

Can Multi-Channel FID Navigators Quantify Head Motion?

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Introduction

Free induction decay (FID) navigators can provide information to detect motion and other artifacts in MR imaging¹⁻⁴. In this work, we aim at exploring the feasibility of employing a series of FID navigator signals from a head coil array to decode and quantify translational and rotational motion parameters in brain imaging experiments. Rigid body tracking data from an optical system⁵ was used as a ‘gold-standard’ reference to formulate and validate an FID-based model to predict all six rigid body motion parameters from head movements.

Materials and Methods

For FID signal acquisition, a non-selective 3D gradient-echo (TR/TE/ α /TA = 25ms/3.0ms/12°/6min) sequence was modified in such a way that every tenth TR, the k-space center was sampled, without changing the timing, to obtain the FID signal. Three healthy volunteers were scanned after obtaining written consent at 3T (Magnetom Trio a Tim System, Siemens, Germany) using a commercial 32-channel head coil array. Subjects were instructed to move their head following four different motion patterns during FID signal acquisitions (Fig. 1): nodding (nod), translation

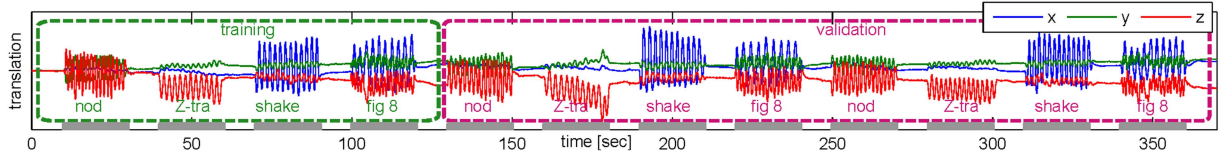


Fig. 1 Translational motion parameters as captured by the camera system from a subject scan performing the 4 motion patterns during the training (green box) and the validation parts (red box). Grey bars at the bottom mark the motion periods.

in scanner’s z-direction (‘Z-tra’), head-shaking (‘shake’), and drawing a virtual eight with the nose (‘fig 8’). Motion periods of 20 sec duration were interleaved with 10 sec periods without motion. This series of patterns was repeated 3 times within one scan, i.e. leading to a total acquisition time of ~6 minutes. This acquisition was performed twice for each of the three subjects. The scanner was equipped with an optical tracking system for motion detection. The system consists of a single in bore camera and a spatially encoded marker allowing for sub-millimeter tracking accuracy⁵. The tracking marker was placed on a customized mouth piece. Following a simplified assumption that FID signal changes detected with multiple coil elements relate linearly to the head position changes within the coil array, a regression model was trained using the complex FID signals (64 dimensions) and the tracking data from the camera. One third of the measurement (2 minutes of FID and camera data) was used to compute the model coefficients. Subsequently, the model was validated by predicting the head motion parameters in the remaining measurement (Fig. 1 - red box). The prediction accuracy of the linear model was evaluated using 3-fold-cross-validation, i.e. shifting the training block to the middle and the end of the same scan, and by computing the prediction errors for translational and rotational motion. The training and validation was always performed within a single 6 minutes scan of one subject.

Results and Discussion

Based on the tracking system, the subjects performed translational and rotational motion up to 15 mm and 7 degrees. The validation showed that the FID-based linear model of all six motion parameters predicts the camera measurements with an overall translational and rotational mean error of 0.2 mm and 0.1 degrees (Fig. 2). We observed errors $\geq 3\sigma$ up to 1.7 mm and 1.7 degrees corresponding to 1.2% and 2.4% of the dataset for translational and rotational motion. That may have various reasons: (a) limits of the simplified linear model, (b) accumulative (linear) phase and magnitude changes of the FID signal over time, possibly arising from hardware imperfections such as B_0 drifts, (c) physiological signal fluctuations, and (d) optical marker shifts, due to non-rigid coupling. This work demonstrates that rigid body motion information is encoded in multi-channel FID navigator sets and can be decoded with mean errors in the sub-millimeter and sub-degree range. With calibration strategies other than an external tracking system, such FID information has the potential to complement existing motion compensation methods in MRI, while having only minor impact on the imaging procedure.

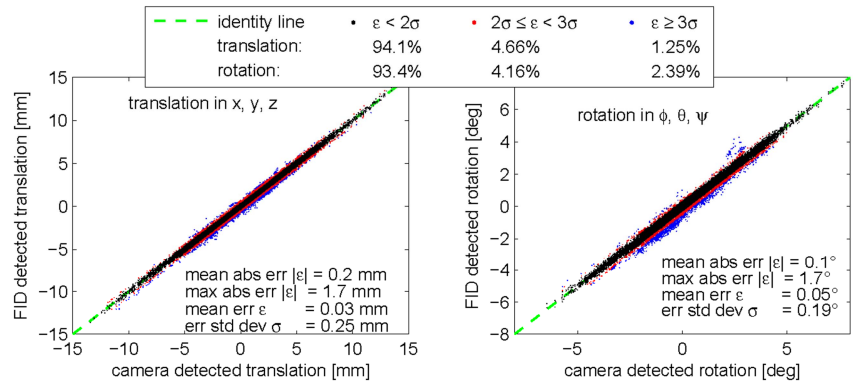


Fig. 2 Predicted FID-based translational and rotational motion versus camera-detected motion from 6 scans of 3 volunteers (2 scans/volunteer) in one plot. The extent of the motion parameter error is coded with different colors corresponding to multiples of the standard deviation together with their proportion relative to the data set. Line-of-identity is indicated in green.

References

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