Weighted echo sharing technique (WEST) for highly undersampled multi-echo T2(*) weigthed data in Cartesian domain

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Introduction

Magnetic resonance imaging (MRI) can provide various contrast images using characteristics of tissues in human body such as tissue relaxation, magnetism and diffusion properties. These multiple contrast images can provide useful information for diagnosis such as myelin water fraction by multi-component analysis, vein structures by susceptibility weighted imaging (SWI), and structures of nerve fibers by diffusion tensor imaging (DTI), etc. [1] However, scan time of these useful multi-contrast images is generally long. To speed up the acquisition of multi-contrast images, raw data of MRI (k-space) can be undersampled during data acquisition. Since this undersampling introduces aliasing and blurring artifacts on images, many techniques to reduce these artifacts such as non-Cartesian acquisition, model-based fitting, compressed sensing (CS) have been introduced. [2] The purpose of this study was to obtain more accurate multi-contrast images with fewer aliasing or blurring artifacts from highly undersampled data in Cartesian domain. In this study, multi-echo T2* weighted images were used to evaluate the reconstruction method. The used reconstruction method was weighted echo sharing technique (WEST) which fills an empty phase encoding (PE) lines in a k-space by weighted combination of PE lines in the same k-space position at other echo times (TEs). [3] Consequently, multi-contrast T2* weighted images obtained by the WEST show substantially fewer artifacts compared to other conventional methods.

Methods

For *in vivo* experiments, a healthy brain was scanned with a multi gradient echo (MGRE) sequence using a 3T Siemens MRI system (Erlangen, Germany). Matrix resolution was 256×256 and the number of echo was 64. Undersampling was performed retrospectively from fullsampled data by the reduction factor 16. All image processing were performed using MATLAB (The MathWorks.Inc. Natick, MA).

In WEST, an empty PE line is filled with a weighted combination of several PE lines at the same k-space position at other time points. The processing step of WEST can be explained by 4 steps. (1) Center PE lines are acquired for all time points during data acquisition; (2) In order to fill the *i*-th empty PE line at the *j*-th time point, time points are selected that contain the *i*-th PE line; (3) Weights are obtained by representing a center PE line at the *j*-th time point as weighted combination of center PE lines at the selected time points in (2). This step can be represented by : $\vec{k}(y_c,t_j)=\sum_{t_k\in P_i, t_k\neq t_j} w_{t_k}(y_c,t_j)\vec{k}(y_c,t_k)$ where $\vec{k}(y_c,t_j)$ is the center PE line at the *j*-th time point, P_i is the set of time points which contain the sampled *i*-th PE line, and $w_{t_k}(y_c,t_j)$ is the obtained weights for the *i*-th PE line at the *k*-th time point to represent the PE line at the *j*-th time point; (4) Finally, the *i*-th empty PE line at the *j*-th time point is filled with weighted combination of acquired *i*-th PE lines by : $\vec{k}(y_i,t_j)=\sum_{t_k\in P_i, t_k\neq t_j} w_{t_k}(y_c,t_j)\vec{k}(y_i,t_k)$.

Basically, the basic concept of this WEST method does well match with multi-contrast images because this method can make various contrast images by weighted combination of k-space lines from other contrast images.

Results

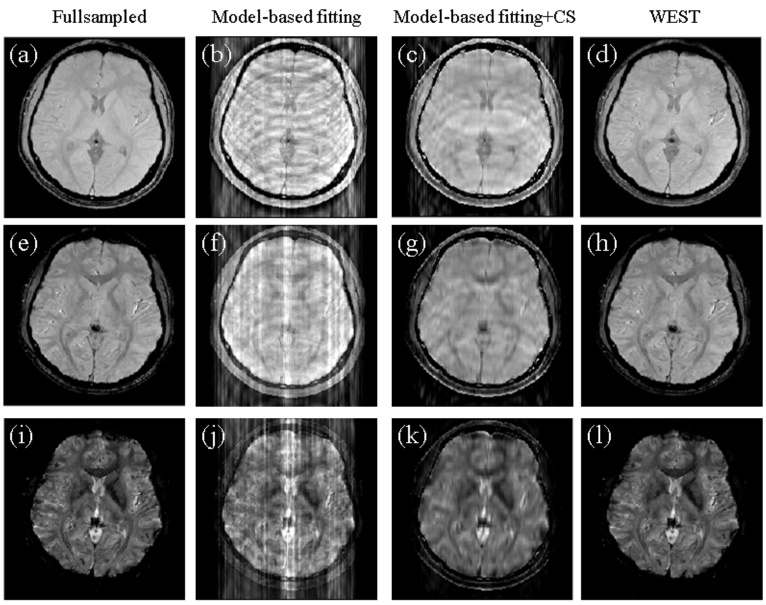

Fig 1. Multi-contrast T2* weighted images were obtained by fullsampling (a), model-based fitting (R=16) (b), model-based fitting+CS (R=16) (c), and WEST (R=16) (d) at TE=5.7ms. (e-h) and (i-l) are T2* weighted images at TE=19.5ms, 56,3ms, respectively

Table 1. RMSEs of T2* weighted images from fullsampled data between T2* weighted images obtained by reconstruction methods

TE (ms)	Model based fitting	Model based fitting+CS	WEST
5.7	7.0	4.9	1.8
19.5	7.1	3.5	0.8
56.3	3.8	2.2	0.6
Total TEs	6.4	4.3	0.8

In Fig 1, multi-contrast T2* weighted images from each reconstruction method are shown. Because extreme undersampling was performed, images obtained by conventional methods show blurring and aliasing artifacts. Images obtained by model-based fitting show severe aliasing artifacts. And images from model-based fitting+CS show fewer aliasing artifacts, but show severe blurring artifacts. Therefore, detail tissues and structures are hard to be distinguished in images obtained by two conventional methods. On the other hand, images obtained by the WEST show substantially reduced aliasing and blurring artifacts compared to conventional methods. They are very similar with images from fullsampled data. Detail tissues and structure can be clearly identified in images obtained by the WEST. In table 1, the RMSE value of the WEST is the smallest compared to conventional methods. Consequently, T2* weighted images obtained by the WEST show most accurate and detailed structures of the brain..

Conclusion

This study demonstrates that the accurate multi-contrast T2* weighted images can be obtained from highly undersampled Cartesian MGRE data by using WEST. While conventional method such as model-based fitting or CS are work with the reduction factor up to 5, the WEST can increase the reduction factor up to 16 in Cartesian trajectory. This method will be well applied for other various multi-contrast imaging such as DTI, SWI, etc.

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Reference

[1] Ung Jang et. al, *Neuroimage*, vol 70 (2013): 308-316
[2] Lustig, Michael, et. al. *Magnetic resonance in medicine* 58.6 (2007): 1182-1195
[3] Taejoon Eo et. al., "*Effective data sharing method for extreme Cartesian undersampling in MRF",* ISMRM, 2014