Optimization and Calibration of EPI Raw Data Reconstruction Parameters to Minimize Image Ghosting using Image-Based Corrections

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Introduction:
Echo planar images (EPI) are applied in a variety of diagnostic techniques that rely on fast acquisition of imaged data. EPI applications in common practice range from dynamic-contrast studies used to monitor the passage of injected contrast over time for stroke, tumor evaluation, and cardiac assessment to fMRI applications where a large series of images (typically thousands) are processed to provide spatial and temporal evaluation of neurological brain function. It is highly desired in these applications to produce a large series of ghost artifact-free EPI images. Higher levels of ghosting can produce more false positive errors in diagnosis and reduce the quality of the images.

Echo Planar Images (EPI), however, have been reported to be particularly vulnerable in producing "ghost images." These "ghosts" are typically positioned at N/2 pixels relative to the desired object position (where N is the number of pixels across the field of view of the object). The ghosts are typically created by differences between the odd and even echo lines of EPI data. In magnetic resonance imaging (MRI), the ghosts can be produced as a result of imperfect gradient application, instabilities in D/A timing, or inherent properties of the imaged substance (susceptibility differences and flow/respiratory changes, chemical shift for example).

One of the most popular methods for EPI ghost reduction is to apply a "reference" scan by turning off the phase encoding gradient [4]. By examination of offsets in the echo between an even and odd echo acquisition a set of phase correction values is determined. The calibration scan is typically incorporated at the beginning of the pulse sequence. The goal of the reference has typically been to remove zero and first order phase differences between the odd and even echoes and has been shown capable of significantly reduce the amount of ghosting. However, in practice, reference scans can occasionally increase the N/2 ghost.

Instead image-based correction such as that proposed by Buonocore, Foxall [1,2] have been shown to be an alternate and effect way to avoid the "reference" scan methods. This abstract discusses the use of optimal design to select reconstruction parameters applied to reconstruction parameters to automatically reduce the amount of coherent N/2 ghosting as well as reduce the number of calculations.

Methods:
1) Raw data is acquired from a EPI readout (typically sinusoidal read-outs)
2) A parameter that shifts the data acquisition window so that the data, and a second parameter which controls the phase correction was evaluated
3) Using a nonlinear mathematical optimization routines on the image-based measure produced the parameters were applied to remove the N/2 ghosts from the images. Several cost functionals were considered for optimization, however, the sum of the magnitude projections over the entire image worked well in most cases.
4) The values for the read-delay and phase values for the parameters were selected for a subset of slices estimates were made for the other slices
5) These parameters can be used over all slice sets at other time points

Results and Discussion:

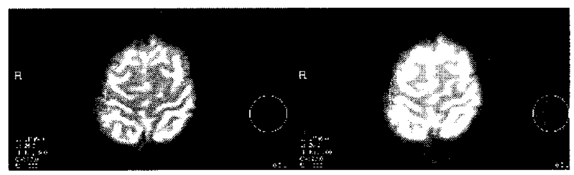

Figure 1: (A) Illustrates the image after automated ghost correction and optimal calibration, (B) illustrates image prior to calibration and ghost removal.

Up to a thirty times improvement was seen after using this method. It was found that occasionally with phase reference scans (though for the most part pretty robust) can at times make the images substantially worse. Phase correction and data shifting was applied to reduce the number of transformations prior to applying the de-ghosting parameters. Image-based corrections required that phase corrections on a subset of all acquired images lead to much faster overall calculations.

References:
1. Buonocore M, Gao L Ghost Artifact Reduction for Echo Planar Imaging Using Image Phase Correction, MRM 38 (89-100) 1997

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3. Noll DC, Nishimura, DG, Macovski A, "Homodyne Detection in Magnetic Resonance Imagin", IEEE Transactions on Medical Imaging Vol 10, No 2 , June 1991

4. Ahn CB, Cho ZH, "A New Phase Correction Method in NMR Imaging based on Autocorrelation and Histogram Analysis, IEEE Trans Med Imag, MI-6 32-36 (1987)