image. Each accuracy value almost reaches a value of 1 (meaning 100%). However, the accuracy values using AC is slightly higher than FM's. In term of sensitivity values, the result of sensitivity shows how well the bone part being portrayed as bone on the segmentation image result is. The sensitivity values for the results using the AC method are 0.9416, 0.9016, 0.9617, 0.9490, and 0.8351. Meanwhile, the sensitivity values obtained using the FM method are 0.8864, 0.7866, 0.6885, 0.8486, and 0.7348. It appears that sensitivity values using the AC method are still slightly higher than those of the FM's.

Table 1. Comparison of the segmentation results by fast marching and geodesic active contours.

	Original image	Segmentation's image			
		Fast Marching		Geodesic Active Contours	
1			*Seed index* : (121, 171) σ : 0.5 α : -0.5 β : 3.0 *Threshold* : 200 *Stopping value* : 180		*Seed index* : (121, 171) *Distance* : 5.0 σ : 0.5 α : -0.5 β : 3.0 *Propagation scaling* : 2.0
2			*Seed index* : (164, 171) σ : 0.5 α : -0.5 β : 3.0 *Threshold* : 100 *Stopping value* : 100		*Seed index* : (164, 171) *Distance* : 10.0 σ : 0.5 α : -0.5 β : 4.0 *Propagation scaling* : 1.0
3			*Seed index* : (231, 309) σ : 0.5 α : -0.5 β : 3.0 *Threshold* : 250 *Stopping value* : 100		*Seed index* : (231, 309) *Distance* : 5.0 σ : 0.5 α : -0.5 β : 5.0 *Propagation scaling* : 1.0
4			*Seed index* : (150, 263) σ : 0.5 α : -0.5 β : 3.0 *Threshold* : 5000 *Stopping value* : 300		*Seed index* : (150, 263) *Distance* : 15.0 σ : 0.5 α : -0.5 β : 8.0 *Propagation scaling* : 10.0
5			*Seed index* : (167, 341) σ : 0.5 α : -0.5 β : 3.0 *Threshold* : 5000 *Stopping value* : 800		*Seed index* : (167, 341) *Distance* : 10.0 σ : 0.5 α : -0.5 β : 6.0 *Propagation scaling* : 2.0

Specificity shows how well the non-bone part being portrayed as non-bone on the segmentation result is. For the specificity value, there is quite a difference from the two previous parameter values. The specificity values obtained by using the AC are 0.9984, 0.9998, 0.9994, 0.9999, and 0.9971. And the specificity values using the FM are 0.9981, 0.9999, 0.9997, 0.9998, and 0.9974. It can be seen that for the images of 1 and 4, the specificity values by using AC are still slightly higher than those using the

FM method. However, for the images of 2, 3, and 5, the specificity values using FM have slightly higher values than AC's.

Table 2. Data of accuracy, sensitivity and specificity.

				Fast Marching			
Picture	TP	TN	FP	FN	Accuracy	Sensitivity	Specificity
1	11057	123043	228	1416	0.9878	0.8864	0.9981
2	1519	130676	1	412	0.9968	0.7866	0.9999
3	378	132027	32	171	0.9984	0.6885	0.9997
4	15076	76752	11	2689	0.9714	0.8486	0.9998
5	5140	99822	255	1855	0.9802	0.7348	0.9974
				Geodesic Active Contours			
Picture	TP	TN	FP	FN	Accuracy	Sensitivity	Specificity
1	11745	123081	190	728	0.9932	0.9416	0.9984
2	1741	130660	17	190	0.9984	0.9016	0.9998
3	528	131992	67	21	0.9993	0.9617	0.9994
4	16860	76756	7	905	0.9903	0.9490	0.9999
5	5842	99788	289	1153	0.9865	0.8351	0.9971

4. Conclusion

The determination of the parameter values in the ITK needs a certain strategy. Users must insert these parameter values based on the experiments until the desired result is obtained. Based on the comparison from the accuracy, sensitivity, and specificity values, both methods Active Contours and Fast Marching have successfully segmented bone images. It can be seen from the values of accuracy, sensitivity, and specificity that the results almost reach the value of 1 (which means 100%). In this study, the segmentation results using active contours method have slightly higher accuracy and sensitivity values than those using fast marching's segmentation results. For the active contours based on the five sample images, the accuracy values are 0.9932, 0.9984, 0.9993, 0.9903, and 0.9865. The sensitivity values are 0.9416, 0.9016, 0.9617, 0.9490, and 0.8351. As for the value of specificity, fast marching produces three image results that have higher specificity values when compared with those of geodesic active contour's. Overall, the geodesic active contours is quite better than the fast marching in segmenting bone images.

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