Correcting Static Interventional Roadmaps for Subject Displacement in Real-Time using One-Dimensional Projections

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Introduction

Static roadmap images acquired before or during an MR-guided intervention enable high-resolution visualization of the anatomy involved. The position of a device can be displayed on these images by using active catheter tracking techniques. Static roadmap images have the potential to be of much higher quality than real-time images, which can be used as a complement to provide dynamic information about the intervention. The major limitation to the use of static roadmap images is patient motion. If motion occurs, device position, real-time images, and the static roadmap become misaligned.

To address this limitation, we propose to correct static roadmap images for three-dimensional patient motion in real-time using data collected from external coils during active catheter tracking using the projection method. Typically, subjects will have a tight-fitting coil or coil array that moves with them. It is possible to use the signal from individual coils in that array for tracking gross motion during catheter tracking without the need for fiducial markers or additional acquisition time.

Theory and Methods

During catheter tracking using the projection method, the MR signal from small coils located on the catheter is projected onto three orthogonal axes [1]. The data collected simultaneously from external surface coils, when Fourier transformed, represents one-dimensional projections of the object. By comparing the projections of the object to reference projections acquired with the roadmap images, it is possible to detect subject translations and correct the roadmap images.

The technique was implemented using custom MR visualization software [2] and used in conjunction with a 1.5 T GE Signa scanner with EXCITE hardware (GE Healthcare, Milwaukee). Immediately after the acquisition of static roadmap images, reference projections of the patient volume are acquired. A real-time GRE spiral sequence (4x3072, FOV=20cm) with catheter tracking (3x256 projections, performed every 4 spiral interleaves) performs real-time imaging and catheter localization. With each catheter tracking acquisition, projections of the volume are acquired. A golden section search is used to determine the translation that maximizes the cross-correlation between the acquired and reference projections (Fig 1). The position of the roadmap images are subsequently corrected to improve alignment with the calculated catheter position and real-time images. The utility of the technique was demonstrated in a water-filled phantom of the aortic arch. An active catheter was navigated through the phantom using static roadmap and real-time images. The phantom was translated in various directions and corrections were performed on the static roadmap to correct for the displacements. The accuracy of the technique was evaluated in phantoms and in-vivo by moving the patient table in 5mm increments between 0 and 5cm and acquiring approximately 30 projections from the external imaging coil using the real-time imaging and catheter tracking sequence described above.

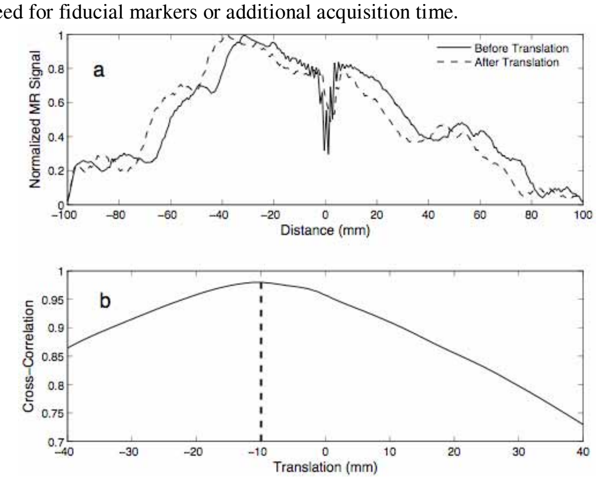

Fig 1. (a) One-dimensional projection along the z-axis of a human leg before and after a 1cm translation. (b) A golden section search is used to find the translation that maximizes the cross-correlation between the two projections.

Results

Static roadmap images of an aortic arch phantom were successfully corrected for translations between 0-5cm while simultaneously tracking a catheter (Fig 2). The technique was able to track a water-filled phantom with distinctive internal details and the aortic arch phantom with sub-millimeter accuracy. In vivo studies showed that one-dimensional projections from a 5-inch surface coil could detect 0-5cm translations of a human upper leg with 1-3mm accuracy and translations of a human chest with 1-4mm accuracy (Fig 3). The technique did have a tendency to underestimate translation slightly. It was also found that there was negligible deviation between successive translation calculations.

Discussion and Conclusion

The proposed technique has the ability to correct roadmap images for patient motion without the use of fiducial makers. Moreover, there is no acquisition time penalty because the data that is needed can be collected during a catheter tracking acquisition from external surface coils (data that would normally be discarded). It is important that the coils used to collect projection data are attached to and move with the body that is being tracked because one-dimensional projections are spatially weighted by coil sensitivity. One drawback with the technique is that it is only valid for rigid translations and is unable to correct for rotational motion. In more realistic interventional situations where rotational components exist, the technique can be used to obtain a first order correction and combined with more local image-based registration techniques. The proposed technique has the ability to accurately correct static roadmap images for patient translations so that an interventionalist can use high-quality images in conjunction with real-time images to guide an intervention.

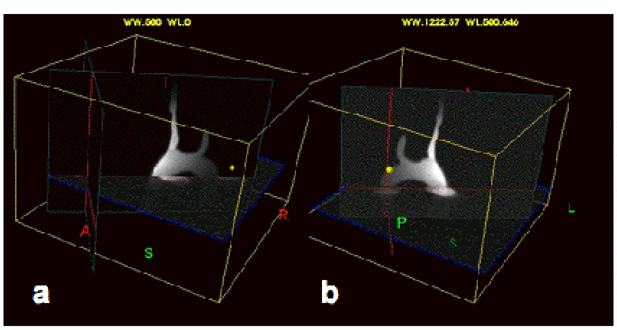

Fig 2. Active catheter tracking in an aortic arch phantom. Catheter tip is displayed as a yellow sphere on a prior volume. A real-time image (outlined in blue) is also displayed. (a) After a translation of 2.2 cm, catheter position and real-time image are no longer aligned with roadmap. (b) After correction, catheter position, real-time plane, and roadmap are aligned.

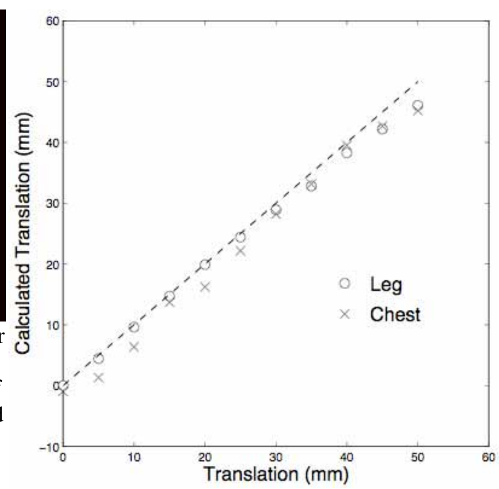

Fig 3. Results showing how the tracking algorithm performed in 2 in vivo situations. One using projections from a 5-inch surface coil on a leg, and the other using projections from a 5-inch surface coil on a chest. The dotted line represents the actual translation.

References:

[1] Dumoulin et al. MRM 1993;29:411

[2] Radau et al. ISMRM 2004: 375.