Active Contours for Measuring Arterial Wall Diameter of Astronauts from Ultrasound Images

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Abstract

The non-invasive assessment of cardiovascular changes with space-flight often involves the measurement of blood vessel dimension using ultrasound imaging. However, many commonly used measurement techniques are often manually intensive and dependent on the individual making the measurements. We propose a new automated method for measuring the vessel dimensions which involves creating a smoothed edge map of the image and using active contours to converge to the upper and lower vessel boundaries. Preliminary results show that we are able to use this method to detect vessels walls for vascular measurements from ultrasound images.

1 Background

Exposure to the microgravity environment during spaceflight is known to result in cardiovascular adaptations which may include changes in vascular structure and function. Ultrasound imaging is a common tool used to non-invasively assess vascular properties, however, many current methods of performing vascular measurements involve using calipers which are time consuming and are dependent on the individual performing the measurements.

Motivated to improve the efficiency of this process we propose a new method to measure the diameter of the arterial wall from an ultrasound image which involves taking the edge map of an image and using active contours to converge on the arterial walls. In Section 2 we introduce this method, and in Section 3 we show some results and briefly discuss some future work.

2 Methodology

Given a gray-scale arterial wall ultrasound image, as seen in Figure 1a, we create a smoothed edge map, as seen in Figure 1b. This is done by creating a Gaussian weighted gradient kernel, K, and convolving it with the entire image. Kernel K is formed by point multiplying a Gaussian weighted kernel with a standard gradient kernel.

Two active contours are then optimized using the generated edge map to find the true arterial wall boundaries. These active contours are initiated by selecting the two extreme points for the upper and lower boundaries of the arterial wall, and drawing a line between these points, as seen in Figure 1c.

An active contour or simply snake, as introduced by Kass et al. [1], is an energy curve, υ, that minimizes the cost function

$$E = \int_0^1 \frac{1}{2}[\alpha(s)|\upsilon'(s)|^2 + \beta(s)|\upsilon''(s)|^2] + E_{external}(\upsilon(s))ds, \quad (1)$$

where α and β are weighting parameters, υ' and υ'' are the first and second derivative of υ with respect to a normalized arc length s. The external energy $E_{external}$ is derived from the image data (e.g. gradient). Recently, active contours have become widely used in image processing and computer vision application [2].

To increase its capture range, Li and Acton [3] replaced the standard external term of the active contour by the convolution of the image edge map f with a vector field kernel k that has all vectors pointing to the kernel origin:

$$f_{vfc}(x,y) = f(x,y) * k(x,y), \quad (2)$$

where $k(x,y)$ is the product of a scalar function m that assigns magnitudes to the forces and a unit vector field n that controls the vectors orientation. We use this vector field kernel approach to find the final optimized boundaries, as seen in Figure 1d which are found using the initial contours and the smoothed edge map.
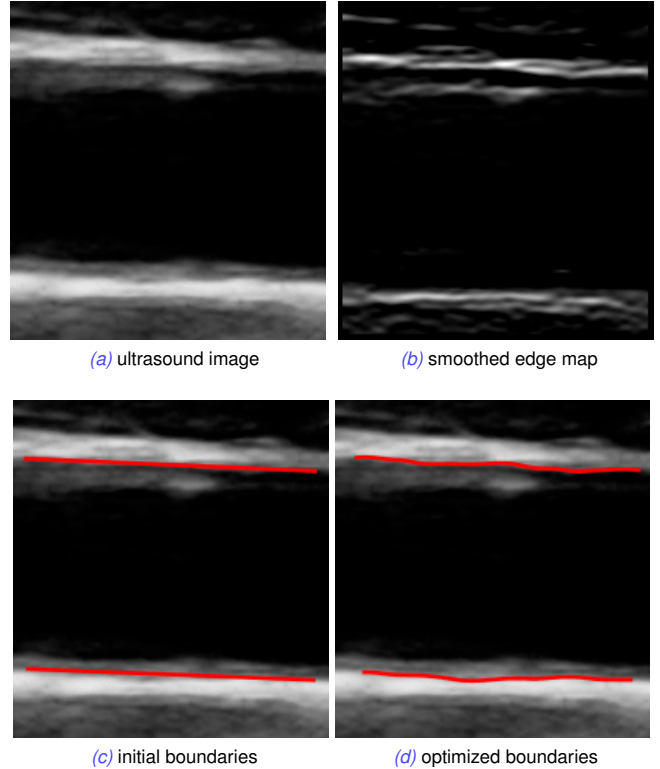

(a) ultrasound image   *(b)* smoothed edge map

(c) initial boundaries   *(d)* optimized boundaries

Fig. 1: (a) Given a artery ultrasound image we (b) create a smoothed edge map. Using this edge map and (c) initial boundaries from the user, we (d) find the optimal boundaries of the arterial wall in order to measure the diameter.

3 Results and Discussion

Using the two fitted contours, illustrated by Figure 1d, we found the diameter of the artery by averaging the distance of all the points in one contour to another. This distance was found by fitting a spline to a point and its neighbours and then projecting a line normal to the tangent of that spline and finding the intersection point in the other contour. In the future we plan to extend this work to measure the artery diameter for each frame of a video allowing for the assessment of vessel dimensions over time. Furthermore, intima-media thickness (IMT) measurements will be incorporated into future procedures in order to calculate blood volumetric flow.

Acknowledgments

References

[1] Kass, M., Witkin, A., and Terzopoulos, D., "Snakes: Active contour models," *Int. Journal of Comput. Vision* **1**, 321–331 (1988).

[2] Gawish, A. and Fieguth, P., "External forces for active contours using the undecimated wavelet transform," in [*Image Processing (ICIP), 2015 IEEE Int. Conference on*], (Sept 2015).

[3] Li, B. and Acton, S., "Active contour external force using vector field convolution for image segmentation," *Image Processing, IEEE Transactions on* **16**, 2096–2106 (Aug. 2007).