# Correction of Motion Artefacts in High Resolution FSE Images

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## Introduction

The quality of MR images is often degraded due to subject motion. The increase in SNR at high field strength allows acquisition of high resolution images, which are more susceptible to motion. The navigator echo technique has been widely used to detect motion since it was first presented (1). Navigators can be collected in most cases without a significant increase in scan time and with no SNR penalty. The navigator signal after Fourier Transformation yields information on the subject motion that can then be used to correct the k-space data. In this study, navigator echoes were added at the end of the echo train of a 2D FSE sequence. Significant improvements in image quality are shown after motion correction.

## Materials and Methods

*Pulse Sequence:* A 2D FSE sequence optimized for high-resolution imaging of the brain at 4.7T (2) was modified by adding navigator echoes for motion detection. The spin-echo navigator signals were collected at the end of the echo train for each slice. The direction of the navigator was alternated from read to phase-encoding directions in slices scanned consecutively (see Figure 1) to obtain in-plane motion information. *Motion Detection and Correction Strategies*: Navigator profiles in two directions (read and phase-encoding) were obtained by Fourier Transformation of the navigator echo signals. The profiles were then processed to extract motion information, using the least-squares method (3). The motion information was used to identify the corrupted k-space lines. Those lines were replaced to eliminate the motion artefacts. Two different strategies were investigated: replacement of the corrupted lines by the same k-space lines from the adjacent slice and replacement by adjacent k-space lines in the same slice. *Motion Device:* Motion was generated using a custom-made device that consisted of loops of wire set over a wooden surface with a cantilever piece. The current flowing through the wires, inside the magnetic field induced a force that made the cantilever rotate. An elastic band attached to one end of the cantilever returned the piece to its original position. *Experiments:* All experiments were carried out on a SMIS MR 5000 4.7 T whole-body MR scanner, provided by Philips Medical Systems. High resolution images of a phantom (a small tomato, placed on the motion generator device described above) were acquired using the 2D FSE sequence, with the following imaging parameters: FOV = (128 mm)$^2$, slice thickness = 1mm, 32 contiguous sagittal slices, matrix size = 256 x 256, TE = 22 msec, echo-spacing = 22 msec, echo-train length = 8+1, BW = 50 kHz, TR = 8 sec, total scan time = 4:47 min. The slices were scanned in an interleaved fashion. Motion was induced at specific intervals during the data acquisition (at 1, 2 and 3min, for short intervals). A data set without motion was also acquired. Images of the brain of a human volunteer were acquired using the same sequence (FOV = 240 x 180 mm$^2$, slice thickness = 1mm, 18 contiguous axial slices, matrix size = 512 x 768, 2 x phase over sampling, TE = 22 msec, echo-spacing = 22 msec, echo-train length = 8+1, BW = 100 kHz, TR = 4 sec, total scan time = 6:45 min). The volunteer was asked to rotate the head by more than 40° three times during the scan (1, 3 and 5 min) and return to the original position each time.

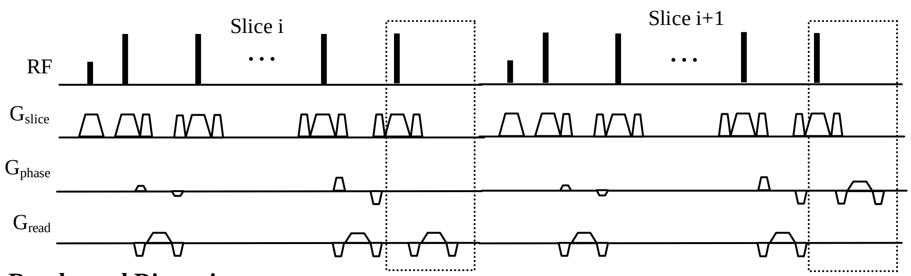


Figure 1. 2D FSE sequence with motion navigators added as the final echo in the echo train. The navigator direction alternates between read and phase encoding, for successive slices.

## Results and Discussion

Figure 2a shows the calculated displacements in the read and phase-encoding directions for the tomato experiment. Motion artefacts are present in the images (Figure 2b). The algorithm identifies the corrupted lines very efficiently; when the 8 lines in the echo train are replaced by the same lines acquired from the stationary object, the artefacts are completely eliminated (not shown). The artefacts are also eliminated or at least significantly attenuated when the corrupted lines are replaced by the same phase-encoding lines from the adjacent slice (Figure 2c) or by the adjacent lines in the same slice (Figure 2d). Notice that because of the way phase-encoding is done in the FSE sequence (where adjacent k-space lines are scanned in different TR's) and the long TR used in the acquisitions, it is very likely that adjacent lines in the same slice are not affected by motion. Similarly, if the slices are acquired in an interleaved fashion, it is unlikely that short bursts of motion will affect neighbouring slices. The correction using lines from the neighbouring slice will not be effective if the slices are not contiguous. Similar results were obtained *in vivo* (Figure 3).

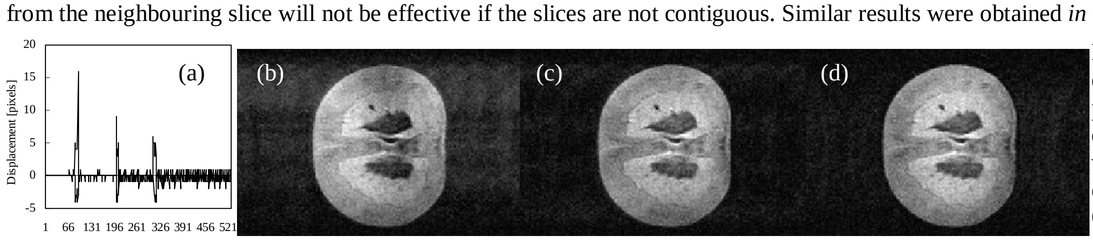


Figure 2. (a) Motion information extracted from the navigator profiles. Displacements in the read direction are shown as positive while displacements in the phase-encoding direction are negative. (b) Original motion-corrupted image of the tomato. (c, d) Images obtained after motion correction.

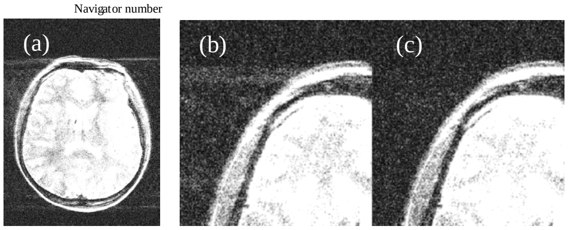


Figure 3. (a) Image of the brain of a volunteer, degraded by motion. Detail (from top, left) showing how the motion artefacts in (b) are eliminated after correction (c).

**Bibliography**

1. Ehman *et al*., Radiology 173: 255 (1989). 2. De Vita, *et al*., Br J Radiol 76:631 (2003). 3. Felmlee *et al*., Radiology 181(P), 237 (1991).

## Conclusions

Navigator echoes were added at the end of the echo train of a 2D FSE sequence, which allowed the detection of motion without an SNR penalty and with a minor increase in scan time. The information obtained from the navigator signals was then used to successfully correct motion artefacts.