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Mammography Image Segmentation: Chan-Vese Active Contour and Localised Active Contour Approach

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Abstract

Breast cancer is one of the most common diseases diagnosed among female cancer patients. Early detection of breast cancer is needed to reduce the risk of fatality of this disease as no cure has been found yet for this illness. This research is conducted to improve the Gradient Vector Flow (GVF) Snake Active Contour segmentation technique in mammography segmentation. Segmentation of the mammogram image is done to segment lesions existence using Chan-Vese Active Contour and Localized Active Contour. Besides that, the effectiveness of these both methods are then compared and chosen to be the best method. Digital Database of Screening Mammograms (DDSM) is used for the purpose of screening. First, the images undergo pre-processing process using the Gaussian Low Pass Filter to remove unwanted noise. After that, contrast enhancement applied to the images. Segmentation of mammograms is then conducted by using Chan-Vese Active Contour and Localized Active Contour method. The result shows that Chan-Vese technique outperforms Localized Active Contour with 90% accuracy.

Keywords: *Mammogram image, Chan-Vese Active Contour, Localized Active Contour*

1. Introduction

Early detection of breast cancer may give positive effect on the outcome of the disease through medical intervention [1, 2]. Mammography has been proven to be an efficient technique in screening the abnormalities of the cancerous cell. Segmentation of the mammogram image is done to partitioning the normal, benign or malignant tissues.

Medical imaging is needed for breast cancer screening, diagnosis and staging [3]. Breast cancer is originated by cell multiplication forming a lesion. This lesion may be malignant; to cause metastases or benign; not spread to other organs. With the aid of image processing and computational vision algorithms, it may decrease the error and make mammograms more reliable. Computer-Aided Diagnosis (CAD) may help the radiologists by providing second opinion and may be used as first stage of examination1.

Normally, there are two types of projection recorded during a mammographic exam; Mediolateral Oblique (MLO) view and Craniocaudal (CC) view. Studies had proven that, these two projections improve detection and diagnosis performances compare to the use of only single oblique mammographic view. MLO shows the view from right and left breast with the standard angle of 45° whereas CC shows the view from the top with the standard angle of 90° [4].

Previously, the research of mammography segmentation has been done using Gradient Vector Flow (GVF) Snake Active Contour method for the segmentation of mammogram images. This GVF method is useful as a basic implementation of active contour technique as it measure the energy minimization and flow towards Region of Interest (ROI) according to indicated crop region [5]. This process is considered as manual segmentation as the placement of initial contour is placed and the ROI is cropped according to desired output. Manual segmentation is time consuming due to the process of placement initial contour and cropping process. It is limited to localized region and can detect only one lesion.

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On the other hand, Chan-Vese Active Contours method purpose is to improvise the weaknesses of previous GVF snake method. Chan-Vese Active Contours does not need cropping process due to the properties of Region-based active contour that locate lesions using globalizing method [6-8]. It is considered as autonomous segmentation due to the placement of initial contour is throughout the whole image and does not need to be defined [8].

Another method for segmentation using Localized Active Contours is used to do comparison of these two methods of segmentation that produced the best results with least number of false negatives. Localized Active Contours is also a type of Region-based active contour but it differs on the placement of initial contours with Chan-Vese Active Contours method. The coordinate of initial contour is set manually and this method is considered as semi-autonomous segmentation [9].

The objective of this paper is to improve GVF Snake Active Contour mammography segmentation technique by applying Chan-Vese Active Contour and Localized Active Contour. The best technique will be chosen based on the accuracy percentage.

2. Research Method

The experiment stage is divided into data collection, image pre-processing, image enhancement and image segmentation. The flow chart of experiment is shown in Figure 1. Two approaches; Chan-Vese Active Contour and Localized Active Contour will be applied as image segmentation.

2.1. Data Collection

The data is collected from the Digital Database for Screening Mammography (DDSM) resource from University of South Florida through their online website. This DDSM project collection is a collaborative project including co-p.i.s at the Massachusetts General Hospital (D. Kopans, R. Moore), the University of South Florida (K. Bowyer), and Sandia National Laboratories (P. Kegelmeyer). DDSM is open for all research community and it is created to encourage and facilitate the research in screening mammogram using computer aided diagnosis development [10]. For the segmentation process of this project, 30 cases of mammogram images from DDSM are selected based on the type of lesions that are 10 cases of benign, 15 cases of malignant and 5 cases of normal tissue.

2.2. Image Pre-processing

As the second process of image processing, image pre-processing is done to ensure the reliability of the image itself to undergo segmentation. Research has proven that the mammogram image that undergoes active contouring without pre-processing produced a poor result and lesions are not fully identified [11]. As for this project, Gaussian low pass filter is applied to remove the digitization noises.The function of continuous 2-D Gaussian from an image using a discrete kernel derived from radially symmetric.

2.3. Image Enhancement

After the process of removing unwanted noise in the digital mammography image, image enhancement is applied to the image. Contrast enhancement is a process to improve the image quality for a better visual appearance for subsequent operations. In this case, contrast enhancement is needed to enhance the mammography image for the purposes of image segmentation.

2.4. Image Segmentation

2.4.1. Chan-Vese Active Contours

The first model active contour proposed by Chan and Vese is piecewise-constant active contour using the Mumford-Shah segmentation model. It moves deformable contours [12]. This model uses a particular level set equation and it is consider as the fastest convergence speed among region-based active contours due to the simple representation.

The second model also proposed by Chan and Vese is improved to piecewise-smooth active contour model using a set of smoothed partial images. The Chan and Vese proposed the multi-phase active contour model which increases the number of subsets that active contour can find simultaneously. This model developed independently based on both previous models of level set equations and multiple subsets are defined by a group of disjoint combination of the level set functions.

By applying this multiphase active contour model by Chan-Vese, multiple numbers of lesions either its benign of malignant are expected to be screened with the least percentage of error. In addition, this method uses global region-based active contour so that the lesions can be located throughout the whole image.

2.4.2. Localized Active Contours

Localized Active Contours is also a type of region based contour similar to Chan-Vese Active Contours. But this segmentation method does not based on global region models. Instead, it allows the foreground and background to be described in terms of smaller local regions, removing assumption that the foreground and background regions can be represented with global statistics. Local region leads to the construction of a family of local energies at each point along the curve. The energy computed is based on the movement of local energies either it is to minimize or maximize. These local energies are computed with local neighbourhoods splitting into local interior and local exterior by evolving the curve. Each of local region energy is optimized by model fitting [9].

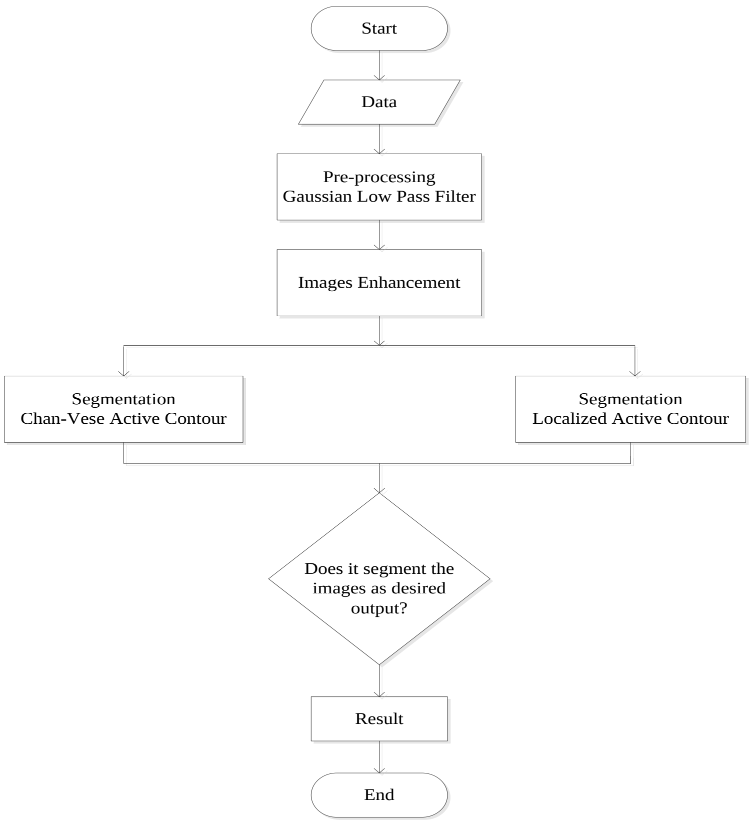


Figure 1. Flow chart of experiment

3. Results and Analysis

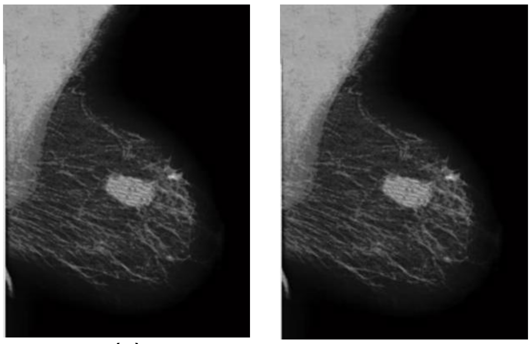
This sub-section described the result of mammography images segmentation were processed and analysed in MATLAB. Thirty images were processed with two proposed technique to meet the objective. The idea is to do comparison between two techniques that gives a better result. The experimental results are then analyses to determine the effectiveness of this project.

Image pre-processing is one of the major processes in this project. Initially the mammogram is difficult to locate the suspicious area for a number of reasons. The small differences between normal and tumorous tissues in human breasts create a little contrast with its image background. Therefore, several steps are taken to maximize the differences of tumours and the background image for the best results.

With comparison and trial of several filters, Gaussian Low Pass filter is chose to filter the image after the resizing process. This is because Gaussian Low Pass filter is capable in filtering digitizing noise and artefacts suitable with the mammography images used. Another important quantitative property of this filter is that the result is always positive due to non-negative properties that will surely produce a result of a valid image.

Figure 2 shows the process of Gaussian Low Pass filter before and after process. In this project, the Gaussian Low Pass filter used a value of (4 3) and 0.6 for row, column vector and standard deviation sigma (positive) respectively. The most suitable value of sigma is 0.6 due to the noise and artefacts are blurred into desired observation. The blurred process is also called Gaussian blurring. After pre-processing, the noise and artefacts are omitted.

There are two possible approaches in enhancing mammographic features. One is to increase the contrast of suspicious areas and the other is to remove background noise. Contrast enhancement is applied on the mammograms image after Gaussian Low Pass filtering in order to enhance the suspicious areas to ease the process of detecting lesions in segmentation process. Contrast enhancement is required to enhance the image especially in a dense breast cases. Due to the low contrast of mammograms image itself, calcifications may not be seen with naked eyes. Therefore, a certain value of enhancement is adjusted to obtain the best results.



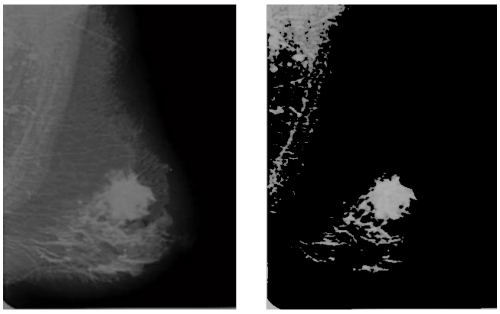
(a) (b)

Figure 2. (a) original image (b) image after Gaussian Low Pass filtering

Figure 3 shows the process of contrast enhancement. In contrast enhancement, it maps the value of filtered image to the new values of enhanced image. Where in this case, gamma specifies the shape of the curve describing the relationship between the values of Gaussian filtered image and new enhanced image. The shape of the curve in this context is the value of gamma used that is less than 1. Therefore, the mapping is weighted towards higher output values. This is needed to totally eliminates noise and artifacts and bring contrast between suspicious areas of lesions and the black background image.

Chan-Vese Active Contours is one of the methods to segment mammograms without searching for edges using two-phase piecewise constant model. The segmentation boundary is represented implicitly with a level set function, which allows segmentation to handle topological changes more easily than explicit snake methods. Fully automated segmentation is done using Chan-Vese Active Contours segmentation due to the properties of capability to place the mask throughout the image will a shorter time processing than few other methods.

Figure 4 shows the initial mask used for this initial contour and are placed throughout the image. This is to certify active contour to segment more than one lesion if there are any other lesions exist. Mammograms images are segmented using a default initialization and without re-initialization process to globally segmented the images.



(a) (b)

Figure 3. (a) Image with Gaussian Low pass filter (b) image after contrast enhancement

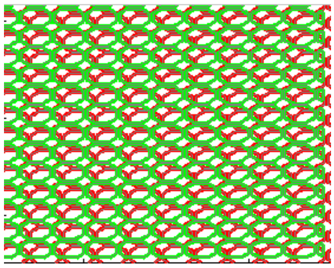
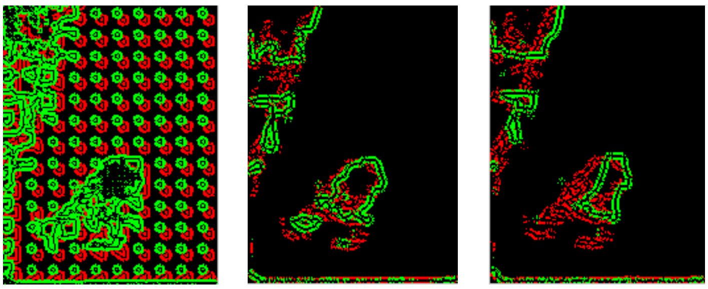


Figure 4. Initial mask of whole

Figure 5 shows the number of iteration process of segmentation. Chan-Vese Active Contours segmentation converges depend on the number of iteration, this project is specified with 500^{th} of iteration. Within this 500^{th} of iteration, the lesions or non-lesion cases are expected to be segmented well. For the normal cases (absent of lesions) the Chan-Vese Active Contours segmentation will directly segment the picture black and no process of iteration is needed. Therefore, lesser time needed to process the image. Chan-Vese Active Contours has a fitting energy functional that forms basis for its algorithm, by minimize this fitting energy of the mammograms image, the minimizing level set function ϕ will define the segmentation [6].



(a) (b) (c)

Figure 5. (a) 100^{th} iteration (b) 250^{th} iteration (c) 500^{th} iteration

Figure 6 shows the image of before and after the segmentation process. Chan-Vese Active Contours has quite a few tuning parameters, the most important is μ. Parameter μ adjusts the length penalty, which balances between fitting the input image more accurately with smaller μ or to create a smoother boundary with larger μ. The value of μ used in this case is 0.2 because lesions are more preferable need higher accuracy rather than smoother boundary.

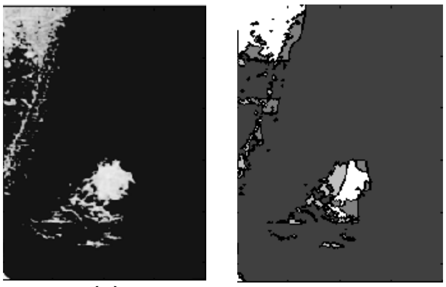


Figure 6. (a) Contrast enhanced image (b) Complete segmented image

Instead of searching the lesions in the image globally as Chan-Vese Active Contours, Localized Active Contours segment the image locally. The foreground of breast and the background is described in terms of smaller region. Local regions construct local energies at each point along the curve. In order to optimize these local energies, each points is considered separately, and moves to minimize or maximize the energy computed in its own local region specified initially. Figure 7 shows the number of iteration taken to complete the segmentation process. The initial contour is placed fixed in every data cases to identify the ability to handle varies placement of lesions spot in thousands of cases.

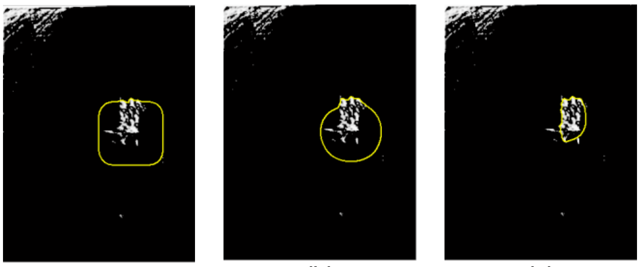


Figure 7. (a) 100th iteration (b) 500th iteration (c) 1500th iteration

Table 1 shows results percentage of segmentation for both methods obtained. From this percentage, Chan-Vese Active Contours shows a total accuracy of 90%. Whereas Localized Active Contours shows a total accuracy of 43.33%.

Table 1. Result of accuracy from Chan-Vese Active Contour and Localized Active Contour

Data Cases (30)	Chan-Vese Active Contour		Localized Active Contour	
	True positive	False negative	True positive	False negative
Malignant (15)	80 %	20 %	33.33 %	66.67 %
Benign (10)	100 %	0 %	30 %	70 %
Normal (5)	100 %	0 %	100 %	0 %
Total accuracy	90 %		43.33 %	

Chan-Vese Active Contours method leads Localized Active Contours method by 46.67%. Chan-Vese Active Contours method is considered as an automated segmentation due to the absence of changing initialization. It used only 500th iteration to complete the whole segmentaion process which is lesser than Localized Active Contours. The processing time for

500th iteration to complete almost in 3 minutes. Whereas for Localized Active Contours initialization is in windows size and it is a lot smaller than Chan-Vese"s method. The window sized contour is the initial contour that is placed fixed throughout each case. It clearly shows that this method is semi-automated segmentation due to the initialization had to be place manually to obtain better results. 18 out of 12 cases are mostly due to the unfit position of initial contour. This method is adjusted to 1500th iteration for the whole process. The processing time for 1500th iteration to complete around 6 to 7 minutes.

4. Conclusion

Active contour model segmentation method is used for this project aimed to develop a good segmentation results on mammogram images which contain many constrains to segment. In order to show the improved performance of the Chan-Vese Active Contours method, 30 data cases are also applied on the Localized Active Contour method that cannot properly segment the lesions due to lack of efficiency in conducting automated segmentation process. Chan-Vese Active Contour gives result 90% accuracy, while Localized Active Contour gives result 43.33%. On the other hand, Chan-Vese Active Contour method has proven to produce satisfying results for image segmentation as well as reducing the computation time and effort compare to Localized Active Contour method.

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