Automatic calculation of gradient delays for center-out radial trajectories using an entropy metric

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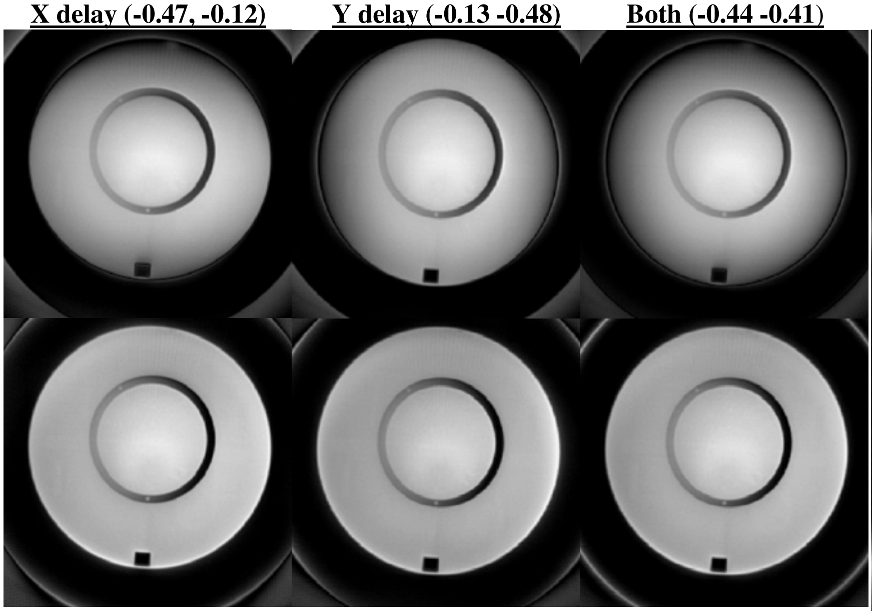
Introduction: Despite many advantages, such as the potential for ultrashort TE and high scan-time efficiency, non-rectilinear k-space trajectories play only a marginal role in clinical imaging. One of the primary reasons for this is the need for calibration of the gradients more or less on a case by case basis. Imperfections in the gradients create a mismatch between the requested and delivered k-space trajectories, which can lead to strong artifacts in the images. Rectilinear imaging is largely immune to such gradient imperfections, since the artifacts produced tend to be benign e.g. phase roll.

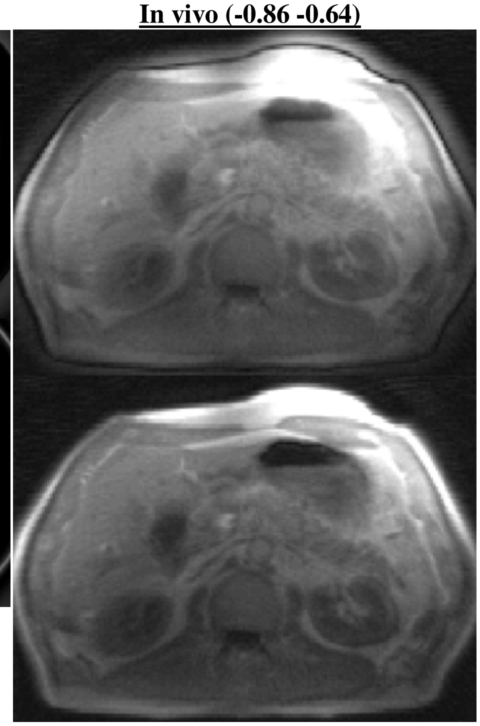
A general solution to the problem is to improve gradient performance or to measure the delivered k-space trajectory using specialized hardware or calibration pre-scans (1,2). Although promising these are not currently convenient for routine use. An alternative post-processing solution might be to assume a model for the expected trajectory deviation and optimize an image quality metric with respect to free parameters in the model (3). This methodology is similar to motion correction techniques that minimize entropy by applying phase rolls and phase offsets to the data (4). The present study investigates this approach using a center-out radial trajectory and assuming a simple time-delay on each physical gradient (5).

Results: Data were acquired on a GE 3.0T Twinspeed. In phantom experiments a 4μs delay was introduced on the X, Y and both axes (top row). The minimum entropy solution was found by the simplex algorithm (bottom row). Images were obtained by interpolating along the trajectory by ±1 point (i.e. ±8μs dwell-time), regridding using this trajectory, FFTing and computing the entropy $-\Sigma p_i \ln p_i$ where p_i is a histogram of the image. Delays (X, Y) are given in points for the minimum entropy image. The *in vivo* result shows the starting image (0 0), the minimum entropy image and the negative entropy surface. The surface appears well-behaved but exhibits local minima on scale of $\sim 10^{-3}$, which can confound derivative-based search algorithms. Only a coarse solution is required anyway owing to the simple model used.

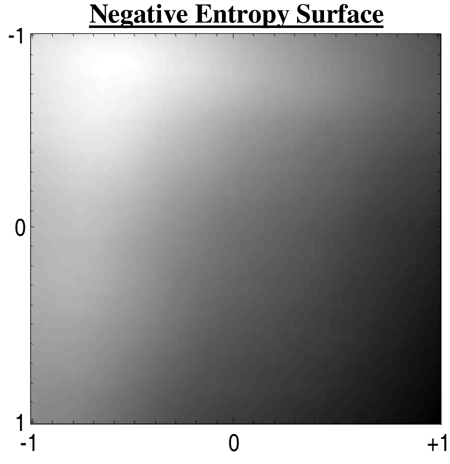
X delay (-0.47, -0.12) **Y delay (-0.13 -0.48)** **Both (-0.44 -0.41)**



In vivo (-0.86 -0.64)



Negative Entropy Surface



Conclusions: To a reasonable approximation, radial trajectory errors can be modeled as delays on the physical gradients. Oblique slices, which use logical gradient axes, must use the rotation matrix to calculate appropriate logical delays. It is unclear if deviations other than delays can be modeled straightforwardly or if the minimum entropy always corresponds with the best image. A different approach might be to acquire a reference image and minimize the joint entropy, which is used in image registration.

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