Prospective Acquisition Correction for Head Motion with Image-based Tracking for   Real-Time fMRI

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Introduction:

In functional Magnetic Resonance Imaging(fMRI) head motion can corrupt the signal changes   indurced by brain activation. Currently retrospective approaches are commonly used to address this problem. The major drawbacks are blurring effects and influence of through-plane motion on magnetization history.   Prospective correction techniques, which avoid these problems, have been presented, but are criticized because of insufficient accuracy(1,2,3). We developed a novel technique for more precise   *P*rospective *A*cquisition *C*orr*E*ction (PACE) by image based detection of head motion.

Materials and Methods:

Scanning and processing of data were performed on a standard MAGNETOM Symphony 1.5 T MR system (Siemens, Erlangen, Germany). For image acquisition a 2D single shot EPI and a fast RF-spoiled gradient echo sequence (FLASH) were programmed with full oblique and off-center functionality for all axes. Calculation of complete sequence timing including the physical gradient pulses is performed   *on the fly* within 3 milliseconds prior to each scanned volume. So real-time adjustment of position and orientation of the slice stack is possible.
The system allows real-time reconstruction of the data using the imaging computer. For further evaluation of the images, the data are transferred to the host computer. Here a motion detection algorithm related to the method introduced by Friston et al.(4,5) is applied, estimating a three dimensional rigid body transformation against a reference volume. The new positional information is passed to the measurement computer, which adjusts the parameters for slice orientation and position for the next acquisition. In this implementation the positional information is fedback with a temporal delay of one acquisition cycle, which is about 4 seconds in usual 2D multi-slice EPI based   fMRI measurements. Clinical datasets show that the residual scan to scan motion is commonly smaller than 50 μm and so almost negligible in the most cases. Thus fine adjustment of the residual motion is performed by the real-time application of additional retrospective correction of the volumes with Fourier interpolation(6). The principal flowchart of the complete real-time acquisition correction (PACE) is shown in figure 1.
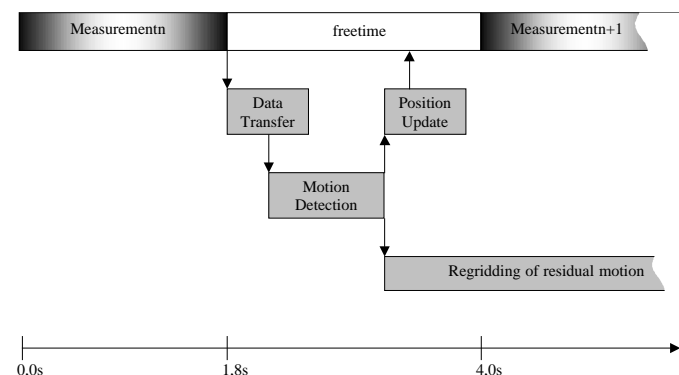

Figure 1: Flowchart of the prospective acquisition correction.

Results:

To validate the function and   consitency of the method, phantom measurements were carried out. The scanned phantom was rotated manually. After the application of motion, the measurement coordinate system was adjusted in a one step process. Subsequent motion detection processes caused no further significant corrections. Additional retrospective motion correction showed no improvement or remarkable motion parameters. These experiments   valtidate the highly accurate consistency (<40   μm; 0,05°) of successively calculated motion parameters and the feedback process.
In vivo benefits of the PACE technique can be visualized by examination of difference images. Figure 2 shows a significant decrease of variance when the PACE method was used in comparison to retrospective techniques.
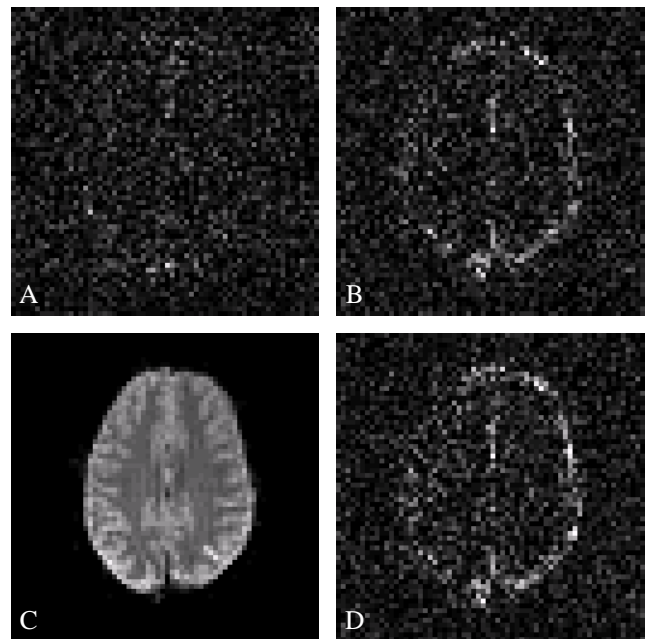

Figure 2: Axial   rotation of about 0.2   degrees: Difference images of a   slice before and after rotation. A: PACE; B: Retrospective Correction(Fourier Interpolation); C: Chosen Slice; D: Uncorrected

Conclusions:

The presented method for prospective motion correction works with high stability and accuracy involving real-time motion correction. An unmodified commercial MRI scanner was used, so the clinical use of PACE is possible. In vivo experiments prove a significant decrease of variance between successively acquired   datasets compared to retrospective correction algorithms. It   is likely to extend the use of PACE to other motion influenced MRI applications.

References:

1. C.C. Lee et al.; MRM 39:234-243(1998)
2. H.A. Ward et al.;   Proc. of ISMRM,7 [th] Meeting 1999; p.270
3. H. Eviatar et al.; Proc. of ISMRM,7 [th] Meeting 1999; p.269
4. K.J. Friston et al.; Human Brain Mapping 2:165-189(1995)
5. K.J. Friston et al.; MRM 35:346-355(1996)
6. W.F. Eddy et al.; MRM 36:923-931