Double-Sampled Echo Planar Imaging with Point Spread Function Mapping at 1.5 Tesla

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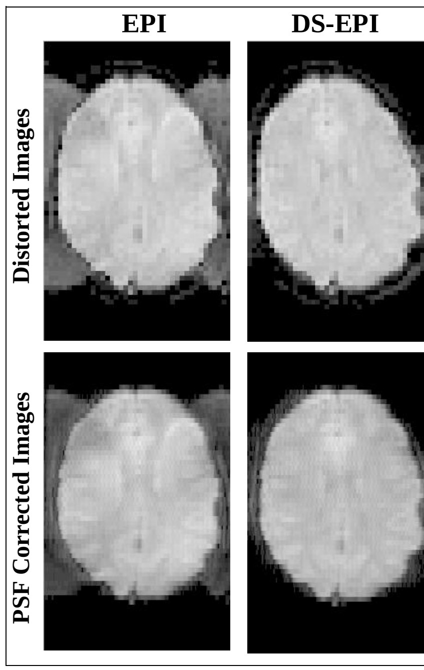
Abstract: The presence of Nyquist ghost artifacts and image distortion are two major drawbacks of Echo Planar Imaging (EPI), a popular choice for Functional Magnetic Resonance Imaging (fMRI). Recently, Double Sampled EPI (DS-EPI) has been proposed to eliminate Nyquist ghost artifacts at the expense of an increase in image distortion due to off resonance effects [1]. Removing this distortion using digital filtering techniques is a challenging ill-posed inverse problem. While Point Spread Function (PSF) Mapping has been shown to be superior at removing distortion from EPI images when compared to commonly used field mapping techniques [2], both PSF Mapping and field mapping methods are ineffective at removing Nyquist ghost artifacts present in conventional EPI images. This abstract investigates the combination of DS-EPI for removing Nyquist ghost artifacts and PSF Mapping for removing distortion at 1.5 Tesla for fMRI experiments.

Introduction: Double Sampled EPI (DS-EPI) has been proposed by Yang et al. to eliminate Nyquist ghost in conventional EPI imaging by sampling every line of k-space twice [1]. DS-EPI also has the additional advantage of improved SNR when acquired with the same receiver bandwidth as conventional EPI. The disadvantages of DS-EPI compared to EPI are 1) a 20% increase in acquisition time for fMRI experiments conducted at 1.5 Tesla, and 2) a significant increase in image distortion due to off resonance effects. The increase in acquisition time can be effectively managed for whole brain fMRI experiments with TRs greater than 2 seconds by employing ramp sampling, fractional k-space acquisitions, or by increasing the receiver bandwidth at the expense of SNR. The increase in image distortion is the major disadvantage of DS-EPI and we surmise is the reason why DS-EPI has failed to gain wide spread acceptance for fMRI experiments. Recently, Point Spread Function (PSF) Mapping with its ability to correct for both geometric and intensity distortions has been shown to be superior to field mapping methods for removing image distortion [2]. Combining PSF mapping with DSEPI may allow the two most persistent problems in fMRI, Nyquist ghost artifacts and image distortion, to be significantly reduced.

Methods: PSF maps, EPI images and DS-EPI images were acquired from a healthy volunteer after obtaining signed and informed consent. The protocol for EPI images was TE=40ms, TR=2.5 seconds, RBW=62.5kHz with no ramp sampling, FOV=24cmx15cm, and resolution = 64x40, echo train length=40 and number of slice=28 slices to obtain whole brain coverage. DS-EPI images were acquired under identical conditions except the ETL was increased from 40 to 80 with phase encode blips applied every other echo. PSF maps were acquired for EPI and DS-EPI under their respective conditions. The PSF maps were acquired with a PSF field of view of 3.75 cm and 40 PSF encodings. Total acquisition time for each PSF map was 1 minute 40 seconds. The PSF map reconstruction algorithm used to correct the EPI images is described in detail by Zeng and Constable [2]. The odd and even echoes of the DS-EPI were corrected separately with their respective PSF maps before being added to together to form the final corrected DS-EPI image.

Results: The figure shows EPI images (left) and DS-EPI images (right) before and after distortion correction with PSF mapping. The Nyquist ghost artifacts are clearly seen in the EPI images and are not removed with the PSF mapping distortion correction. As expected, the Nyquist ghost artifacts are absent in the DS-EPI image while the image distortion has been increased by a factor of 2. A fast spin echo reference image of the same slice is shown for comparison. The PSF mapping is able to effectively remove the distortion in both the EPI images and the DS-EPI images, as long as the PSF field of view is greater than the largest pixel displacement.



Comparison of EPI and DSEPI before and after PSF correction. Fast Spin Echo reference image (lower right corner). Nyquist ghosts and image distortions have been increased for illustrative purposes in this figure. Images windowed and leveled separately.

Conclusion: DS-EPI with its lack of Nyquist ghost artifacts and improved SNR compared to conventional EPI in combination with PSF-Mapping has the potential of being a viable option for fMRI experiments at 1.5T with temporal resolutions greater than 2 seconds.

References:

1. Yang, Q.X., S. Posse, D. Le Bihan, and M.B. Smith, *Double-sampled echo-planar imaging at 3 tesla.* J Magn Reson B, 1996. **113**(2): p. 145-50
2. Zeng, H. and R.T. Constable, *Image distortion correction in EPI: Comparison of field mapping with point spread function mapping.* Magn Reson Med, 2002. **48**(1): p. 137-46.

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