Image-Based Coronary Tracking and Beat-to-Beat Motion Compensation for Robust Coronary MR Angiography

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Introduction

Current state of the art coronary imaging methods [1,2] perform reasonably well but still suffer from robustness and repeatability issues in healthy volunteers as well as in patients. This is primarily due to the complexity and unpredictable variability in coronary motion [3,4] and the imperfect assumption that the diaphragm and coronary motion are well correlated [5,6]. More recently, some approaches [7, 8] have improved image quality through patient specific motion measurements during prescan, used online during scanning. However, these approaches suffer from the disadvantage that the motion model built initially is not updated during acquisition to take into account variability in both respiratory and cardiac cycles.

In our recent work [9,10], we presented the feasibility of a subject-specific coronary imaging approach that involved tracking motion of the coronary arteries directly using real-time imaging (image-based navigators) in specific orientations (short axis and 4-chamber views) which can then be used to predict the acquisition window and coronary location on a beat-by-beat basis for high resolution imaging with slice correction. Figure 1 shows the sequence-timing diagram of the proposed approach. In [9] we demonstrated significant improvements in CNR and SNR with this approach using motion data obtained from human subjects combined with an offline simulation.

As a futher step towards integrating the approach on an MR scanner, we have developed a real-time tracking interface that allows for testing and validation of the proposed approach without significant modifications to the scanner. In this work, we present our preliminary results from this system.

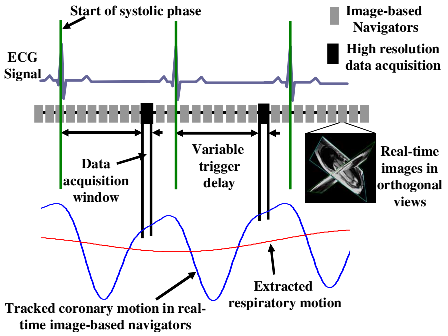


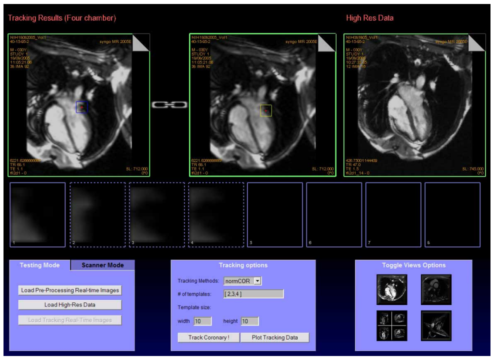
Figure 1: *Sequence-timing diagram of proposed approach*

Methods

Tracking: In [10], we developed an algorithm for tracking the coronary artery in real-time MR images that uses an affine combination of multiple templates (reference regions). We showed good comparison of the tracked coronary motion in real-time images with coronary motion in high resolution cine images. To integrate the approach on the scanner, the tracking algorithm was implemented in Visual C++. with a computation time of less than 0.5 millisecond per image frame on a standard laptop.

Process Flow: The process flow for the tracking algorithm is as follows: 1) a set of images in the two orientations is acquired over a few cardiac cycles; 2) a representative set of multiple templates is selected in these images for tracking (done offline); 3) the user selects the tracking parameters and 4) online images in both orientations are acquired in which the coronary location is tracked in real-time.

User Interface: The interface was developed using RadBuilder (Siemens Corporate Research, Inc), a platform for rapid application development. The RadBuilder framework is built on top of a family of open source libraries (ITK, Open Inventor). As the proposed approach involves tracking in multiple views, the interface allows for toggling between each view for tracking initialization. Figure 2 shows the screenshot of the 4-chamber toggled view. The interface allows for loading both real-time low resolution and high resolution cine images for the template selection process. The user can view the selected templates and easily edit/modify selections. The tracking parameters can be selected from a task card. After selecting the templates and parameters, the user switches to scanner mode to start tracking on live images from the scanner. The tracking result is overlaid on the image and shown to the user. The interface also provides a toggled view to see the tracking results in both views simultaneously as well.

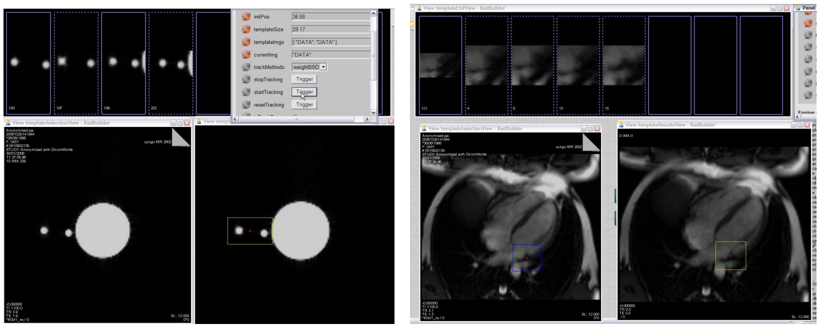


Tracking Methods: normCOR
# of templates: [2,3,4]
Template size:
width 10 height 10

Figure 2: *Screenshot of the 4-chamber toggled view of the coronary UI*

The coronary tracking interface runs on an independent workstation connected via ethernet to the scanner host computer. The approach similar to that used in the IFE framework [11] is used for communication with the scanner to obtain images and send slice updates.

Testing: The interface was first tested offline by tracking in pre-acquired sequences of 4-chamber and short-axis images. The online testing was done on a volunteer and a simple phantom consisting of two tubes where the relative distance of tubes was changed to simulate non-rigid motion. The online testing was done in each orientation seperately. The scanning parameters were as follows: TrueFISP images with TR/TE/FL=3.08/1.54/56, GRAPPA accel=2, in-plane resolution = 2.3mm, slice thickness = 12mm.



initPos 36 68
templateSize 29 17
templateImgs ["DATA", "DATA"]
currentImg "DATA"
trackMethods weightSSD
stopTracking
startTracking
resetTracking

Figure 3: Online testing (left) on a simple phantom and (right) in the 4-chamber view (tracking LCX)

Results

Figure 2 shows the offline tracking in 4-chamber view. Screenshots from online testing for the phantom and a volunteer are shown in Figures 3**.** The tracking accuracy was visually assessed and was found to be as accurate as the previous offline version of the tracking algorithm.

Discussion

We have presented an integrated system for real-time coronary motion tracking that will provide a basis for implementation of the proposed approach [9] on the scanner. Future work will include integrating slice position feedback based on the tracking algorithm into the framework. More generally this interface and the approach can be used for motion correction of other cardiac structures, such as valves.

References

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