In-line Automated Tracking in Cardiac Cine MRI

B. Li[1], Y. Liu[1], B. R. Cowan[1], and A. A. Young[1]
[1]Auckland MRI Research Group, The University of Auckland, Auckland, Auckland, New Zealand

Introduction: The tracking of anatomical features in cardiac cine MR images facilitates the analysis of myocardial motion. For example, wall thickening is an important clinical index of myocardial function. Non-rigid registration methods allow fast, automatic tracking of image features through a temporal sequence [1]. We implemented an efficient non-rigid registration algorithm on the scanner's image reconstruction computer to perform in-line calculation of deformation maps. The method was evaluated in a clinical setting by comparing manual wall thickening measurements with the automated tracking results in 36 patients with cardiovascular disease.

Methods: A standard SSFP (trueFISP) cardiac cine acquisition sequence was modified to use a custom reconstruction algorithm which included a non-rigid registration feature tracking step after the standard image reconstruction. The method was implemented on a Siemens 1.5T Avanto system (VB15) with a reconstruction computer comprising dual AMD single core Opteron 248 CPUs (2.2 GHz) and 8Gb RAM. The non-rigid registration was performed between successive image frames, in both the forward and backward time directions, using a free-form deformation algorithm, as described previously [1]. A sum of squares objective function was minimized using a non-linear least squares Levenburg-Marquardt (LM) algorithm, incorporating a multi-level coarse to fine optimization, in a 128x128 pixel region of interest in the center of the image. The Siemens ICE environment was used to parallelize the registration to exploit both CPUs. The ACML BLAS library was used for efficient solution of the linear equations resulting at each LM iteration. The final deformation maps between each image pair were stored in the DICOM image headers, so that they could subsequently be used for tracking and wall thickening analysis. The time taken for the in-line non-rigid registration algorithm was recorded in six short axis and three long axis slice acquisitions for single normal volunteer. Imaging parameters were: TR/TE/flip angle: 27.1ms/1.27ms/69deg; iPAT factor 2; segments 9; bandwidth 930 Hz/pixel; FOV 340x276.25mm; image matrix 256x208; slice thickness 6 mm; retrospectively gated with 25 cardiac frames and a breath-hold duration of 12 seconds. Image deformation maps were calculated in-line and compared with a previously validated offline registration procedure [1].

To evaluate the method in the context of wall thickening evaluation, mid-ventricular short axis cines from 36 patients with cardiovascular disease, enrolled in the ONTARGET MRI sub-study [2], were processed with the same registration software. Wall thickening results obtained using the centreline method [3] were averaged over the slice and compared with results obtained from a manual segmentation procedure (guide point modelling using CIM V6.0 [4]). Inter-observer errors were calculated for both manual and automated methods, from contours placed by two independent experienced observers. In the automated method, contours placed at end-diastole by each observer were automatically tracked to end-systole (ES) using the in-line image deformation maps.

Results: The time required for the image reconstruction and registration calculation was 10.1 +/- 1.9 seconds (mean +/- std dev, range from 7.4 to 14.1 seconds) per slice. Of this less than 1 second was required for image reconstruction. Deformation maps are shown for the in-line calculation compared with a previously validated off-line calculation [1] in Figure 1. Average wall thickening over the mid-ventricular short axis slice in 36 patients are displayed in Figure 1d at ES for the two observers, showing increased reproducibility with the automatic tracking method. The inter-observer errors in wall thickening using the manual method were 1 +/- 14 % at ES, and -1 +/- 5 % for the automated method. The errors between automated and manual results were 8 +/- 13 % at ES for Observer 1 and similar for Observer 2.

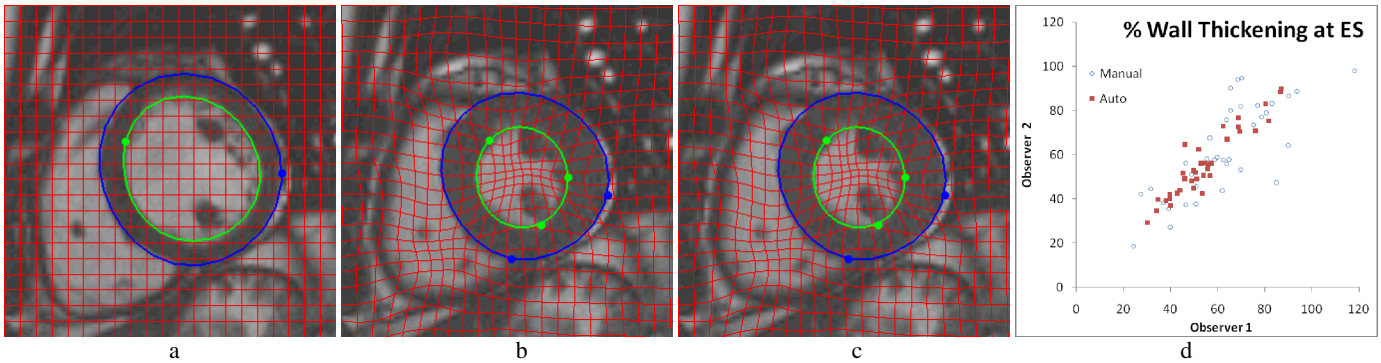

Figure 1: (a) midventricular short axis slice at end-diastole, with initial rectangular tracking grid (red) and manual contours (green endocardial and blue epicardial – dots show location of manually place guide points [4]); (b) same slice at ES with previously validated off-line tracking [2]; (c) same slice at ES with in-line tracking; (d) inter-observer comparison of % wall thickening at ES for manual (circles) and automated (squares) methods 36 patients with cardiovascular disease (averaged over the mid-ventricular short axis slice).

Discussion: Most manufacturers now supply very powerful reconstruction computers which are not heavily used between standard cardiac protocols. This power can be exploited to perform image processing tasks in-line, to facilitate subsequent analysis. The in-line image registration procedure implemented here resulted in an extra delay of ~10 seconds before images could be displayed to the console. This was considered to be clinically acceptable, given the 12 second breath-hold duration and the time required to allow the patient to recover from the breath-hold. Wall thickening was more reproducibly determined using the automatic tracking method, with a bias of 8% with respect to manual results. This bias may be due to inconsistent manual tracking of endocardial trabeculae.

Conclusions: Image feature tracking with non-rigid registration is feasible as part of the image reconstruction process, facilitating fast evaluation of wall thickening. The in-line registration procedure could also be exploited for many other applications, including image-based gating and myocardial deformation from tagged images.

References: [1] Li B *et al.* MICCAI 2008;2:880–887. [2] Anderson C. J Int Med Res 2005;33(Suppl 1):50A-57A. [3] Sheehan FH *et al.* Circulation 1986;74:293-305. [4] Young AA *et al.* Radiology 2000;216:597-602.