Viewpoint Planning for Quantitative Coronary Angiography

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Purpose

In coronary angiography the condition of myocardial blood supply is assessed by analyzing 2-D X-ray projections of contrasted coronary arteries. This is typically done using a flexible C-arm system. Due to the X-ray immanent dimensionality reduction projecting the 3-D scene onto a 2-D image, the viewpoint is critical to guarantee an appropriate view onto the affected artery and, thus, enable reliable diagnosis [1]. Previous work on viewpoint determination systems for quantitative coronary angiography (QCA) [2] require several views of the vessel [4] or a 3-D model [1, 3, 5]. In this work we introduce an algorithm that computes optimal view-points for the assessment of coronary arteries without the need for 3-D models.

Methods

We introduce the concept of optimal viewpoint planning solely based on a single angiographic X-ray image. The subsequent viewpoint is computed such that it is rotated precisely around a target vessel, while minimizing foreshortening of that vessel. In the simplest case, the target vessel is in the C-arm isocenter and not foreshortened in the initial X-ray projection. While this assumption will almost never be satisfied in clinical practice, it is a good starting point to grasp on the general idea. First, we estimate the rotation axis of our transformation. In this very simple case, assuming a rotation axis that is simply the backprojection of the vessel to the isocenter, will produce exact results as we know that the vessel of interest is a) in the isocenter and b) not foreshortened. Thus, we can use this axis and rotate the gantry around it.

However, in clinical practice the target vessel is not necessarily in the isocenter, nor is it projected without foreshortening. This makes an exact determination of the rotation axis infeasible as depth cannot be recovered from a single image, but we can make some adjustments to perform substantially better than by just assuming a centered, foreshortening-free vessel.

Assume the vessel is off centered e.g. 5mm parallel to the detector. In this case, due to the X-ray cone, we already observe the vessel from an orientation rotated compared to the principal ray. In a first step, we find an intermediate view, that compensates this offset, such that the backprojection-plane of the vessel is parallel to the principal ray. To compute that intermediate view we rotate around an isocenter, that does not necessarily correspond to the center of the vessel. Therefore, in a second step we can minimize the difference between the true isocenter and the isocenter of rotation by translating either the table or the gantry. These two steps can be summarized as isocenter rotation and isocenter offset correction. After applying these two steps the desired angulation is performed with a physician determined angle ξ.

Results

The accuracy of the proposed algorithm is depicted in Fig. 1 and Fig. 2, respectively. The shown errors are computed in a worst case scenario and depict the maximal inaccuracy that is to be expected. Our algorithm reduces foreshortening substantially compared to the input view and completely eliminates it for 90° rotations (cf. Fig. 1). Rotations around foreshortening free vessels passing the isocenter are exact. The precision, however, decreases when the vessel is off centered in depth-direction or foreshortened (cf. Fig. 2). The evaluated worst case boundaries can be used to design viewpoints guaranteeing desired requirements, e.g. a true rotation around the target vessel of at minimum 30°.

Conclusion

We introduce an algorithm for optimal viewpoint planning from a single angiographic X-ray image. The quality of the second viewpoint — i.e. vessel foreshortening and true rotation around vessel — depends on the first viewpoint selected by the physician, however, our computed viewpoint is guaranteed to reduce the initial foreshortening. Our novel approach to viewpoint planning uses fluoroscopy images only and, thus, seamlessly integrates with the current clinical workflow for coronary assessment. In addition it can be implemented in the quantitative coronary angiography workflow without increasing user-interaction, making vessel-shape reconstruction more stable by standardizing the viewpoints.

Disclaimer: The concepts and information presented in this paper are based on research and are not commercially available.

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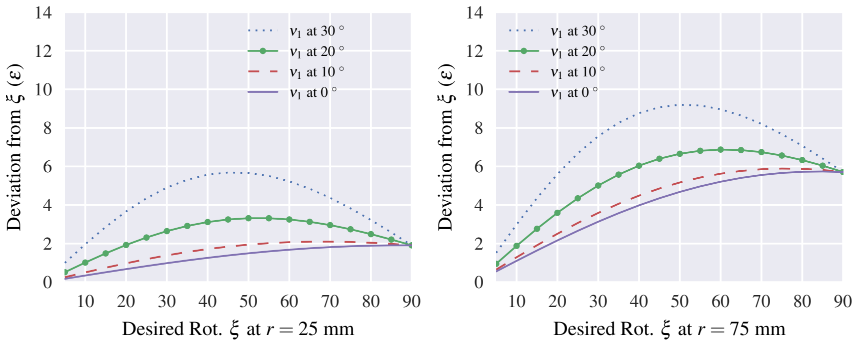

Fig. 1. Accuracy plots depicting the residual rotation ε as a function of the desired rotation ξ. The inaccuracy is depicted for different initial foreshortening v_1.

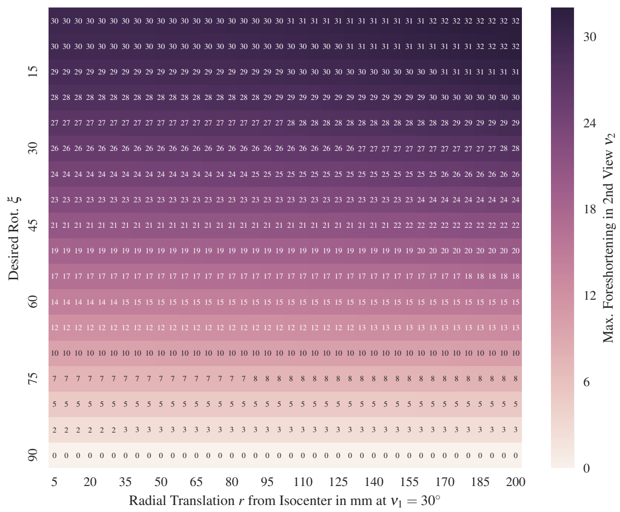

Fig. 2. Heatmap showing the maximal foreshortening in the second view for vessels having an initial foreshortening of $v_1 = 30°$. The inaccuracy is depicted for different offsets r of the vessel from the origin and desired rotations ξ.