Multimodality Visualization of MR Functional Information Fused with CT Coronary Vasculature

R. Mullick[1], V. Vaidya[1], K. Raghu[1], S. Clarkson[2], C. Comeau[3]

[1]GE Research, Bangalore, India, [2]GE Healthcare, Milwaukee, WI, United States, [3]ACI, CRF, New York, NY, United States

Introduction: A comprehensive diagnostic cardiac work-up today cannot be limited to a single modality and this underlines the need for multi-modality fusion of multiple imaging sources. In addition to significant enhances in multi-channel rapid MR acquisition suitable for Cardiac studies, Multi-Detector CT has made great strides in recent years in acquiring high resolution images of coronary vasculature. In order to offer the radiologist and referring physician a unified diagnostic and prognostic assessment of coronary vascular disease we propose a fast and automated method for co-registered visualization of the anatomy and physiology. In the past, several attempts to align complimentary cardiac data [1][2][3] have been proposed and have predominantly used a segmented coronary tree or myocardial surface using ICP or similar surface based methods to align the data, methods which can be prone to registration error. Our method leverages the Mutual Information paradigm and a rapid localized non-rigid step to align the multi-modality data using robust intensity based methods. Automated vascular segmentation methods are further employed to make this process emendable to clinical reporting.

Methods: *Acquisition*: MR - Four patients with coronary artery disease were scanned on a 1.5T Signa CV/i MRI scanner (GE Healthcare, Waukesha, WI) under IRB approved protocols after obtaining informed consent. MDE Images (FGRE) TR: 5.2ms; TE: 1.4ms (fractional); Bandwidth: 25kHz; Inversion Time: 200ms; FoV 37 x 37cm; Slice Thickness: 8mm; Matrix: 224 x 160; NEX: 2; Scan time: 18secs.; Zoom Mode of Twin gradient coil. FIESTA Images: TR: 3.4ms; TE: 1.5ms; Bandwidth: 125kHz; Matrix: 192 x 160; NEX: 1; Scan time: 10secs per location; Zoom Mode of Twin gradient coil. CT - 16 slice LightSpeed Pro CT Scanner (GE Healthcare, Waukesha, WI); Detector size: 0.625mm; Rows: 16; Coverage per rotation: 10mm; Scan time: 20 seconds; Rotation Speed 0.4sec; kV 120; mA: 500; mAs: 200; recon 512 x 512; Snap shot mode; Scan Field of View: 50cm; Heart rate: 55 beats/min; and Gantry tilt: 0 degrees.

Processing: The core challenges in fusing these multi-modality datasets were: 1) Vastly different scan orientations MR(short-axis) and CT(Axial); 2) DFOV differences owing to scan orientation; and 3) Resolution differences; and 4) Motion artifacts. In order to overcome these broad challenges, the approach begins with Motion Corrections and Quantitative Perfusion map generation for MR sequences. The second step requires temporal registration between MR and CT scans to align the datasets on the basis of the cardiac phase (End Diastolic Phase). This is followed by leveraging the DICOM header information in the MR scan (Oblique acquisition: Scan Orientation 0x0020|0x0037) to reslice the CT dataset. The Coronary vasculature is segmented on the GE Advantage Windows Workstation [4]. Following appropriate centering of the cardiac ROI, we deploy a custom designed registration algorithm [5] for rigid and piece-wise non-rigid transforms based on the Mutual Information (MI) [6] paradigm developed using the Insight Toolkit (www.itk.org). An overview of the fusion workflow is shown in Figure 1. The result of reorienting the CT data to match MR scan orientation is shown in Figure 2.

Rendering: A VTK (www.kitware.com) based visualization to display the fused results using MPR for MR Perfusion and 3D MIP for CTA highlighting calcification was developed using the wxWidgets [7] multi-platform GUI toolkit. The design was defined to enable display temporal data in orthogonal and/or oblique sections along with volume rendered views of the CT data in near real-time interactivity.

Results: Four patient datasets with both MR and CTA cardiac acquisitions were fused using the schema defined here. The registered data was visualized to analyze the structural-functional correlation between perfusion/MDE data and Coronary Vasculature. A screenshot of the unified multimodality fusion is presented in Figure 3. The tool allows interactive control of various parameters to enable an effective reporting tool.

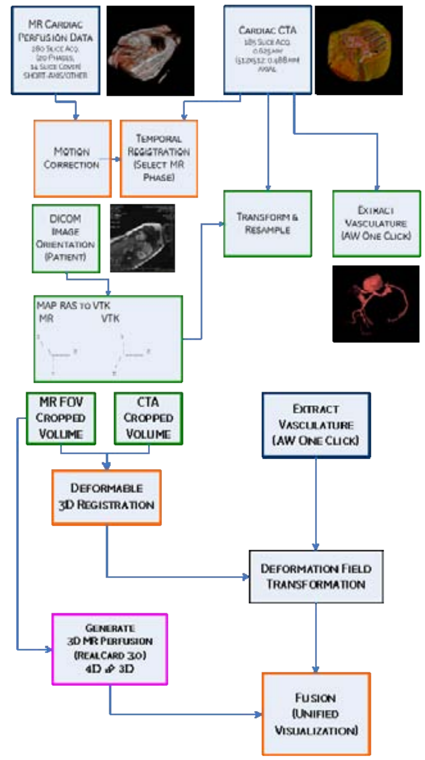

Figure 1: Flowchart illustrating the Cardiac MR-CT Fusion Pipeline.

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5. Gopalakrishnan *et. al*, "*A Fast piece-wise Deformable Method for Multi-modality Image Registration*," Proc. of the IEEE Appl. Imagery Patt. Rec. Workshop, 2005.
6. Maes *et. al*, "*Multimodality Image Registration by Maximization of Mutual Information*," IEEE Trans. Med. Imag., 16 (2), 187-98, 1997.
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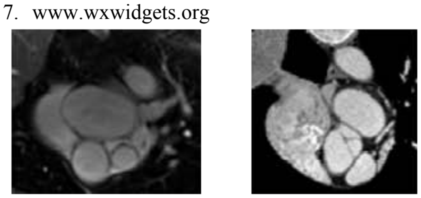

Figure 2: Resampled CT dataset matching orientation & DFOV of MR Data

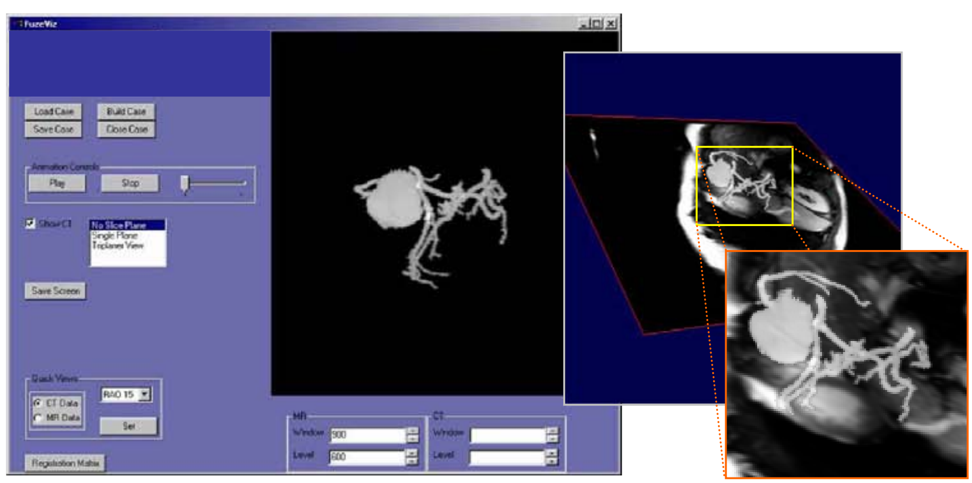

Figure 3: FuseViz: VTK Based interactive environment to visualize Cardiac MR & CTA Data. MIP View of CTA with MR MPR underlay (enlarged)