A method for automatic determination of the global polarity of phase sensitive inversion recovery images

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Introduction:

Region growing has been shown useful for reconstructing phase sensitive inversion recovery (PSIR) images [1, 2]. However, the global polarity (GP) of a PSIR image reconstructed by a region-growing algorithm is determined by the polarity of the initial seed pixel. As a result, the final PSIR image may display globally inverted contrast if the polarity of the initial seed pixel is incorrectly selected (e.g., see Fig. 1). Although the problem can be easily detected and corrected with human intervention, an automatic solution by a computer is not trivial. Previously, the total net magnetization (NM) [1] and the "moment of inertia (MI)" [2] of an image have been proposed for determining GP. The success of such methods, however, has been found to depend on imaging parameters such as the inversion time (TI) and the magnetic field strength. In this work, we removed this dependency with a theoretical calculation of white matter signal polarity and demonstrated that a combination of NM and MI can be used to correctly determine GP for images acquired over a wide range of TI (150ms to 600ms) and at both 1.5 T and 3.0 T.

Method:

According to Ref. [1] and [2], the NM and MI of a PSIR image are defined as:

$$NM = \sum S(x,y) \qquad MI = \sum S(x,y)\left(x^2 + y^2\right)$$

where $S(x,y)$ is the pixel intensity. The summation is over all (x, y), which are the pixel coordinates relative to the center of the image.

The rationale for using NM is that for a PSIR image with correct GP, the total positive signal is expected to be greater than the total negative signal. In comparison, MI weighs the signals towards the periphery (e.g., of subcutaneous fat) more heavily than the signals at the center (e.g., of CSF from the ventricles). In practice, MI has been found to be a more consistent predictor than NM for the image GP [2]. However, requiring a PSIR image with correct GP to have a positive MI or NM is not valid for all imaging parameters. For example, when an image is acquired with a TI that nulls fat, both MI and NM are negative because the signal from most other brain tissues should be negative.

We found that the white matter intensity provides a good metric to predict when MI will transition from being positive to being negative. When white matter is positive, fat signal is almost fully recovered and thus will result in a positive MI. When white matter is negative, other brain tissues such as grey matter and CSF are strongly negative, which will result in a negative MI. Challenge arises when white matter signal is close to 0. In this case, the polarity of MI fluctuates and is difficult to define. As an alternative, NM was found to be a more stable predictor for GP during the transition regime. We used the following theoretical calculation to define when NM or MI is applicable, which has an added advantage of removing the dependency of the white matter signal on scanning parameters (e.g., TI and filed strength):

$$WM = 1 + \exp(-TR/T1) - 2\exp(-TI/T1)$$

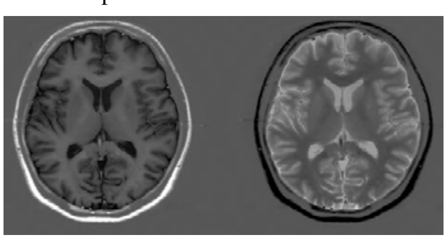
The hybrid scheme using both MI and NM to determine the GP of a PSIR image is thus as follows:

1) when $WM > 0$, MI is required to be positive;
2) when $WM < 0$, MI is required to be negative;
3) when WM is close to 0, NM is required to be negative.

Experiments and Results:

The hybrid scheme for GP determination was implemented in Matlab. To evaluate its performance, over 400 brain images of different planes (axial, sagittal and coronal) were acquired of two different volunteers at both 1.5 T and 3.0 T. A commercially available T1flair pulse sequence (GE Healthcare Technologies) and an 8-channel phased-array head coil were used for all image acquisitions. The scan parameters were as follows: TE ≈ 8ms, ETL=16, FOV=20cm, slice thickness/slice gap =4/1mm, RBW = ±32kHz, acquisition matrix = 256x160. TR ranged from 2500 to 7175 ms, and TI ranged from 150 ms to 600 ms. Phase correction and PSIR image reconstruction were performed using the algorithm described in Ref. [2]. The GP determined from the hybrid scheme was compared against the correct GP based on visual inspection.

The T1 values used for WM calculation at 1.5 T and 3.0 T were chosen as 540ms and 670ms, respectively. Empirically, [-0.2, 0.001] was found to be an appropriate range for defining WM as being close to 0. It is noted that the T1 values we used are somewhat different from what has been reported in the literature [3]. The discrepancy may be due to some inconsistencies such as the fact that the WM calculation we used was for a gradient echo based inversion recovery while the images were actually acquired with a fast spin echo based pulse sequence. The proposed hybrid algorithm was able to determine GP correctly for all the PSIR images acquired. The table below illustrates the GP determination results for images from some representative TI values and two different field strengths.



Correct GP Inverted GP

TI	200	300	350	400	250	350	450
B_0	1.5 T	1.5 T	1.5 T	1.5 T	3.0 T	3.0 T	3.0 T
WM	-0.38	-0.14	-0.04	0.05	-0.38	-0.19	-0.02
NM	-	-	-	+	-	-	-
MI	-	-	+	+	-	-	-
GP by the hybrid algorithm	correct	correct	correct	correct	correct	correct	correct

Conclusion:

By using a theory-guided hybrid algorithm involving both MI and NM, the polarity dependence of MI and NM on the imaging parameters and the field strength can be removed. In comparison to using MI or NM alone, our results show that the correct polarity of the PSIR images acquired over a wide range of TI and at both 1.5 T and 3 T can be automatically determined with this hybrid algorithm.

References:

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