

Color Doppler to Characterize Malignant Breast Lesion

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Abstract- Doppler ultrasound is an important non-invasive diagnostic tool for identifying breast diseases. Ultrasound utilizes spectral Doppler techniques for quantitative evaluation of blood flow velocities, and these measurements play a crucial role in the diagnosis. In this paper, we describe a computer vision approach to automate the Doppler malignancy estimation. We present a technique for segmenting blood vessels in ultrasound color Doppler images based on image processing techniques. The technique decomposes a complex object representing either two or more vessels artificially linked together or a main vessel with its branches. We segment out the blood vessels in ultrasound color Doppler images and count the number of vessels to detect breast malignancy. MATLAB has been used to simulate the algorithm and the results obtained are presented in this paper. The result represents distinct vessels that can be used in further object recognition and quantification applications.

Keywords- Breast Cancer; Color Doppler; Sono-mammography; Ultrasound

I. INTRODUCTION

In the last two decades of the twentieth century, a combination of modern treatment methods and strategies for early detection through screening and better public awareness, have improved survival of breast cancer despite a worldwide rise in its incidence. Different macro imaging like X-Ray mammography, Sono-mammography and Breast MRI play a major role in detection. Sono-mammography is a promising one among them for it is non-invasive and also cost effective for mass screening.

Ultrasound imaging systems offer two main image types-gray-scale images and color Doppler images, each of which has its own clinical usage. Gray-scale images are used to visualize the anatomy of different body organs, while color Doppler images are used to visualize the blood flow [1] within the organs. Both images are used simultaneously for diagnosis as shown in Figure 1.

To improve the accuracy of USG, additional techniques like Doppler imaging can be used. Doppler ultrasound technique is associated with reflection of continuous ultrasound waves. When an interface has back and forth movement, the transmitter and receiver frequency of the reflected ultrasound wave decreases or increases respectively. Doppler Effect refers to a change in the perceived frequency of sound emitted by a moving source. Doppler machines have the capability to note down the frequency changes. Doppler Effect in reflected wave gives information about the motion of the tissue interfaces. Transducers used for Doppler instruments consist of double-crystal, one transmitter and another receiver. Transmitter generates continuous ultrasound

beam and they have no or very little damping material inside. Quantitative blood flow measurement can be done using this technique and it produces 2D images of region where blood-flow or tissue movement is occurring. The cost of this instrument is also very low.

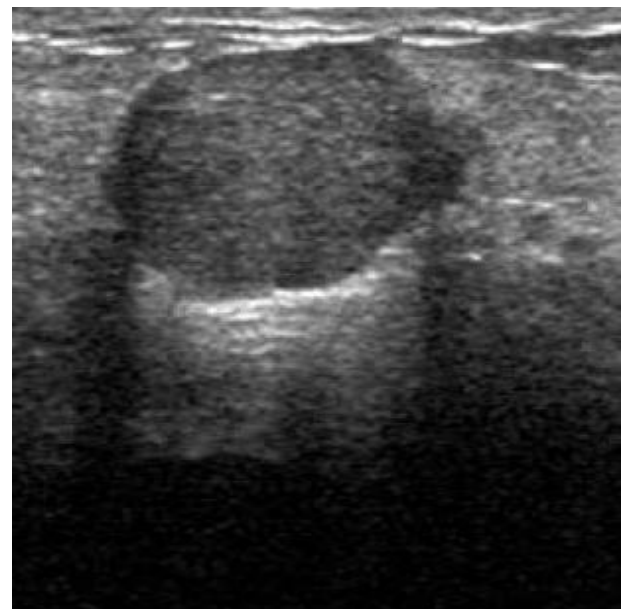


Fig. 1(a) The gray-scale image of mass

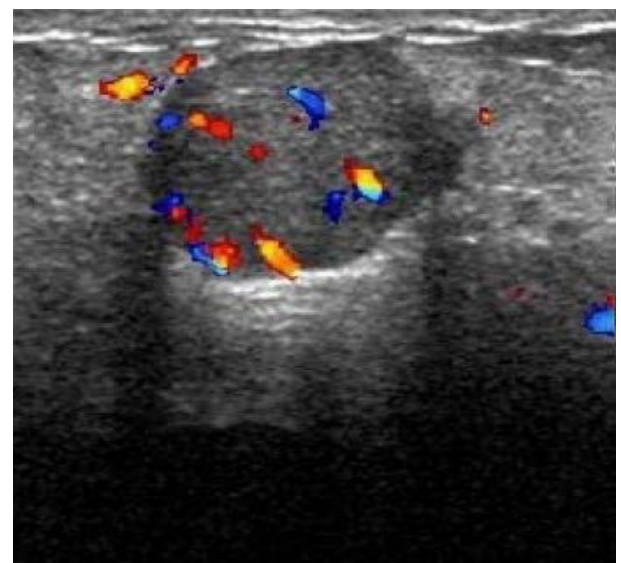


Fig. 1(b) The composite color Doppler and gray-scale ultrasound image



Fig. 1(c) The color Doppler image palette and velocity range

The ultrasound Doppler image construction relies on the frequency shift present in ultrasonic pulses backscattered from moving blood cells [1]. Color Doppler is a specific type of Doppler Scanning procedure. Color-Doppler ultrasound shows blood flow in real time and color by combining the features of M-mode ultrasound and Doppler Effect. The mean frequency shift is color-coded for direction and velocity. All non-moving structures are shown in shades of gray and all the moving structures in shades of red or blue depending on direction and velocity. Most systems code blood-flow toward the transducer as red and flow away as blue. Differences in relative velocity of flow can be accentuated and the presence of turbulence can be indicated by different maps that utilize variations in brightness and color. Color Doppler helps in investigation of body organs breast, kidney, certain renal diseases like primary renal vein thrombosis and vascular complications of renal transplantation. It also allows a rapid diagnosis and guides the subsequent radiological assessment, prenatal detection of abnormalities of the heart and great arteries. It improves the diagnostic accuracy of 2D gray-scale imaging [2].

Color Doppler is useful in distinguishing between an echogenic lipid layer or tumefactive sludge within a cyst and true intra-cystic papillary lesions. Intra-cystic papillary lesions, whether benign or malignant, is demonstrable with color or power Doppler [10]. Single large feeding vessel within such an intra-cystic area indicates benign intra-cystic papillomas, whereas multiple vessels indicate malignant intra-cystic papillary lesions.

We have captured ultrasound (USG) and color Doppler images of the same mass which are suspected by radiologists. For processing of images, we have used median filter to reduce the speckle noise, multi-value thresholding and edge detection for distinct vessel segmentation and counted the number of vessels for detection of malignancy. We also analyze the results for different USG color Doppler images to identify a subgroup of mass as benign or malignant to avoid or reduce biopsies.

Gray-scale ultrasound images suffer from speckle noise, shadowing, and fuzzy or incomplete vessel boundaries [1]. Color Doppler images suffer from flash artifacts, noise and color bleeding, which causes distinct vessels to appear as if they are linked [4]. All these factors make it difficult for a segmentation algorithm to succeed.

The organization of the paper is as follows: Section II and Section III cover the Methods (contain Features and Proposed Algorithm) and Simulation Results. Conclusion is given in Section IV.

II. METHODS

A. Ultrasonic Image Database

The USG images used in this paper were provided by the I.P.G.M.E.R. & S.S.K.M. Hospital, Kolkata, India. The database contained 77 digital ultrasonic images, composed of 56 benign and 21 malignant images confirmed through biopsy by onco-pathologists and radiologists. Solid mass with no histological confirmation was excluded as well as simple and complicated cysts. All lesions were histologically confirmed using a core needle, an excisional biopsy, or both. The patients' ages ranged from 18 to 85 years (mean 47 years). US are performed by one breast radiologist by using a Toshiba Nemio or a Siemens Antares with a 10-MHz transducer and freeze-frame capability. Images used in this study were selected from the plane showing the longest diameter of the mass. A 640×480 digital image is captured from the US scanner, where 1 pixel size corresponds to 0.1 mm.

B. Feature Extraction

Easily adaptable by humans, Doppler USG, is performed non-invasively and used for the evaluation of tumor vascularity. Color Doppler is mainly used as a qualitative and quantitative tool to differentiate between benign and malignant lesions of the breast and to predict various prognostic factors such as axillary infiltration or grade of the tumor [3][4]. Doppler estimation can be used to predict the response to chemotherapy in patients with breast cancer and it correlates well with histo-pathological response [5].

Doppler USG feature, that most reliably characterizes masses as benign or as malignant, is the number of tumor vessels [7]. Feature, that characterizes masses as malignant, includes greater than 3 tumor vessels [5]. Breast cancers have a greater total number and greater number of vessels than those in benign lesions [7].

C. Pre-processing

The ultrasonic images suffer from speckle noise due to interference of back-scattered signal, and this noise significantly degrades the image quality and hinders to obscure the fine details [8][10]. Therefore, the image is pre-processed with 3×3 median filter to reduce the speckle noise. Median Filter is quite popular because for certain types of random noise, it provides excellent noise reduction capabilities with less blurring, and it is effective in the presence of salt pepper noise.

D. Processing

The image is converted to binary image using three threshold [8] value which is determined by the Red – Green –Blue component of the image. Thresholding produces a relatively large region together with many separated or interconnected regions. Among the remaining objects, one closest to the center of ROI is then automatically selected as the vessel.

After segmentation, the object is smoothened by filling the holes inside the vessel by applying image opening and closing operation with a structuring element [7][10]. The opening smoothes from the inside of the object contour and the closing from the outside of the object contour. Holes inside the nodule are filled by applying closing algorithm. Finally, we obtain the boundary pixels of the vessel by removing interior pixels. The whole image processing procedure is illustrated in Figure 2(a-b).

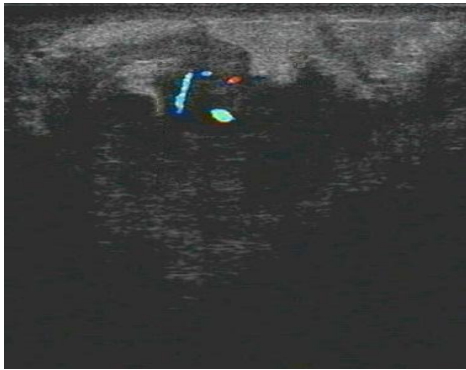


Fig. 2(a) A color doppler image of vessels



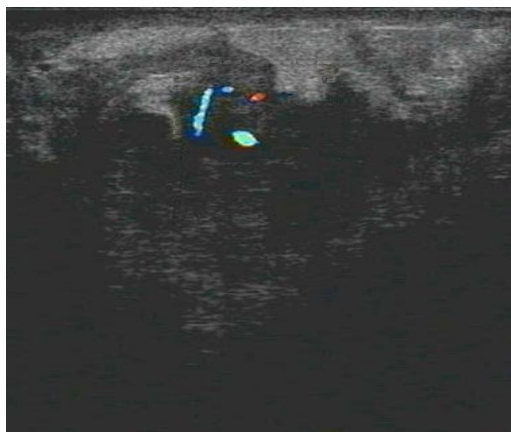
Fig. 2(b) A binary representation of the color doppler image: example of an unacceptable low-resolution image

After edge detection and identification of the vessel we apply 4-connected algorithm [8] to automatically count the number of vessels within the image.

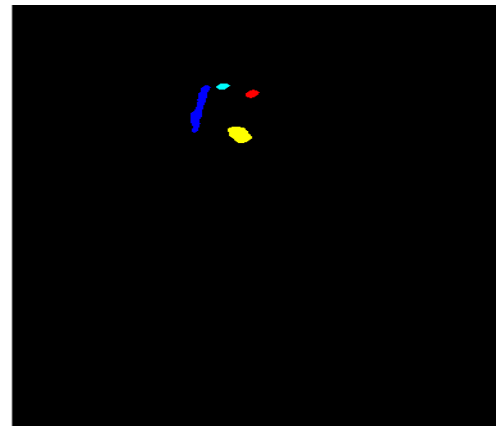
III. SIMULATION RESULTS

Figures 3(a) and 4(a) display the original color Doppler image captured by USG device, and Figures 3(b) and 4(b) the segmented and identified colored vessels of typical malignant and benign nodules, respectively.

Number of vessels of the malignant nodule is always greater than 3 and that of the benign nodule is always less than three. After identifying the vessels we calculate the number of vessels in the mass to automatically detect the breast malignancy. Example of the nodule [Figure 3], having the number of vessels 4 (greater than 3) is therefore a malignant one. The nodule [Figure 4], having the number of vessels 2 (less than 3) is therefore a benign one.



(a)



(b)

Fig. 3 Example of malignant nodule with (a) original color doppler image captured by USG device; (b) colored vessels 4 Nos. (number greater than 3)



(a)



(b)

Fig. 4 Example of benign nodule with (a) original color doppler image captured by USG device; (b) colored vessels 2 Nos. (number less than 3)

We have tested our technique on 77 images. The sensitivity $[TP / (TP+FN)]$, the specificity $[TN / (TN+FP)]$ and the classification accuracy $[(TP + TN) / (TP+FN + TN+FP)]$ of the system is 90.5% (19/21), 89.28% (50/56) and 90% (69/77) respectively. The positive predictive value is 76% (19/25) and the negative predictive value is 96.15% (50/52).

IV. CONCLUSIONS

The technique is not without limitations. As with any USG technique, Color Doppler USG results may vary depending on the operator. It is also subject to motion artifact from the transducer, which can simulate blood flow. The analysis of the images is subject to variability in the way the regions of

interest are drawn and the tumor is framed within the analysis software. Attempts were made to center the image of the tumor in the Doppler USG box, and regions of interest were drawn to include only tumor.

In this paper, we analyzed the technique to segment ultrasound color Doppler images based on image processing and to successfully recognize distinct vessels. To assess the diagnostic performance of Color Doppler USG measures in conjunction with gray-scale USG criteria in differentiating benign from malignant breast masses, by using histological findings as the reference standard we have tested our technique on benign and malignant cases, and it successfully segmented and counted the number of vessels in every image.

Our future work will focus on improving the detection algorithm.

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