Detection and Repair of Transient Artifacts in fMRI Data

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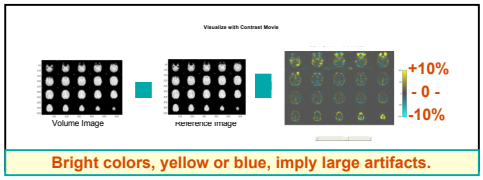
Objective and Background

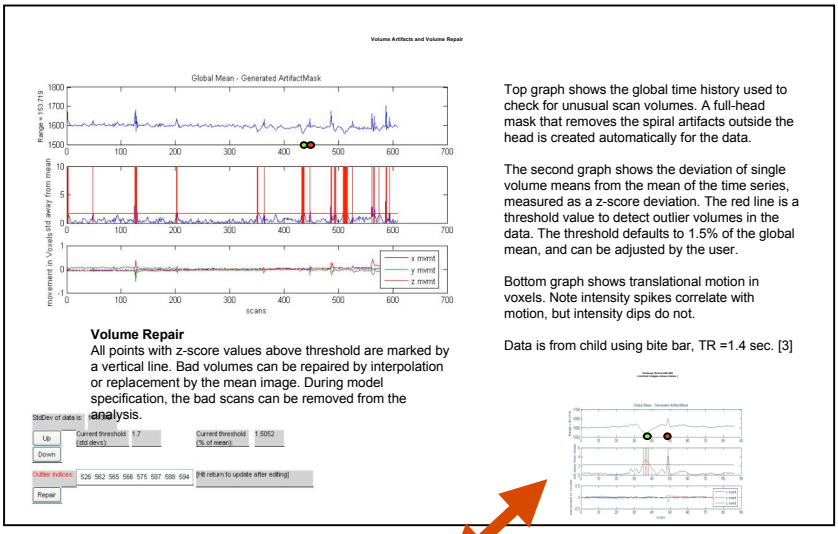
Cognitive processes in the frontal lobes have small BOLD activations (often less than 1%), consequently, large data artifacts can make true activations disappear or cause false activations to arise. Artifacts may arise from sudden motions, deep breaths, swallowing, or electrical noise. One approach to correct outliers is to diagnose physically-based abnormal events in the data (Luo and Nichols [1]). Another method is to screen for statistical outliers on a voxel-wise basis and repair them automatically (Cox [2]). Our objective is to automatically detect physically-based artifacts, and provide user-friendly tools to repair large amounts of data.

Methods

Automated and semi-automated algorithms were built to detect and repair volume artifacts, and detect and repair slice artifacts. Visualization with contrast images helps identify the physical sources of the artifacts. Movie viewing of the contrast images allows for rapid user review of intensity changes in every voxel over time.



Bright colors, yellow or blue, imply large artifacts.



Volume Repair

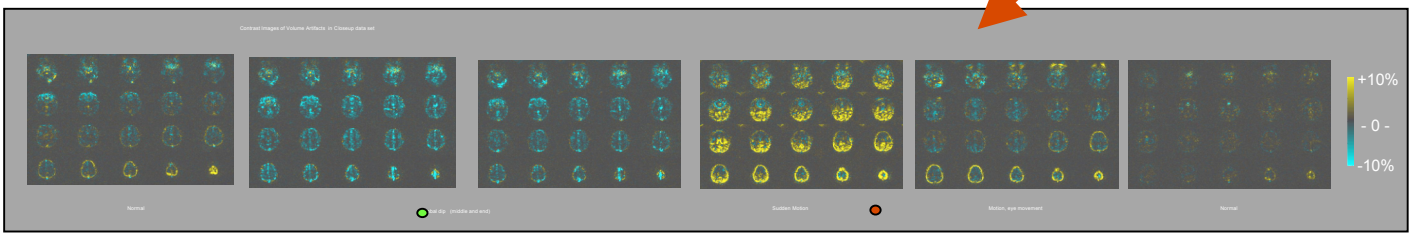
All points with z-score values above threshold are marked by a vertical line. Bad volumes can be repaired by interpolation or replacement by the mean image. During model specification, the bad scans can be removed from the analysis.

Top graph shows the global time history used to check for unusual scan volumes. A full-head mask that removes the spiral artifacts outside the head is created automatically for the data.

The second graph shows the deviation of single volume means from the mean of the time series, measured as a z-score deviation. The red line is a threshold value to detect outlier volumes in the data. The threshold defaults to 1.5% of the global mean, and can be adjusted by the user.

Bottom graph shows translational motion in voxels. Note intensity spikes correlate with motion, but intensity dips do not.

Data is from child using bite bar, TR =1.4 sec. [3]



Results

Transient Artifacts

Transient artifacts (large amplitude and short duration noise bursts) occur in many data sets. They cause 1.5% fluctuations of the global mean, and over 10% fluctuations on individual voxels. The contrast images above show a global dip from unusual breathing ( ) which lasts about ten seconds, and a spike fro sudden motion ( ). Other common transient artifacts include motion, eye movement, and slice noise (right box). "Normal" fluctuations in the global mean are within 0.5% of the time series mean.

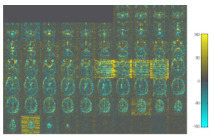
Performance Comparison

A sample comparison in activation strength is shown, with and without using the artifact tools. The artifact tools are used regularly for data processing in the Gabrieli Cognitive Neuroscience Lab.

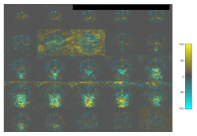
Software

The algorithms automatically remove the spiral alias, create a head mask, set up a GUI for a user to set thresholds for volume and slice repair, and will write repaired volumes. Default thresholds were set based on 100,000 volumes of data. The software is written in Matlab, and is compatible with SPM. Artifact detection and repair is applied before any preprocessing.

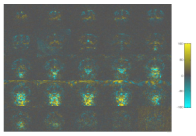
Slice Artifacts and Slice Repair



Slice artifacts in EPI data



RF Coil Noise in spiral data [4]

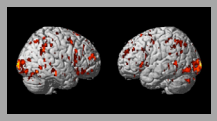


After bad slice repair

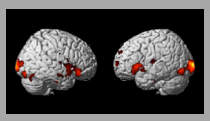
Slice repair screens all data for bad slices and writes BadSlice logfile. Repairs by interpolation with adaptive threshold for each slice. Bad slices (and single voxel noise) can also be repaired by 3-point median filter in time.

Comparison of activation results

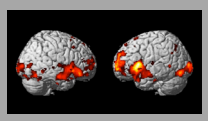
P=0.05 FWE corrected, EPI [5]



No global scaling, no motion regression



Global Scaling and Motion Regression

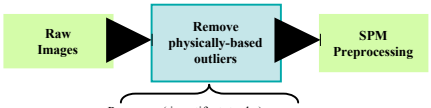


Median filter, no scaling or motion regression

Conclusions

Physically-based outliers can be removed without compromising data integrity. Automated detection and repair methods are used to clean up physically-based transient artifacts to improve statistical analysis. The software is compatible with SPM and user-friendly for bulk fMRI data processing. Software and documentation are available at http://gablab.stanford.edu/tools.htm.

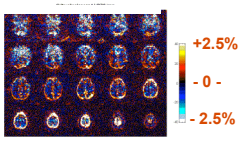
Artifact Software Package



Programs (in artifact_tools)
- art_global (bad volumes)
- art_movie (visualization)
- art_slices (bad slices, median filter)

http://gablab.stanford.edu/tools.htm

High Contrast Image



High contrast view range is 5%, sufficient to see single voxel noise and strong activations.

Acknowledgements and References

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