Texture-mapped Polygonal Reformatting for Interactive Visualization of 3D Coronary MRA

M. Solaiyappan[1], U. Blume[2], D. Maintz[3], R. G. Weiss[4], M. Stuber[1]

[1]Department of Radiology, School of Medicine, Johns Hopkins University, Baltimore, Maryland, United States, [2]University of Applied Sciences Koblenz, Remagen, Germany, [3]Department of Radiology, University of Muenster, Muenster, Germany, [4]Cardiology Division, Department of Medicine, School of Medicine, Johns Hopkins University, Baltimore, Maryland, United States

Introduction:

Three-dimensional visualization of coronary magnetic resonance angiograms (MRA) is generally addressed by maximum intensity projection (MIP) or multi-planar reformatting (MPR) methods. Alternative and relatively newer approaches attempt to tailor the visualization to take advantage of a-priori knowledge about the distribution of the coronary vessels that the user can easily specify in a volumetric image dataset. Based on this specific detail, a 3D surface representing the distribution of the coronary vessels over the epicardium is generated using suitable geometric criteria. The volumetric coronary image data can then be interpolated over the polygonal surface to provide a three dimensional display. This approach can be particularly useful when generic approaches do not provide sufficient selective details of the coronary vessels. However, intricate geometry-based image computation makes interactive 3D visualization with this approach especially challenging because of the significant compute times.

Rationale:

The capabilities of current graphics subsystems allow us to extend the scope of conventional MPR to address polygonal shapes and surfaces. This can benefit specialized imaging techniques such as 3D coronary MRA. Thus, with the rationale to facilitate rapid development of visualization tools that require geometry and image data to be spatially correlated for interactive analysis, we introduce here the concept of texture-maps to manage polygonal reformatted image data. Texture maps provide a parametric representation of the image data that can be applied to a geometric form.

Methods:

3D coronary MRA were acquired using a previously described axial free-breathing navigator gated and corrected whole-heart SSFP imaging sequence (270 FOV and 272 matrix, 80 slices (interpolated to 160) with 1.5mm slice thickness, α=90º, TR/TE=5.4ms/2.7ms, acquisition window per RR interval=125ms, T2Prep (TE=50ms), SENSE factor 2) [1]. We used the Soap Bubble approach proposed in [2] to generate the 3D surface of the epicardium. In this approach, the user pre-selects a set of candidate points that represent salient points along the coronary vessels in the 3D image data. From this, a triangular mesh is generated by applying the principle of Delaunay triangulation [3] (Fig. 1(a)). To generate the texture maps, a rectangular bounding box is computed for each triangle with its largest side as the length and the perpendicular height as the width of the rectangle. Using the orthogonal sides of the rectangle to represent the image axes for the texture map, the rectangular area is filled with interpolated pixels from the image data (Fig. 1(b)). The pixel dimensions can be same as the unit dimensions of the rectangle or smaller if a more detailed representation is desired and a small border pixel around the rectangle can be included for precise interpolation near the boundaries. Once this image rectangle is

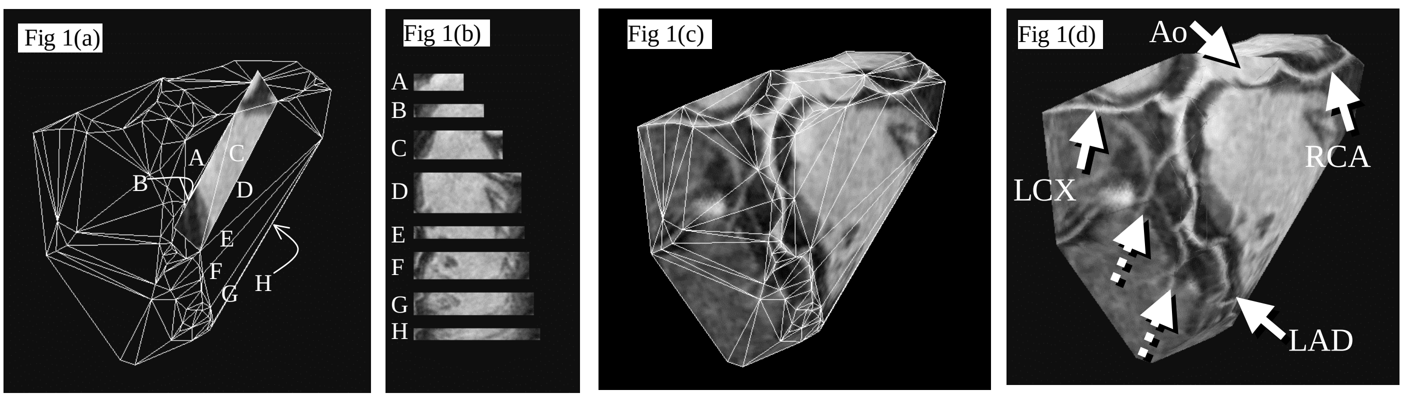

Fig.1(a) shows the epicardium as a 3D mesh generated using Soap Bubble approach. The image rectangle (C) illustrates the mapping of volumetric image data in a given triangle. Fig. 1(b) shows an example set of texture maps corresponding to 8 adjoining facets of the triangular mesh (A-H). Fig.1(c) shows the textures associated with the 3D mesh. Fig. 1(d) shows the final texture mapped 3D epicardial surface (Ao=ascending aorta, RCA=right coronary artery, LAD=left anterior descending, LCX=left coronary circumflex. Dashed arrows=diagonal branches)

defined as a texture map in the graphics subsystem, any polygon that lies inside the rectangle can be readily drawn using texture mapping functions.

Results:

The interpolated volumetric data of 512x512x160 voxels was processed using Soap Bubble approach to generate a 3D mesh of 228 triangles with an average size of 53 (base) by 14 (height) pixel units. On a Pentium-III 930 MHz system with a 32 MB texture memory graphics card, the initial delay due to texture computation was ~500msec. The texture mapped 3D epicardial surface took ~15msec to render (> 60 fps) and it can be freely rotated and scaled without performance limitations for a selective visualization of all the epicardial coronary segments included in the 3D MRA dataset.

Conclusion:

The graphics texture mapping approach to represent multi-planar reformatted coronary MRA enables us to conveniently map image data on to the 3D polygonal shape corresponding to the epicardial surface. We believe that ease and speed of implementation of this approach can benefit, in particular, coronary MRA imaging techniques and in general, similar MR imaging techniques where the image data require correlation with associated geometry data to provide a comprehensive 3D spatial context.

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