Lesion and Deep Grey Matter Visualization in Phase Images Using a Local Polynomial Filter with Moving Window

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Introduction

Susceptibility-weighted imaging (SWI) and phase imaging provide enhanced visualization of veins and iron-containing structures. Global field variations in the phase image, often arising from air-tissue interfaces, must be removed before these images can unveil phase changes from local susceptibility differences. Several techniques have been developed to remove unwanted phase variation, with most methods based on the assumption that the phase changes slowly and therefore elimination of low spatial frequency components in the phase will leave the local phase shifts of interest. The method demonstrated by Haacke [1] is widely employed using a 2D filter to remove high spatial frequencies in k-space then complex dividing into the original image to produce a high pass filtered phase image. Several polynomial fitting methods have also been developed that begin with phase unwrapping. An eighth order 2D polynomial fit of the entire unwrapped brain was used by Yao to removed large-scale susceptibility effects in phase images [2]. Deistung has used local polynomial fitting for SWI reconstruction [3]. In our study, we use a moving window local polynomial fitting method in normal volunteers and multiple sclerosis (MS) patients in comparison to a standard approach for phase imaging and SWI of human brain. In particular, we focus on lesion visualisation, where enhancement of the often subtle lesion contrast would be valuable.

Methods

MRI Acquisition: Eight healthy control subjects and ten MS patients were examined at 4.7T. The phase/SWI acquisition used a 2D method with 50 slices of 2mm thickness, TE/TR=15/1540ms with readout and slice selection first order flow compensation, 62º flip, FOV=200x180mm^2, matrix size=512x256, a 4-element receiver array was used.

SWI Reconstruction: The phase images from each receiver were unwrapped individually using the ΦUN program [4]. After unwrapping the phase, both filtering methods were applied to each dataset with each receiver image filtered individually. For the polynomial filtering method, moving windows of size 35x35 pixels were fit with a third order polynomial weighted by magnitude squared, and a 5x5 box in the central region of the larger fitted window was allocated to the polynomial fit matrix. This smaller 5x5 box minimizes edge transitions between neighbouring areas. Slowly varying background field effects were removed by subtracting the final polynomial fit image from the original unwrapped phase image. For the standard filtering approach, a 2D filter of size 64x58 points was used, which corresponds to a square filter with equal dimensions in absolute k-space (accounting for 12.5% of the matrix size in frequency direction and 23% in the phase encode dimension). Phase images from each coil were first weighted by their corresponding magnitude and the combined phase image was obtained by taking the weighted average. The SWI images were then constructed by multiplying the thresholded phase mask four times into the magnitude image. Lesions and deep grey matter tissue were analyzed using ROIs placed on the phase images, with angle difference measurements made relative to the local background.

Results

Table 1 illustrates the results from MS lesions and deep grey matter structures using the two filtering methods. The local polynomial method with moving window consistently provides increased tissue contrast over the standard method. Figure 1 shows representative examples where the hypointense lesion is better depicted with the moving window polynomial, and for deep grey matter where less artifact is seen with enhanced tissue discrimination. For the polynomial technique, negative and positive phase peaks were more significant relative to those of the standard method. The polynomial method produces images with both better contrast and improvement in wrap areas. The improved contrast in the polynomial images not only makes structures more visible, but it also makes MS lesions more visible.

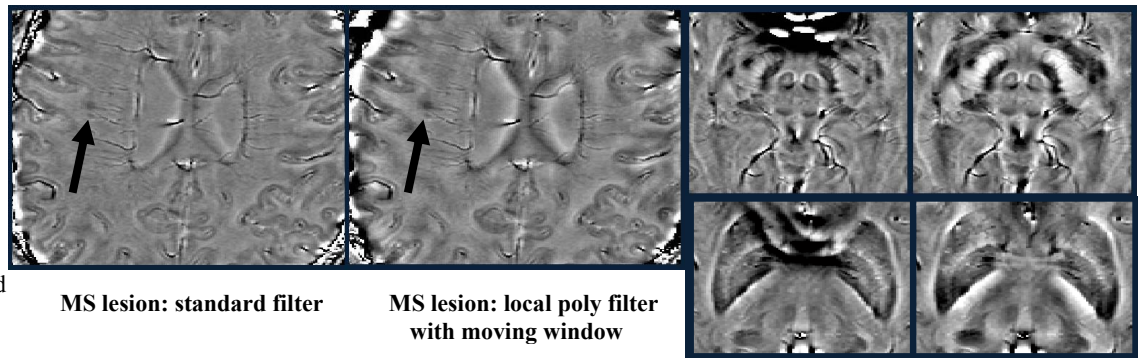

Figure 1 (at right) Comparison of filtering methods. The local polynomial filter with moving window shows increased lesion contrast (arrow). In deep grey matter (far right), reduced air tissue effects and enhanced contrast are evident.

Conclusions

For qualitative viewing of lesions and deep grey matter structures, local polynomial fitting with a moving window can provide improved results over standard filtering.

Table 1: Effect of Filtering Method on Quantitative Phase*

Structure	Mean Phase Angle Difference(°)		Enhancement
	Polynomial	Standard	Factor (%)
Putamen	-5.5 ± 2.8	-5.0 ± 2.0	11
Sub Nigra	-17.9 ± 5.5	-15.1 ± 3.8	18
Red Nucleus	-8.3 ± 5.9	-7.5 ± 3.5	10
Lesions in MS	-6.6 ± 2.7	-5.8 ± 2.4	14

* tissue- neighboring background

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

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