# Reverse Retrospective Motion Correction

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***Introduction***: One of the barriers for using Prospective Motion Correction (PMC[1]) in the clinic is the unpredictable nature of a scan because of the direct interference with the imaging sequence. Here, we suggest using the framework of retrospective motion correction[3] to reverse the effects of prospective motion correction ("reverse retrospective correction") for brain scans. The result is that each scan yields two sets of images, one reconstructed from the original data with PMC enabled, and a second "reference" set that mimics a scan with PMC disabled. This allows for a direct evaluation of the effects of PMC on image quality when motion is present, and provides a means to restore an uncorrected image set in case of erroneous corrections.

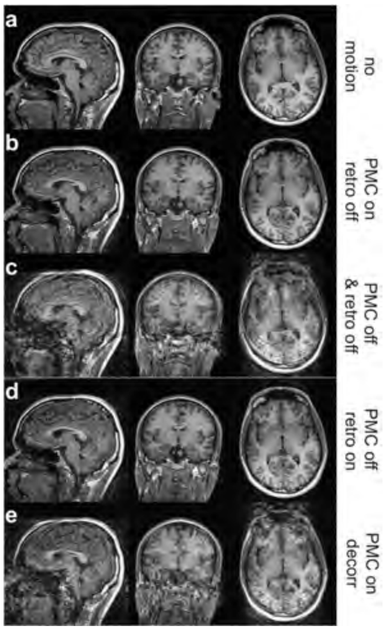


**Figure 1 Equivalency of PMC, RMC and reverse PMC**

***Theory***: For 3D scans, the effects of PMC can be undone by performing a retrospective reconstruction based on the assumption that PMC and retrospective correction (RMC) perform equally well and mutually invert the effects of each other. Retrospective reconstruction was performed using a generalized SENSE approach[2,4] with continuous motion tracking. For head motion during a scan described in the logical frame (phase, read, slice) by the 4x4 homogeneous matrix $\mathbf{A}(t)$, reconstruction is based on $s(t) = \int \rho(\mathbf{r}_0) e^{i\mathbf{r}_0^T \mathbf{k}_{\mathrm{retro}}(t)} dV$, where $\mathbf{k}_{\mathrm{retro}}$ is the transformed k-space trajectory derived from the uncorrected Cartesian trajectory $\mathbf{k}_n^0$ (line index n) according to

$$\mathbf{k}_n^{retro} = \begin{cases} \mathbf{A}_n^T \mathbf{k}_n^0 & & \text{RMC} \\ \mathbf{k}_n^0 & for & \text{no correction} \\ \mathbf{A}_n^{-T} \mathbf{k}_n^0 & & \text{reverse PMC} \end{cases}$$

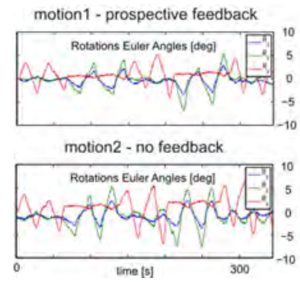


**Figure 2 Motion traces**

***Methods:*** Experiments were performed on a 3T Trio (Siemens). Motion tracking was performed with an optical system based on Moiré-Phase-Tracking. PMC was performed using a magnetization prepared gradient echo sequence (MPRAGE) capable of adapting the scan geometry according to object motion in real time. The communication interface between the sequence and the camera was provided by the XPACE library[1]. MPRAGE sequence parameter were: TR/TE/TI = 2000/5/1100, base resolution 192x192x160, voxel size 1.1 mm isotropic, partial Fourier 6/8 in phase direction and 7/8 in slice direction.

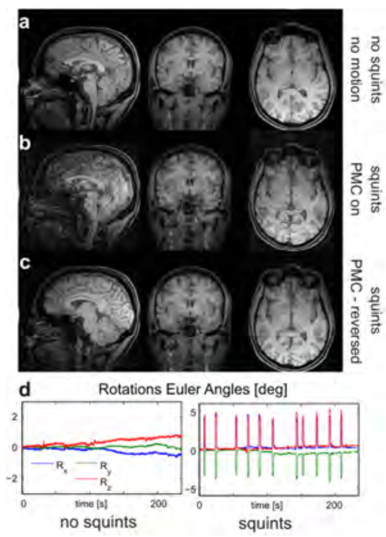


**Figure 3 Reversing erroneous PMC**

***Results:*** Figure 1a displays three orthogonal slices of a "baseline" MPRAGE sequence with no motion and no prospective feedback. A second scan with PMC enabled (Fig.1b) results in virtually identical image quality despite severe head motion, with rotations of over ±5° (trace I). For a 3rd scan (trace II) PMC feedback was disabled and thus plain reconstruction results in substantial motion artifacts (Fig.1c). Reconstructing the same dataset with retrospective correction (Fig.1d) yields comparable image quality as in Figs.1a or 1b. In Fig.1e it is shown that reversing the effects of PMC from Fig.1b essentially reproduces motion artifacts from the uncorrected case in Fig.1c. The ability to de-correct scans acquired with PMC makes it possible to remove artifacts that were introduced by inaccurate motion feedback. Figure 3a shows a reference MPRAGE scan (no motion, no PMC). Next, a scan was acquired with PMC enabled, and the subject was asked to keep his head still but to squint and yawn periodically. Since the marker was attached to the forehead above the eyebrows, this resulted in substantial spikes in the otherwise flat motion data (Fig.3d). Because of these erroneous tracking data, the PMC enabled images exhibit motion artifacts (Fig.3b). Reverse-correction of this PMC enabled scan improves image quality in Fig.3c, which is comparable to the baseline scan in Fig.3a.

***Discussion:*** Reverse retrospective reconstruction can almost perfectly undo the effects of prospective feedback, and thereby provide a second image data set with the effects of motion correction removed. In case of correct feedback, one can directly compare the quality of the corrected with that of the decorrected scan. Additionally, since erroneous feedback during PMC may introduce artifacts, it is possible to eliminate artifacts in a corrupted scan by reversing the false gradient updates.

***Conclusion:*** The ability to perform forward and reverse prospective and retrospective motion correction provides a great deal of flexibility. Reverse corrections promise simplified testing and validation of PMC sequences in the research setting. However, the most important impact will most likely be in the clinical application of PMC, where our approach guarantees that a data set can be presented whose quality is at least as good as a scan acquired without PMC. This feature should eliminate one of the remaining barriers in introducing PMC into the clinic.

**References**
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