Abstract 45599

The importance of priors for l2 regularisation and total variation methods in quantitative susceptibility mapping

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Purpose / Introduction

Phase imaging has been demonstrated to offer a good contrast between and within brain tissues at 7T[1] with iron and myelin concentration being amongst the main modulators of the observed contrast due to their para- and dia-magnetic properties.Phase imaging suffers from a non-local contrast variation which can be overcome by calculating the underlying magnetic susceptibility maps[2].As this problem is ill-posed, many regularized methods have been proposed over the past years[2,3,4].The regularized single-orientation (RSO)[2] based on the l2 regularisation and the morphology enabled dipole inversion (MEDI)[3] method based on the l1 total variation incorporate prior knowledge of the expected edges taken from the magnitude image.In this abstract a systematic evaluation is performed of a l2 RSO method[2,5] and a l1 total variation method (TV)[3] using numerical data and different morphology priors.

Subjects and Methods

Two methodologies were implemented:RSO using a least-square conjugated algorithm to minimize equation1,Fig.1,where C represents the convolution with the dipole kernel,B the measured field,β is a regularization parameter and M_B is defined as equation3,Fig.1,where M_{image} is the magnitude image,σ is the noise standard deviation and n is a threshold parameter.MEDI minimizes the TV-norm of χ subject to the data equation2,Fig.1,where ε can be measured from the data.

1) $min_\chi(||C\chi - B||_2^2 + \beta||M_B\nabla\chi||_2^2)$

2) $min_\chi||M_B\nabla\chi||_1 \quad \text{s.t} \quad ||C\chi - B||_2^2 < \varepsilon$

3) $M_B = \begin{cases} 0, & \text{if } \nabla M_{image} > n\sigma \\ 1, & \text{if } \nabla M_{image} < n\sigma \end{cases}$

4) $SNR = 10log_{10}\frac{\sigma^2_{image}}{\sigma^2_{noise}}$

Fig.1 equations a)RSO, b)MEDI, c)prior information, d)SNR

Using a numerical phantom with different susceptibility compartments,Fig.2,the field map was calculated[6] and random noise was added.

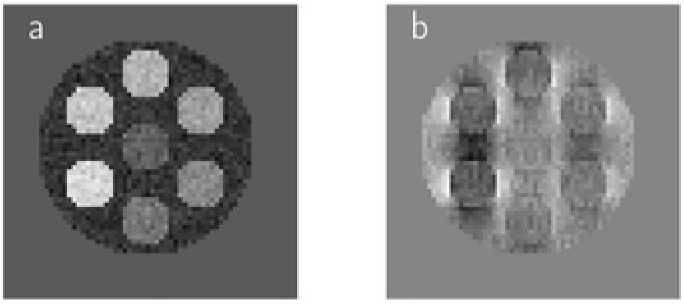

Fig.2 shows a) 3D numerical phantom of 128x16x128 pixels with 7 cylinders with different magnetic susceptibilities (between 4-16au) b)Field map calculated by numerical convolution with dipole kernel under a magnetic field of 7T aligned at z-direction. Zero mean Gaussian noise was added to the numerical phanton and the field map with result SNR=10, defined as equation4.

Susceptibility maps were calculated with both methods while prior information parameter n(Fig.3) as well as the parameters β and ε were varied systematicly.The quality of the reconstruction was measured.

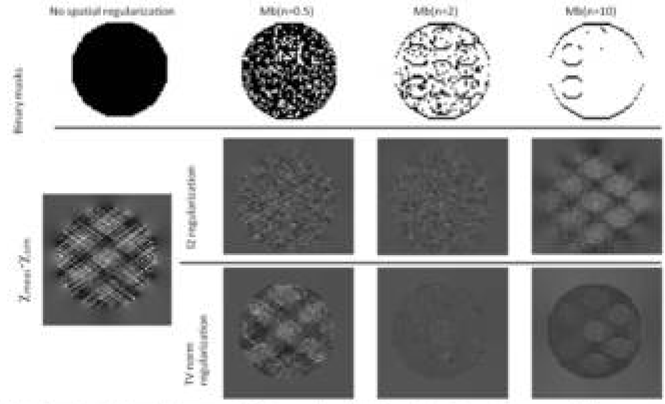

Fig.3, first row shows the used binary masks Mb, second and third rows show the resulting susceptibility maps subtracted from the ground truth susceptibility map using the l2 and the TV methods respectively. As the threshold value n increases, the used prior information decreases together with its noise contamination. The streaking artifacts seen when no regularization is used clearly disappear for any of the reconstruction methods and binary masks used. The TV norm outperformed the l2 regularization in terms of denoising the reconstructed susceptibility maps.

Results

Figure 4 shows the reconstruction quality of both RSO and TV methods.While the optimum ε value remains constant throughout for different n's,the optimum β increases with the reduction of n reflecting the reduction of number of points in which the regularization is imposed.Both methods benefit from having the threshold set at approximately twice the noise level as this gives both the lowest reconstruction error and the highest independence from the regularization parameters β and ε used.

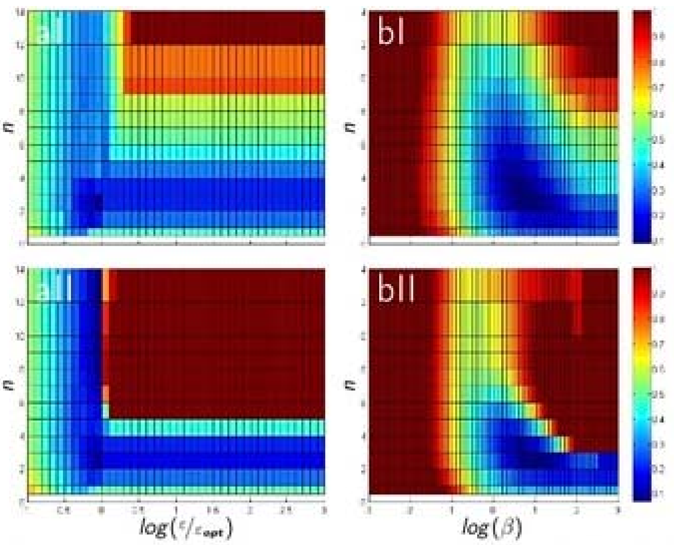

Fig.4 shows $||\chi_{meas}-\chi_{opt}||/||\chi_{opt}||$ dependence on regularisation parameters a)$log(\epsilon/\epsilon_{opt})$ and b)$log(\beta)$ in the x-axis and the threshold value for the binary mask n in the y-axis reconstructed with a)MEDI, b)RSO for I)whole data, II)only cylinder $\chi = 8$. II) contains lower relative SNR (higher noise level) and requires better prior information as the low artifact range decreases.

Discussion/Conclusion

The results shown suggest that both methods are effective at calculating susceptibility maps,with the TV formalism having advantages in terms of independence of ε and the l2 having advantages in terms of computation efficiency.The usage of low thresholds allows a good compromise between:having as much morphological information as possible and applying the spatial constraint in the smoothness or sparsity in enough contiguous areas in order to penalize magic angle related artifacts(Fig. 3b).

References

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