1st International Conference on Experiments/Process/System Modelling/Simulation/Optimization
1st IC-EpsMsO
Athens, 6-9 July, 2005

DEVELOPMENT OF A REMOTELY ACCOMPLISHED EDGE – DETECTION ALGORITHM ON BREAST ULTRASOUND

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Keywords: boundary detection, dynamic contours, remote processing, ultrasound breast lesions.

Abstract:
Purpose: The development of an edge detection algorithm, accomplished remotely, utilizing a server and a client in a local network Material and Methods: 150 breast ultrasound (US) images, depicting various aspects of breast lesions, were captured employing a HDI-3000 ATL digital US system with 512x512x8 image resolution. The basic configuration comprised a client and a server. Image processing was distributed, both to the client and the server; the client pre-processed images in order to enhance the lesion boundary, while the server delineated the lesion boundary. Client-side processing involved: (i) median filtering, (ii) adaptive three-level wavelet-based soft-thresholding for de-speckling, and (iii) image histogram thresholding for lesion boundary enhancement. Server-side processing comprised dynamic contour processing for accurate lesion boundary detection. Results (boundary points) were sent back to the client, were superimposed on the original image, and were compared with the free-hand selection performed by the physician (N.D.). Results: Agreement between lesion boundaries selected by the physician and boundaries determined by the proposed algorithm was 92%. Overall processing time was less than 3s (including transfer time from Client to Server and vise-versa), requiring only minimum operator intervention. Conclusion: The proposed edge detection algorithm is fast and accurate enough, therefore, it may be valuable for assisting physicians in assessing the size of breast lesions on US.

1 INTRODUCTION

The distribution of processing is an important issue when computer processing time demands are high. Distribution of workload may be accomplished on different workstations that may be situated at remote sites. The remotely accomplished processes are distributed by a server and they may run in parallel at a number of clients (nodes), thus leading to faster implementation of time consuming algorithms. Previous studies have implemented distributed processing for a number of applications ranging from distributed systems on spiral CT architecture [1], to parallel medical image analysis for diabetic diagnosis [2].

In the present study, an edge detection algorithm was developed, based on active contours and wavelet assisted pre-processing, for delineating lesions on breast ultrasound (US) that could run in parallel on remote work stations. Image processing algorithms were developed in Java and included a combination of steps performed at both the client and the server sites. Image processing comprised (i) client-side processing, involving median filtering, adaptive three-level wavelet-based soft-thresholding for de-speckling, and image histogram thresholding for lesion boundary enhancement, and (ii) server-side processing, involving dynamic contour (snakes) processing for accurate lesion boundary detection. For lesion extraction, the physician (N.D.), at the client site, manually selected on the US image a few points, roughly encompassing the lesion. The client workstation pre-processed the image and sent the selected points and the processed image to the server, for lesion outline delineation, using TCP/IP Java Sockets interface.

On receiving the data, the server delineated the lesion boundary, by employing a dynamic contours algorithm. Thus, the lesion boundary delineation workload was distributed between the server and the client.

2 MATERIALS AND METHODS

The local area network employed was an Ethernet 802.3 CSMA/CD 100BASET with 108 Mps data transfer speed. Two remotely connected workstations (Intel Pentium 4, 1.8 GHz / 512 MB RAM) were used and the open source software platform Java 2 Standard Edition was employed for the development of the application (algorithms and connection interface).

The depicted breast lesions comprised the following types of verified lesions: 7 simple cysts, 32 complicated cysts, 52 malignant and 59 benign solid masses. Images were digitized by connecting the video output of the ultrasound scanner to a Screen Machine II frame grabber with 512x521x8 image resolution.

2.1 Client processing.

Median Filtering

The first step of the client-side processing, involved image smoothing by means of the median filter [3, 4]. The latter transformed the image lesion histogram into bimodal shape (see Figures 1, 2 and 3), each peak corresponding to background and lesion pixels respectively, thus facilitating lesion segmentation.

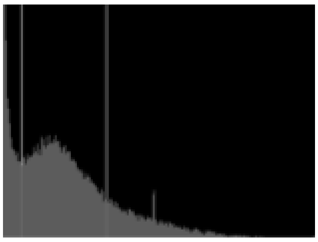	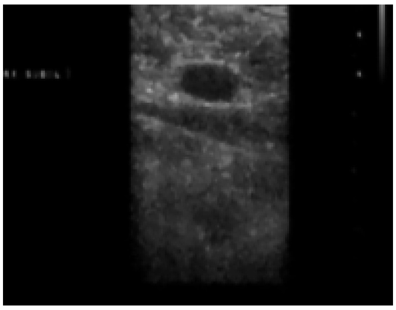	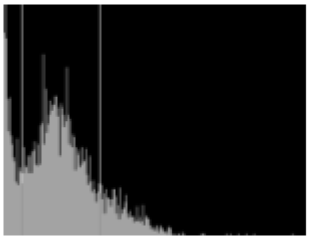
Figure 1: Histogram before median filtering.	Figure 2: Us breast image with lesion.	Figure 3:Histogram after median filtering.

Wavelet-based soft thresholding

In the second step of the client-side processing, the 3-level wavelet soft thresholding (SWTF) was employed for noise suppression [5] (see Figure 4). The wavelet detail coefficients of all decomposition levels were modified according to Eq. (1).

$$W_{out}(W_{in}) = \begin{cases} 0 & \text{if } |W_{in}| \leq T \\ W_{in} - T & \text{if } W_{in} > T \\ W_{in} + T & \text{if } W_{in} < -T \end{cases} \quad (1)$$

After soft thresholding, the original image was reconstructed (Figure 5).

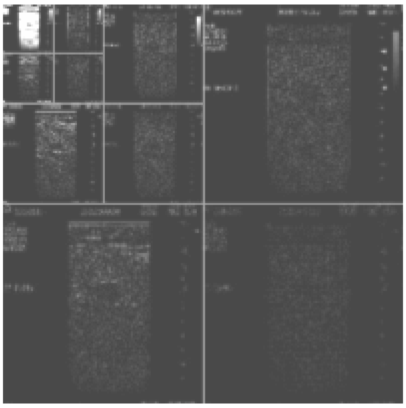

Figure 4: The wavelet details and appoximations
in three levels.

Figure5: The reconstructed image after soft-thresholding

Image histogram thresholding

In the third step of the client-side processing, the reconstructed image f(x,y) was processed by a simple histogram thresholding operation for segmenting the lesion from the background (see Figure 6).

Figure 6: Image thresholding

2.2. Communication

The communication set-up among the work stations included the usage of RMI (Remote Method Invocation) protocol and the Java Socket interface. Initially, the server listens to a group of communication ports waiting for requests from the clients. For the transmision of the image from the one workststation to the other the Java Socket interface was employed. Regarding the transmision of the image, the whole procedure was supervised by security policies offered by the RMI protocol. The policies secured the connection by permissions and acceptances defined by parameters for setting up a trustworthy connection.

2.3. Server processing

The user on the client side marks the initial snake points enclosing the detected boundaries of the lesion (see Figure 7). The polyline is formed after linking the points using piecewise linear interpolation between the selected control points. The coordinates of the marked points and the entire image are transferred to the server. Transfer time is approximately 5 sec for an image of 512x512x8 from node to node. After data are transferred successfully, the server informs the client to invoke the snake's routine and waits at its port for the results.

Dynamic contour (snakes) processing

For lesion boundary delineation the dynamic contour algorithm [6] was developed in C++. Figure 8 shows the snake initialization and Figure 9 illustrates the snake adaptation to the lesion boundary.

Figure 7: The ROI selected by the physician.

Figure 8: The initial Snake contour outlines the target contour produced by the edge detection algorithm.

Figure 9: The Snakes is attracte by the edges and falls into the p

Figure 10: Filling operation for lesion area determination.

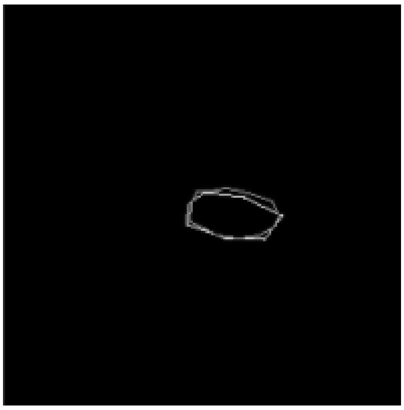

Figure 11: Comparison between the manually and automatically outlined ROIs.

The final points of the active contour were sent to the client. The latter isolated the snake contour and calculated the ROI surface (see Figure 10), by counting the number of pixels encompassed within the ROI. Finally, the ROIs determined the physician and the snake were compared as shown in Figure 11.

3 RESULTS AND DISCUSSION

Surface differences between the physician's manually drawn ROIs and the automatically detected ones, for the various types of pre-processing algorithms, are shown in Table 1**:**

Preprocessing Algorithm	**Average Surface Difference (%)**
No Pre-processing	16.12
Median Filtering (MF)	18.16
Soft Thresholding	9.71
MF+Soft Thresholding	8.56

Table 1: Mean average values of surface differences between the physician's manually drawn ROIs and automatically detected ROIs.

The average difference between hand-drawn and automatically detected ROIs without pre-processing the image, was high due to the presence of image speckle noise, which caused discontinuities in the detected edges. Application of the median filtering algorithm deteriorated the algorithm capability in determining the ROI's boundaries, due to the image smoothing. Application of the soft-thresholding algorithm resulted in the reduction of ROI-surface differences to 9.71%. This can be explained considering the despeckling effect reduction by the algorithm. When the aforementioned algorithms were combined, ROI-surface difference was further reduced to 8.56%. The time required for lesion segmentation, employing the active contours algorithm, as well as the transmission of the final active contour's points to the client, was approximately 2 to 3 seconds. The time required for the transmission of the image to the server was 10 seconds approximately.

4 CONCLUSION

The proposed edge detection algorithm is fast and accurate enough, therefore, it may be valuable for assisting physicians in assessing the size of breast lesions on US.

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