Simultaneous Projection of Multi-Branched Vessels with Their Surroundings on a Single Image from Coronary MRA

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Introduction

Recently, whole heart magnetic resonance angiography (MRA) has been successfully applied as a non-invasive imaging modality for the visualization of the coronary arteries and potential coronary artery disease [1]. This imaging technique produces large three-dimensional (3D) data sets that require efficient visualization techniques for data evaluation. Common imaging techniques available to the radiologist or cardiologist at standard workstations are multi-planar reformation (MPR), maximum-intensity projection (MIP), shaded-surface display (SSD), and volume rendering (VR). Volume rendering provides good 3D visualization of the entire data with an appreciation of the general anatomy. However, the VR and SSD require careful segmentation of the raw data, which is not likely to be performed in a clinical environment [1]. The main disadvantage of the MPR methods is the high dependence on the manual orientation of the planes that can introduce false-positive or false-negative stenoses. Furthermore, only one branch of a vessel can be displayed at a time. Therefore, MIP becomes the most promising method for the visualization and evaluation of coronary arteries. Whole volume MIP will result in other cavities and vascular structures to overlap the coronaries. Therefore, masked MIP based on segmentation is required. Such masked MIP will only display the coronaries without depth information or their adjacent anatomy. Two visualization tools were introduced recently to improve the visualization of the coronary arteries [2, 3]. The SoapBubble visualization tool [2] is intended for targeted volume data and relies on in-plane vessels to some degree. The CoroViz tool for processing and display of whole-heart data sets was introduced to overcome these problems [3]. The CoroViz provides MIP projection onto a deformed sphere defined by the coronary vessels. Although the projected MIP does provide visualization of the surrounding anatomy, it is limited to display the coronaries spanning the visible part of the sphere. Therefore, it is not possible to visualize the entire right and left coronary trees in one view. Therefore, we sought to develop a method for visualizing coronary MRA datasets, with simultaneous projection of multi-branched vessels and their surroundings on a single image without distortion and artifacts that is not limited to display only the vessels spanning the visible part of a sphere from a given viewing direction.

Methods

The algorithm uses the vessel centerlines specified by a semi-automatic tracking algorithm and/or manual user specification. After the definition of the vessel centerlines, a set of tubes with specified radius along each vessel is created. For a given viewing direction, a depth image is calculated by casting a ray through the 3D data for each pixel in the resulting image, preserving only points on the tubes that are closest to the viewpoint along these rays, thereby creating a depth image with each pixel representing the closest distance to the viewer. Rays that do not intersect the tubes produces background values in the depth image. The depth image is then completely filled using tri-linear interpolation between points that has a no-background depth value. The result is a manifold that passes exactly through the visible surface of the vessels and their nearby surroundings. Translating the manifold by a specified distance along the viewing direction creates a volume of interests with a specified thickness. MIP projection is then performed by casting a ray through the 3D data for each pixel in the resulting image, preserving only the highest-attenuation voxels found inside the generated volume of interest. This final result is shown in Figure 1. The view can be interactively rotated, zoomed, panned, and windowed. In addition, the radius of the tube representing the vessels and the thickness of the visualized volume can be changed. The display of the vessels surroundings can be toggled to provide local assessments of the coronary arteries alone. If the viewing direction changes, due to user rotation of the scene, the process is repeated and a new projected image is generated. This is done in interactive rates, allowing the user to interactively manipulate the viewing direction and find the best view of the vessels.

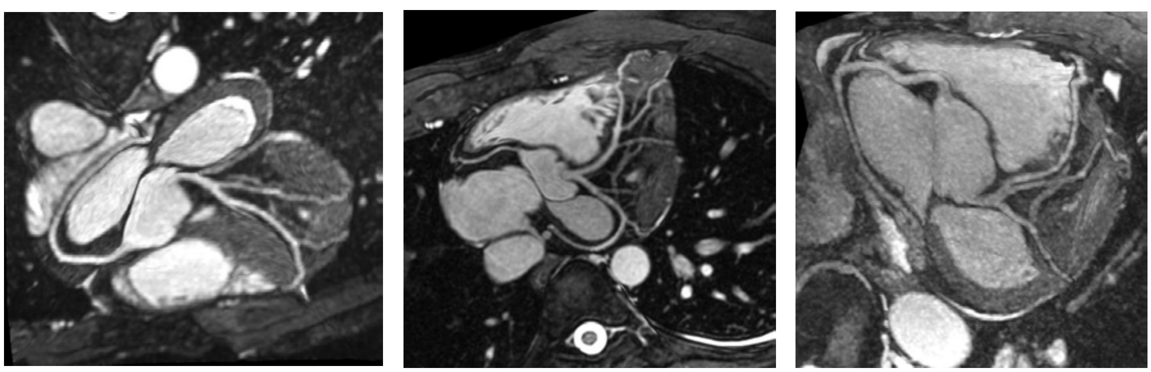

Figure 1: Simultaneous visualization of the left and right coronary arteries from three different patients' MRA data sets.

Results

We assessed the method on coronary MR data from eight patients, with processing time for an inexperienced user of less than 5 minutes per data set. Simultaneous projection of the right coronary arteries (RCA) and the left coronary arteries (LCA) with their surroundings was successfully processed on all data sets. Figure 1 depicts the visualization examples from three different patients. The surrounding anatomy provides additional reference for orientation and localization of the arteries. In addition, the exact 3D location of every point on the projected image is known, allowing accurate measurements of the vessels length.

Discussion

We have presented a tool that enables the visualization of MRA data, and provides simultaneous display of multi-branched vessels on a single image, together with their surroundings without distortion. The method is not limited only to the vessels spanning the visible part of a sphere from a given viewing direction, and provides simultaneous display of the entire RCA and LCA trees. Future work will include evaluation of the clinical utility and acceptance of the tool.

References

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