SPI Motion Correction Using In-plane Estimates

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OBJECTIVE: Spiral Projection Imaging (SPI)[1,2] collects data on spiral planes that are rotated to fill a sphere in k-space. Arranging the planes as shown in figure 1a, such that they are sequentially orthogonal[3], allows for the intrinsic tracking of rigid-body patient motion in three-dimensions[4,5]. The current state of the in-plane estimation method[4] (see figure 1b) is herein presented. Typical corrected image results are shown, and estimation error values are provided.

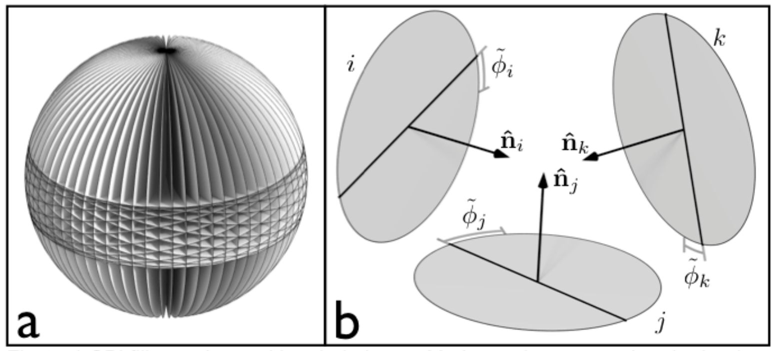

Fig 1: a) SPI fills a sphere with spiral planes. Motion estimates can be obtained intrinsically from spatially orthogonal sequential planes. b) Two-dimensional motion is estimated for each plane by comparing their data to the intersecting data from all other planes. An estimate, $\tilde{\mathbf{r}}$, of 3D rotation is obtained for a plane j using 2D rotation estimates, $\tilde{\phi}$, from three sequential planes i, j, and k according to: $\tilde{\mathbf{r}} = \mathbf{N}^{-1}\tilde{\phi}$, where $\tilde{\mathbf{r}}$ is a vector describing the axis and angle of rotation, $\tilde{\phi} = \left[\tilde{\phi}_i, \tilde{\phi}_j, \tilde{\phi}_k\right]^T$, $\mathbf{N} = [\hat{\mathbf{n}}_i, \hat{\mathbf{n}}_j, \hat{\mathbf{n}}_k]$, and $\hat{\mathbf{n}}_i$ is a vector normal to plane i.

MATERIALS AND METHODS: T1-weighted, spoiled gradient echo data were acquired on a GE 3.0 T Signa Excite HDx with two gradient modes (i.e. the vendor's "whole" and "zoom" modes). SPI data were simulated with known rigid body motion from Cartesian data. SPI data were also acquired in-vivo with and without voluntary subject motion. To validate the in-vivo results, stationary data sets were acquired at five different positions and registered using the FMRIB Software Library (FSL) to estimate the relative rotation and translation between sets. Subsets of planes were then taken from each of the five sets to produce a composite in-vivo set with simulated motion. The proposed method was applied to the simulated, in-vivo, and in-vivo validation sets. The estimates were compared to the "known" motion when applicable.

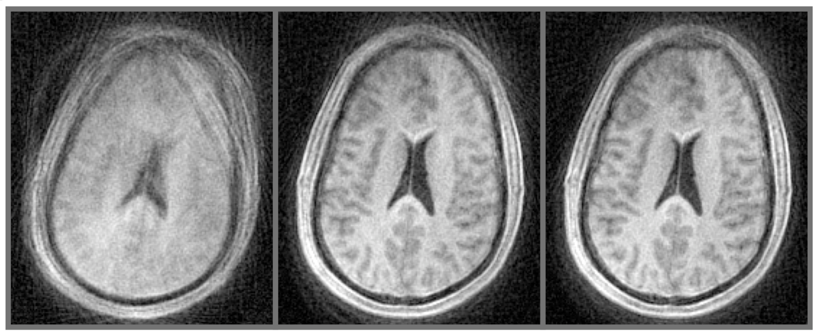

Fig 2: Sample in-vivo validation results (8-channel head coil, zoom gradient mode, 59 spiral interleaves). Left: motion corrupted data. Middle: corrected using estimates from proposed method. Right: corrected using FSL estimates.

RESULTS: Motion corrected results are shown for in-vivo validation and in-vivo data in figures 2 and 3. Table 1 provides measures of rotational and translational motion estimation error for the simulated data and the validation data.

CONCLUSIONS: The proposed method is capable of estimating and correcting for three-dimensional rigid-body head motion using SPI acquired data. Simulated results demonstrate small estimation error. Estimation error in the validation data is slightly larger, due partially to the sharp transition regions between the five stationary sets (i.e. error is much larger for spiral planes at these transitions).

TABLE 1	ROTATIONAL ERROR (degrees)		TRANSLATIONAL ERROR (pixels)	
Data Type	Average	RMS	Average	RMS
Simulation	0.63	1.03	0.11	0.12
8-channel, zoom, 59 interleaves	1.13	2.92	0.34	0.38
1-channel, zoom, 59 interleaves	0.96	2.58	0.31	0.36
1-channel, whole, 59 interleaves	1.13	2.42	0.38	0.43
8-channel, zoom, 127 interleaves	1.03	2.75	0.34	0.39
8-channel, zoom, 29 interleaves	1.08	2.69	0.36	0.41

Table 1: RMS and absolute average motion estimation error. For the validation data, the sets are labeled according to the number of coil channels, number of spiral interleaves, and gradient mode used.

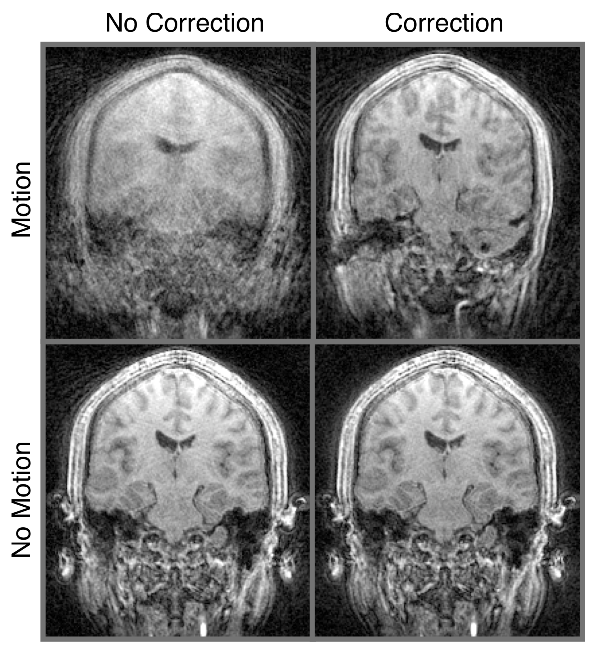

Fig 3: Sample in-vivo results.

REFERENCES: 1) Irrazabal, Mag. Res. Med. 33; 656-662. 2) Robison, Proc. ISMRM 2007, Abstract 1664. 3) Johnson, ISMRM Workshop on Data Sampling and Image Reconstruction. 4) Robison, Proc. ISMRM 2008, Abstract 1470. 5) Johnson, Proc. ISMRM, Abstract 1469.