Artifact Repair of fMRI data from High Motion Clinical Subjects
(with new results from 3-D large motion correction)

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Paul K. Mazaika*, Susan Whitfield-Gabrieli[a], Allan Reiss*, and Gary Glover[b]

*Center for Interdisciplinary Brain Sciences Research, Stanford University

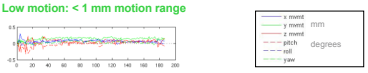
[a]Department of Brain and Cognitive Sciences, MIT, [b]Director, Lucas MRI Center, Stanford.

Artifact Repair

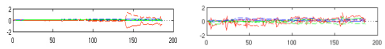
Clinical subjects often exhibit large motions during fMRI scan sessions that dominate the BOLD effects which are trying to be measured. The most severe motions are beyond current repair methods (Friston, et.al. 1996, Luo and Nichols, 2003, Diedrichsen, et.al 2005). We divide motion errors into two parts: (1) Rapid motions which cause artifacts from spin history and volume reconstruction effects, and (2) Large total movements (but slow motions) which cause motion residuals (after realignment) from physical deformation and interpolation effects. Our objective is to provide robust and user-friendly software that can recover most fMRI data sets from clinical subjects.

Motions of male adolescents in FraX study

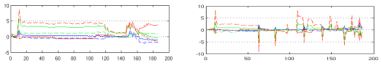
Low motion: < 1 mm motion range



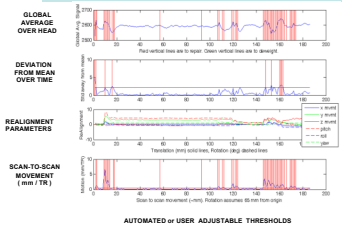
High motion: 1 - 3 mm motion range 33% of the data sets



Severe motion: > 3 mm max motion 50% of the data sets

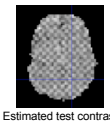


Automated artifact detection and repair

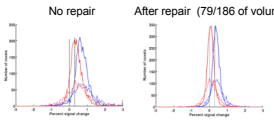


Outlier volumes are first repaired by interpolation to avoid side-effects in the high-pass filter. These volumes are then deweighted in GLM estimation to maintain unbiased estimates.

Performance Measures: RMS Error and Global Quality

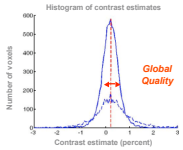


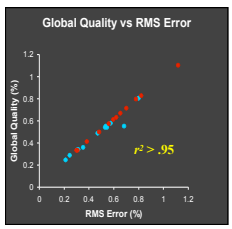
Estimated test contrasts



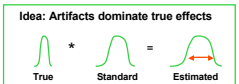
RMS Error = 0.68% RMS Error = 0.30%

Test injections of size 0.3% are added to half the voxels, after preprocessing and before artifact repair. Ideally, the contrast estimates will sharply spike at 0.3% for the blue voxels, and 0% for the red voxels. The RMS error measures the average error of these estimates. For real fMRI data, the test truth is unknown, so instead we use Global Quality on a subject by subject basis. Global Quality assumes that the estimation error is larger than true effect sizes, when motions and artifacts are dominating the data.



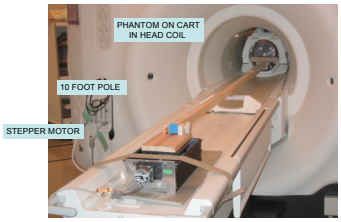


Idea: Artifacts dominate true effects

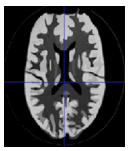


3-D Large Motion Correction

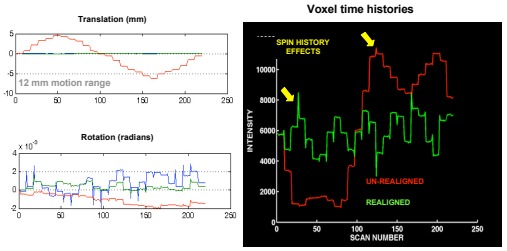
Motion residuals are variations on timeseries even after realignment. They are caused by physical and interpolation effects (Friston, et.al. 1996, Grootoonk, et. al. 2000). We measured these residual motion effects by moving a Hoffman brain phantom over a 12 mm distance while scanning. The experiments included a head coil for high signal-to-noise ratio, and rapid motions while scanning to observe spin history effects.



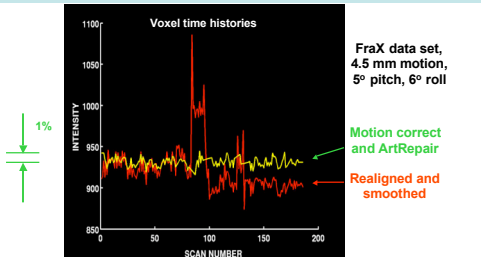
1.5T, GE Head Coil, Spiral I/O, 4x4x4 mm
TR = 2 sec., EPrime driver to stepper motor



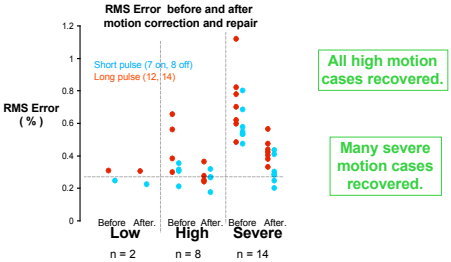
Hoffman Brain Phantom - Hoffman, et.al. 1990



3-D Large Motion Correction of Clinical Data Sets

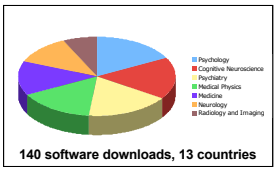


The measurements showed that motion residuals from large 1-D motion could be corrected with periodic regressors (as in Grootoonk, 2000). We derived the corresponding algorithms to correct the large 3-D translation and rotation head movements that occur for clinical subjects. The figure above shows a sample time series after correction. The figure below shows the improvement to RMS error for 24 cases of test injections added to clinical fMRI data sets with different levels of motion severity.



ArtRepair Software Package for SPM2, SPM5

http://cibsr.stanford.edu/tools.htm
or
SPM Extensions website,
ArtRepair Toolbox



140 software downloads, 13 countries

Conclusions and Acknowledgements

Tests show that the combination of ArtRepair, Global Quality, and 3-D large motion correction algorithms can recover many high motion and severe motion clinical fMRI data sets. The ArtRepair software for SPM2 and SPM5 is available at the CIBSR website. Future research will focus on clinical group studies and disseminating easy-to-use motion correction software.

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