A System Identification Approach to Fusing Multiple Concurrent Motion Measurements and Estimating a Dynamic Model of Head Motion for MRI Motion Correction

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Purpose: Motion-compensated MRI is a promising technique to mitigate the effects of motion on MRI. This works best when accurate real-time motion measurements are available. Many measurement techniques track motion with a delay and produce noisy measurements. We propose an estimator that uses a dynamic system identification approach to estimate rigid body head motion from multiple concurrent measurements of position and orientation, which can be used to predict motion shortly into the future. We compare our method to a Kalman filter-based method in our experiments.

Methods: Given concurrent measurements of multiple correspondence points and orientations from the head, we are able to simultaneously estimate rigid body motion parameters and their dynamics, which can be used to predict parameters that occur shortly after measurement times. The method is based on recent work on robust dynamical system identification published in the control theory literature that allows for simultaneously denoising and estimating the dynamics of a noisy sequence of data [1]. We extend that work by incorporating a model of rigid body motion to simulated measurements from motion parameters. The dynamic estimates resulting from this algorithm outperform static estimates of rigid body motion parameters, as well as an Unscented Kalman Filter (UKF), similar to the Extended Kalman Filter (EKF) in PROMO [2]. The UKF requires choosing a driving noise variance (v), whereas our method requires choosing a maximum model order (w) for the dynamic system.

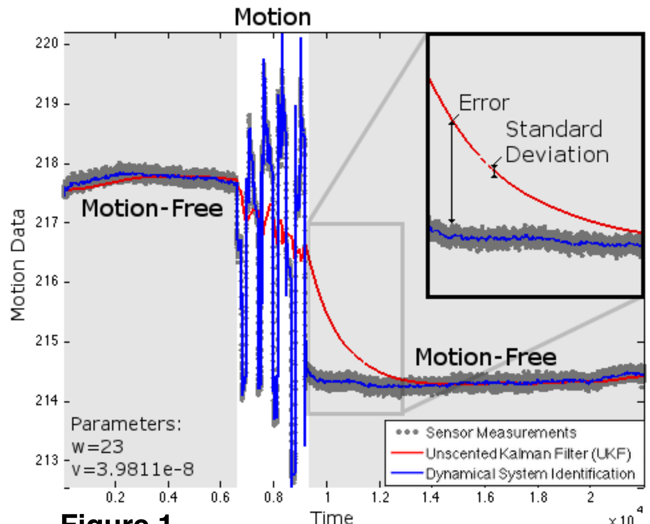

Figure 1

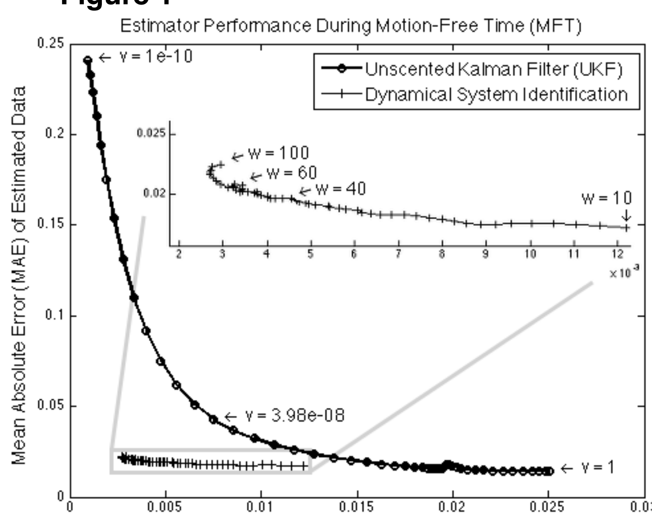

Figure 2 Standard Deviation of Estimated Data

Results and Discussion: The algorithms were tested in volunteer studies using measurements from two electromagnetic trackers (Robin Medical, Inc.) placed on the head, and simulation studies. Volunteers were instructed to move in predetermined patterns of motion during scans. Rigid body motion parameters were estimated from the data and predicted one time step into the future. Data was simulated from these parameters and compared to the measured data. Figure 1 shows a qualitative comparison of the two prediction methods for two parameter choices (w=23, v=3.9811e-8), with the data in gray, our method in blue, and the UKF in red. In Figure 2, we also compared the two methods quantitatively for a wide range of parameters using two criteria: (1) the mean absolute error between the predicted observations and the measured observations during motion-free time (MFT), and (2) the standard deviation of the estimates about their own means during MFT.

Conclusions: The proposed method offers a better trade-off between noise reduction and converging to the data during motion-free periods, as compared to the UKF. The method can be used as part of prospective motion correction methods, to make more efficient use of motion-free time.

References: [1] Ayazoglu, M., Sznaier, M. IEEE CDC 2012, [2] White, N., *et al. MRM* 2010