Alexandria Engineering Journal (2017) **xxx**, xxx–xxx

HOSTED BY

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

A modified segmentation method for determination of IV vessel boundaries

Mazhar B. Tayel [a], **M.A. Massoud** [b,*], **Y. Farouk** [b]

[a] *Faculty of Engineering, Alexandria University, Egypt*
[b] *Faculty of Engineering, El-Minia University, Egypt*

Received 2 May 2016; revised 29 March 2017; accepted 2 April 2017

KEYWORDS

Intravascular;
Contour segmentation;
Fast search;
3D reconstruction

Abstract Coronary heart diseases are ranked as the top diseases causing death in many countries worldwide. Intravascular Ultrasound (IVUS) directly images the vessel from inside and allows the extraction of vessel bounders and the measurement of vessel cross-sectional area. This paper introduces an approach for detection of lumen and media-adventitia borders in an Intravascular (IV) image. In the proposed method, a modified fast algorithm is applied to determine the lumen and media-adventitia contours. The modified fast algorithm is fully tested and it showed an improvement in speed of up to 200% while preserving an accuracy rate of 98%.

1. Introduction

Intravascular ultrasound (IVUS) imaging, as a diagnosis tool, is a catheter-based technique which renders a 2D cross-sectional image of arteries, and provides information concerning the lumen and wall morphology [1]. The importance of IVUS imaging came from the very critical role in determining the specifications of a stent in arteries [2]. Generally the arteries are characterized by two distinct borders. The lumen border corresponds to the lumen -wall interface and the media-adventitia border represents the boundary between the media and adventitia [3]. Fig. 1 shows the Lumen and Media-adventitia borders of a typical IVUS image.

Although IVUS segmentation techniques have many advantages in diagnosing the coronary artery diseases, real-time and reliability restrictions are still the main weakness points of IVUS.

The IVUS segmentation and 3D vessel reconstruction, required during Percutaneous coronary intervention (PCI), is a real-time system. By introducing a modified algorithm to speed up the IVUS segmentation algorithms, this study is aimed to reduce the search time without affecting the performance of the segmentation process.

Researchers' efforts on image processing related to IVUS segmentation began in 1992 or even earlier when a semi-automated segmentation method was developed [4].

Biomedical Image processing and analysis algorithms are required in software engineering to improve the speed and accuracy of the algorithms. Some researchers use linear programming while some use Artificial Intelligence and others

---

[*] Corresponding author.

E-mail addresses: profbasyouni@gmail.com (M.B. Tayel), massoud300@yahoo.com (M.A. Massoud), eng.yasseen.farouk@mu.edu.eg (Y. Farouk).

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2017.04.002
1110-0168

Please cite this article in press as: M.B. Tayel et al., A modified segmentation method for determination of IV vessel boundaries, Alexandria Eng. J. (2017), http://dx.doi.org/10.1016/j.aej.2017.04.002

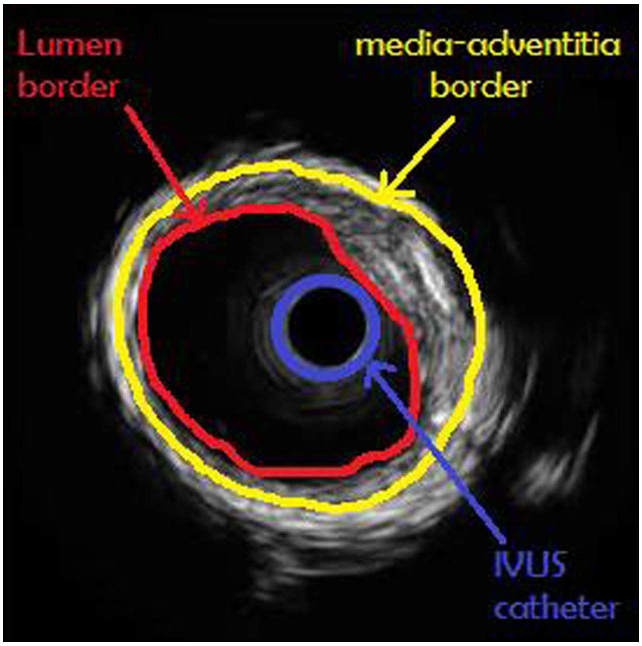

Figure 1 A typical IVUS image.

use statistical algorithms for diagnosis based on images. Time is a very important parameter in IVUS critical cases. Almost all previous research efforts were made by combining two or more imaging-processing techniques to achieve their robust algorithms.

Segmentation of media-adventitia in IVUS images algorithm improved the accuracy by combining a set of image processing techniques (Speckle Reducing Anisotropic Diffusion (SRAD), Wavelet, Otsu and Mathematical Morphology) [5]. In [6] a cost function was derived using a combination of complementary texture features. The isolation of the blood pool by using 2-D brushlet coefficient clustering to estimate the lumen borders with the surface function active (SFA) framework was designed as a new technique [7].

Artificial intelligence had been used to improve the IVUS image process and analysis. In [8] Fuzzy C-Means segmentation and Harris Corner detection were used to detect and measure from the IVUS image the width and arc of a calcium deposition. The application of a Genetic Fuzzy Rule-based Classification System (GFRBCS) for tissue characterization of IVUS images is proposed in [9]. In [9], the authors not only segmented the vessel boards in IVUS images but, also, segmented and classified the plaque region into four primary tissue types: namely, calcium, necrotic core, fibrous and fibro-fatty. The artificial intelligent exploited all provided information from the texture extraction process using a fuzzy classifier which allowed this approach to produce accurate and highly interpretable classification models. In the feature extraction process, they used a set of techniques which included first-order statistics, gray-level co-occurrence matrices, run-lengths, wavelets, Local Binary Patterns (LBP) and Local Indicators of Spatial Association (LISA) features. The usage of artificial intelligence was achieved by exploiting the provided information through using a fuzzy classifier which enabled this approach to produce accurate and highly interpretable classification models.

Studies aimed not only to provide segmentation but, also, to enhance the IVUS image in order to reduce the error in segmentation and to improve for the naked human eye the interpretability or perception of information in the image.

A comparison between the performances of the curvelet transform and the adaptive complex diffusion filter method for ultrasound de-speckling was used in [10].

Shadows artifact is the main problem faced in the Media-adventitial contour segmentation process because of the shadow appearing always behind the calcification plaque. In [11], using an adaptive threshold method, an algorithm was developed for shadow region detection to enhance the IVUS image.

Studies tried, also, to improve the results of the vessel 3D reconstruction by taking advantage of IVUS with X-ray (angiography) and ECG. The following paragraphs illustrate the researchers' efforts on this task.

In [12], the authors introduced an approach for the 3D reconstruction of vascular lumen based on a geometric and then probabilistic fusion between X-ray and IVUS data. In a similar study [13], the method, introduced for the 3D reconstruction of coronary arteries, was based on the fusion of biplane angiographic and IVUS images. This study introduced, also, a new method of 3D catheter path extraction through using swept B-Spline surfaces. It proved that the 3D reconstruction, based on the biplane angiographic and IVUS, could be applied in clinical practice to provide further information on vessel morphology and atheromatosis.

In [14], a new method was introduced for the 3D reconstructing of the coronary vessel from an ECG-gated IVUS image sequence. Using this method, the determination of the IVUS orientation along the 3D catheter pullback path compensated directly for the in-plane rigid motion caused by cardiac dynamics.

In general, the efforts, related to this field, can be divided into four categories. The first one includes focusing on an imaging technique as in [15–26]; the second one includes the combination of two or three imaging techniques as in [12–14]; the third one includes comparisons between imaging techniques as in [7,27]; and, as in [28], the fourth one includes efforts to create a standard benchmark database in order to evaluate the algorithms.

In this article, a new modification has been introduced to Method-3 [15]. In the following, the discussion is for this modification. Then, the effect of this modification on the time and accuracy of the process time is studied. Finally, compared to that previously, the results of this modification increase the speed of the algorithm faster by 200% with an accuracy rate of 98%.

The modification algorithm was implemented on Samsung computer with OS Windows 7, a 2.53 GHz Intel Core i3 processor, and a 4 GB RAM. The MATLAB, version 7.8.0.347 (R2009a) 64-bit software was used. The MATLAB can use a DICOM, so that the DICOM can implement in this algorithm after some processing. Because this study is not of clinical institute, so the Internet free data set of Human Coronary artery was used. The result was seen and tested by an expert doctor.

Please cite this article in press as: M.B. Tayel et al., A modified segmentation method for determination of IV vessel boundaries, Alexandria Eng. J. (2017), http://dx.doi.org/10.1016/j.aej.2017.04.002