Advantages of a Local Polynomial Filter with Moving Window for Phase Reconstruction in Susceptibility Weighted Imaging

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Introduction

Susceptibility weighted imaging (SWI) is an emerging technique that combines the magnitude and phase images to emphasize blood vessels and iron-containing structures [1]. Phase images offer an additional source of contrast due to susceptibility contrast; however, they require extensive reconstruction to minimize wrap effects due to field inhomogeneities and susceptibility differences at air-tissue interfaces, which can obscure the image [1,2]. Several different techniques have been developed to overcome these limitations. The most widely employed method, developed by Haacke [2], uses a 2D homodyne filter to remove high spatial frequencies within k-space, resulting in a low pass filtered image. This low pass image is then complex divided into the original phase image to produce a high pass filtered image. Polynomial fitting has also been applied. Yao used an 8th order 2D polynomial fit of the entire unwrapped brain in order to remove large-scale susceptibility effects in phase images [3]. Local polynomial fitting has been applied for SWI reconstruction by Deistung [4]. In this study, we demonstrate a moving window local polynomial fitting method in normal volunteers and MS patients in comparison to a standard approach for SWI of human brain.

Methods

MRI Acquisition: 3D gradient echo data SWI images were obtained on a 4.7T Varian system using a 27 cm diameter cylindrical birdcage coil for transmission and reception. Images were fully flow compensated in both read out and slice selection directions and typical imaging parameters were as follows: TR/TE=70/20ms, flip angle=20, FOV=200x180mm^2, slice thickness=3mm, matrix size=512x256. Subjects consisted of 1 healthy volunteer and 2 MS patients.

SWI Reconstruction: For the polynomial filtering method, phase images were first unwrapped using the ΦUN program developed by Witoszynskyj, *et al* [5]. After phase unwrapping, small moving windows of size 35x35 were fit with a third order polynomial weighted by magnitude squared, and the central region of this fitted window (a 5x5 box) was allocated to the polynomial fit matrix. The idea is that a better fit can be produced for a smaller 2D matrix since the smaller matrix contains less phase variation. The final polynomial fit image was subtracted from the original unwrapped phase in order to remove slowly varying background field effects. These settings were determined to be optimal after testing several different window sizes and orders. This method was compared to the conventional homodyne approach [2] using a filter size of 64x58 (which corresponds to a square filter with equal dimensions in k-space).

Results

The local polynomial method showed noticeable improvement in problem wrap areas such as the sinus and auditory canals, uncovering blood vessels that were obscured by artifacts with the conventional method (Fig. 1). The polynomial images also showed better grey white matter contrast (Fig. 2). For example, in globus pallidus relative to local white matter, contrast difference averaged over the 3 subjects was 0.35 ± 0.06 radians for the polynomial method and 0.19 ± 0.05 radians (mean ± standard error) for the conventional method. A profile across the brain in Fig. 2c demonstrates this improvement in contrast: for the polynomial technique, positive phase peaks were increased relative to those of the conventional method, while phase of negative peaks was reduced. For smaller structures such as blood vessels, the two techniques were more similar. One drawback of the polynomial technique was the artifact seen at edges of the brain, which was due to the fit of a sharp discontinuity in phase at the brain edge. The magnitude squared weighting of the polynomial fit improved this effect, so the majority of unusual peaks in signal at edges were found to occur just outside of the brain, and the actual edge of normal brain phase was only found to creep inwards by a few pixels. Edge effects with the local polynomial filter suggest combining filtering methods in the future.

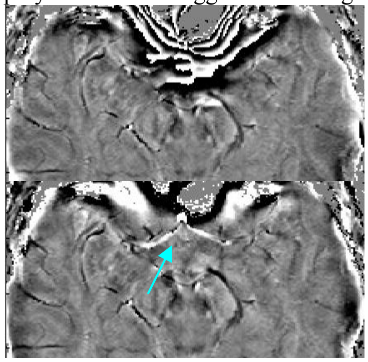

Figure 1. Conventional (top) and polynomial (bottom) phase images. The wrap area in the polynomial image is improved, enabling the visualization of an artery which cannot be seen in the conventional image (see arrow).

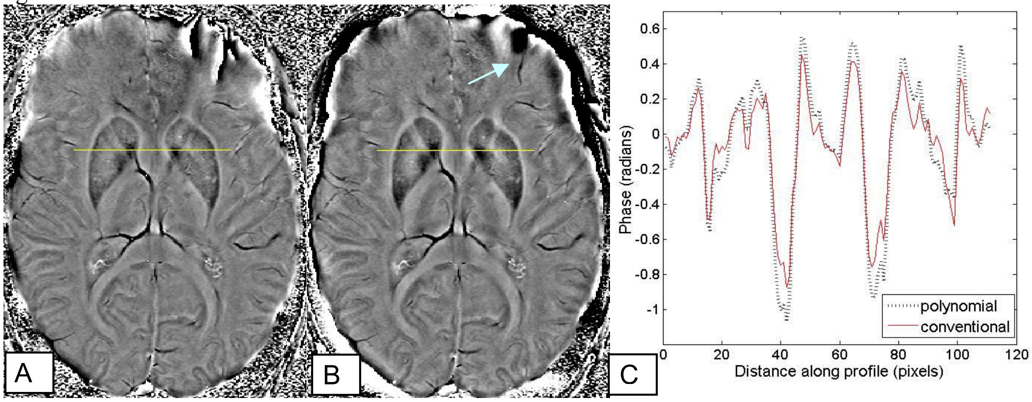

Figure 2. Phase images for conventional (A) and polynomial (B) methods. A profile across the putamen (C) is shown at the location of the line in A and B. A blood vessel is seen in the polynomial image (arrow), which is obscured by wrap in the conventional image.

Conclusion

While the conventional method of phase filtering is quick and relatively simple to use, it suffers trade-offs between air-tissue interface phase wrap correction and contrast. The moving window polynomial filter overcomes these difficulties, producing images with both better contrast and improvement in wrap areas. Thus, for qualitative viewing of brain structures, the local polynomial moving window approach provides benefit over the conventional homodyne technique for phase reconstruction.

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1. Haacke EM, et al. MRM 2004;52: 612–618. 2. Wang Y et al. JMRI 2000;12:661–670. 3. Yao B et al. Neuroimage 2009;44:1259-1266.
4. Deistung A et al. MRM 2008;60:1155-1168. 5. Witoszynskyj S, et al. Med. Image Anal. 2009;13(2):257-268.