THREE DIMENSIONAL CORONARY ARTERY RECONSTRUCTION USING FUSION OF INTRAVASCULAR ULTRASOUND AND BIPLANE ANGIOGRAPHY

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THREE DIMENSIONAL CORONARY ARTERY RECONSTRUCTION USING FUSION OF INTRAVASCULAR ULTRASOUND AND BIPLANE ANGIOGRAPHY

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Abstract

We have developed an efficient method for three-dimensional reconstruction of coronary arteries. Our approach is based on the fusion of intravascular ultrasound (IVUS) and biplane angiography. The method includes an efficient algorithm for the automatic identification of the regions of interest in IVUS images and a novel methodology for the extraction of the catheter path from biplane angiographies. The estimation of IVUS frames relative twist and the computation of first IVUS frame absolute orientation is also investigated. To assess the performance of the method a validation procedure is introduced. Several metrics are obtained to verify the reliability of our method in the description of coronary artery morphology.

Keywords: 3D artery reconstruction, intravascular ultrasound, biplane angiography, deformable models.

1. Introduction

Contrast angiography has been for decades the golden standard for the investigation of the coronary arteries disease. X – ray angiography provides a detailed map of arterial lumen in which atherosclerotic lesions are identified as local narrowings. However, angiography cannot differentiate the plaque burden or the composition of the plaque which is important in

2.3 Estimation of the relative axial twist of IVUS frames

The IVUS frames are placed perpendicular to the catheter path and their axial twist is estimated using the well-established sequential triangulation algorithm [4].

2.4 Absolute orientation of the first IVUS frames

The coronary artery is reconstructed with an arbitrary orientation of the first IVUS frame. Then, the first frame is rotated and the projections of the reconstructed lumen and catheter path to the biplane angiographies are compared with the lumen's and catheter path's outlines. The angle at which these outlines best match is the correct absolute orientation [5].

3. Quantitative Validation

3.1 Detection of the regions of interest in IVUS frames

Our automated contour detection method is validated as follows: from the IVUS examinations performed in 10 patients 80 IVUS frames are selected. In 5 of the patients a stent had previously successfully implanted. Two expert observers identified manually the regions of interest. The average of their estimation was considered as the golden standard and compared with the outcome of our segmentation method. Several metrics are computed: the interobserver variability, the correlation coefficient, the slope and the y – interception for area and perimeter, the Williams Index (WI) for area, perimeter and non-overlapping areas, the Hausdorff distance and the mean distance.

3.2 Catheter path extraction

Our path extraction method is validated in vitro and in vivo. In vitro a metal wire with 16 radiopaque markers (Fig. 3) was coiled around a cone segment and reconstructed. The length of the reconstructed wire and the intervals of the radiopaque markers were compared with the real values. To quantify matching we compute the root mean square (RMS) distance between the reconstructed radiopaque markers and their X-ray projections. IVUS data, supported by an automated pull-back device, from 11 patients are used. The length of the reconstructed path is compared with the original which is defined by the pull-back duration.

3.3 Axial twist of IVUS images

The performance of the sequential triangulation algorithm is examined in a gutter model and in the coronary arteries of six cadaveric sheep hearts. A gutter was machined in helical course in the internal surface of a plastic cylinder. A cylinder is placed inside it. In this way a watertight gutter is formed and its cross-sections had a flat side perpendicular to the horizontal plane. The gutter is reconstructed (Fig. 4) and the performance of our sequential

5. Discussion

A novel method for 3D coronary artery reconstruction is described. Our method includes a deformable model based algorithm for border identification in IVUS frames and a methodology for accurate path extraction from the biplane angiographies. Compared to other works [2-3], our approach is not based on the definition of corresponding pair points in the two-path projections and approximation in the registration of 3D path points. This leads to more accurate extraction of the catheter path. The proposed method can also overcome problems such as reconstruction from S-shaped curves.

Considering that a more reliable path extraction methodology affects the performance of the sequential triangulation algorithm and the estimation of the absolute orientation of the first IVUS frame we validated each stage of the proposed approach. For this reason several experiments have been performed. The obtained results demonstrate that our method can accurately depict coronary artery morphology.

References

1. Klein HM, Gunther RW, Verlande M, et al. 3-D surface reconstruction of intravascular ultrasound images using personal computer hardware and a motorized catheter control. Cardiovascular and Interventional Radiology 1992; 15: 97 – 101.

2. Evans JL, Ng KW, Wiet SG, et al. Accurate three-dimensional reconstruction of intravascular ultrasound data: spatially correct three-dimensional reconstructions. Circulation 1996; 93: 567 – 576.

3. Shekhar R, Cothren R, Vince D, Cornhill J. Fusion of intravascular ultrasound and biplane angiography for three-dimensional reconstruction of coronary arteries. Computers in Cardiology 1996.

4. Wahle A, Prause GPM, DeJong SC, Sonka M. Geometrically correct 3-D reconstruction of intravascular ultrasound images by fusion with biplane angiography – methods and validation. IEEE Trans. on Medical Imaging 1999; 18(8): 686 – 698.

5. Slager CJ, Wentzel JJ, Schuurbiers JCH, Oomen JAF, et al. True 3-Dimensional reconstruction of coronary arteries in patients by fusion of angiography and IVUS (ANGUS) and its quantitative validation. Circulation 2000; 102: 511 – 516.

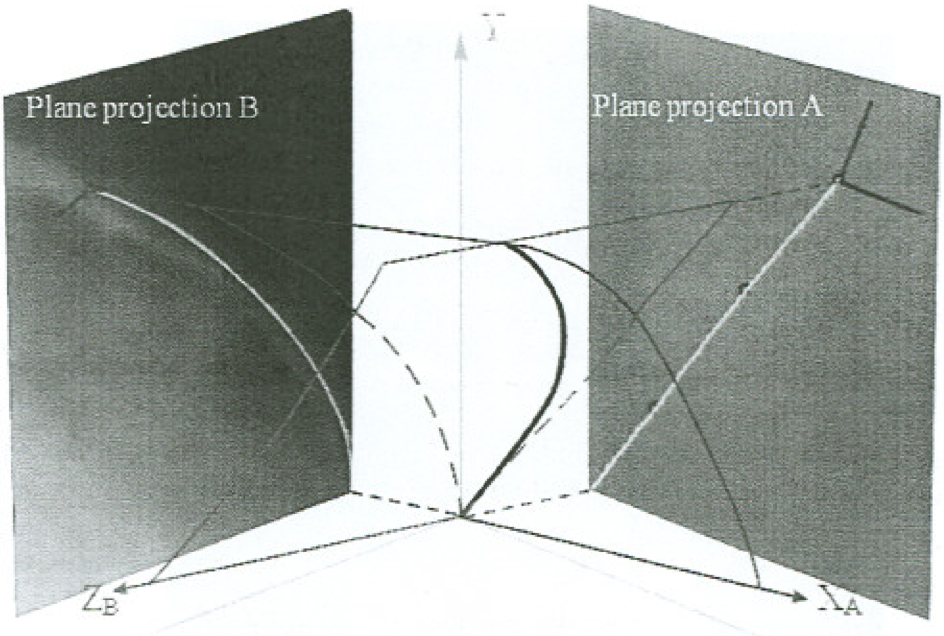

Figure 2: 3D path reconstruction. The catheter 3D path is the intersection of the two surfaces which derive from the extrusion of the path projections.

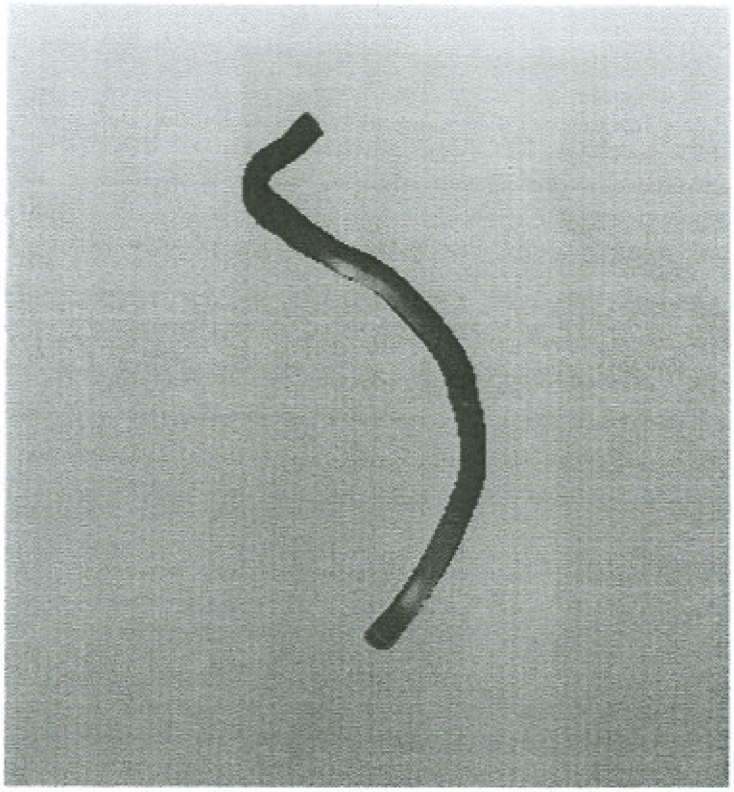

Figure 4: 3D reconstructed gutter.

Table 1: WI and its 95% confidence interval for area and perimeter values.

	WI	CI (95%)
Media – Adventitia (area)	0.67	(0.64,0.70)
Media – Adventitia (perimeter)	0.81	(0.78,0.84)
Lumen (area)	0.91	(0.89,0.93)
Lumen (perimeter)	0.84	(0.82,0.86)
Stent (area)	0.82	(0.78,0.86)
Stent (perimeter)	0.73	(0.69,0.77)

Figure and Table Captions

Figure 1: 3D reconstructed lumen of a left anterior descending coronary artery.

Figure 2: 3D path reconstruction. The catheter 3D path is the intersection of the two surfaces which derive from the extrusion of the path projections.

Figure 3: X-ray projection of the wire model used for the validation of the path extraction method.

Figure 4: 3D reconstructed gutter.

Figure 5: Gutter cross section. The angle φ represents the angle error between the ideal reconstructed gutter (blue gutter) and the reconstructed by our method gutter (white blue gutter).

Table 1: WI and its 95% confidence interval for area and perimeter values.

Table 2: WI and 95% confidence interval for Hausdorff distance and mean distance.