Use of Multi-Channel Coil Sensitivities for Improved Detection of Motion with Orbital Navigator Echoes

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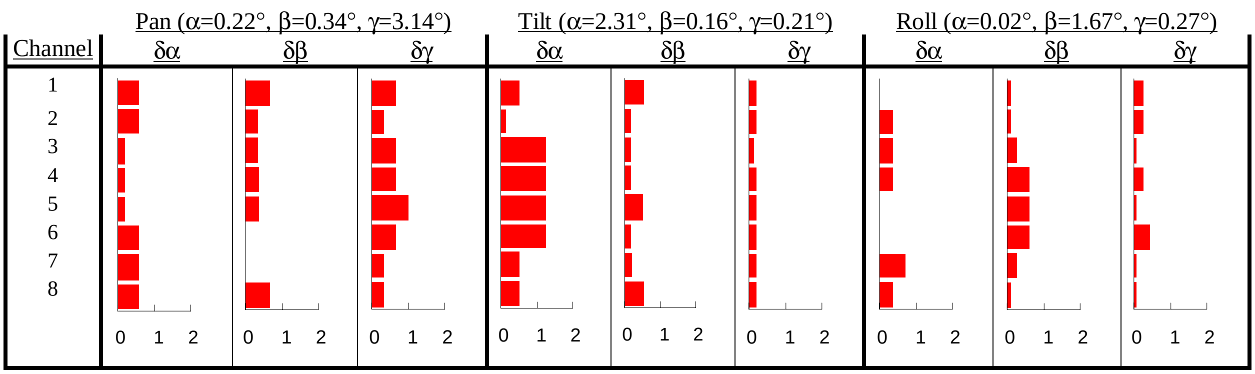
Introduction: Several motion detection techniques for prospective motion correction in functional MRI (FMRI) have been previously introduced, each with its own set of challenges [1-4]. In particular, a series of orthogonal orbital navigators (ONAVs) has been demonstrated to be effective for reducing motion artifacts in FMRI maps [5]. However, due to the planar nature of each ONAV acquisition, the technique can be sensitive to motion orthogonal to the plane of acquisition, potentially limiting the accuracy of motion detection in the absence of additional data collection. Spherical navigators (SNAVs) were introduced in an effort to acquire all data for motion detection in a single acquisition, avoiding the problem of through-plane motion. Unfortunately, due to the complexity of the algorithms and acquisition, it remains questionable whether SNAVs can be implemented on a real-time basis while still providing the necessary resolution for motion detection.

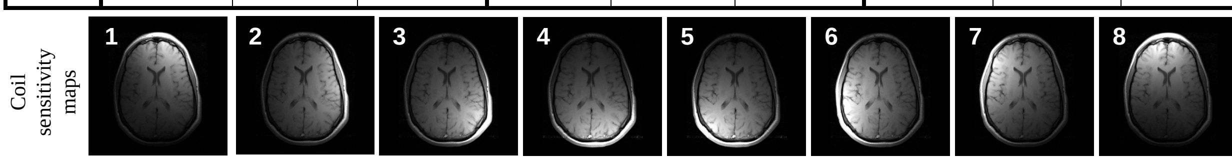
State of the art imaging techniques for FMRI have also evolved. The use of partially parallel imaging techniques can shorten the echo-train in echo planar imaging (EPI) [6]. The resulting increase in image resolution or decrease in sensitivity to off-resonance effects make this technique attractive for applications such as diffusion-weighted imaging or FMRI. Of course, parallel imaging requires the differential spatial sensitivity of multi-channel coils to achieve the desired acceleration factors.

Here, we consider how the differential spatial sensitivity of an eight-channel head coil affects the accuracy of motion detection by the ONAV acquisition for motions in each of the axial, sagittal and coronal planes. Specifically, we hypothesize that the accuracy of ONAV motion detection will vary on a channel-by-channel basis, depending on the corresponding anatomy sampled by that channel. Thus, certain channels may be identified as containing data weighted towards motion detection in a particular plane, while data from other channels may be discarded for contributing information about through-plane or non-rigid motion.

Methods: A volunteer was imaged on a 1.5T GE 11.0 EXCITE system using an eight-channel head coil (MRI Devices). At specified times, the volunteer was instructed to rotate his head in one of the orthogonal planes (pan – axial, tilt – sagittal, roll – coronal). For each new head position, a set of three orthogonal ONAVs was acquired, as well as a 3D phase-cycled SSFP (FIESTA-C) dataset. The ONAVs were acquired with the parameters described in [5], and the FIESTA-C datasets were acquired in the sagittal plane with 4.7ms/2.2ms/±64kHz (TR/TE/BW), 45° flip angle, 256x224 image matrix, 25cm FOV and 64-2.4 mm slices interpolated to 128. The 3D datasets from each position were registered using AFNI [7] to establish "true" values for the performed motions. Raw data from the ONAVs was saved and processed individually for each channel, comparing the resulting measured rotations to the "true" measured rotations. A map of the coil sensitivities was also obtained for reference.

Results: The absolute error (δα, δβ or δγ in degrees) between the rotation measured by the ONAV and the "true" rotation is shown in the chart. The magnitudes of the "true" rotations are indicated in parentheses. The coil sensitivity maps for a single axial slice through the brain are also shown.





Discussion: The plots demonstrate that for certain motions, larger error is observed from channels located posterior to the head (channels 3-6). This is most likely due to signal from stationary neck tissues that do not move with the head as a rigid body. Comparing the anatomical datasets after image registration, the largest differences were observed in the posterior neck, which correlates well with the observed decrease in accuracy from posterior channels. These preliminary results demonstrate that ONAV motion data can be obtained from each of the remainder of the channels (1-2, 7-8) within the accuracy obtained with a single-channel head coil [5].

The adoption of multi-channel coils to improve echo planar imaging using parallel imaging provides new opportunities for tuning the ONAV motion detection algorithm. The slowly varying coil sensitivity for each channel provides a means of weighting the ONAV signal to the geometry of interest without requiring the use of special RF pulses or selective excitations that may cause artifacts in the ONAV signal. Because the coil sensitivities are stationary with respect to the magnet, it is probable that the accuracy of motion detection will be degraded for larger motions as tissues move both into and out of the region of sensitivity. Further analysis will need to be performed to determine the range of motion over which ONAV motion detection with multi-channel coils provides reasonable results.

References: [1] Lee et al, MRM 39:234, 1998. [2] Derbyshire et al, JMRI 8:924, 1998. [3] Thesen et al, MRM 44:457, 2000. [4] Welch et al, MRM 47:32, 2002. [5] Ward et al, MRM 43:459, 2000. [6] Griswold et al, MRM 41:1236, 1999. [7] Cox, Comput Biomed Res 29:162, 1996.