Fast automatic correction of non-rigid motion artefacts in MRI of the abdomen

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To reduce both scanning time and cross-talk during full pelvic MR scans, interleaved image (or multi-packet) acquisition is commonly used. However patient motion during this acquisition can result in non-linear "staircase" imaging artefacts which are readily visible on sagittal and coronal reconstructions (eg. Fig. 1a). These artefacts can affect organ segmentation, registration and visualization. Previous methods to limit patient motion have involved pharmacologic sedation, mechanical devices, motion gating, measuring gross patient movement and correcting for its effects. Postprocessing techniques typically require the acquisition of the frequency domain (k-space) data, which is difficult in routine acquisition protocols. [1]. Recently Gedamu et al. [3] suggested a method to reduce the effects of MRI inter-packet movement correct for brain imaging. Their approach involved extracting motion affected slices from a shot which have been affected by motion, blur those packets in the slice direction to fill slice gaps; rigidly register the other packets to the motion affected packet, and finally interpolate (using a Kaiser-Bessel function) a new isotropic volume from the registered packets. This process was then repeated for 10 iterations.

In this abstract we present a method to significantly reduce the effects of interleaving motion artefacts in a single-plane MR acquisition of the abdomen without k-space information. Rigid or affine registration is not suitable for correcting these artefacts as they occur primarily on the anterior side (where respiratory and patient motion are more prevalent) and are not evident in sagittal reconstructions along the patients backs and spines.

Method

A fast ITK-based implementation was developed to interpolate missing slices based on Frakes et al. [2]. This method involves registration between neighbouring slices using a modified control grid interpolation algorithm that selectively accepts displacement field updates (to optimize performance). A cubic interpolator is then applied to pixel intensities correlated by the displacement fields.

We applied this interpolation method to correct the motion affected MRI volumes by: 1. Creating a new volume where every axial slice from the artefact affected shot is removed and replaced with an interpolated slice and then; 2. For each of these slices, we used 2D non-rigid registration to register each original axial slice back to it's matching interpolated slice. As this registration is mono-modal, we used the 2D Demons algorithm [4,5] for non-rigid registration.

Axial proton density-weighted (PDw) whole body pelvic MR images were acquired for prostate cancer radiotherapy treatment planning at Calvary Mater Newcastle Hospital, Australia from a GE Signa 1.5 Tesla scanner using a phased array surface coil with an echo time (TE) of 44.2ms, repetition time (TR) of ~5000ms, voxel size 1.56x1.56 mm, and slice thickness 3 mm. Three sagittal reconstructions showing significant motion artefacts are referred to as: A007 (repetition time (TR)=5020, 70 axial slices); C011 (TR=5060, 64 slices) and H003 (TR=5440, 75 slices).

Results

Fig. 1(a) shows an original sagittal reconstruction of the PDw MRI acquisition, (b) displays the reconstruction after alternate axial slices were replaced with the interpolated slices. Fig. 1(c) shows the final corrected reconstruction. Fig. 2 shows significant reduction in interleaving artefact around the patient's bladder. These corrected reformations show significant correction of the bladder, rectum and prostate which should have an effect on manual and automatic organ segmentation for radiotherapy planning.

Fig 1. An original sagittal reconstruction from patient A007 is shown in (a), (b) shows the reconstructed volume after axial slice interpolation, and (c) displays the result of interleave correction (non-rigid registration of original to interpolated axial slices).

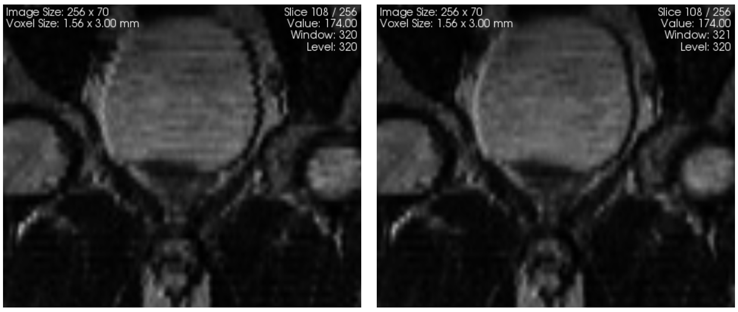

Fig 2. Coronal reconstruction from A007 (a) pre and (b) post correction. Note the clearer bladder boundaries.

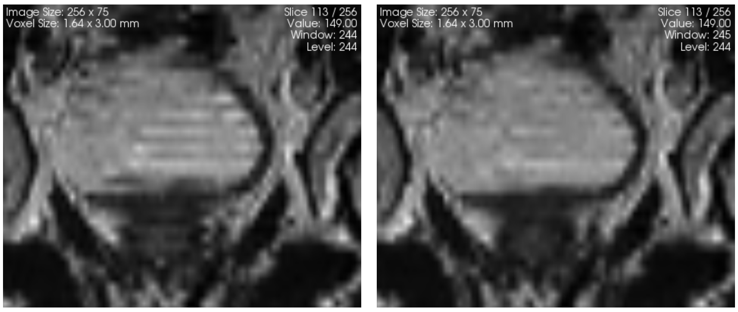

Fig 3. Coronal reconstruction from H003 (a) pre and post correction (b). The prostate boundaries are improved.

The interpolation step for a 70 slice Ax PDw acquisition required 14 minutes in a Dell GX620 (1Gb RAM, Pentium 4 dual processor, 3.2 GHz) using B-Spline interpolation . The registration step required an additional 8 minutes. In future work the influence of this MRI artifact reduction on prostate radiotherapy (including organ delineation and dose planning) will be further validated and evaluated.

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