TRELLIS MRI: A Novel Approach to Motion Correction

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Introduction: Motion artifacts are a common problem in MR imaging due to the relatively long acquisition times required to form an image. Using a new technique called TRELLIS (**T**ranslation & **R**otation **E**stimation using **L**inear **L**east-squares & **I**nterleaved **S**trips), motion information can be gained at no cost in additional acquisition time and artifacts can be corrected. Initial simulation results show the algorithm to be effective in the presence of realistic noise levels.

Method: Data are acquired using the k-space trajectory shown in Fig. 1. K-space is filled using interleaved horizontal and vertical strips. The phase and frequency encode directions are alternated so that the frequency encode direction always runs lengthwise along each strip. In the example shown, the number of strips, N, is 16. For the purposes of motion correction, it is assumed that little motion occurs during the acquisition time of a single strip. Using a multi-shot FSE sequence (or EPI) such as that used in PROPELLER [1], this assumption is not unreasonable.

Motion detection is achieved by comparing repeated data points. Each point in k-space is sampled twice: once as part of a vertical strip and once as part of a horizontal strip. If the object is unchanged, both samples will ideally be identical; if the object has been rotated about the imaging axis, corresponding points in k-space will be rotated about the origin; if the object has been translated by an amount ($\Delta x, \Delta y$), the phase of the second sample will differ from the phase of the first sample by an amount proportional to ($\Delta x, \Delta y$) and dependent on the location in k-space. Rotation is measured using correlated magnitude data while translation is quantified though use of the well-known phase correlation method [2]. Thus the motion of the object between the sampling of each pair of overlapping strips can be deduced. A system of equations linking the motion of the object between each pair of overlapping strips is then formed. By solving this overdetermined system of equations in a least-squares sense, the position of the object can be determined for all sampling times.

Once the motion of the object between the sampling of each strip has been deduced, motion correction is straightforward. Each strip is rotated back to a fixed reference position (rotational motion correction) then phase-adjusted (translational motion correction).

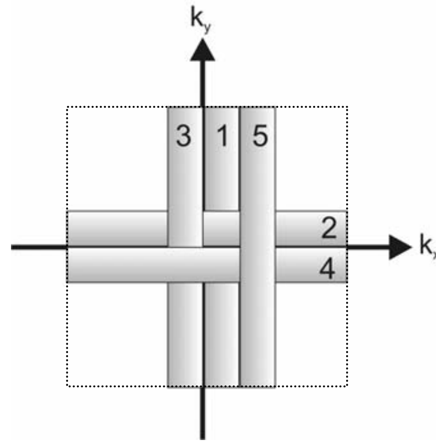
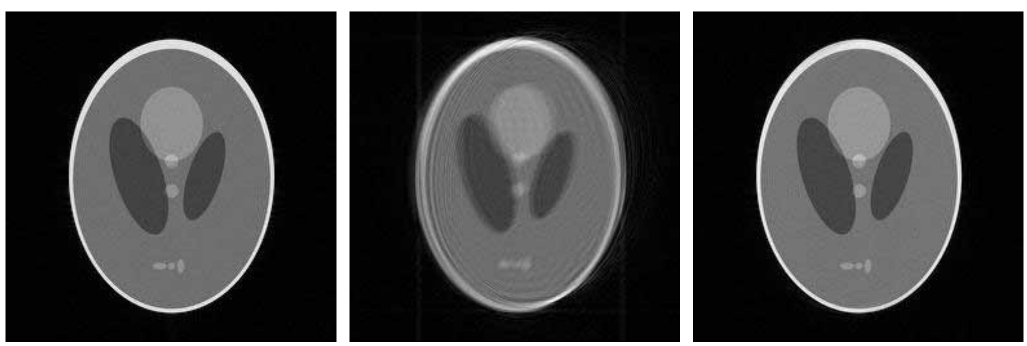


Fig. 1: The TRELLIS k-space trajectory for $N = 16$. The first 5 strips are shown; their numbers indicate the order of acquisition.

Results: Preliminary simulation results using the Shepp-Logan head phantom [3] are shown in Fig. 2. The SNR used was 25 dB, calculated on the basis of signal 'energy', averaged over the entire field of view. This is comparable to the SNR expected under clinical conditions. This sequence has also been implemented on a GE 3T scanner.



(a) (b) (c)

Fig. 2: Simulation results using the Shepp-Logan head phantom: (a) the original phantom (SNR = 25 dB); (b) the uncorrected image after motion consisting of a shift (30 pixels horizontally, 15 pixels vertically) and a rotation (15° clockwise) occurring over the course of the entire acquisition time; and (c), the corrected phantom using the TRELLIS method. N, the number of strips in the lattice, was 16 and the image resolution was 256 × 256 pixels.

Discussion: The TRELLIS algorithm has an efficiency advantage over existing methods. All collected data is used for both motion correction and image reconstruction. Unlike PROPELLER, k-space is sampled evenly without redundancy near the origin. Thus the same acquisition time and SNR as in a conventional algorithm (sampling twice then averaging as is often done in practice) can be achieved. While TRELLIS has been demonstrated here using a square FOV, the method is equally applicable to a rectangular FOV. Currently, no assumptions are made about the nature of the motion as a function of time. Incorporating prior knowledge of the maximum possible values of velocity or acceleration, for example, should further improve results in the presence of noise. Clinical trials will commence shortly.

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