Quantitative framework for prospective motion correction evaluation

Nicolas Pannetier[1,2], Theano Stavrinos[2], Peter Ng[2], Michael Herbst[3,4], Maxim Zaitsev[4], Karl Young[1], Gerald Matson[1,2], and Norbert Schuff[1,2]
[1]*Radiology, UCSF, San Francisco, CA, United States,* [2]*VAMC, San Francisco, CA, United States,* [3]*Radiology, JABSOM, Honolulu, HI, United States,* [4]*Radiology, University Medical Center Freiburg, Freiburg, Germany*

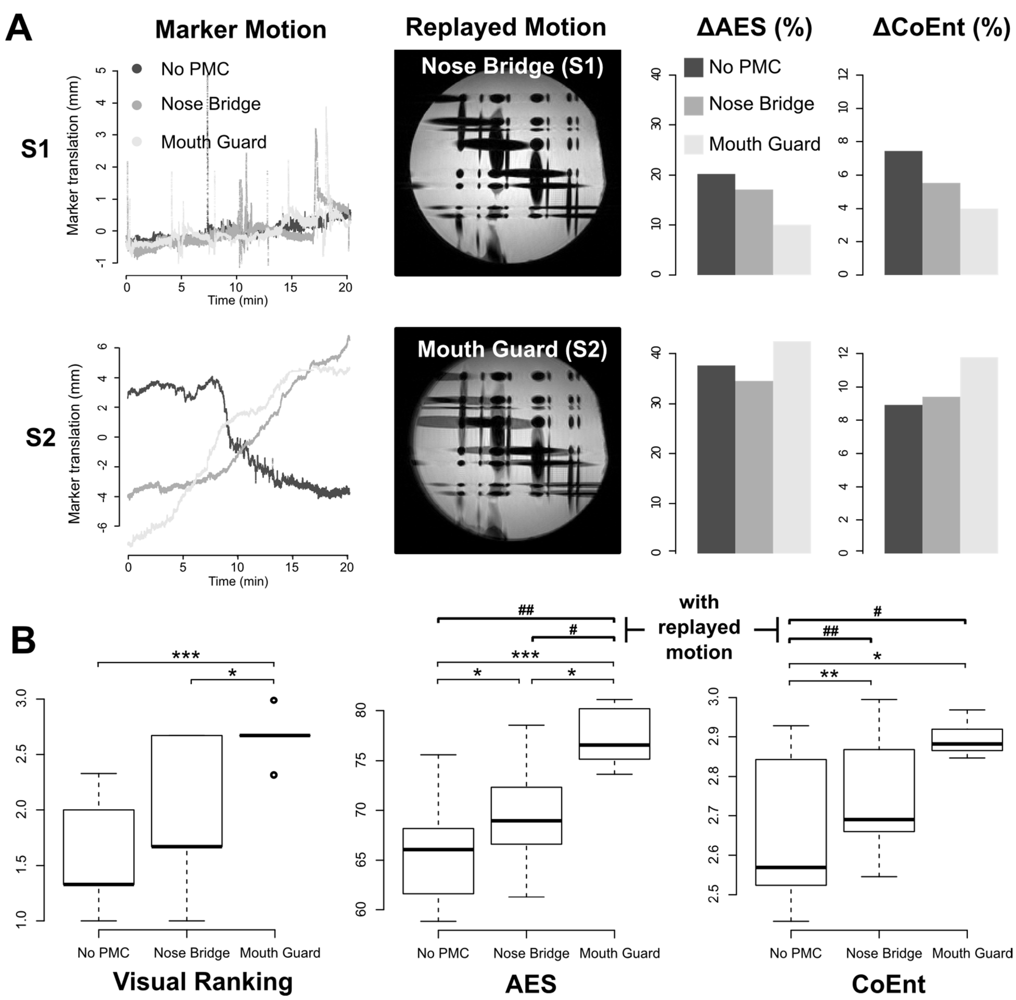
Target Audience: This work is relevant to scientists and engineers with an interest in the quantitative assessment of prospective motion correction (PMC) techniques.

Purpose: To provide a framework to quantitatively evaluate the image quality improvement provided by PMC techniques while considering the intrinsic motion variations between MRI acquisitions.

Background: Motion in magnetic resonance imaging remains one of the main sources of image degradation. PMC overcomes it by updating the MRI system in real time according to the motion of the subject in the scanner. In most prospective motion setups, the motion is monitored indirectly by tracking the position of a marker rigidly attached to the patient's head [1]. Promising results have been obtained with different setups. However, finding a sensitive measure to quantify the effectiveness of the correction has been elusive. Specifically, the difference in the subject's motion between acquisitions as a possible bias in the comparison has not been entirely addressed. In this work, a framework was developed to obtain quantitative comparisons between different motion correction setups, considering the intrinsic motion patterns between acquisitions as a covariate.

Methods: Five healthy subjects were scanned at 3T with T1w MRI (3T Siemens Skyra, MPRAGE, .7mm isotropic, 2 Averages, 19min) and asked to remain still. The motion tracking setup described in [2] was used for PMC. The same protocol was repeated with 3 different setups: no correction (No PMC), correction with the marker attached to the nose bridge (Nose Bridge) and correction with the marker attached to the mouth guard (Mouth Guard). To quantify the images, visual scroing by 3 experts (1 – low quality, 3 – high quality) and two indexes were used: Average Edge Strength (AES) [3] and Entropy of the Co-Occurrence matrix (CoEnt) [4]. The same MRI protocol was performed on a phantom with the motion reproduced artificially by replaying the tracks recorded during the in vivo scans as described in [5]. A phantom free image was acquired as reference and relative variation of AES (ΔAES) and CoEnt (ΔCoEnt) were evaluated in the phantom experiment as a measure of the intrinsic motion impairment. A linear mixed effects model with random variations of intercepts for each subject was designed to compare the performance of the two configurations (***<0.001, **< 0.01, *<0.05). The impact of the intrinsic motion on the evaluation was considered by comparing the statistical significance with (#) or without (*) considering the intrinsic motion as a covariate in the fixed effect.

Results: Figure A – The first column shows the marker motion trajectories for subject S1 and S2 for all 3 configurations. A large disparity is observed which is also found in the phantom images (e.g. next column). ΔAES and ΔCoEnt are then used to summarize the intrinsic motion and results are shown in the last two columns. AES and CoEnt assessed the images artifacts differently. Figure B – From visual ranking, the Mouth Guard outperforms the Nose Bridge. No statistical difference, however, is found between the No PMC and Nose Bridge setups. Using AES and CoEnt indexes, the statistical differences differ depending on whether the intrinsic motion is considered as a covariate or not. The statistical significances between the setups are reduced when using AES and unchanged when using CoEnt.



Conclusion: Differences in the intrinsic motion patterns can impact comparisons between PMC configurations and must be considered to achieve a robust evaluation. The present works proposed a framework to measure this intrinsic motion and to consider it a covariate in the statistical analysis. This framework could be useful to compare PMC configurations in larger studies involving larger cohort and additional PMC setups.

References: [1] Maclaren J et al. MRM 2013, 1;69(3):621-36. [2] Maclaren J et al. PLoS ONE 2012; 7:e48088. [3] Aksoy M. et al., MRM 2012, 64:1237-1251. [4] Haralick R. Proc. of the IEEE 1979, 64:5 786-809. [5] Herbst M. et al., MRM 2013, e24645.