

A REAL-TIME FEEDBACK OPTIMIZATION METHOD FOR AUTOMATIC CALIBRATION OF FUNCTIONAL SENSITIVITY-BAND OF TRANSITION-BAND BSSFP FMRI SEQUENCE

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Introduction

Transition-band balanced steady-state free precession (TB-bSSFP) fMRI has been shown promising for mapping brain activation with high resolution and distortion-free images [1]. However, the narrow functional-sensitivity band of transition-band SSFP fMRI leads to serious instability in spatial and temporal field, even with advanced shimming [1-2]. Previous studies have proposed a slice-dependent calibration method to focus the high functional-sensitivity band on brain areas of interest in TB-bSSFP fMRI trials by using an additional sweep scan with stepwise increment of bSSFP angles [3-5]. Although the phase angle adjustment enhances the sensitivity of TB-bSSFP fMRI effectively, the requirement of a long sweep scan and post-processing delays the subsequent fMRI studies. In this study, we proposed a real-time feedback optimization method to search the optimal frequency automatically and rapidly. Transition-band SSFP experiments were performed to evaluate the efficiency of the proposed method.

Material and Methods

The automatic real-time feedback optimization method includes three major procedures: immediate image transfer from MR scanner to a personal computer, an optimization algorithm of SSFP phase angle, and automatic on-line feedback control of current scan parameter. Figure 1 exhibits the flow-diagram of feedback system. By modifying the configuration of the Image Calculation Environment (ICE, Siemens, Germany) and connecting the scanner and PC through 1Gbs/s Ethernet network, the reconstructed images are transferred to PC immediately subsequent to data acquisition. The optimization algorithm is the Brent's local searching method based on quadratic interpolation. The cost-function of the optimization is summation of signal intensity of a pre-defined region-of-interest (ROI). The newly estimated SSFP angle is stored in a text file (SSFP-text), and then the TB-bSSFP sequence reads the updated value and adjusts the SSFP angle between adjacent RF repetitions for the subsequent scan.

Two volunteers underwent the TB-bSSFP imaging on a 3T whole-body MR system (Siemens, Tim Trio, Germany) equipped with an 8-channel head coil. Two sets of images were acquired for each volunteer. One was a sweep scan with range from -180° to 179° with step size of 1°, the other was a real-time optimization acquisition with initial SSFP angles of {-50°, 0°, 50°} and the criterion of optimization convergence set was 1°. The imaging parameters were (TR/TE/Flip angle: 6ms/3ms/5°, matrix: 128×128, dynamic delay=1 s).

Results

In this study, a ROI was selected near the occipital lobe from an image acquired by TB-bSSFP sequence with SSFP angle of 0° (see Fig.2a). In Fig.2b, the summation of signal intensity in ROI for each image frame in sweep scan was plotted as a function of SSFP angle (blue dot). In this study, SSFP angle of 40° was associated with highest signal intensity and was therefore considered as optimal SSFP angle for the selected ROI. The search-path of the real-time (RT) optimization was demonstrated with red triangles in Fig.2b. In this case, the optimized SSFP angle of the real-time method was 40.39°, which closely matched the result of the sweep method. Figure 3 exhibited the effect of SSFP angle adjustment. Both the proposed real-time method and the sweep method effectively enhanced the signal intensity of the selected region and the sensitivity-band was correctly calibrated.

Discussion and Conclusions

In TB-bSSFP fMRI studies, several challenges about temporal and spatial frequency drift should be overcome for detecting accurate activation maps. In this study, we implemented an effective and fast SSFP angle calibration method by an automatic real-time feedback optimization method. The sensitivity band of TB-bSSFP was shifted to the brain region expected to have functional activations. In this preliminary study, the iteration time needed for the optimization was about 10 times (i.e. scans) and the obtained SSFP phase angle was close to the result obtained by the long sweep scan (360 scans). Applying optimization of multi-slice studies, the acquisition of the slices can be optimized with different SSFP phase angles. This automatic calibration method uses the same sequence as the one used in fMRI study. The calibration scans and the fMRI scans can be combined into a single run. The real-time method can be an automatic pre-adjustment module of the following fMRI acquisitions. In conclusion, the real-time feedback optimization method is an effective sensitivity calibration method and can be a practical tool for transition-band SSFP fMRI studies.

Reference

- [1] Miller KL et al., MRM 2003;50:675
- [2] Miller KL et al., MRM 2006;55:161
- [3] Lee JH et al., MRM 2006;55:1197
- [4] Wu ML et al., ISMRM 2006:#2815
- [5] Wu ML et al., ISMRM 2007:#1944

Real-time feedback optimization system

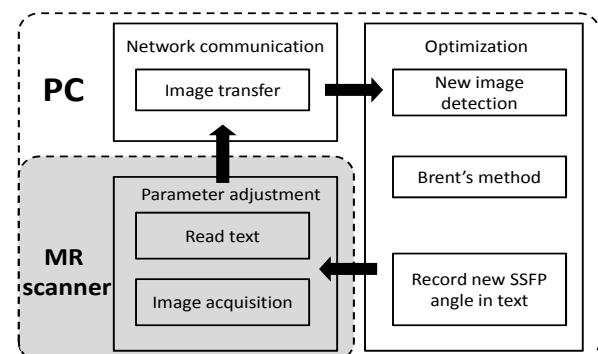


Fig. 1 The flow-diagram of real-time feedback optimization system.

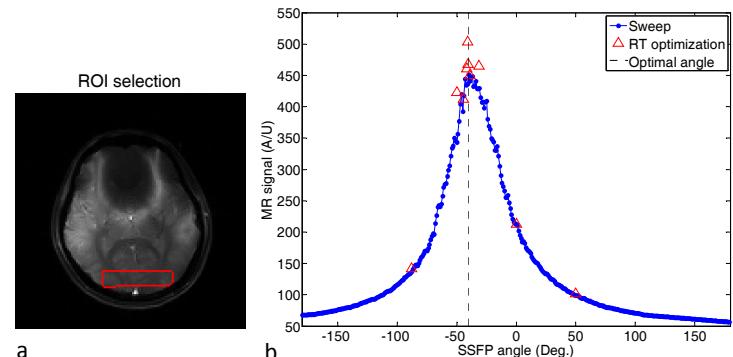


Fig. 2 (a) the pre-scan for manual ROI selection (red rectangular). (b) the comparison of signal-time curve between sweep scan and real-time optimization. Iteration of optimization is 10 times and the converged SSFP angle (40.39°, black vertical dash line) is close to the optimal result from sweep scan (40°).

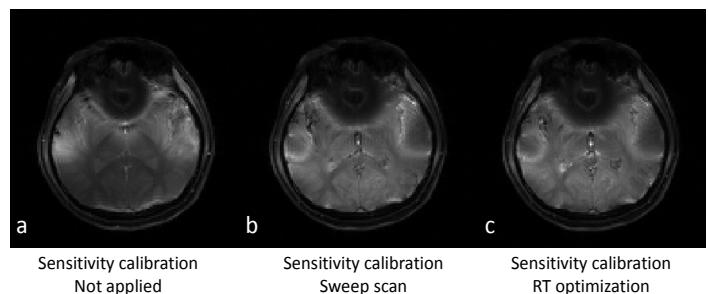


Fig. 3 The TB-bSSFP images with/without SSFP angle calibrations. (a) the original image (i.e. without sensitivity calibration) with SSFP angle of 0°. (b,c) the images with sensitivity calibration based on the real-time optimization method and the sweep scan (c), respectively.