

S. Sampath¹, J. L. Prince¹¹Electrical and Computer Engineering, Johns Hopkins University, Baltimore, MD, United States

Introduction: A full characterization of cardiac motion can be obtained by tracking its material points in three dimensions (3D). Early experiments involved imaging implanted markers in the heart, a highly invasive process. With MR tagging techniques, non-invasive markers could be tracked by finding the intersections of moving tag planes [1]. This was recently extended to the tracking of arbitrary points in 3D using a 3D CSPAMM technique combined with harmonic phase (HARP) image analysis methods [2]. These MR marker techniques are generally not suitable for clinical application either because of long image processing time or long image acquisition time. In contrast, 2D HARP methods yield both real-time imaging (FastHARP) [3] and real-time tracking [4]. This paper presents SF-HARP, a novel approach combining 2D HARP imaging and processing with the slice-following method in CSPAMM tagging to yield 3D MR marker motion for a collection of points within the myocardium.

Method: The SF CSPAMM technique [5], selectively tags a thin slice at an early time frame A while imaging a large slab that always encompasses the moving tagged slice even at a later time frame B (Fig.1.). After subtracting the complementarily signed tag-modulated images, the reconstructed images represent the same material slice at all time points irrespective of where it has moved in the through plane direction. Therefore, performing 2D HARP point tracking [6] on these SF images yields a true 2D displacement of the material point. Now consider two orthogonal SF tagged slices, both of which have two tag orientations, and consider a point lying on the intersection of the original tag planes of these slices. Such points have two projected pathlines that can be computed using 2D HARP tracking on orthogonal planes (Fig. 2), and these projected pathlines can be combined into a single 3D pathline representing the 3D motion of an MR marker. This can be done on any such intersection point, and can be computed automatically.

We implemented SF-HARP on a 1.5T GE Signa CV/I whole body MR system using the FastHARP pulse sequence modified to include the SF feature (SF-HARP). Eight short axis (SA) slices and four long axis (LA) slices were acquired in a normal volunteer in three breath-holds each lasting 24 heartbeats. The first two breath-holds were used to acquire the four short axis slices and the last breath-hold was used to acquire the long axis slices. For each slice, four CSPAMM images were acquired in four heartbeats. Additional two heartbeats per slice were necessary to acquire the dc peak for coil-sensitive phase reconstruction later. The imaging parameters used were: 32 X 32 matrix, RBW = 62.5KHz, TR/TE=12.25ms/2ms, ETL = 8, and an incrementing train of imaging flip angles was used with the final flip angle of 20°. Eleven time frames were acquired with a temporal resolution of 50ms. The acquired data was view-shared in the time domain to synthesize one image every 25 ms in the range [50ms-550ms]. Intersections of SA and LA tag planes were determined (Fig. 2.), and lines intersection points (red dots in Fig. 2) were tracked using 2D HARP. Points within the myocardium were automatically determined based on their motion, and the SA and LA trajectories (yellow traces in Fig. 2) were combined to obtain a collection of MR marker 3D pathlines.

Results and Discussion: Fig. 3a shows the motion of ~120 points on one of the long axis image at five timeframes. There is evidence of longitudinal compression with a large downward basal motion. Fig. 3b shows the motion of ~75 points tracked on three SA slices at three timeframes. There is clear radial compression and an apical twist at systole. Fig. 3c, shows all tracked points in two orientations at systole and diastole. Evidence of all major modes of normal LV motion are evident in this data.

Conclusion: We have demonstrated true 3D tracking of material points using SF-HARP. Experimental results from a normal volunteer show typical characteristics of longitudinal compression, radial thickening and apical torsion. With automated post processing tools, 3D tracking of material points could potentially be obtained during a clinical exam.

References:

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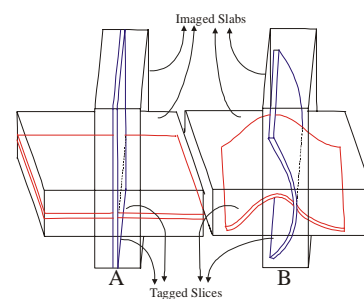


Fig. 1.

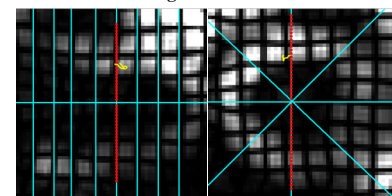


Fig. 2.

