3D+t Modeling of Coronary Artery Tree from Standard Non Simultaneous Angiograms[⋆]

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1 Method

X-ray angiography provides two-dimensional projections of opacified arteries. Utilizing temporally synchronized projections, from different angles, a 3D model can be reconstructed. Biplane angiography [1] systems can provide two simultaneous acquisitions, but are not as widely available as single-view systems. Using the latter systems, the different projections are acquired sequentially. During the time required to change the position of the imaging system, patient motion or breathing motion may be introduced. We propose a method to construct a 3D+t model of the coronary tree from non-simultaneous sequences, synchronized with the electrocardiogram and acquired on single-view angiography systems.

The first step is extraction and labeling of the coronary tree in the different projections. We chose to address this computationally expensive problem [2, 1] by using a semi-automatic method. All the images are preprocessed with a multi-scale model-based algorithm [3]. Then, the arteries to be reconstructed are selected and labeled by the cardiologist in one image of each sequence with a tool inspired by the intelligent scissors [4], relying on the multi-scale magnitude: from a user-defined seed point, the artery centerline is captured in the neighborhood of the mouse with a shortest path algorithm to the current mouse position. Only the n last pixels are constantly optimized and the correction is possible by guiding the optimized segment using an alternative orientation. Finally, the hierarchical structure of the coronary tree is automatically constructed.

In the second stage of this method, segmentation and labeling information has to be propagated in the different projections through at least one cardiac cycle. Our approach relies on the hierarchical description of the coronary tree, and the modeling of the arteries by B-snakes with an internal energy derived from the multi-scale model-based preprocessing. A two-step optimization - a global transformation followed by a local optimization of the control points - reduces the effects of large displacements, crossings and overlapping arteries.

Then, in the third stage, 3D modeling of the coronary artery tree is performed from two segmented projections corresponding roughly to the same cardiac phase. Since they are extracted from two different sequences, heart motion

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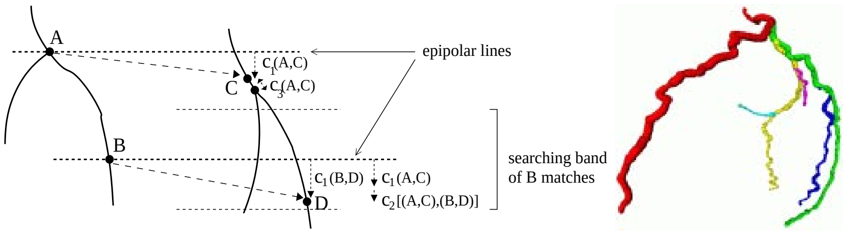

Fig. 1. Left: the penalties of the matching criteria: c_1 penalizes matches which do not respect epipolar geometry, c_2 ensures the deviation continuity from epipolar geometry and c_3 encourages the matching of A and C bifurcations. Right: the final reconstructed tree with sections.

may have occured due to patient's motion or breathing (in the latter, about 10 mm for the inferior-superior translation of the Left Anterior Descending artery). We overcome this difficulty by creating a coherent 3D model by alternately matching the artery pixel strings - as illustrated on figure 1 - and optimizing the sensor parameters by a classical bundle-adjustment method, accomplished on the whole tree. Finally, the 3D skeleton is enriched with sections estimated from the acquisition geometry and the detection scale from the multi-scale preprocessing.

2 Discussion

coronary tree from standard non-simultaneous angiograms has been successfully applied to angiograms acquired on both single-view and biplane angiography systems.

We hope to improve the robustness of the tracking by directly deforming the 3D model obtained at one cardiac phase rather than independently computing the 3D reconstructions. Using its back-projections in all the available sequences would eliminate the artery overlap and crossing problems. Moreover, the measure of sections in all the projections will enable a better quantification of the shape and size of the 3D sections.

After clinical validation, this model could be used to help diagnose cardiovascular diseases. It can also be integrated in a planning and simulation system for robotically assisted surgery [5] and used in the operating theater to guide the surgeon by augmented reality [6].

References

[1] P. Windiga, M. Garreau, and J.L. Coatrieux. Estimation of search-space in 3D coronary artery reconstruction using biplane images. *Pattern Recognition Letters*, 19:1325–1330, September 1998.

[2] Y. Sato, T. Araki, M. Hanayama, H. Naito, and S. Tamura. A viewpoint determination system for stenosis diagnosis and quantification in coronary angiographic image acquisition. *IEEE Transactions on Medical Imaging*, 17(1), 1998.

[3] K. Krissian, G. Malandain, N. Ayache, R. Vaillant, and Y. Trousset. Model-based detection of tubular structures in 3D images. *CVIU*, 80:130–171, 2000.

[4] E. Mortensen and W. Barett. Intelligent scissors for image composition. In *Computer Graphics Proceedings*, pages 191–198, 1995.

[5] L. Adhami, E. Coste-Manière, and JD. Boissonnat. Planning and simulation of robotically assisted minimal invasive surgery. In *Proceedings MICCAI*, volume 1935 of *LNCS*, pages 624–633. Springer, October 2000.

[6] F. Devernay, F. Mourgues, and E. Coste-Manière. Towards endoscopic augmented reality for robotically assisted minimally invasive cardiac surgery. In *Proceedings of Medical Imaging and Augmented Reality*, 2001.