3D RECONSTRUCTION OF PATIENT-SPECIFIC CAROTID ARTERY GEOMETRY FROM 2D ULTRASOUND IMAGES

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Abstract:

Visualization and consideration of morphological structure of carotid artery are necessary for understanding the etiology of carotid artery diseases. Carotid artery stenosis (CAS) is one of the diseases in human cardiovascular system which may potentially cause debilitating stroke and its accurate early detection is therefore important [1]. This paper aims to propose image-processing techniques for better 3D reconstruction of a carotid artery by using 2D ultrasound images. The 3D reconstruction of patient-specific carotid artery is performed using the available clinical imaging data for the particular patient. The methodology is summarized in the following stages: pre-processing of the images, image segmentation which includes lumen segmentation and outer wall segmentation, centerline calculation of the segmented carotid artery parts and finally 3D reconstruction of carotid artery. The 3D lumen and wall geometries of a carotid artery were obtained by rendering of several 2D slices. The image geometry is refined based on the indicated centerlines by calculating the corresponding points. The corresponding points are used for the calculated imaging geometry to generate 3D centerlines. The proposed methodology is an innovative approach for reconstruction, since it provides 3D models of the outer wall and 3D models of the lumen.

Key words: carotid artery, ultrasound imaging, 3D reconstruction, image segmentation

1. Introduction

Developments from 2D images to 3D models have revolutionized the field of imaging. Compared to observing 2D ultrasound images, 3D models are more suitable for diagnostic analysis. These improvements help in diagnosing various diseases in the early stages and contribute in making clinical decisions [2]. Cardiovascular diseases (CVDs) are a group of disorders of the heart, blood or blood vessels. Carotid artery stenosis is common manifestation of CVDs. Recuring damages in the region of carotid artery result in formation of an atherosclerotic plaque. Rupture of an atherosclerotic plaque in the carotid artery is a major cause of stroke and it leads to the obstruction of the blood flow to the heart or to the brain [3]. Ultrasound (US) technique is an examination technique which is used to analyze the state of carotid artery. This is a noninvasive, accurate and low-cost mode for diagnostic imaging. US technique integrates two procedures: the first procedure is traditional B-mode (grayscale) ultrasound, wherein images are produced from the reflected ultrasound waves and the second procedure is color-Doppler ultrasound that visualizes the motion of blood. This technique generates a two-dimensional (2D) cross-sectional images [4]. The dataset consists of US images and coordinates for the region of

lumen and wall. The proposed centerline extraction methodology is uncomplicated and easy to implement by uploading the given coordinates on the image. The objective of this study is to develop a method to obtain a patient-specific and generate a 3D geometry of the carotid artery using ultrasound imaging.

2. Materials and methods

A dataset of original and annotated ultrasound images was used. The US images were annotated by the clinical experts. It consists of images of 52 patients. Images of carotid artery in transversal and longitudinal projections for each patient were given. Important regions were extracted from each ultrasound image. All images were labeled thus creating two datasets, one for the lumen and the second one for the wall. The ultrasound images of the carotid artery have typically low image quality, incorporating significant noise and shadowing. These images are affected by the multiplicative speckle noise, which tends to reduce the image quality and blurring diagnostically important details. Segmentation of the axial and longitudinal segments is enabled by loading the coordinates on the corresponding image. The original images and their corresponding masks are given on the Figure 1. After segmentation, a centerline or center point, depending on whether the image shows a longitudinal or axial section, was found. In order to allow the 3D reconstruction process, finding a centerline or center point was relevant.

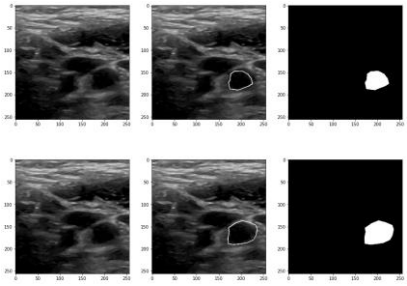

Fig. 1. Carotid artery ultrasound images. The first row represents the lumen masks and the second row represents the wall masks.

3. Results

The proposed methodology includes image segmentation phase and a computer-based automated 3D reconstruction method that is capable of generating a semi-generic geometrical model of the carotid artery that is adapted to the specific patient, using data obtained from only several transversal US images.

4. Conclusion

This methodology was developed to enable efficient segmentation, extraction of segmented parts of wall and lumen and reconstruction of 3D geometrical model of the carotid artery that is adapted to the specific patient. Three-dimensional ultrasound imaging is a recent development that holds promise for improving the visualization and monitoring progression of carotid artery stenosis. The improved methods to treat the disease non-surgically and a noninvasive 3D imaging techniques are becoming dominant in serial monitoring of disease progression or regression.

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