Improved robustness of 3D region-growing reconstruction algorithm for Phase-Sensitive Inversion Recovery

S. T. Witt[1], H. A. Ward[2], J. A. Polzin[2], A. Thompson[2], J. D. Port[3]

[1]Department of Medical Physics, University of Wisconsin-Madison, Madison, WI, United States, [2]GE Healthcare Technologies, Waukesha, WI, United States, [3]Department of Radiology, Mayo Clinic College of Medicine, Rochester, MN, United States

Introduction:

Phase-sensitive Inversion Recovery (PSIR) based pulse sequences allow for imaging with optimal inversion times, and thus can yield greater T_1 contrast in shorter scan times when compared to phase-insensitive image reconstruction. To accurately reconstruct the phase-sensitive image, phase accumulation from other sources such as inhomogeneous magnetic field or data sampling errors must be corrected. Several PSIR reconstruction methods have been proposed, requiring either additional data acquisition, user intervention or automated image-processing algorithms. Of these, the image-processing algorithms are appealing due to their simplicity in data acquisition and independence from user intervention. However, in the past, these algorithms have been implemented primarily in two dimensions due to lack of computing power and lacked robustness in the presence of pathology or across disconnected tissue within the two dimensional slice. Thus, there is the potential for localized anatomical contrast inversions or slice-to-slice contrast inversions.

A new PSIR reconstruction algorithm has been developed by extending a two-dimensional, intra-slice region growing algorithm [2-3] to a three-dimensional inter-slice region growing algorithm. It will be shown that the extension from 2D to 3D robustly corrects localized anatomical inversions.

Methods:

The complex image data can be thought of as the matrix product of the magnitude of the data, a polarity factor, and a phase factor.

$$\tilde{C}(x,y) = M(x,y)\cdot S(x,y)\cdot e^{i\theta(x,y)} \quad [1]$$

The polarity factor, S(x,y), is a map identical in size to the image matrix initially containing +1 at every point. A new vector field parallel to the complex image matrix with magnitude normalized to unity is defined. This vector field contains the phase and polarity maps.

A phase-slope image is then calculated from a down-sampled version of the vector field [2]. Instead of performing a direct phase correction of the image data, we use a region growing algorithm to determine the polarity of the data. Using the resulting polarity map, we are able to indirectly correct for the phase accumulation in the image.

For the region growing, a seed is randomly planted in one pixel in the phase-slope image, and the phase differences between adjacent pixels are analyzed. Adjacent pixels with a phase difference less than 17° are assumed to have adequate signal to be included as part of the region. To create the polarity map, the sign of the phase difference between adjacent pixels is determined; the polarity is reversed if the phase difference is negative. At each step in the region growing, the phase differences between the six neighboring pixels – four intra-slice and two inter-slice, excluding any pixels previously visited – are checked. Once no more pixels can be added to a region, a new seed is planted to capture non-adjacent regions.

Once the polarity map is complete, the complex image data can be phase-corrected by multiplying by the complex conjugate of the vector field, resulting in a reconstructed IR image in which signal polarity is preserved.

Five patients were imaged on 1.5T GE scanners using the following protocol: 2D T1flair, 256x256, TR/TE/TI=3000/10/400 msec, 20mm FOV, 4mm slice thickness, 1mm slice spacing, 2 NEX. Images were reconstructed both with the 2D and 3D region growing algorithms and were compared for the presence of contrast inversion.

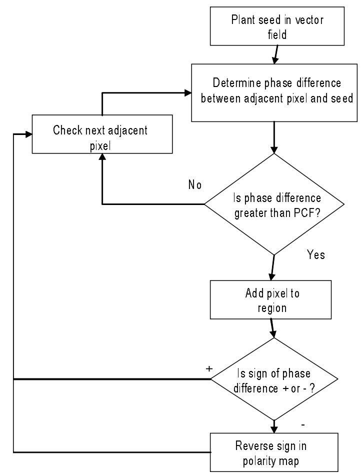

Figure 1: Flow chart depicting region growing algorithm.

Results and Discussion:

Of the five patients, three displayed localized contrast inversions within the scalp after 2D region growing. With the 3D algorithm, no contrast inversions were observed in any of the patients. Figure 2 shows multiple slices from a single subject demonstrating multiple, non-adjacent localized contrast inversions after performing 2D region growing, and the corresponding slices after performing the proposed 3D region growing PSIR reconstruction. One can see that the local anatomical inversions that appear in the 2D region growing reconstructed image are corrected in the 3D region growing reconstructed image.

To date, a fairly standardized PSIR imaging protocol has been tested. Further work remains to optimize the 3D region growing algorithm for 3D imaging protocols as well as to determine the lower bounds on the SNR necessary for the 3D algorithm to retain its accuracy.

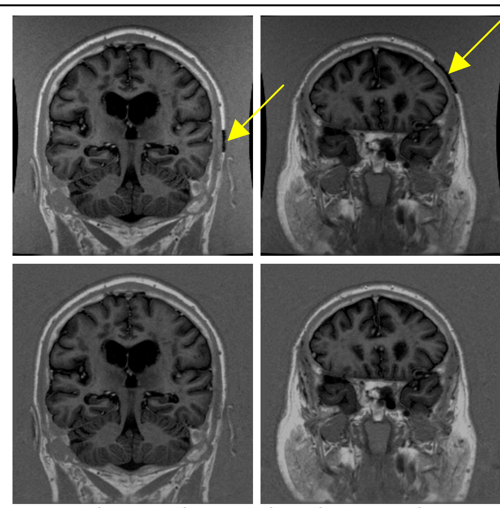

Figure 2: Top images show results using 2D region-growing algorithm demonstrating localized contrast inversions (arrows). Bottom images show results using 3D region growing algorithm.

Conclusion:

We have demonstrated improved PSIR reconstruction performance using an automated 3D region-growing algorithm over a 2D region-growing algorithm. Further clinical evaluation is ongoing.

References:

[1] Young et al. MRM 1985: 2:81-85. [2] Borrello et al. MRM 1984: 14:56-67. [3] Xiang. JMRI 1996: 6:775-782. [4] Park et al. MRM 1986: 3:15-23. [5] Moran et al. MRI 1986: 4:229-235. [6] Gowland and Leach. MRM 1991: 18:224-231.