Co-registration of X-ray and MR Fields of View in a Truly Hybrid System

H. Yu1, R. Fahrig2, N. J. Pelc2

Synopsis

X-ray fluoroscopy and MRI are both used to guide interventions but have complementary strengths and weaknesses. To fully integrate an x-ray/MR hybrid system, a real-time x-ray/MR interface is proposed. A key step to implement this interface is co-registration of x-ray and MR fields of view (FOVs). In our method, sixteen fiducial markers are placed in the FOV. X-ray and MR measurements of the markers are then used to calibrate the system, thereby enabling the use of x-ray images as “scouts” to prescribe MR slices. Two sources of errors are studied and results from simulations and experiments are presented.

Method

X-ray and MR FOVs should be co-registered to implement this real time interface. The key step is to find the accurate positions of the x-ray components in MR coordinates. This includes 7 geometric parameters: the position of the x-ray focal spot (3 parameters), the detector (one corner, three parameters) and in-plane rotation of the detector (one parameter). Sixteen fiducial markers that are visible in both MR and x-ray images are placed in the FOV. By fitting the MR and x-ray measurements of the fiducial markers to a non-linear function describing the projection behavior, the values of the seven geometric parameters can be determined. This procedure can be viewed as the system calibration. The second or excitation phase is when the cross-calibration is used to excite the desired slice. Two points on the x-ray image of the target structure are identified and are used to calculate the target slice utilizing the previously fitted geometric parameters.

Results

The phantom was easily imaged by both MR (Fig 1) and x-ray (Fig 2a). The location of the crossing points could be measured with sub-pixel reproducibility. In computer simulations with only fiducial marker reading noise, use of 16 fiducial markers, arranged as four planes of 4 crossing points, yielded a mean error of about 0.14mm and worst-case error of around 0.45 mm. In our system, gradient nonlinearity can be a significant issue, causing the curved slice to miss the target point in the FOV by an average of 0.44 mm and worst case of 3.54 mm. The least-squares correction method decreased the mean and worse case errors to 0.35 mm and 3.34 mm respectively. Results of the accuracy test using the phantom are shown in Figure 2 for cases with and without least squares plane correction. Two neighboring slices in each case are shown. In the original target slice excitation, the effect of the warped curve plane is easily seen as imperfect visualization of the entire line. However, the amount of the target line visualized is clearly improved with least squares correction.

Conclusions

We have demonstrated that using sixteen fiducial markers to co-register x-ray/MR FOV can offer satisfactory accuracy in both simulations and experiments. This registration process is a key step to implement a real time x-ray/MR hybrid system interface.

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References