Model-free phase processing of multi-gradient-echo images at 9.4T

Gisela E Hagberg[1,2] and Klaus Scheffler[1,2]
[1]Biomedical Magnetic Resonance, University Hospital Tuebingen, Tuebingen, Germany, Germany, [2]High Field Magnetic Resonance, MPI for Biological Cybernetics, Tuebingen, BW, Germany

INTRODUCTION

Unwanted phase effect hampers the use of phase information for anatomical imaging, SWI and QSM applications. Therefore, model-based or model-free filtering methods are required to clean the data[1-7]. At ultra-high magnetic field strengths using parallel imaging methods, the B_1 phase of the transmit channels and phase displacement between receiving channels add to strong unwanted contributions from the macroscopic B_0 field variations. In the present work, we explored the performance of two model-free, high-pass filtering methods for data cleaning of multi-echo data at 9.4T. Along with the widely used Gaussian kernel, we explored the use of a smoothing spline function that adapts its shape to the actual k-space appearance of the MR signal. We qualitatively assessed this approach and found that phase wraps were more efficiently removed, while desired phase features were maintained.

METHODS

MRprotocol. Six healthy subjects who volunteered to participate in this ERB approved study, were scanned at 9.4T equipped with whole body gradients, using a 16ch transmit/32ch receive coil[8], with the following protocol: scout imaging, Actual Flip Angle Mapping, and 3D spoiled GRE multi TE (voxelsize:.38x.38x1mm3; TR=41ms; TE=6, 12, 18, 20, 24, 30ms; nominal flip angle: 10°; TA=7min39s).

Data analysis. Phase processing was performed in 2D for each channel, partition and echo time by two model-free approaches. The first method used a standard Gaussian kernel with a FWHM in image space of 8mm. The second method used a smoothing spline function closely matching the absolute value of the k-space data. For each subject, the knots and tolerance of the spline were adapted to yield a kernel with a similar width as the Gaussian at the early echo times. After complex division of the unfiltered and the filtered k-space data, magnitude weighted summation of all receiving channels was performed for each phase processing method.

RESULTS, DISCUSSION

As the echotime increases, the k-space data spreads out and the full width half maximum of the absolute value increases, consistent with increasing B_0 effects and echo dephasing. The smoothing spline, but not the Gaussian kernel, can mirror this temporal evolution of the MR signal (Fig, row1). After image reconstruction, phase wraps are still prominent after Gaussian filters, (Fig. 1 middle row) while the spline function mitigates strong B_0 inhomogeneities (Fig.1 last row).

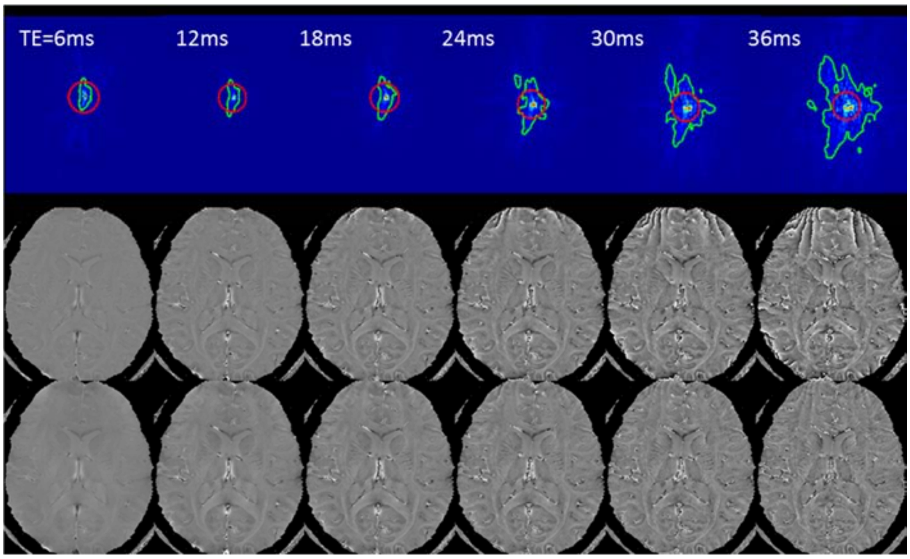

Fig. 1 First row: 2D k-space magnitude data from a multi echo GRE dataset at 9.4T. The Gaussian kernel (red circle indicates the 10% isointensity) or a smoothing spline that adapts to the measured MR signal showing an increasing width of the 10% isointensity line (green) with echo time. Second row: reconstructed phase images after Gaussian filtering. Third row: reconstructed phase after filtering with the smoothing spline function.

CONCLUSION

Smoothing spline functions represent a viable alternative for model-free phase processing but requires tuning to the underlying MR signal.

References:

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