Real-Time Dynamic Prediction of Motion during Prospective Motion Correction Helps Reduce Errors Caused by Fast Motions and Delayed Motion Measurements

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Purpose: Prospective motion correction of MRI steers the imaging field of view (FOV) to image as if the subject was not moving. This technique relies upon accurate real-time motion measurement, and sequence modifications to steer shots in order to acquire k-space samples despite the presence of motion. All existing prospective motion correction techniques to date will perform the action of steering the FOV using motion measurements made in the past, because all motion measurements are available after some delay. Moreover, all of these existing techniques assume that this delay is infinitesimal. However, recent work (Erem, 2014a/2014b) (Keating, 2014) demonstrates that this assumption is wrong and leads to poor motion compensation, especially when motions are rapid. Rather than assuming infinitesimal delays, these same recent works have proposed to use prediction of motion parameters shortly into the future as a way to reduce errors due to measurement delays and improve motion compensation. Here we assess how the dynamic prediction method, as described in (Erem, 2014b), performs in comparison to the Kalman filtering called "PROMO" (White, 2010) and the usual method of steering based on static FOV estimates (i.e., treating each time instant independently).

Methods & Materials: A 3D GRE sequence was used to image 3 healthy volunteers on a Siemens 3T Trio scanner. To perform a fair head-to-head comparison between prospective motion correction methods, we simulated the effects of motion on each

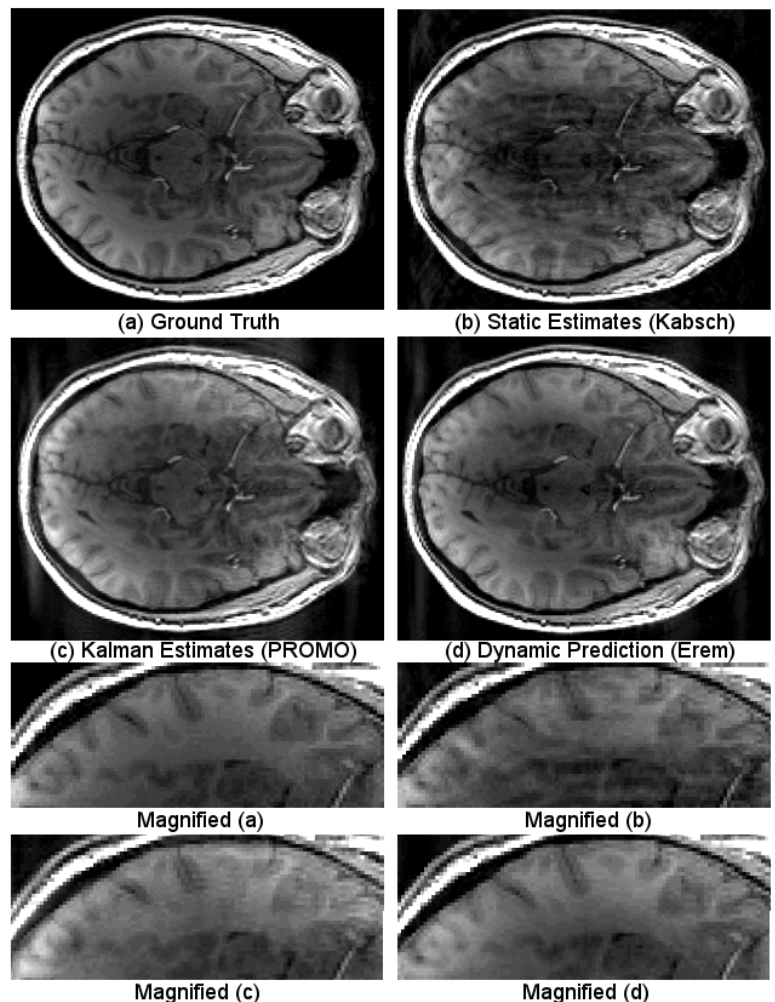**Figure 1:** Prospective correction results with/without prediction.

scan and provided the same data to each method. Noise was added to correspondence points generated from true motion traces and provided, with a delay of one TR, to each correction method as simulated motion measurements. The dynamic prediction method was implemented based on (Erem, 2014b), and the nonlinear Kalman filter was implemented based on (White, 2010). Static estimates for FOV steering were obtained using the Kabsch algorithm (Kabsch, 1978).

Results: Example images and magnified views for one subject are shown in Figure 1. Ranked from best to worst, dynamic prediction resulted in a normalized root mean squared error (NRMSE) of 0.0131, the Kabsch algorithm resulted in a NRMSE of 0.025, and PROMO resulted in a NRMSE of 0.0258. Qualitatively, dynamic prediction produced the closest result to the ground truth, PROMO was next best, and static estimates from the Kabsch algorithm performed worst.

Conclusions: The dynamic prediction approach to prospective motion correction provided a clear advantage over PROMO and the Kabsch algorithm, suggesting that it may be possible to overcome errors due to non-infinitesimal delays.

References:
1. Erem B, *et al.* (2014a) ISMRM Workshop on Motion Correction in MRI. **2.** Erem B, *et al.* (2014b) MICCAI INTELLMR Tutorial and Workshop. **3.** Keating B, *et al.* (2014) ISMRM. **4.** White N, *et al.* (2010) MRM. **5.** Kabsch W. (1978) Acta Crystallographica.