Prospective Acquisition CorrEction With Additional Retrospective Positioning (PACEWARP)

T. Benner[1], A. J. van der Kouwe[1], A. M. Dale[1,2], A. G. Sorensen[1]

[1]Department of Radiology, Athinoula A. Martinos Center, Charlestown, MA, United States, [2]Department of Neurosciences, University of California at San Diego, La Jolla, California, United States

Introduction

In fMRI experiments a large number of measurements are needed for sufficient statistical power. These measurements are usually split up in multiple scans due to scanner limitations, stimulus presentation limitations, and subject compliance. As a result of subject motion during and between scans and because of scanner drift, the images of individual measurements are not aligned perfectly. This is usually corrected by applying retrospective motion correction. Subject motion during a scan can also be corrected using online motion correction e.g. Prospective Acquisition CorrEction (PACE) [1]. However, the current implementation of PACE performs motion correction only within a single scan and does not take subject motion between scans into account. We propose a modification of PACE, called PACEWARP (**P**rospective **A**cquisition **C**orr**E**ction **W**ith **A**dditional **R**etrospective **P**ositioning), which aligns all scans to a common reference scan, thereby effectively removing all subject motion and scanner related motion artifacts from all fMRI scans of a complete fMRI experiment.

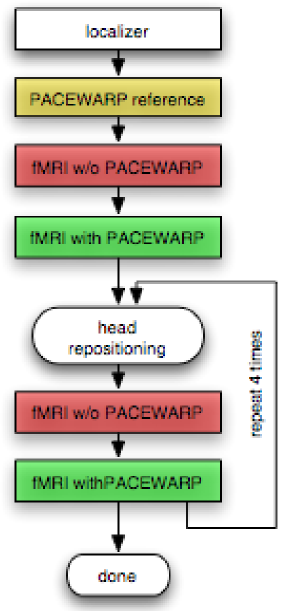

***Figure 1**: Chronological order of scans.*

Methods

The modified PACE implementation works by storing a reference volume for the duration of the session which is then used by any succeeding scans instead of the first volume of this scan. PACEWARP was installed and tested on a 1.5 T Avanto MRI system (Siemens Medical Solutions, Erlangen, Germany). A healthy volunteer was scanned after our institution's committee on human research approved the study protocol. Image acquisitions were performed as shown in Figure 1. The first two fMRI runs without and with PACEWARP were performed to get a baseline for the co-registration error. The scan parameters for the fMRI scans were as follows: TR 2 s, TE 40 ms, FoV 200 mm, 26 slices, 5 mm thickness, 1 mm gap, matrix size 64x64. The PACEWARP reference scan consisted of one measurement and took 2 s. All other fMRI scans consisted of 6 measurements and took 12 s each. The volunteer was instructed to move the head by a few degrees/millimeters to simulate subject head motion during and between the scans. As a measure of co-registration, root mean square errors (RMSE) were calculated between the reference and follow-up scans.

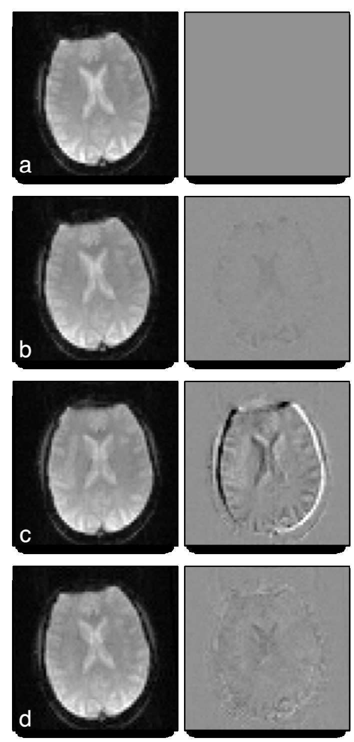

***Figure 2**: One slice out of 26 of acquired fMRI images. Left column: a) PACEWARP reference image, b) fMRI with PACEWARP image before head movement, c) fMRI w/o PACEWARP image after head movement, d) fMRI with PACEWARP image after head movement. Right columns: difference images between a)-d) and reference image a).*

Results and Conclusion

Figure 2 shows one slice of the fMRI scans with and without PACEWARP before and after head movement as well as the corresponding difference images. PACEWARP without head movement does not cause any artifacts beyond differences in noise when compared to an fMRI scan without PACEWARP (not shown). After head movement, an obvious ring-shaped artifact can be seen in the fMRI image without PACEWARP. With PACEWARP, the ring-shaped artifact is effectively removed.

RMSE values before head movement were 13.4 and 13.0 for fMRI scans without and with PACEWARP, respectively. After head movement, mean RMSE values were 60.4 and 26.0 for fMRI scans without and with PACEWARP, respectively. While RMSE values with PACEWARP did not reach the level of RMSE values for scans without head motion, a strong reduction of RMSE values was achieved. Further experiments have to be performed to test the accuracy and reliability of this new method.

In conclusion, the application of PACE and PACEWARP in an fMRI experiment should allow statistical image analysis without the need for an additional co-registration step, thereby making it easier to perform the evaluation on the MR scanner as well as off-line. Furthermore, PACEWARP could also be used in combination with auto-align [2,3] to correct for head motion in non-fMRI scans e.g. clinical scans by measuring a single volume just before each clinical scan and adjusting the slice prescription accordingly. Thus, a complete study could be performed with accurate slice prescription and with a valid localizer image for the whole session with only minimal increase in scan time.

Acknowledgements

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References

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