Magnitude-weighted phase based edge detection for navigator gated imaging

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Introduction: Navigator echo technique has been widely used to reduce respiratory motion artifacts in cardiac and abdominal free-breathing imaging. Navigator analysis based on the magnitude profile has some difficulties in the position detection of the diaphragm, when the navigator tracker is partially saturated by the RF pulse of the imaging sequence. On the contrary, the phase of the navigator spatial profile is insensitive to the saturation effect, and the edge detection analysis based on the phase profile of navigator enables the navigator gated T1 weighted imaging even with the saturation effect [1] [2]. However, the phase profile of navigator is sometimes unstable in the lung, and wrong position can be detected due to the disturbed phase. In this work, we present a hybrid algorithm utilizing both magnitude and phase information to detect the diaphragm position robustly.

Methods: A navigator echo was acquired using a cylindrical RF excitation with 10° flip angle and 256 data points, and the middle 128 points were used for analysis. The algorithm consists of the following steps: 1) Smooth the magnitude profile of the navigator echo by mean filter. 2) Take the differential data of the unwrapped phase profile. 3) Make hybrid data by multiplying the smoothed magnitude profile by the absolute value of the differential phase data. 4) Take the maximum point of the hybrid data. The search range for the maximum point was limited based on the navigator pre-scan, which was executed to monitor the patient respiratory information and acquired navigator echoes only without RF interference [2].
A navigator gated 2D Fast SPGR pulse sequence was used for all experiments, and a navigator echo was acquired at the beginning of each TR. Free breathing scans were performed on a 1.5T scanner (Signa HDx and HDxt, GE Healthcare, Waukesha, WI, USA) and informed consent was obtained from volunteers.

Results and Discussion: We compared the proposed method to the conventional phase based edge detection method [2]. Though the conventional method detected incorrect edge in the lung (Fig.1a), the proposed method detected the diaphragm position correctly (Fig. 1b). Fig. 2 shows the signal profiles, with which wrong position was detected by the conventional method. The unwrapped phase profile (Fig. 2b) showed less susceptibility to the saturation effect than the magnitude profile (Fig. 2a) in the liver, and both profile showed sharp edge at the diaphragm position. However, the phase profile was unstable in the lung, and the differential phase data had a large peak in the lung (Fig. 2d). In the proposed method, the peak in the lung was suppressed by multiplying the differential phase data by the smoothed magnitude profile, and the correct peak was detected (Fig. 2e). As the dotted lines show in the Fig. 2a and 2b, the edge position in the phase profile shifted from the magnitude edge into the lung direction. Even when the magnitude was small at the phase edge (Fig. 2a, arrow), the differential peak was kept unsuppressed in the hybrid data by using the smoothed magnitude profile (Fig. 2c). The phase based edge detection was applicable to the data with a fuzzy magnitude edge. However, the phase signal shown in the lung came from the side lobe of the cylindrical RF excitation, and it could be noisy when the signal from the side lobe was weak. Moreover, the phase profile could be disturbed by blood flow or coil sensitivity, and phase edges were sometimes observed in the unexpected positions. We used the differential data rather than the unwrapped phase profile for edge detection to handle the phase data more robustly. The saturation effect was mitigated in the smoothed magnitude profile, and the edge detection using the smoothed magnitude profile worked well in some cases. However, the diaphragm position was not detected correctly when the edge signal was saturated as in Fig. 3a. By using magnitude weighted phase data, the edges in the lung were suppressed, and the proposed method detected the diaphragm position correctly even when the data had a fuzzy magnitude edge (Fig. 3a) or noisy phase in the lung (Fig. 3b).

Conclusion: A new algorithm using magnitude-weighted phase information was presented for phase based navigator analysis and the diaphragm position was detected accurately. Further work will be carried out to increase the stability of phase based navigator algorithm.

References: [1] Kanda et al. ISMRM 2008, p1466. [2] Iwadate et al. ISMRM 2008, p1468.

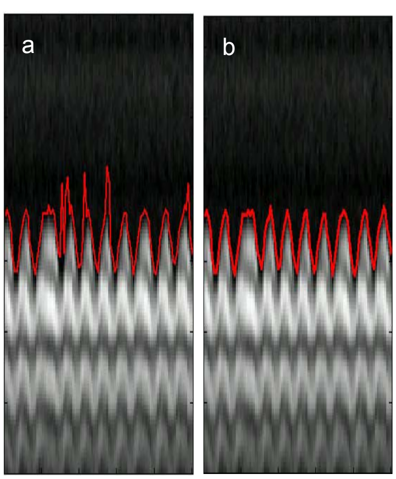

Fig. 1 Navigator echo signals and detected edges (red lines) with
a) conventional, b) proposed method

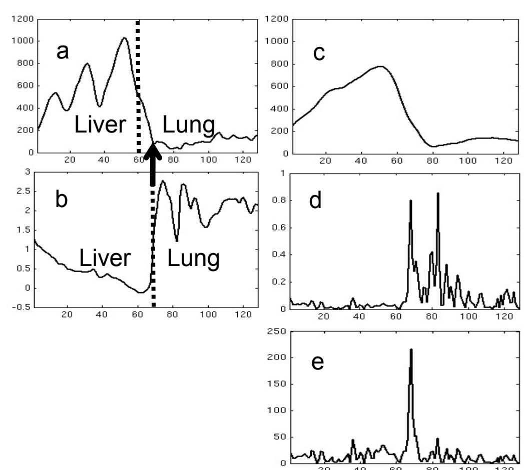

Fig. 2 Signal profile of navigator echo
a) Magnitude, b) Phase,
c) Smoothed mag, d) Absolute phase diff,
e) Hybrid (phase diff x mag)

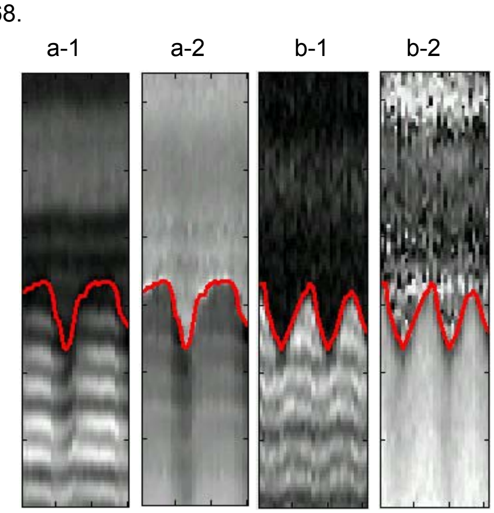

Fig. 3 Navigator echo signals and detected edges (red lines) with
a) Fuzzy magnitude edge, b) Noisy phase data
[1) mag background, 2) phase background]