Simultaneous Imaging and Catheter Tracking: More Robust Performance with Joint Use of All Data

S. Kecskemeti[1], E. Brodsky[1], W. Block[1], and O. Unal[1]
[1]Medical Physics, University of Wisconsin, Madison, Wisconsin, United States

INTRODUCTION

Accurate tip-tracking of endovascular devices such as catheters is necessary to guide them to the desired position and avoid damage to vasculature. Current methods of catheter tracking [1] periodically interrupt the imaging sequence to acquire several projections to determine the position of the catheter. We have a taken a different approach and have developed a robust method to extract active tip-tracking data directly from the imaging data by using an interleaved 3D radial (VIPR) k-space acquisition. In the original implementation [2], an interleaved acquisition was used which uniformly sampled a sphere in *k-space every 1/8 s*. In each interleave, three projections nearest to the x, y, and z axis were used to determine the location. The method presented in this abstract uses the information from all the projections within a VIPR interleave to determine the catheter location. This results in a more robust prediction of the catheter location (especially in situations where SNR is limited) and reduces the perception of jitter in the catheter position.
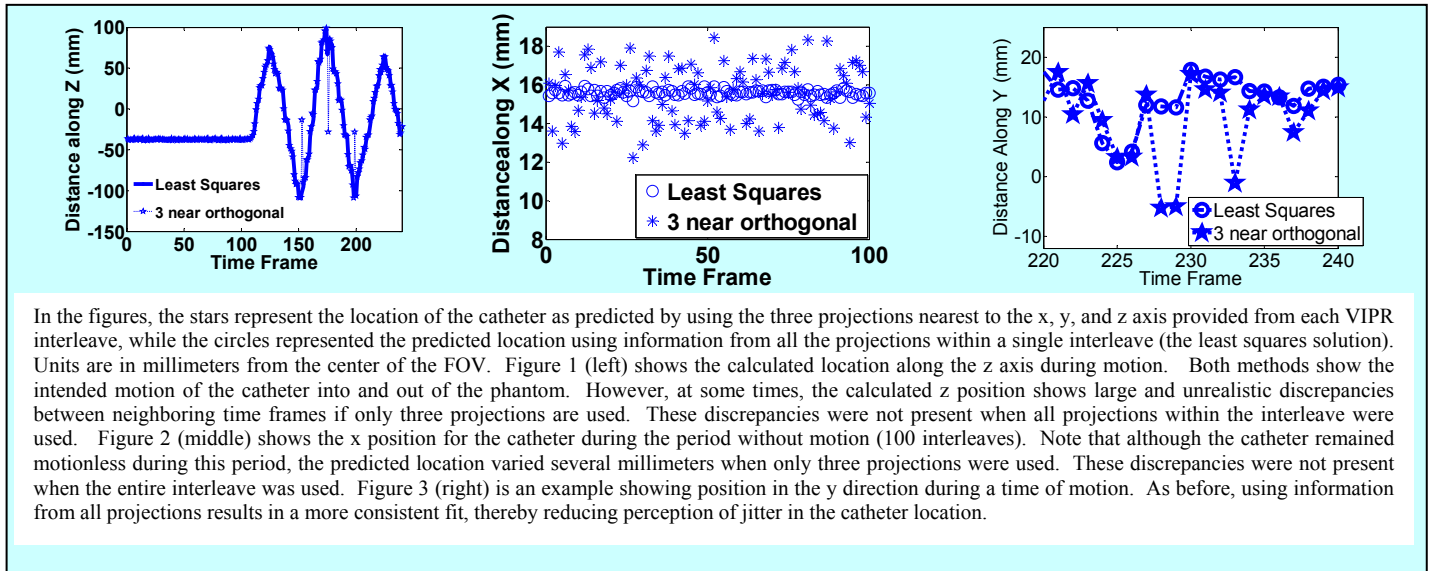
THEORY

By the Projection Slice Theorem, the 1D Fourier transform of a line through the center of k-space provides a projection of the 3D image space onto a vector. Each point in the vector represents a plane integral. If the signal from the tracking coil on a catheter is strong, the index r of the largest value in the vector will correspond to the catheter location along that projection axis. Then, the plane containing the catheter is described by $\vec{g} \cdot \vec{x} - r = 0$, where $\vec{x}$ is the position vector of the catheter and $\vec{g}$ is the unit vector describing the direction of the acquired projection. Although only three linearly independent gradient vectors are required to solve for the position vector $\vec{x}$, we combine all the vectors $\vec{g}$ and peak indices r from a single VIPR interleave into the over-determined matrix equation $Gx = R$ and find the least squares solution. This reduces errors caused by catheter motion in between acquisition of the approximate x, y, and z projection in each interleave. Sensitivity changes due to catheter orientation within the main magnetic field as well as low SNR, or object-dependent parameters can lead to occasional violations of the necessary assumption that the planar integral containing the catheter is greater than all others. When using only three projections, a single violation significantly affects the calculated catheter position. However, effects from even a few violations can be offset when combined with consistent data from the rest of an entire interleave.

METHODS

To study the performance of this method, a catheter was inserted into a water-filled phantom. Simultaneous imaging and tracking [2] was performed using an interleaved 3D PR VIPR sequence, with the data processed offline after completion of the scan. The catheter held stationary for the first half of the scan, then manually moved along z, with some motion also permitted in the xy plane. Each interleave evenly sampled the unit sphere in 1/8 s, with 58 projections per interleave. Catheter position was determined both with the old method, which used only three projections nearest to the x,y,z, axis, as well the new method, which used as all 58 projections in each interleave.

RESULTS

In the figures, the stars represent the location of the catheter as predicted by using the three projections nearest to the x, y, and z axis provided from each VIPR interleave, while the circles represented the predicted location using information from all the projections within a single interleave (the least squares solution). Units are in millimeters from the center of the FOV. Figure 1 (left) shows the calculated location along the z axis during motion. Both methods show the intended motion of the catheter into and out of the phantom. However, at some times, the calculated z position shows large and unrealistic discrepancies between neighboring time frames if only three projections are used. These discrepancies were not present when all projections within the interleave were used. Figure 2 (middle) shows the x position for the catheter during the period without motion (100 interleaves). Note that although the catheter remained motionless during this period, the predicted location varied several millimeters when only three projections were used. These discrepancies were not present when the entire interleave was used. Figure 3 (right) is an example showing position in the y direction during a time of motion. As before, using information from all projections results in a more consistent fit, thereby reducing perception of jitter in the catheter location.

DISCUSSION

We have developed a method to track the position of catheters directly from the imaging data at high update rates that is robust to inaccuracies in tracking performance or orientation. The 3DPR acquisition may also generate data used for simultaneous imaging, if data from an additional external or endovascular coil is collected. Interleaved 3DPR acquisitions are amenable to flexible reconstruction in which the spatial resolution, temporal resolution, SNR, and degree of undersampling artifacts can be chosen retrospectively during reconstruction, rather than fixed as part of the acquisition pattern. This tracking has been incorporated into a .real-time system which overlays the position of one or more endovascular tracking coils onto a continuously updated 3D roadmap image.

REFERENCES

1. Dumoulin, *et al*., MRM, 31, 309, 1994. **2.** Unal, *et al*., 6th *Interventional MRI Symposium* 2006, Leipzig, Germany.