The Effect of Navigator Resolution on Registration Accuracy in Rigid Head Motion Correction

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Introduction. In MR motion correction schemes often make use of a navigator image for detecting the amount of motion. However, a trade-off exists between the resolution of this navigator and the minimum TE that can be accomplished. It is necessary to choose the navigator resolution large enough so that the registration routine used for detecting the motion parameters is accurate. On the other hand, the readout length for the navigator resolution has to be as small as possible to allow short TE values. It has been shown that subpixel registration is possible using low resolution navigator images. In this study, we examined the effect of navigator resolution on registration accuracy using a parallel-imaging based rigid head motion correction scheme that we developed in-house [2]. Our experiments showed high registration accuracy without further improvement in motion corrected image quality above a navigator resolution of 32 x 32.

Materials and Methods. Our novel motion correction algorithm uses a spiral in & out readout to detect and eliminate rigid head motion. The spiral in part is used to get a low resolution navigator image for each interleaf and the spiral out part makes up one interleaf of the final high resolution image. The navigator images are used to obtain relative rotation and translation between interleaves. Translational motion is corrected by applying a linear phase to k-space data. Rotational motion is corrected by counter-rotating the k-space trajectories during gridding. This causes undersampling in k-space. An Augmented SENSE reconstruction is used to compensate for this undersampling and to get the final motion-corrected image [2]. In order to assess the impact of navigator resolution on the final image quality, both computer simulations and *in vivo* studies were performed. **1) Computer Simulation**: A 256 x 256 high resolution image was rotated and translated with ranges of +-15 degrees and +- 10 mm at 200 equally spaced values for both rotation and translation. Thereafter, each image was multiplied by a coil sensitivity profile to simulate the effect of altered exposure to the sensitivity field. Then, the original and the rotated & translated images were downsampled to resolutions of 16x16, 24x24, 32x32, 48x48, and 64x64. Registration was performed between the downsampled original and the downsampled rotated & translated image. Graphs of $\Delta x_{simulated}$ vs. $\Delta x_{measured}$, $\Delta y_{simulated}$ vs. $\Delta y_{measured}$, and $\Delta\phi_{simulated}$ vs $\Delta\phi_{measured}$ were obtained including the results for 200 simulations corresponding to the different rotation and translation amounts. Using linear regression analysis, the correlation coefficient (R) and the error (σ) between the fitted line and real values were calculated. **2) *In vivo* experiments** were performed with the navigator resolutions of 16x16, 24x24, 32x32, 48x48 and 64x64. For each navigator resolution, the subject was asked to perform rigid head motion at 3 different ranges. In addition, a data set was acquired where the subject was asked to remain still. The experiment was performed with a T1w GRE sequence with TR/TE = 550/15ms and a T2w SE sequence with TR/TE=3000/90ms, matrix size=256x256, and 24 interleaves. The reconstructed images were compared to the reference images. The Correlation Coefficient between the reference image and the motion-corrected image was used to quantify image quality.

		navres=16	navres=24	navres=32	navres=48	navres=64
x	R	0.999782	0.999841	0.999925	0.999961	0.999976
	σ	0.110199	0.0968776	0.0680726	0.0498330	0.0397912
y	R	0.999802	0.999910	0.999948	0.999976	0.999982
	σ	0.107670	0.0738078	0.0566544	0.0392259	0.0341824
φ	R	0.999349	0.999807	0.999925	0.999968	0.999984
	σ	0.277557	0.162262	0.103673	0.0684389	0.0485496

Table 1 – *Simulation Results for different navigator resolutions. Sub-pixel registration was possible for all values of navigator resolution*

Results and Discussion The results of computer simulations are shown in Table 1. It can be seen that, even with the lowest navigator resolution, the estimated positional error was in the sub-millimeter range, as shown by the σ parameter. It can be seen that the correlation coefficient (**R**) and error (σ) are close to each other for navigator resolutions 48x48 and 64x64. After the break-off point at navigator resolution = 32x32, the increase in error is relatively more rapid. A similar trend was seen for the final image quality on the *in vivo* scans, i.e., there was no further substantial improvement above 32x32 navigator resolution. Figure 2 shows a side by side comparison of images reconstructed using different navigator resolutions and corresponding reference images. It can be observed that, the reconstructed image with 16x16 navigator resolution has serious aliasing artifacts resulting from individual navigator image misregistration. Misregistration related artifacts are much more significant for T1w images. The reason for that is T2w images have better contrast compared to T1w weighted images. The high contrast structures act like landmarks and thus improve registration accuracy.

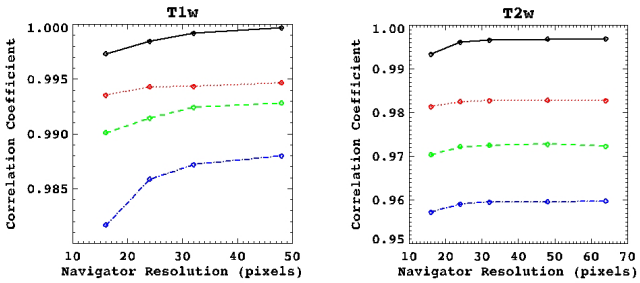

Figure 1 – *In vivo results showing the effect of navigator resolution on image quality. Image quality was assessed by measuring the Pearson Correlation Coefficient between the motion corrected images and the reference motion-free image reconstructed without motion correction. For both T1w (left) and T2w (right) cases, different lines correspond to motion corrected images with no motion (solid line), small motion (+-2 degrees rotation, dotted line), medium motion (-+4 degrees rotation, dashed line) and large motion (-+10 degrees, dotted and dashed line)*

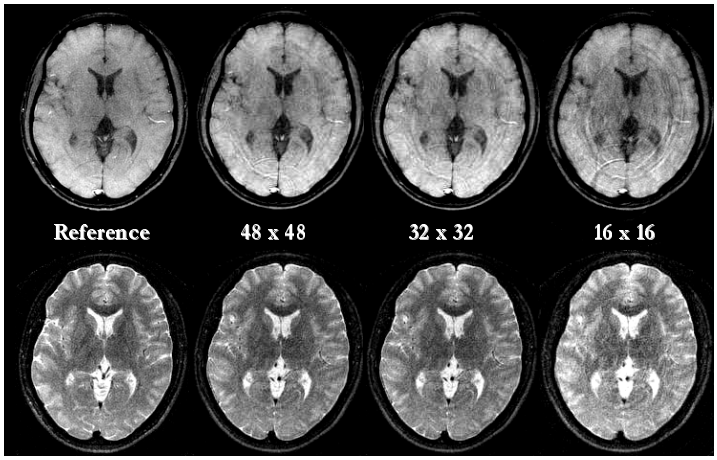

Figure 2 – *In vivo results showing the effect of navigator resolution on image quality corresponding to T1w and T2w images with large motion. Reference images and motion corrected images with navigator resolutions of 48x48, 32x32 and 16x16 are given. Serious aliasing artifacts resulting from misregistration are visible in images reconstructed using 16x16 navigators.*

Conclusion The effect of navigator resolution on registration accuracy was examined in this study. Accurate and reproducible subpixel registration was possible for images at all resolution levels. *In vivo* studies showed that navigator images as small as 32x32 provided adequate image quality. No substantial improvement in image quality could be made above 32x32.

References [1] Maintz, Viergever, "A Survey of Medical Image Registration", Med Image Anal., 1998 [2] Bammer, Aksoy, Liu, "Augmented Generalized SENSE Reconstruction to Correct for Rigid Body Motion", MRM, in press. **Acknowledgements** This work was supported in part by the NIH (1R01EB002711), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation and Oak Foundation.