Reducing fluctuation of train trajectories in 3D TSE imaging with compressed sampling

Guobin Li[1], Maxim Zaitsev[1], Esther Meyer[2], Dominik Paul[2], and Jürgen Hennig[1]
[1]*University Medical Center Freiburg, Freiburg, Germany,* [2]*Siemens Healthcare, Erlangen, Germany*

Introduction: In MR imaging using a 3D TSE sequence with long echo trains, *k*-space reordering is a critical part of the sequence design to achieve the contrast specified by an effective TE. Flexible linear reordering in Cartesian *k*-space is a commonly used technique to achieve T2-weighted contrast in 3D TSE sequences[1], which contains two steps: First, views in the *k*-space grid are sorted by their position in one phase encoding direction, and equally divided into *L* segments, where *L* is the number of acquired echoes in a single echo train; next, views in each segment are sorted by their position in the perpendicular phase encoding direction; a train number is correspondingly assigned to each view according to its order in the sorted list (Fig.1 a). Compressed sampling (CS) is a rapidly growing technique[2], which can also be applied to 3D TSE for shortening the acquisition time. However, the irregular distribution of sampled views in CS leads to dramatic fluctuations of the train trajectories in the traditional linear reordering. In this work, we present a modified linear reordering to obtain smooth train trajectories in CS 3D TSE imaging.

Method: *Technique* **-** views are sorted and divided into *L* segments in one phase encoding direction. *N* adjacent segments are combined to form a bigger segment; here *N* is called echo ambiguity. There is a total of *L*/*N* combined segments. In each combined segment, views are sorted by their coordinates in the perpendicular phase encoding direction. In the sorted list, a train number is assigned to each view. The first *N* views are assigned to train 1; next *N* views are assigned to train 2, etc. *N* views with the same train number form a collection. Each complete echo train trajectory consists of *L*/*N* collections. Each collection has *N* echo numbers, which can be freely assigned, for example, the first collection has echo number 1… *N* to assign; the second collection has *N*+1… 2*N* (Fig.1 b). In order to obtain the shortest trajectory, an exhaustive search method is used to find the optimal assignment of these echo numbers. Some constraints are applied to simplify the computation: exhaustive search is performed in each collection separately; the initial point in a collection is the target point in the previous collection; the target point in a collection is the one with the largest coordinate in the echo train direction; the initial point of the first collection is the one with the smallest coordinate in the echo train direction. *Experiments* – simulation in Matlab was first performed to verify the algorithm. The method was also implemented for a 3D TSE sequence with variable refocusing flip angles, and volunteer measurements were performed twice on a 3T scanner (MAGNETOM Trio A Tim System, Siemens, Erlangen, Germany) with same parameters, but different echo ambiguities: TR/TE = 3200ms/376ms; turbo factor = 250; [SL x PE x RO] = [150 x 224 x256]; sampling factor = 25%; echo ambiguity = 1 in the first scan, and 4 in the second scan.

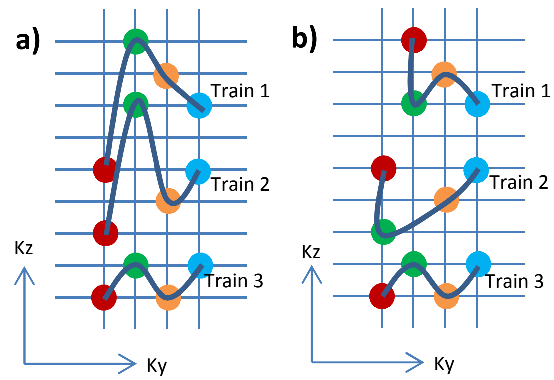

Fig.1 Illustration of different reordering schemes in a small subregion of *k*-space, here colors indicate the segmentation, curves indicate the echo train trajectories; a) traditional linear reordering; b) modified linear reordering with echo ambiguity = 4. It is observed that drastic fluctuations of echo train trajectories occur in traditional linear reordering where the *k*-space is strictly segmented along the K_y direction. However, the fluctuations are dramatically reduced in modified linear reordering, where 4 segments are combined, and *k*-space segmentation is adjusted to shorten the length of echo train trajectories.

Results & Discussion: In the Matlab simulation (Fig.2~3), it is shown that the train trajectory is much smoother in the modified linear reordering than that in the traditional linear reordering. The introduction of echo ambiguity in the flexible reordering actually performs a compromise between the smoothness of echo train trajectories and contrast purity. However, a small echo ambiguity does not lead to visible change of contrast when echo train length is long, as observed in our experiments (Fig. 4 and Fig.5). The concept of echo ambiguity can also be applied in radial reordering to reduce the fluctuations of trajectories. Smoother trajectories may be useful to reduce eddy currents and peripheral nerve stimulation when strong gradients are applied. Furthermore, it can help to improve the coverage of the *k*-space central region in partial averaging in CS SPACE, where only a very limited number of trains are acquired twice [3].

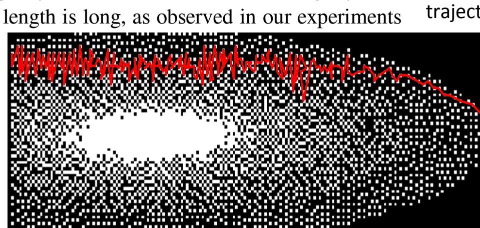

Fig.2 The trajectory of the 2nd train in traditional linear reordering (see red line)

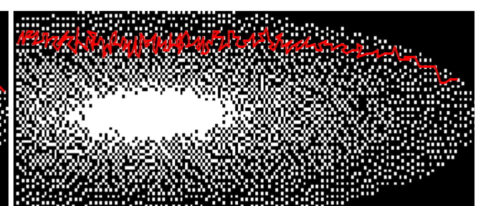

Fig.3 The trajectory of the 2nd train in modified linear reordering (see red line), where echo ambiguity = 4.

Conclusion: A modification of the flexible linear reordering scheme was presented to reduce the fluctuations of train trajectories in 3D TSE imaging with Compressed Sampling.

References: 1. Busse. ISMRM 2008, p837; 2.Lustig M et al, MRM 2007, 1182-1195; 3. Mugler, ISMRM 2004, p695;

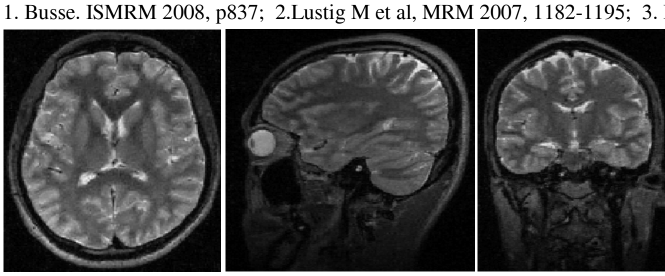

Fig.4 T2w head images using 3D TSE with traditional linear reordering

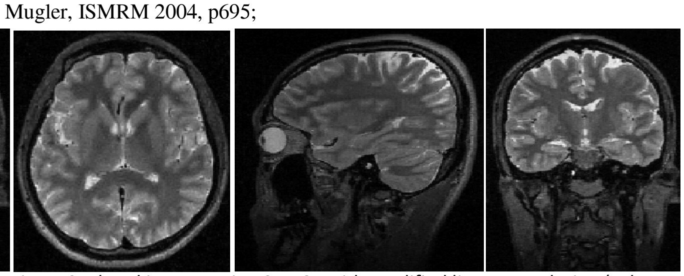

Fig.5 T2w head images using 3D TSE with modified linear reordering (echo ambiguity = 4)