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碩士論文

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基於區域成長法的3D超音波乳房腫瘤切割

Breast Tumor Segmentation on Ultrasonography Based on 3D Region Growing Method

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Breast Tumor Segmentation on Ultrasonography Based on 3D Region Growing Method

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摘要

乳癌是現今婦女最常罹患的癌症，然而隨著醫療科技的進步，若早期發現則治癒率可相對提高，在醫學影像的工具中可用來診斷乳房腫瘤的方法有許多，例如：乳房X光攝影、超音波影像或是核磁共振影像。其中，超音波影像是一個很好的選擇，它不具侵入性而且可以及時造影，相較與核磁共振影像成本較低，因此乳房超音波影像檢驗為目前普遍的診斷方式。但超音波影像有些特性需要克服，它通常包含大量的雜訊及斑點，若依賴醫師的臨床經驗來判斷腫瘤的位置及良惡性，很可能會因為影像本身的雜訊導致錯誤判斷，進而影響醫生的判讀結果，因此，本文提出一個腫瘤輪廓自動描繪法來輔助醫生判讀影像資訊。

此方法的前處理先採用高斯濾波和各項擴散異性濾波降低影像的雜訊，再來調整對比度使得腫瘤和背景區分出來，並讓邊緣更加明顯，切割的方法採用區域成長法，此方法的優點是簡單且省時，後處理使用型態學的方法將切割的結果進行修補，使得切出來的腫瘤可以更貼緊邊緣，與醫生手繪的結果更為相似。所有的切割方法皆為三維，相較於二維切割可以考慮較多的關聯性，使結果更為準確。本研究總共使用30個病例進行實驗，分別為15個良性及15個惡性，最後實驗切割出的結果會與醫師手動描繪的腫瘤及自動切割方法VOCAL(virtual organ computer-aided analysis)進行比較。

關鍵字：乳癌、超音波、影像切割、三維區域成長法、腫瘤輪廓描繪

ABSTRACT

Breast cancer is the most common cancer in the woman. There is an upward trend in the number of such cases in the past years. Early diagnosis and early treatment is the most effective way of reducing mortality caused by breast cancer. Ultrasound is the common examination technology because of fast, cheap and noninvasive. The difficult part is that there are many noises and speckles on the ultrasonic images. Malignant and benign breast tumors are present different shape and size, thus this study propose a robust segmentation method to assist the physician on contouring tumor boundary. The proposed method first utilizes a pre-processing procedure to reduce the noises and speckle in imaging. After that, three-dimensional (3D) region growing method is applies to segment the tumor area. Finally, the proposed method made the area smoother and correctly though a post processing step. This study evaluated total of 30 tumor cases and four practical similarity measures (similarity index, overlap fraction, overlap value, and extraction fraction) are used to evaluate the result between the manually determined contours, an automatically method named virtual organ computer-aided analysis (VOCAL) and the proposed segmentation method.

***Keywords*:** breast cancer, ultrasound, image segmentation, 3D region growing, tumor contour approximation

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Nowadays, breast cancer is the most common cancer in the woman. Early diagnosis is very important because it would increase the cure rate. There are many medical imaging tools performed to diagnosis the breast cancer, such as Mammogram, Magnetic resonance imaging (MRI) and Ultrasound. Ultrasound is widely used for patients in regular physical examination due to its lower cost, high efficacy and real-time scanning, particularly palpable tumors. Therefore, the ultrasound examination has become the widespread tool to diagnosis the breast cancer. Physicians also assisted by computer-aided diagnosis (CAD) system [1] to retrieve useful information as a basis for diagnosis. However, the disadvantage of ultrasound imaging is that always has a large number of noises and speckles. If we rely on the physicians to determine the position and malignant degree of tumor by own experience, the noise of the image might influence the objectivity of the physician's judgment. Thus a robust segmentation method to obtain the tumor contour would help the physicians on interpretation the information in ultrasound imaging. This work could decrease the wrong judgment because of physician's inexperience and subjectivity.

Three-dimensional (3D) ultrasound image has become a popular medical imaging technique. It not only obtains the entire volume of the breast tumor in the 3D ultrasound image but also have more information on the space, relative to the two-dimensional (2D) ultrasound imaging. Conventional 2D ultrasound displayed a breast tumor by slices, physician had to mentally build the impression of 3D tumor by many 2D ultrasonic images. Some correct diagnostic decisions required entire volume information of the tumor and tumor contour. The volume data of breast tumor [2, 3] has been considered as an useful characteristic for identify malignant breast tumor [4, 5].

Many segmentation methods have been performed in medical imaging, such as threshold segmentation method, clustering-based segmentation method, edge-based segmentation method and region-based segmentation method. The threshold segmentation methods [6] assume that the image contains two classes of pixels, it then calculates the optimum threshold separating the two classes so that their combined spread is minimal. The Otsu's method [7] is a famous threshold segmentation method. The threshold segmentation methods are easy but always obtain the undesirable result when the grayscale in the image is complicated.

Clustering-based segmentation methods [8-10] minimize the intensity distance between every pixel and cluster center. Neural-net segmentation method is one of the clustering-based segmentation methods. The method gathered the image areas without using spatial information, disconnected area of the image are grouped together and training sample required. Segmentation by using edge detection relies on the change of gradient in the image. One of the classical methods of edge detection method is Canny method[11], which effortlessly influenced by the noise and speckle.

This study utilized the region based method [12, 13] to contour the tumor. 3D region growing method [14-17] gathered the area by using spatial information in image. The advantage of 3D region growing method is that performs well with noise, speckle and the disconnected area of the image were not grouped together. Moreover, the method is simple and only need a seed point to grow the desired region. In order to obtain the better result of segmentation, pre-processing procedure was applied to promote the image quality. The proposed method used the Gaussian and the anisotropic filtering in the pre-processing procedure which could decrease the noise and speckle validly. The proposed method adjusted the contrast to make the edge of the tumor clear and definite. Then the ultrasonic image was segmented the tumor area by using the 3D region growing method. Finally, the morphological operators were applied to smooth the edge and fill the hole inside the tumor. Flowchart of the proposed method is shown in FIGURE1.1.

Four practical similarity measures between the manually determined contours and the automatically detected contours were calculated for quantitative analysis of the contouring result. This study compared the proposed method with a common contouring method called virtual organ computer-aided analysis (VOCAL). The result of computer simulation showed that the proposed method always reached the reliable performance.

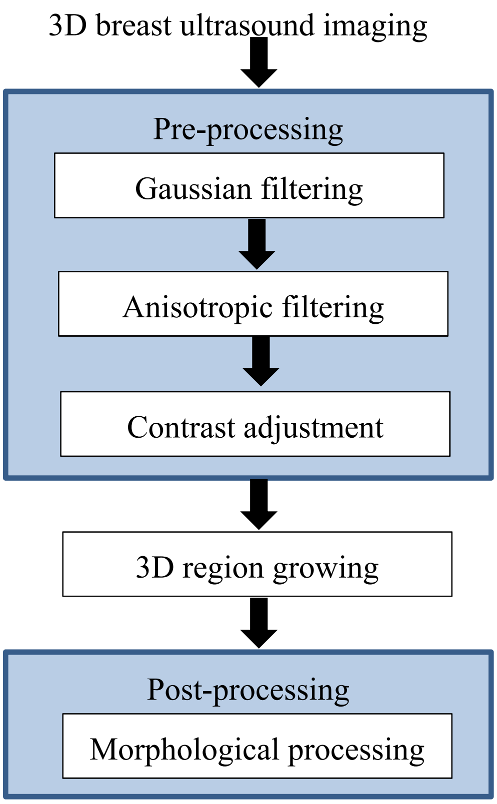


FIGURE 1.1: Flowchart of the proposed method

CHAPTER 2

MATERIALS AND METHODS

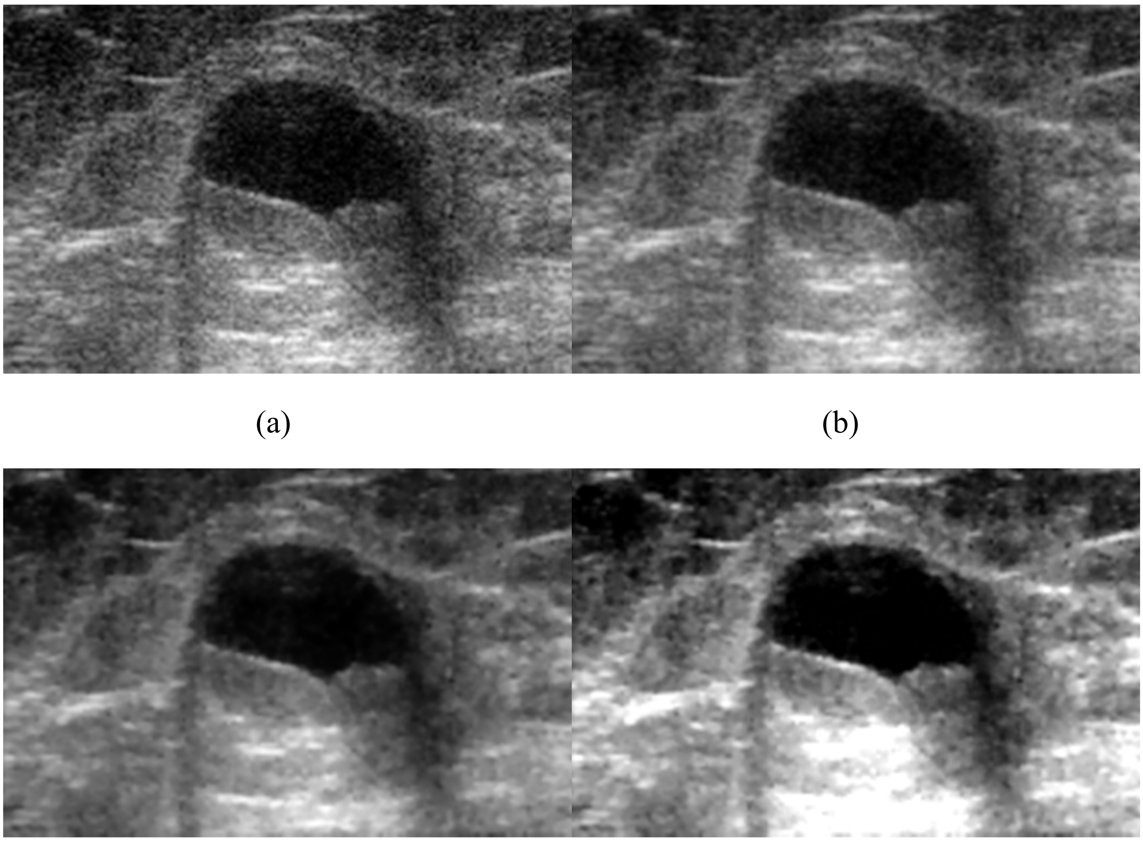
2.1 Image Data Acquisition

This study collected 15 benign and 15 malignant breast tumor patients aged from 17 to 76 years old (mean age 43 years). There were approximately 200 ultrasound images of each case and the image resolution was 200 × 150 pixels. In this study, sonographic examinations were done by using 3D power Doppler ultrasound with the high definition flow (HDF) function (Voluson 730, GE Medical Systems, Zipf, Austria). A linear-array broadband probe with a frequency of 6–12 MHz, a scan width of 37.5 mm, and a sweep angle of 5° to 29° to obtain 3D volume scanning was used. Physician kept a fixed sweep angle of 20° and power Doppler settings of mid frequency, 0.9 kHz pulse repetition frequency, -0.6 gain, and ‘low 1’ wall motion filter in all cases. All obtained images were stored on the hard disk and transferred to a personal computer using a DICOM (Digital Imaging and Communications in Medicine) connection for image analysis.

2.2 Image Pre-processing

Due to the ultrasound images include considerable noises, speckles and tissue textures that make segmentation complicated. Thus preprocessing is a significant step before the segmentation. The effective preprocessing method for segmentation should aim to reduce noises and preserve the useful information, such as edge and boundary of the mass lesions. In the part, the proposed method applied two filters, i.e. Gaussian 3D low-pass filter and 3D anisotropic filter, to enhance ultrasound images. Gaussian low-pass filtering [18] is a linear smooth filter, which is done by convolving each point in the input array with a Gaussian kernel and then summing them to obtain the output array.

Anisotropic filter [19] could get rid of the major drawback and improve the image quality. Unlike other filters, some filters would obtain a satisfied performance on reducing noise but always lose the detail information simultaneously. The advantage of anisotropic filter is that can preserve the important boundary information. After pre-processing filtering, the proposed method adjusted the contract in order to make the tumor more clear behind from the background, which could prove the accuracy of segmentation substantially. FIGURE2.1(a) is an original breast ultrasound image that includes a tumor with various contrast levels and noises. The processed images obtained by 3D Gaussian low-pass filter, 3D anisotropic filter and the contrast adjustment are shown in FIGURE2.1 (b)-(d), respectively. The result showed that the noises and speckles in pre-processed image would be cut down obviously.



(a) (b)

(c) (d)

FIGURE 2.1: Results of the preprocessing: (a) original image, (b) processed image after Gaussian low-pass filtering, (c) processed image after anisotropic filtering and (d) processed image after contrast adjustment

2.3 Image Segmentation

The conventional 2D ultrasound image showed the breast tumor by slices. Some correct diagnostic decisions required entire volume information of the breast tumor. Moreover, the volume data of breast tumor had been considered as a useful characteristic for identifying malignant breast tumor. Physician observed the tumor in breast ultrasound by experience and manually selected rectangular region of interest (ROI) including the tumor border of three specific slices, i.e. the first, middle and last slices in 3D ultrasound imaging. The first, middle, and last slices were the slice with originally appeared tumor, the largest diameter of the tumor and the tumor get to disappear, respectively. This study extracted the volume of interest (VOI) in 3D ultrasound images from the three ROIs, which was the important information to segment the tumor area.

The proposed segmentation method is based on region growing techniques. Region growing is one of simple region-based methods, which only need a seed point to grow the desired region. The method separated the tumor region from background by checking the neighboring pixels of initial seed points. If the neighboring pixels close to the standard of seed point, it will be added to the region. The criterion could be, for example, pixel intensity, texture or color. The growing procedure was iterated on, in the same manner as general data clustering algorithms. Considering the accuracy of the segmentation, the proposed method adopted the 3D region growing with 26-neighborsizes as growing condition [20, 21]. FIGURE2.2 shows the neighbors of a voxel within 26-adjacency and a basic region-growing algorithm based on 26-connectivity is stated as follows:

1. Select the center voxel of middle slice as the seed point.

2. Find the local 26-adjacency voxels of the seed point.

3. Absolute difference of intensity between a voxel the seed point. If the intensity of the voxel $<$ threshold T_P, it was assigned into tumor region; otherwise, it was considered as the background.

4. The entire procedure was repeated until no further changes occur.

The 3D region growing method grouped the area using spatial information, it could perform well to image with noise and speckle and the disconnected area of the image were not grouped together. The proposed method set the center of the middle slice as an initial seed point by the information of VOI due to the largest diameter of the tumor always appears in the middle slice.

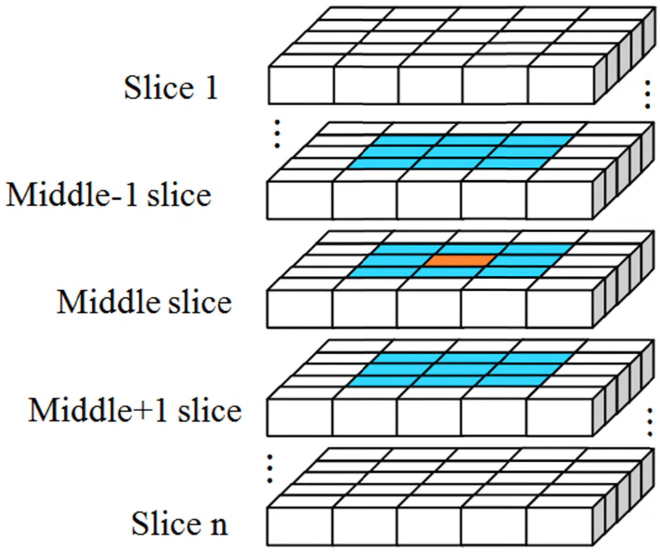
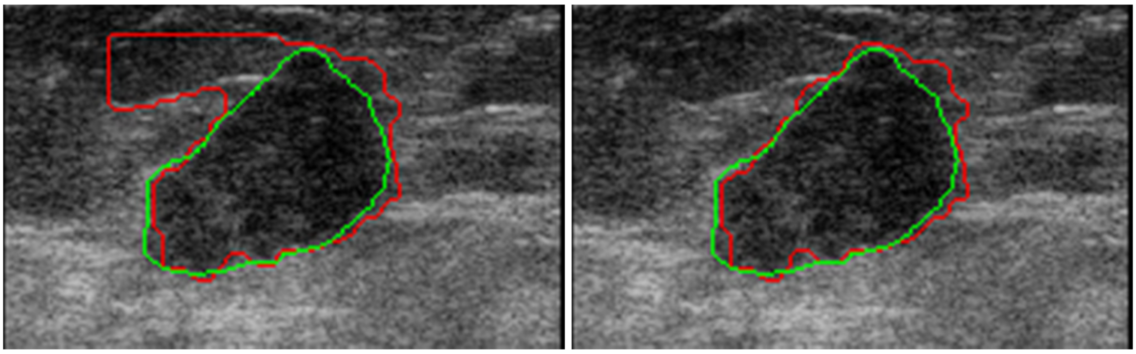


FIGURE 2.2: Neighbors (the blue voxels) within the 26-connectivity

2.4 Contour Post-processing

A supposed tumor area was obtained after the segmentation of 3D region growing. Morphology processing was applied on the supposed tumor area by using the opening and closing operators, which could make the bordering smoother and fill the holes inter of tumor. The problem was found that even applied the pre-processing, the shadow and noise cannot be eliminated totally. Those noises would lead the region to diffuse and debase the accuracy rate. The situation of spread always happened on from beginning to end slices. The tumor was non-distinct on from beginning to end slices due to the tumor was similar to the shadows. The middle slice which was the largest diameter of the tumor always performed well on segmentation, thus the middle slice was used in the proposed method to solve the problem. The middle slice, suggested as the slice with the biggest tumor size, was considered as a standard to check each slice. This step could avoid the most of diffusions and increase the accuracy. FIGURE 2.3 shows the result after the post-processing step.



(a) (b)

FIGURE 2.3: Result after the post-processing, red contour is the result of proposed method, green contour is the result of manual sketched: (a) the result without post-processing, (b) the result after post-processing

2.5 Contour Evaluation

This study performed four indices to evaluate the quality of results in quantitative way. FIGURE2.4 demonstrates that contour segmented by the proposed method (*SEG*) and contour segmented by physicians (*REF*) are overlapped [22]. The term *REF* ∩ SEG denotes the area of *overlap*. The areas of *miss* and *extra* represent segmentation errors of the proposed method. The four indices assessed the similarity between *REG* area and *SEG* area, i.e. similarity index (*SI*), overlap fraction (*OF*), extra fraction (*EF*) and overlap value (*OV*). The four similarity measures were defined as

$$SI = \frac{2 * (REF \cap SEG)}{REF + SEG}, \tag{1}$$

$$OF = \frac{REF \cap SEG}{REF}, \tag{2}$$

$$OV = \frac{REF \cap SEG}{REF \cup SEG} \tag{3}$$

$$\text{and} \quad EF = \frac{\overline{REF} \cap SEG}{REF}. \tag{4}$$

When SI, OF and OV are close to 1, and EF is close to 0, it means the tumor segmented by the proposed automatically method is more similar to the manual contours by physician.

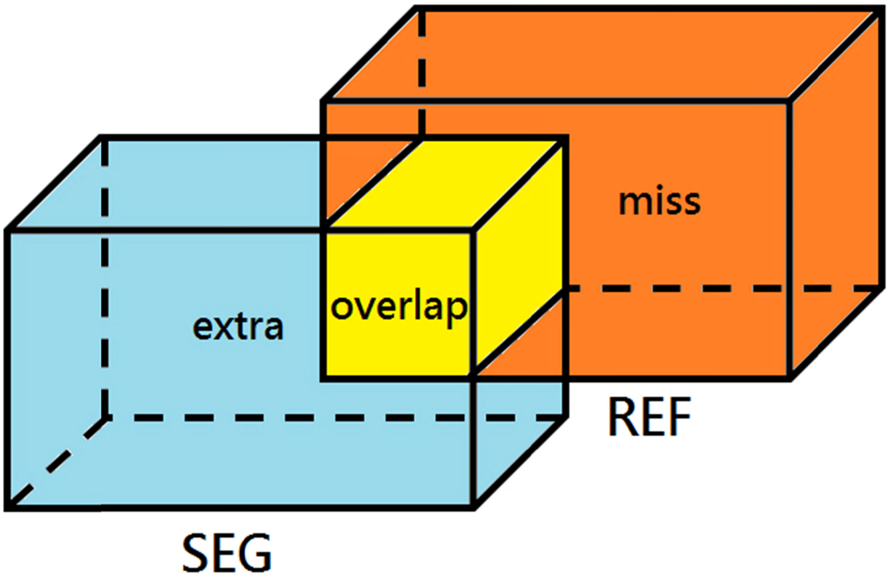


FIGURE 2.4: Comparison of an automated contouring area (*SEG*) with the manual contouring area (*REF*), with (*overlap*) the correctly segmented pixels, (*extra*) the false positives and (*miss*) the false negatives

CHAPTER 3

EXPERIMENTAL RESULT

In this study, the proposed method compared with the virtual organ computer-aided analysis (VOCAL) method [23, 24] with 30^{o} rotation step. The six preliminary tumor contours in 0°, 30°, 60°, 90°, 120° and 150° slice images were manually sketched by physician. The simulations totally evaluated 30 cases with manual sketched contours (including 15 benign and 15 malignant breast tumors) to evaluate the accuracy of the proposed method. The average measures (SI, OF, OV, EF) of proposed method and the VOCAL method were (0.87, 0.87, 0.76, 0.15) and (0.82, 0.88, 0.69, 0.36), respectively.

The result of segmentation between proposed method and manual sketched are shown on FIGURE 3.1 and FIGURE 3.2. FIGURE 3.1 shows the original magnified monochrome breast ultrasound images with a malignant tumor. The green line shows the contours manually sketched from the ultrasound images, the red line plots the contours determined by the proposed system and the result of measures (SI, OF, OV, EF) are (0.93, 0.94, 0.87, 0.08). FIGURE 3.2 shows the original ultrasound images with benign masses. The green line shows the manually sketched contours, the red line illustrates the corresponding contours using the proposed method and the results of measures (SI, OF, OV, EF) are (0.84, 0.98, 0.73, 0.34). FIGURE 3.3 shows the evaluation index of proposed method and VOCAL between manual contours by physician. Besides, the study also compared the truth tumor size with that of the proposed method segmentation. Due to the benign tumor cases had no truth tumor size records. Ten cases with size record in the 15 malignant tumor cases were measured by the surgical excision. The comparison of size estimation shows on FIGURE 3.4.

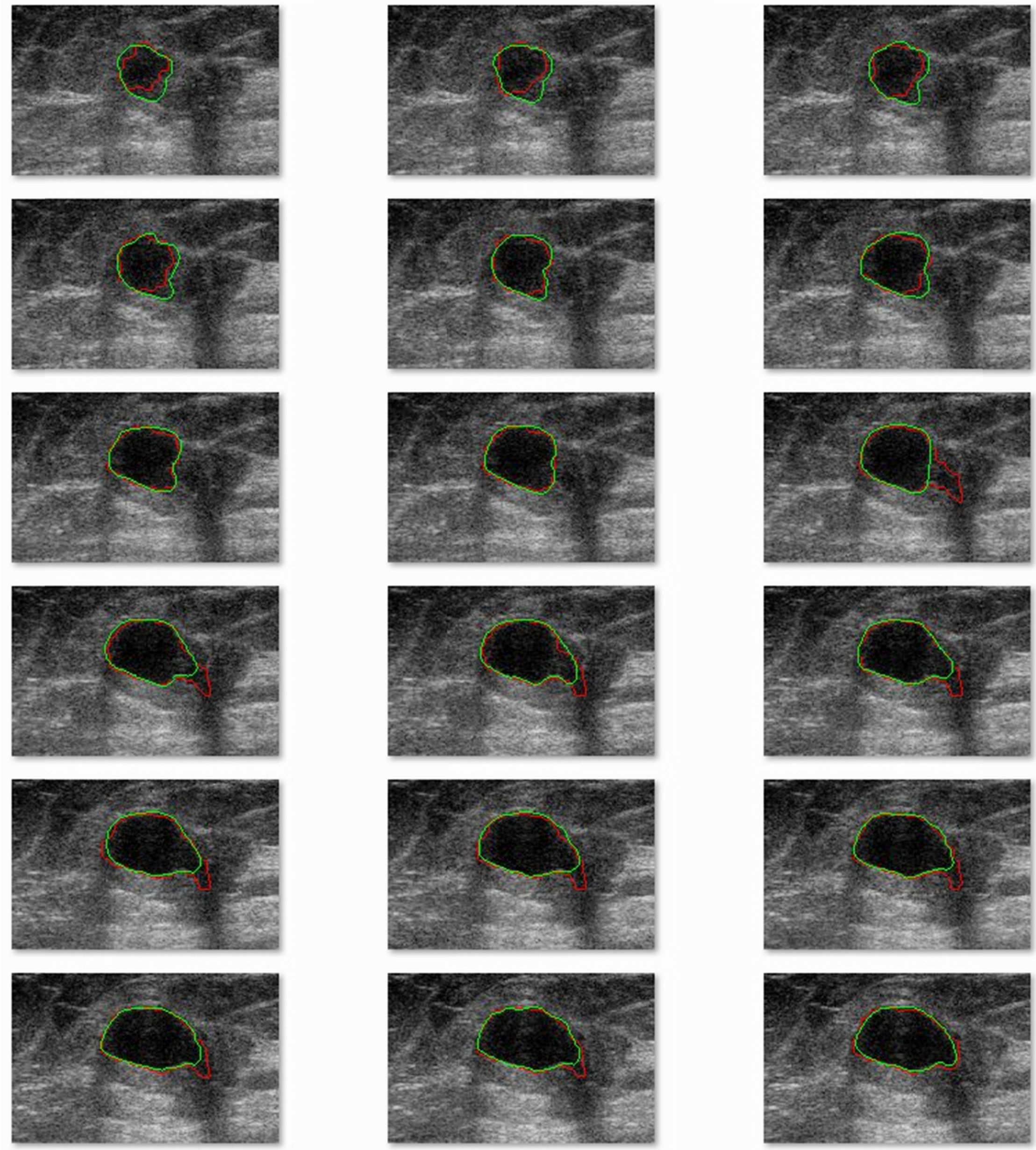


FIGURE 3.1: The result of proposed method (a malignant case): the red contour is the result of proposed method and the green contour is the manual sketched contours (continued)

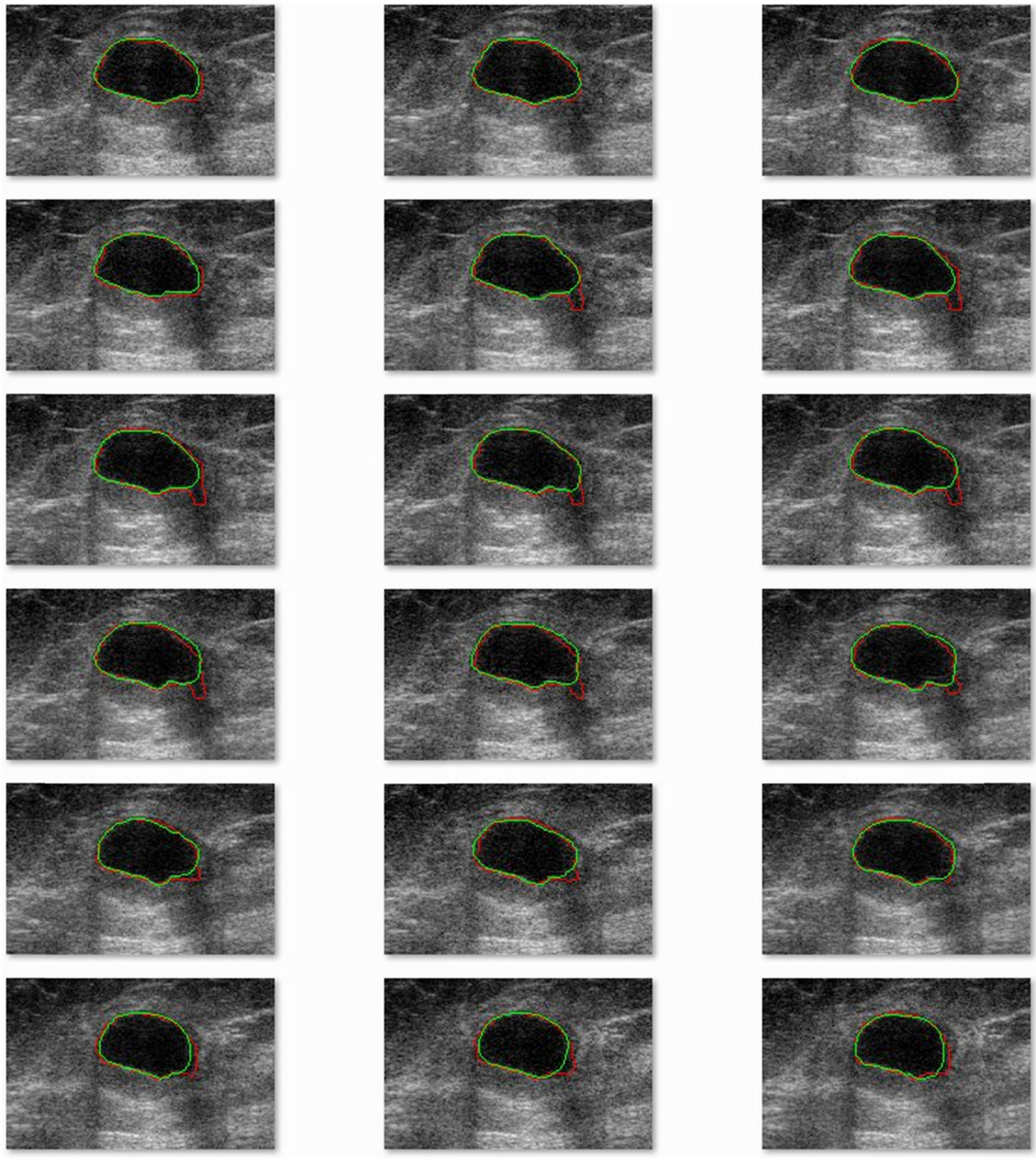


FIGURE 3.1: The result of proposed method (a malignant case): the red contour is the result of proposed method and the green contour is the manual sketched contours (continued)

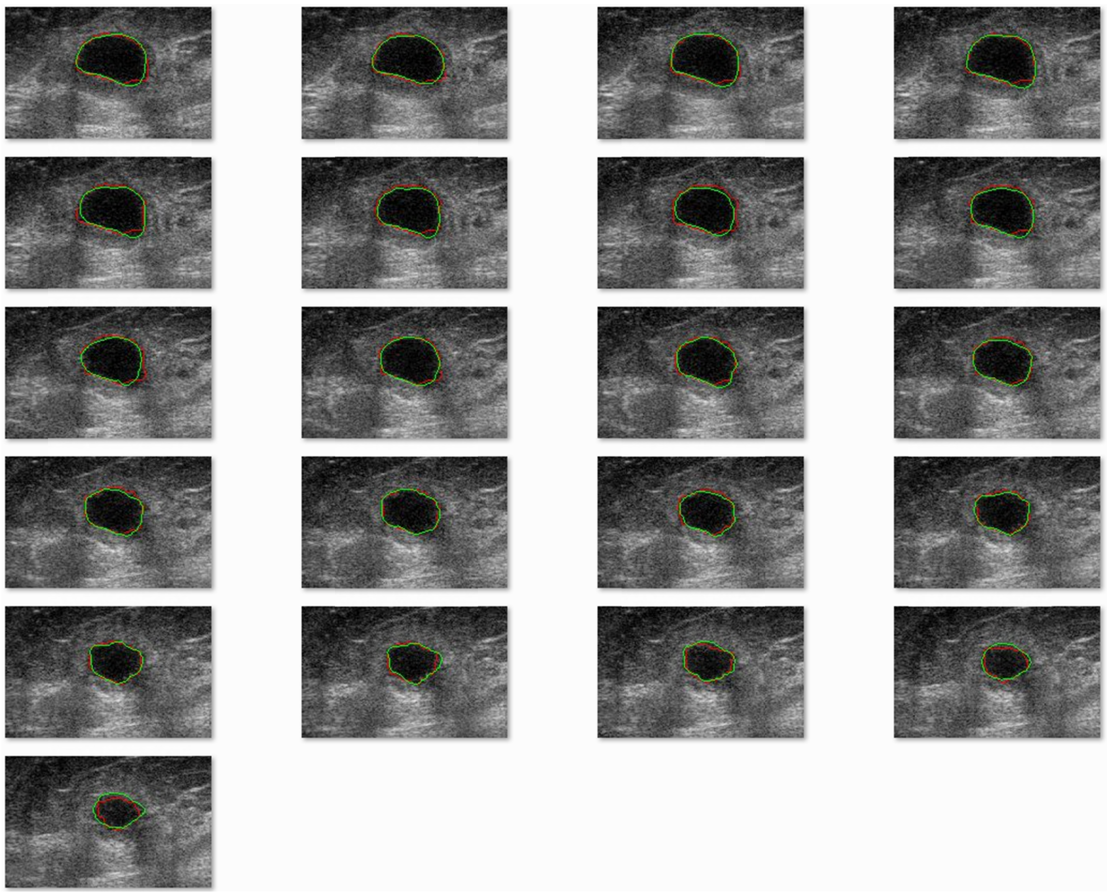


FIGURE 3.1: The result of proposed method (a malignant case): the red contour is the result of proposed method and the green contour is the manual sketched contours

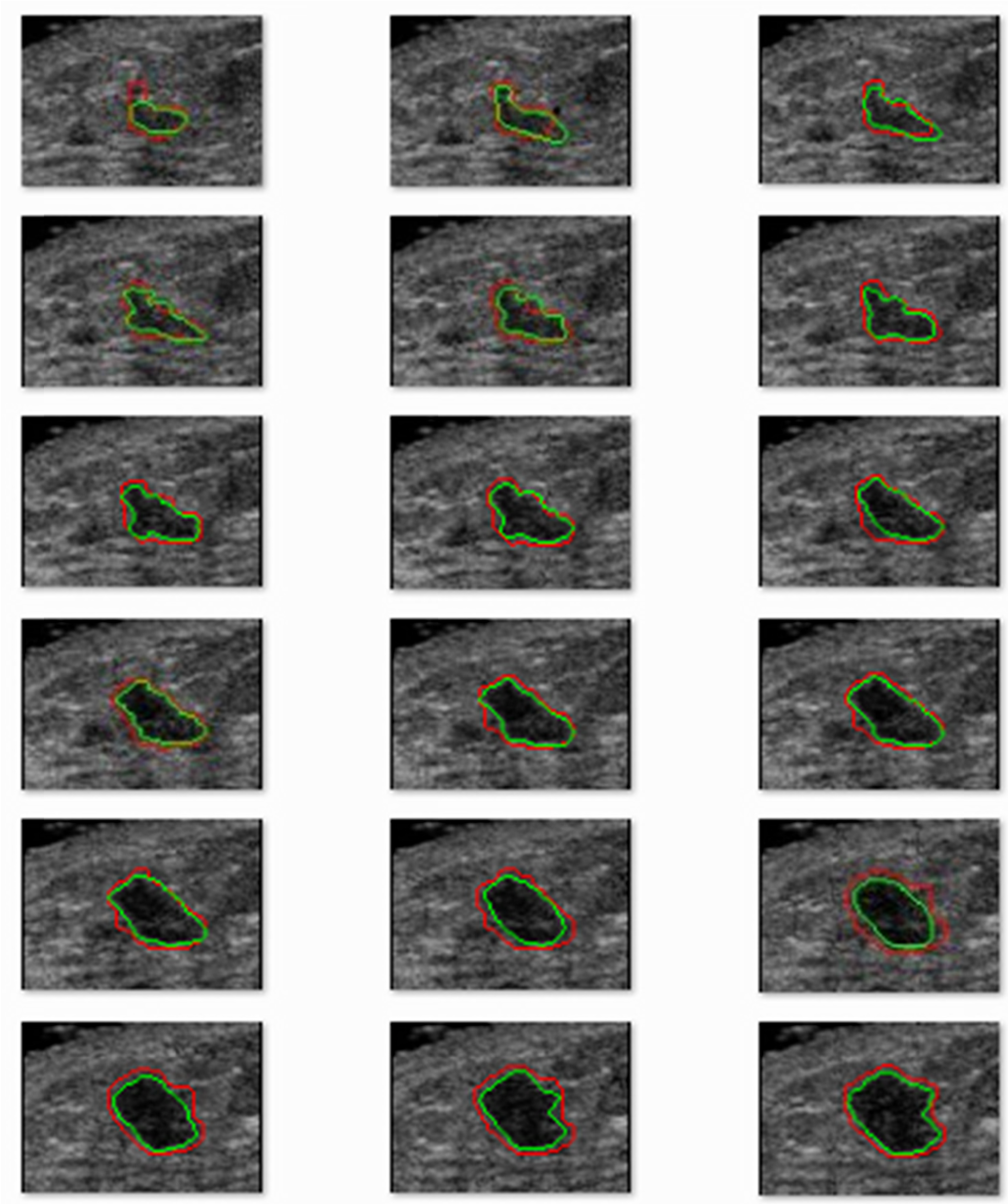


FIGURE 3.2: The result of proposed method (a benign case): the red contour is the result of proposed method and the green contour is the manual sketched contours (continued)

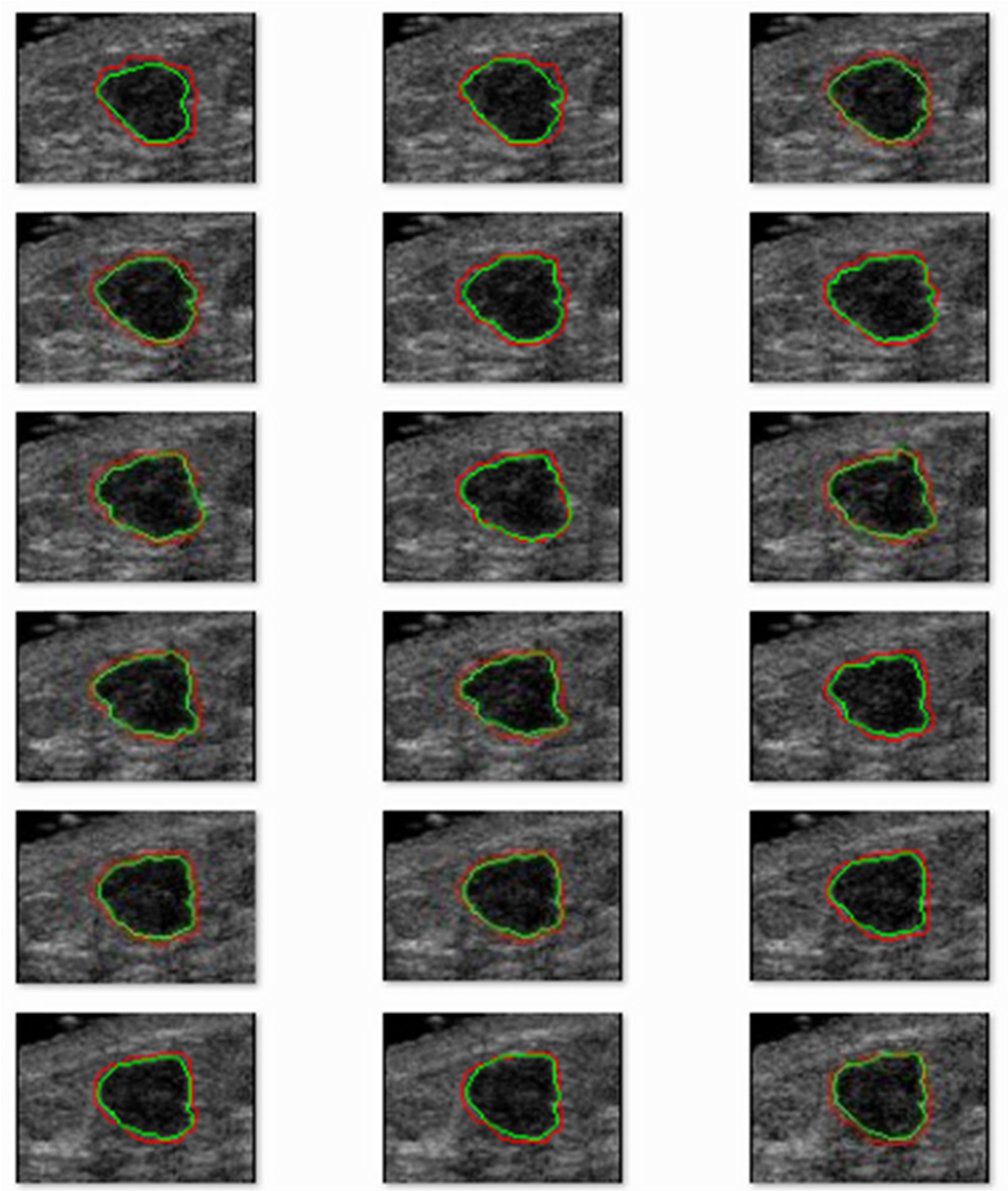


FIGURE 3.2: The result of proposed method (a benign case): the red contour is the result of proposed method and the green contour is the manual sketched contours (continued)

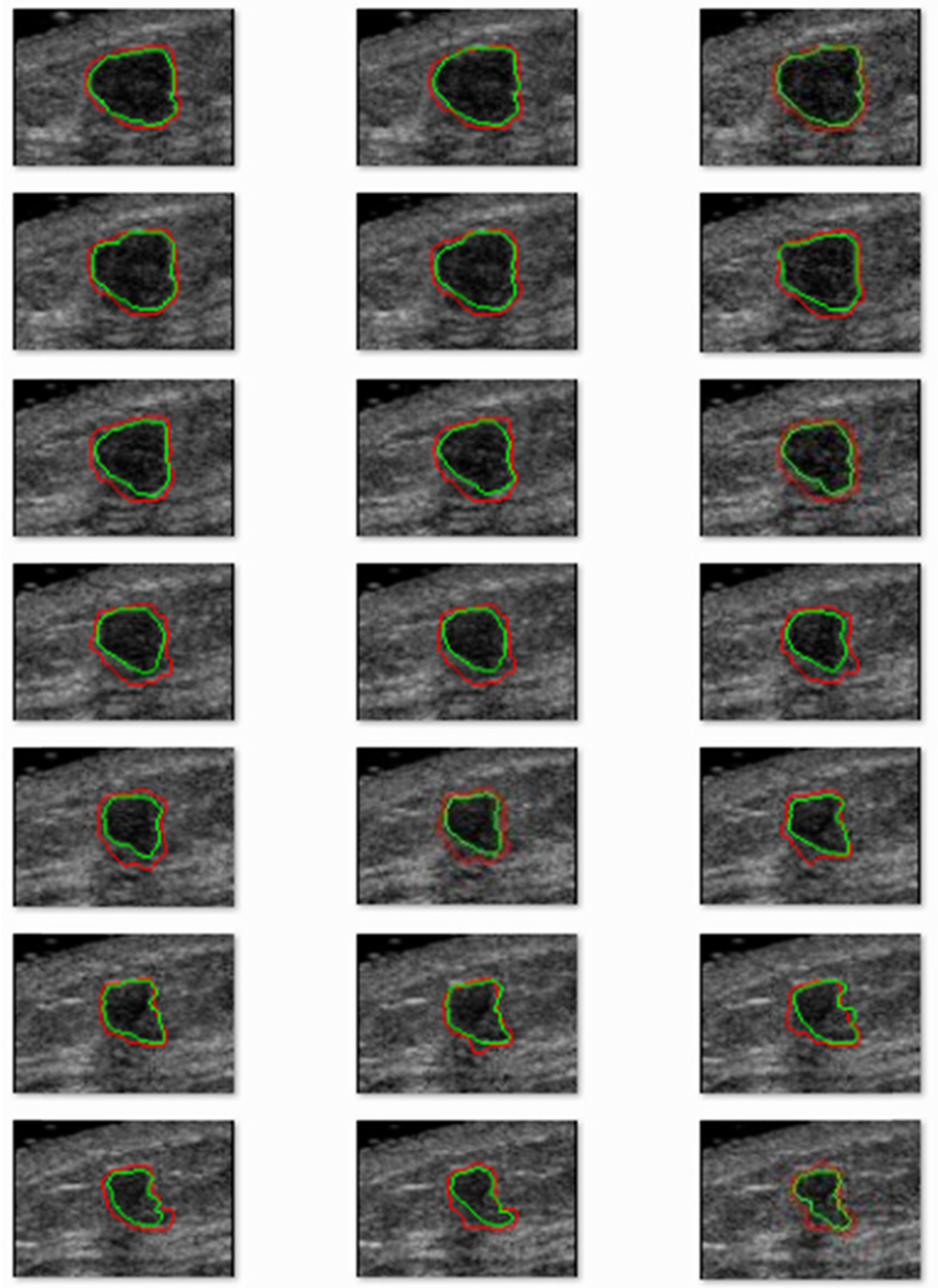
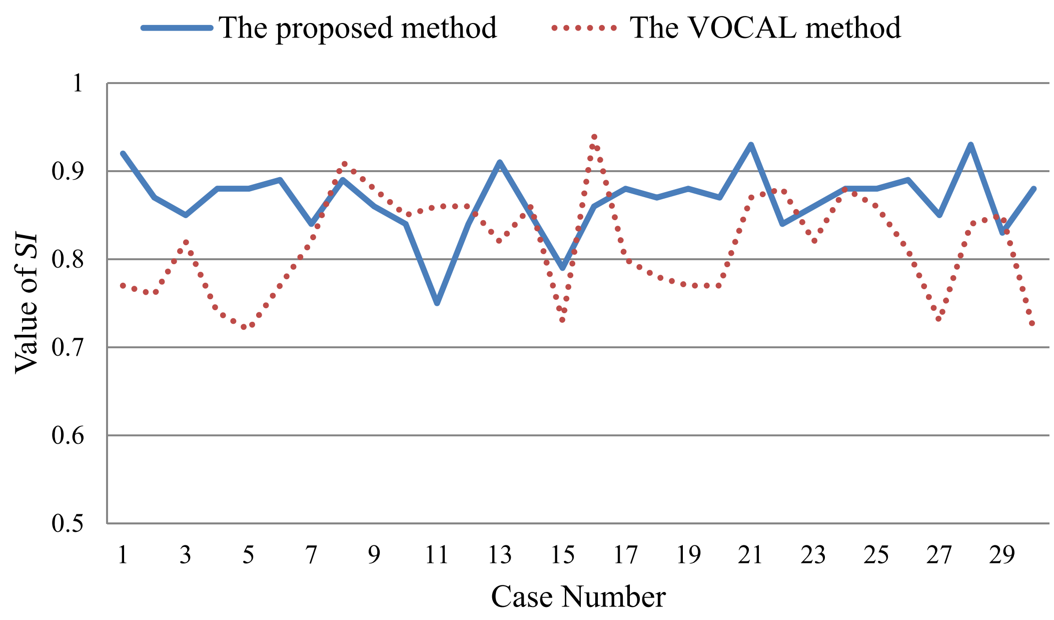
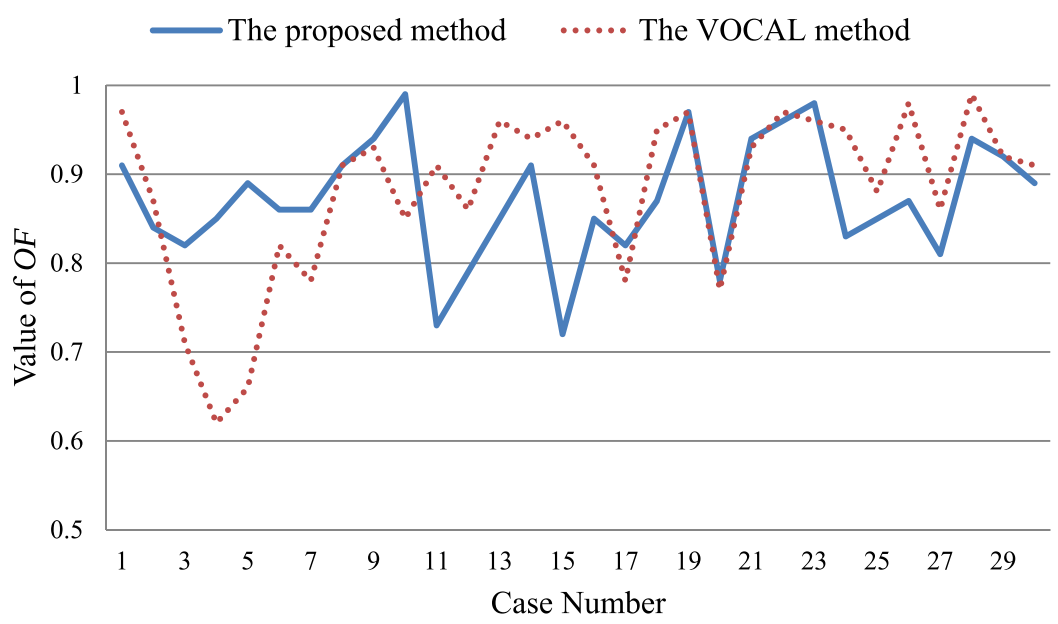


FIGURE 3.2: The result of proposed method (a benign case): the red contour is the result of proposed method and the green contour is the manual sketched contours

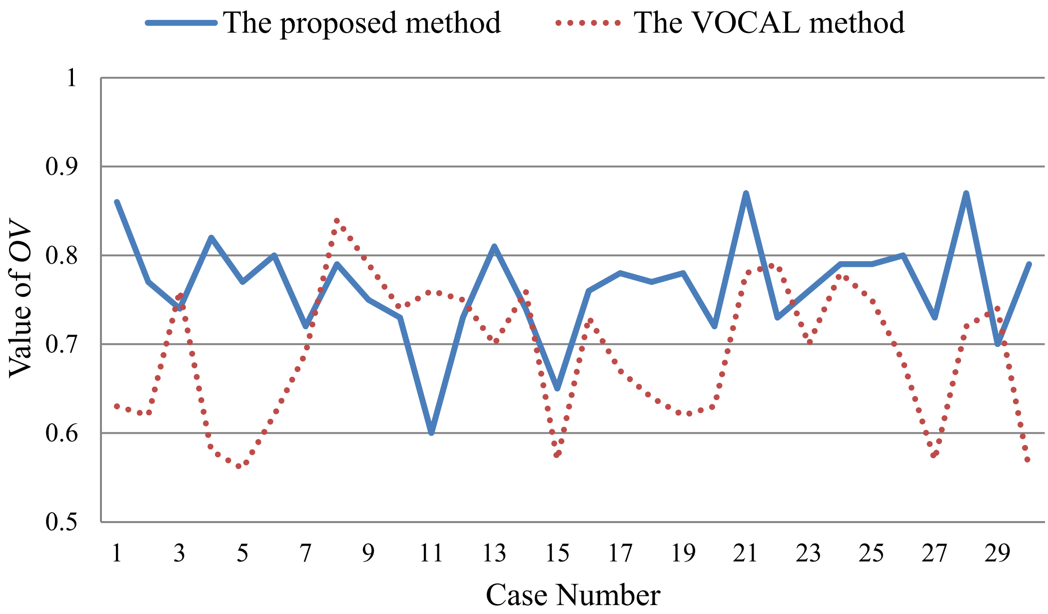


(a)

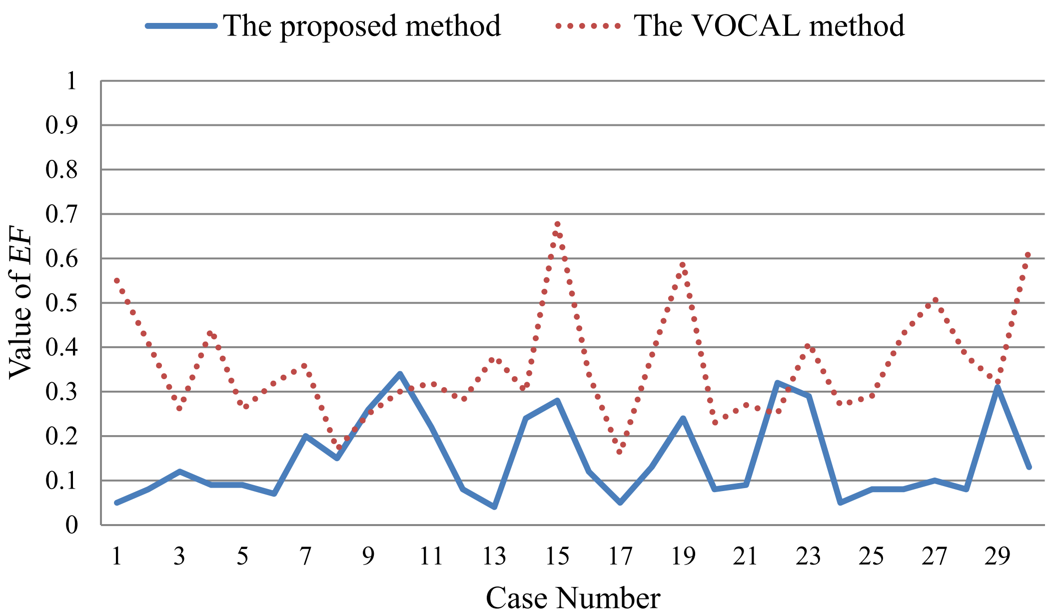


(b)

FIGURE 3.3: Comparisons of contouring performance: (a) similarity index (*SI*), (b) overlap fraction (*OF*), (c) overlap value (*OV*) and (d) extra fraction (*EF*) (continued)



(c)



(d)

FIGURE 3.3: Comparisons of contouring performance: (a) similarity index (*SI*), (b) overlap fraction (*OF*), (c) overlap value (*OV*) and (d) extra fraction (*EF*)

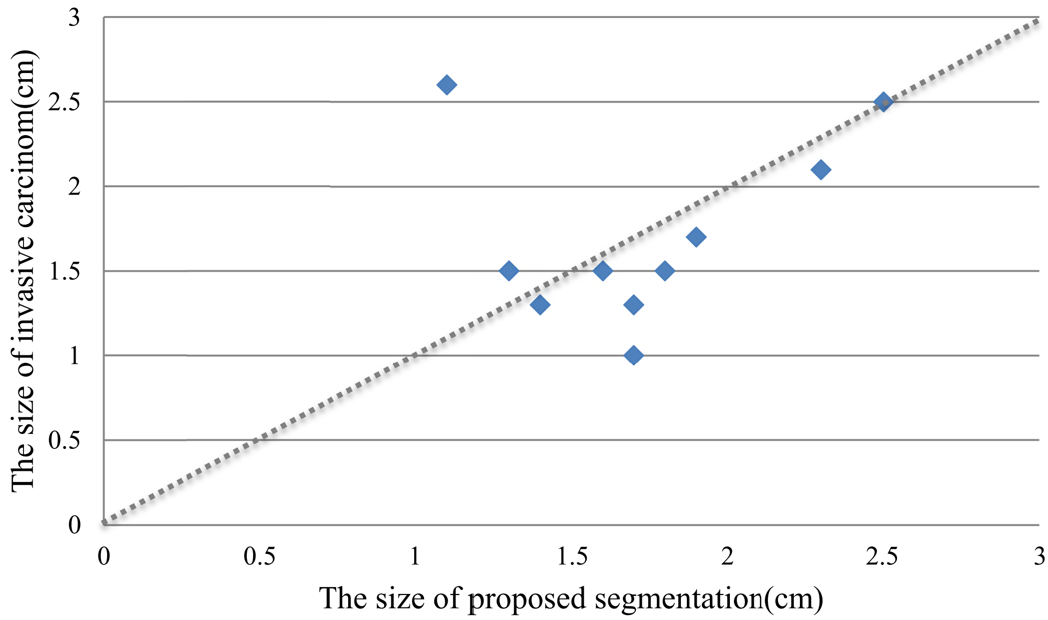


FIGURE 3.4: Comparisons the size of invasive carcinoma between the truth and the proposed segmentation

CHAPTER 4

DISCUSSION AND CONCLUSION

This study proposed a robust segmentation method to obtain the tumor contour and help the physicians on interpretation the information in 3D ultrasound imaging. This work could decrease the wrong judgment because of physician's inexperience and subjectivity. The proposed method segmented the tumor contour was based on 3D region growing techniques. The pre-processing of the proposed method applied to reduce the any amount of noises but preserve the shape and contrast of breast tumor. After segmentation, morphology processing could obtain the bordering of the supposed tumor contour smoother and fill the holes inter of tumor contour.

Four practical similarity measures were estimated the performance of the proposed segmentation method. TABLE 4.1 to 4.4 shows the four practical similarity measures comparison between proposed method and the VOCAL method. The results showed that the proposed method were better than the common VOCAL method. Besides, the advantages of proposed method are: (1) The proposed method was adaptive and useful to every case. It did not adjust the parameter to each case. (2) It was easy and only needed one seed point. The VOCAL method required the six extracted tumor regions by manual. (3) It was fast. The whole segmentation only took five to ten minutes, including pre-processing and post-processing procedures.

However, the performance of some cases was unsatisfactory because all the cases used the same parameters. Some cases might have the situation of overcutting even the post-processing was applied to avoid. In the future, we could discover the resemblance between the overcutting cases to retard the problem much more. It is believed that superficial measure and shape information from tumor's contours can be used in clinical diagnosis. Shape based ultrasound diagnosis of breast tumor takes the advantage of nearly independent to the different ultrasound machines. The development of automatic contouring method is important and its medical application is urgent.

TABLE 4.1: The evaluation using similarity index (SI) between the proposed segmentation method and the VOCAL method

	Average similarity index (SI)	
	The proposed method	The VOCAL method
Benign cases	0.86	0.81
Malignant cases	0.87	0.82
Total cases	0.87	0.82

TABLE 4.2: The evaluation using overlap fraction (OF) between the proposed segmentation method and the VOCAL method

	Average overlap fraction (OF)	
	The proposed method	The VOCAL method
Benign cases	0.86	0.85
Malignant cases	0.88	0.91
Total cases	0.87	0.88

TABLE 4.3: The evaluation using overlap value (OV) between the proposed segmentation method and the VOCAL method

	Average overlap value (OV)	
	The proposed method	The VOCAL method
Benign cases	0.75	0.69
Malignant cases	0.78	0.69
Total cases	0.76	0.69

TABLE 4.4: The evaluation using extra fraction (EF) between the proposed segmentation method and the VOCAL method

	Average extra fraction (EF)	
	The proposed method	The VOCAL method
Benign cases	0.15	0.35
Malignant cases	0.14	0.36
Total cases	0.15	0.36

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