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The Method of Evaluation Artery Diameter from Ultrasound Video

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***Abstract*—**The cardiovascular system has become the most important subject of clinical research, particularly measurement of arterial blood flow. Therefore correct determination of arterial diameter is crucial. We propose a novel, semi-automatic method for artery lumen detection. The method is based on Gaussian probability function. Usability of our proposed method was assessed by analyzing ultrasound B-mode CFA video sequences acquired from eleven healthy volunteers. The correlation coefficient between the manual and semi-automatic measurement of arterial diameter was 0.996. Our proposed method for detecting artery boundary is novel and accurate enough for the measurement of artery diameter.

***Keywords*—**Ultrasound, boundary detection, artery diameter, curve fitting.

I. Introduction

NOWADAYS the cardiovascular system has become the most important subject of clinical research. Particularly two cardiovascular parameters are crucially important in the assessment of cardiovascular function: arterial pressure and arterial blood flow. The recent noninvasive methods, such as Ultrasound imaging and tomography, give opportunity to perform non-intrusive measurements, unlike before. However, despite the aforementioned achievements in this field, the problem of convenient and reliable automatic analyses of imaging date still remains. For accurate blood flow calculation the important parameter is diameter of artery.

There is a variety of automatic methods for detecting the vessel wall in vascular and intravascular ultrasound [1-8]. These methods are based on evaluating the shape function that is best fitting to internal boundaries of artery. Traditionally, shape function is computed from the image gradient, which is very sensitive to image noise [5]. When artery is tilted (usually approx. 15°) boundaries become blurred and it is difficult to detect a precise diameter from such ultrasound image. Moreover, motion artifacts which are unavoidable during patient movement can cause flotation of artery in the B-mode image.

Therefore the aim of present work was to develop a method for the accurate detection of artery boundaries in ultrasound B-mode image sequence.

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II. Methods

A. Hardware

The High-resolution portable ultrasound device Sonosite Titan was used for ultasonography of human left common femoral artery (CFA). All ultrasound video samples were captured with Miro Video DC30+ video grabber connected to PC and saved to AVI file, with MPEG4 video compression, 25 frames per second, resolution of 768x576 pixels.

B. Algorithm of detecting artery boundaries

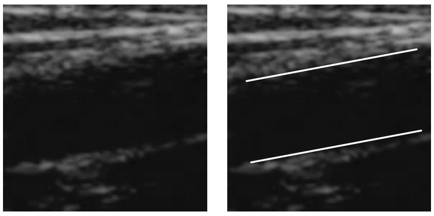
We propose a novel, semi-automatic method for artery lumen detection. The main idea of this method is that artery lumen is accurately assessed with minimal intervention of the operator. In the beginning of video frame sequence, the operator visually marks lines, which are close to inner artery boundaries. Then the algorithm automatically corrects these lines to boundaries by best fitting method. In addition to this method there is a probability function of fitting that decreases outside from the center of a selected line in the gradient image. This probability function has a Gaussian nature and this improves the fitting in a simple and sophisticated way which requires less computation power.

Video processing was performed offline using Matlab software. The Matlab provides a comprehensive environment for developing algorithms for image and video processing.

After choosing the video file, the software displays first frame of video sequence (Fig.1). The operator manually selects lines near the inner upper and lower boundaries of the artery. The X and Y coordinates of each line are stored to memory and are used for further calculations. The following operations have been performed for each line: the artery image has been rotated by angle so that the line approaching artery becomes parallel to X axis (Fig.2,a). Then the vertical gradient of image dI/dY was calculated (Fig.2,c). The gradient maxima points correspond to the locations of artery boundary. The next step was smoothing image toward X axis (Fig.2,d). On this stage the gradient image becomes well visible near the artery boundary. In some cases, when the boundary of artery is not well visible and the structure near it consists of several layers, it is still hard to detect boundary from gradient image. Then a more precise evaluation of artery boundary can be done if Gaussian distribution of intensity I near the boundary is assumed in each X slice of the image:

$$I_x = I_{0x} \cdot \exp\left[-\left(\frac{y-a/2}{a}\right)^2\right] \tag{1}$$

Where I_0 is intensity distribution in each X slice containing y pixels, a is a height of image.



a b

Fig. 1 Manually selecting inner artery boundaries

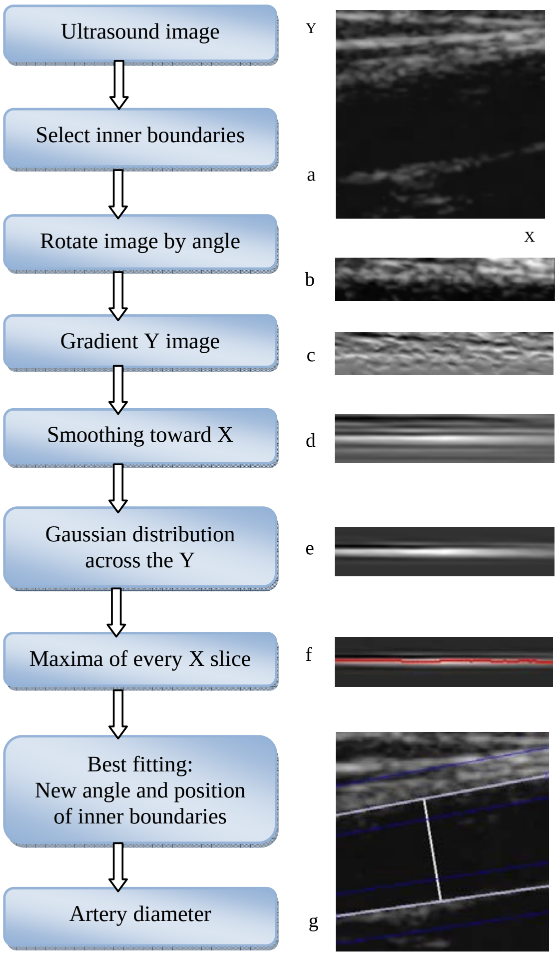


Fig. 2 The algorithm of artery boundary detection: a) manually selected line near the boundary, b) rotated image, c) gradient image, d) smoothed toward X axis gradient image, e) Gaussian distributed gradient image, f) maxima values of every X slice, g) fitted artery boundary lines

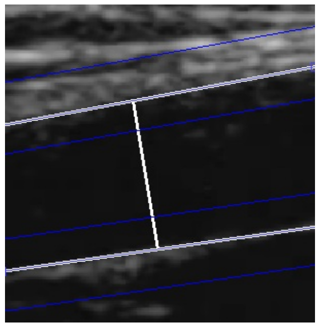


Fig. 3 Fitted lines to inner artery boundaries

From the Gaussian distributed gradient image, maxima pixel value was evaluated in every X slice of the image (Fig.2,f). Then least-square fitting was applied to these data in order to obtain a new line well fitted to artery boundary. The coordinates of the fitted line give an extra angle and shift relative to initial center of image, so the image can be rotated back and the line was shifted according to position of artery boundary. Fig.3 shows upper and lower lines fitted to the artery boundary and line connected by shortest distance. The diameter of artery can be evaluated from the distance between these two lines.

C. Method validation study

Usability of our proposed method was assessed by analyzing ultrasound B-mode CFA video sequences acquired from eleven healthy volunteers (5 males and 6 females in the age group of 19-27 years). The total of 11 ultrasound images was analyzed both automatically with the automated boundary detection method and manually by an experienced sonographist using Scion Image software. ANOVA and Regression analysis was performed in order to derive a correlation coefficient between these measurements.

III. Results and Discussion

A. Evaluation of artery diameter

In order to perform a validation of our method we chose a manual measurement of artery diameter by an expert as the gold standard. The criterion used for method assessment was accuracy of the measurements. The correlation coefficient between the two sets of measurements (manual and semi-automatic) of the diameter was 0.996, and the one-way ANOVA analysis confirmed that the two data sets are obtained from distributions having the same mean value, see Fig. 4.

Fig. 5 shows arterial diameter changes evaluated from 20 seconds video sequence. The figure shows CFA diameter changes caused by arterial pressure changes. Detected artery boundaries are accurate enough that there are well seen fast pulsations regarding to cardiac activity and slow components of breathing.

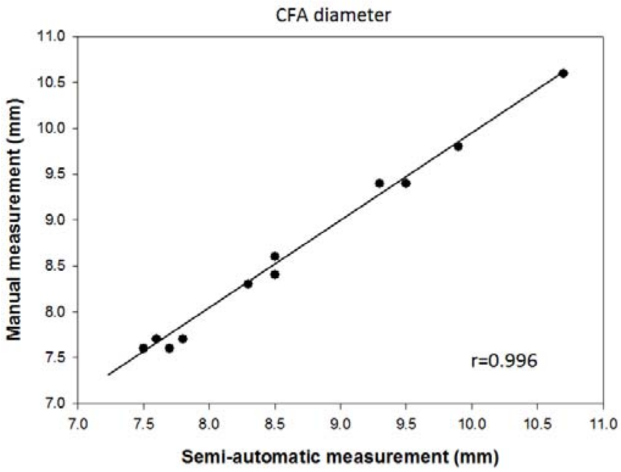


Fig. 4 Correlation between manual and semi-automatic measurements

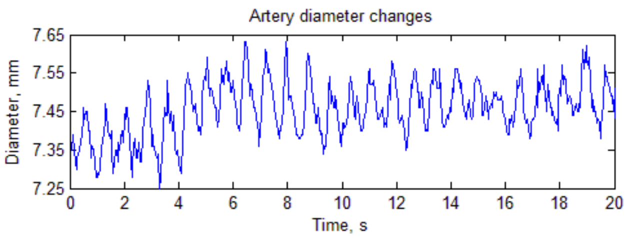


Fig. 5 Artery diameter over time

IV. Conclusion

Our proposed method for detecting artery boundary is novel and accurate enough for measuring artery diameter.

The potential fields of application of this method could be medicine and sports physiology. Analysis of ultrasound video is crucially important for accurate calculation of blood flow during exercise or cardiovascular stress testing. It is advantageous to use this method in the case when artery boundaries are not sharp and artery is changing position.

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