Ghost Reduction for Oblique EPI using Entropy Based Regridding

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INTRODUCTION

Oblique echo planar imaging is a challenge due to ghosting, both in the frequency and phase encoding direction. In the phase encoding direction system time delays and eddy currents result in phase offsets (1). These offsets induce phase shifts in every other line in k-space, which cause ghosting in image space. Artifacts are also caused by shifts in the frequency encoding direction. Different approaches have been suggested to reduce the ghosting artifacts, both in the frequency and phase encoding direction. Reconstruction approaches for ghost reduction have previously been used mainly to reduce artifacts in the frequency encoding direction. To quantify the ghosting artifact in images the use of entropy has been presented (2). Methods for reducing phase offsets in the phase encoding direction using hardware approaches have also been suggested (1).

In oblique EPI data is sampled in a Cartesian coordinate system, but phase offsets will cause the phase encoding lines to be non-equidistantly separated, resulting in non-Cartesian data. This study proposes a non-Cartesian approach for Cartesian data sets with ghosting artifacts due to erroneous phase encoding.

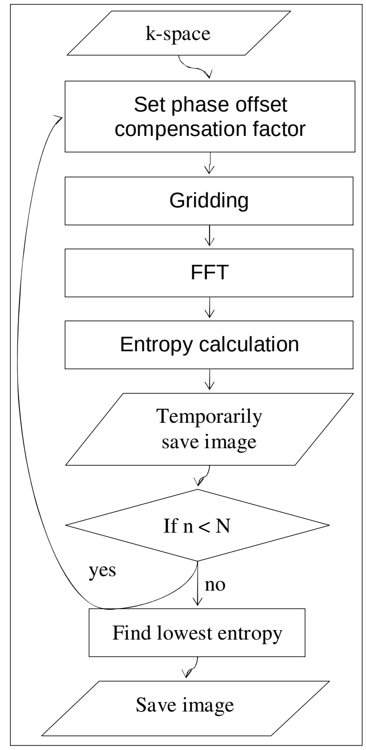

Figure 1 Flow chart of the algorithm.

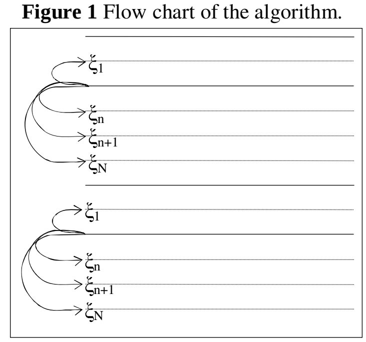

Figure 2 Full lines show acquired lines. Dotted lines show the positions of lines after regridding.

METHOD

This study proposes a phase offset compensation factor, ξ, to adjust the phase encoding lines so that they are equidistantly separated. This is done in an iterative manner, following the algorithm shown in the flow chart in figure 1. The phase offset compensation factor is applied to the gridder (3) which adjusts every other phase encoding line to a new position, increasing or decreasing the distance between phase encoding lines as seen in figure 2. The gridded k-space is then reconstructed using a method with ghost correction for phase offsets in the frequency encoding direction (4). An entropy calculation is then executed for the reconstructed image. The procedure is then repeated with a new phase offset compensation factor. After iterating through the range of phase offset compensation factors the image with the lowest entropy is used.

RESULTS

The method proposed reduces the ghosting artifacts caused by the non-equidistant separation of phase encoding lines. Preliminary results are shown in figures 3,4 and 5. Figure 3 shows the calculated entropy of the images with the different compensation factors ξ applied. The image in figure 4 shows a phantom obtained with the scan plane tilted 45 degrees in the axial plane with no correction performed. Figure 5 shows an image reconstructed from the same raw data as the image in figure 4, but regridded using the method described above. This compensated image reveals a reduction of ghosting artifacts.

DISCUSSION

A comparison between figures 4 and 5 shows a clear reduction of ghosting artifacts. The method described is applicable to EPI scans such as DWI, PWI and fMRI, especially when acquiring oblique images. It can also bee used for quantifying the phase offset when using hardware methods for phase offset compensation.

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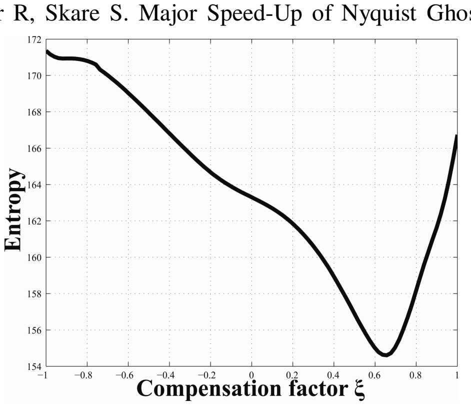

Figure 3 Calculated entropy for compensation factor range

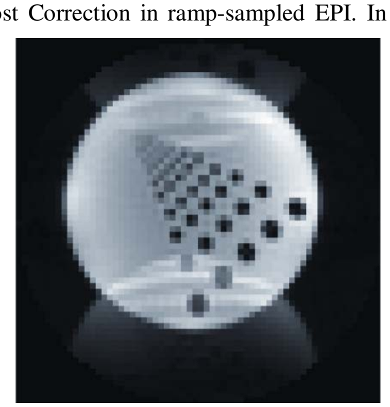

Figure 4 Uncompensated phantom image

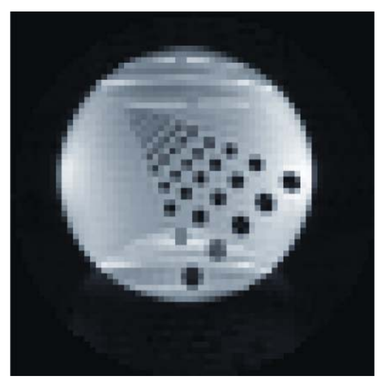

Figure 5 Compensated phantom image