Evaluation of Coil Selection Algorithms for Body Navigators

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Introduction: Respiratory navigators use a periodic excitation spanning the diaphragm to monitor breathing motion throughout a scan [1,2]. Navigators can improve MR image quality by synchronizing data acquisition with motion, but their success depends on the ability of the processing algorithm to accurately extract motion information. Several processing algorithms have been evaluated, including least-squares and edge detection [3,4]. These algorithms benefit from having a high-SNR, well-defined edge at the liver-lung interface from which to calculate motion. When using a multi-channel receive coil such as a 32-ch torso coil, not all of the coil elements "see" the diaphragm in the navigator signal, thus combining the navigator data from all channels can introduce other competing structures (e.g. chest wall, pulmonary vessels, or aliasing) along the navigator profile that reduce the accuracy of motion detection. By selecting only a subset of channels, the localized coil sensitivity can be exploited to enhance the prominence of desired features in the navigator signal as well as reduce real-time computation requirements. Here we compare coil selection methods for use with navigator echoes and propose a method based on a matched filter.

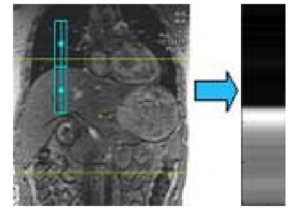

Fig. 1. Navigator spanning liver-lung interface; ideal navigator profile used as template with sharp, high SNR edge.

Methods: Navigator data was recorded from 16 subjects during routine abdomen scans on a 1.5T scanner (GE Signa HDx) with an 8-channel torso coil and a 3.0T scanner (GE Discovery MR750) with a 32-channel torso coil. The navigator consisted of a 2D RF excitation prescribed on the right hemi-diaphragm with a 10' flip angle, 10cm length, 2cm width, and 256 readout points. After Fourier Transform and Gaussian filtering, the navigator profile was processed with 3 different coil selection algorithms: 1) peak-SNR, 2) peak-derivative, and 3) peak correlation with matched filter. The matched filter used a 256-point template, based on an ideal navigator signal profile centered on the diaphragm with dark lung signal transitioning rapidly to bright liver signal (Fig. 1). Different templates can be used based on the expected navigator profile characteristics for a given pulse sequence and coil setup. The correlation y between the received navigator signal x and the template h was computed as a function of displacement n for each coil according to: $y[n] = \sum_k h[n-k]x[k]$. A subset of coils exhibiting the peak correlation over all n was selected for navigator processing. Correlation of the navigator with the template over n serves to emphasize coils exhibiting the desired signal profile without knowing a priori the exact location of the diaphragm edge, which can vary due to motion or user prescription. The selected coils can be combined using a weighted sum-of-squares (sos) according to their relative correlation values. The output of different coil selection algorithms was compared based on visual assessment and definition of the lung-diaphragm edge.

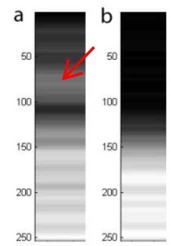

Fig. 2 a) Navigator profile from **32** combined coils. b) Navigator profile from 2 coils selected via matched filtering removes extraneous structures in lung region (arrow).

Results: Fig. 2 demonstrates the benefit of coil selection for a sample 32-channel dataset. The combined sos navigator profile from all 32 channels lacks a clearly delineated liver-lung interface in (a), whereas the weighted sos combination of 2 coils selected via matched filtering in (b) removes extraneous structures from the lung region (arrow) and produces a more clearly defined edge for navigator processing.

The comparison of coil selection algorithms revealed that in 12/16 cases, equivalent coil selection results were obtained between all 3 methods, whereas in 4/16 cases, the matched filter method offered improved results compared to peak-SNR or peak-derivative methods. For example, Fig. 3a shows navigator signal profiles acquired from each channel of an 8-coil array. The peak-SNR algorithm erroneously selected coil 8 due to bright signal at the superior edge of the navigator profile (red arrow), possibly from the chest wall, whereas the matched filter (Fig. 3b) selected coil 6 as having maximum correlation with the template signal (red circle), confirming visual assessment that coil 6 provided the highest-SNR and sharpest edge. Fig. 4a shows navigator profiles from a 32-coil array. The peak-derivative algorithm erroneously selected coil 32 due to a spurious bright edge (yellow arrow), whereas the matched filter output correctly identified coil 9 as the optimal coil (yellow circle).

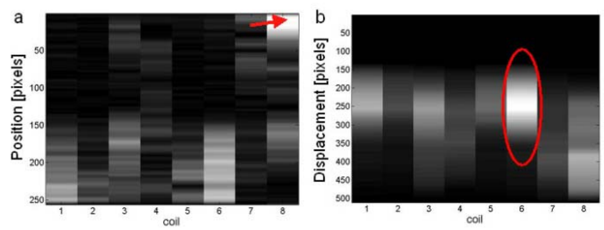

Fig. 3 a) Navigator profiles from 8-coil array at 1.5T. Peak-SNR coil selection method incorrectly chose coil 8 due to bright signal, whereas b) matched filter method correctly chose coil 6 based on matched filter.

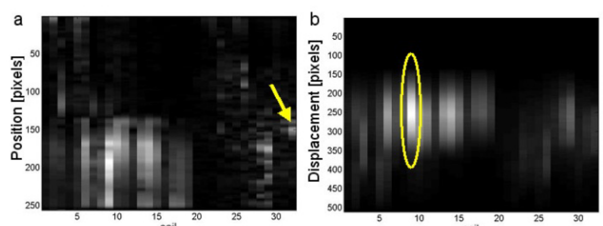

Fig. 4 a) Navigator profiles from 32-coil array at 3.0T. Peak-derivative method incorrectly chose coil 32 due to spurious edge, whereas b) matched filter method correctly chose coil 9.

Fig. 5 shows a sample navigator waveform after matched filter coil selection and the corresponding navigated LAVA liver image obtained during free-breathing, showing good suppression of motion artifacts.

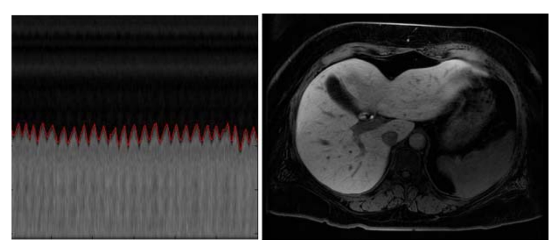

Fig. 5 a) Navigator waveform using 2 coils from matched filter coil selection, b) corresponding navigated liver image.

Discussion: Coil selection is performed to isolate the features of interest in the navigator signal and thus improve the accuracy of the motion detection algorithm. Choosing the channel with maximum SNR is suboptimal because it can select channels having high SNR in pixels far from the area of interest, whereas choosing the channel with the maximum derivative is suboptimal because it can select channels with spurious signals. The matched filter method considers the entire navigator profile at once rather than at the individual pixel level to identify the coil(s) whose signal profile match the desired characteristics. For a 32-channel coil, a subset of only 2 channels provides a robust navigator profile for motion detection, greatly reducing real-time computation requirements.

References 1. Ehman et al. Rad 173:255–263, 1989. 2. McConnell et al. MRM 37(1), 148-152. 3. Wang et al. MRM 36A17-123, 1996. 4. Du et al. JCMR Vol. 6, No. 2, pp. 483–490, 2004.