A k-t variable-density undersampling technique (ktVDUST) for dynamic imaging

Y. Tao[1], and I. Marshall[1]

[1]Medical Physics and SFC Brain Imaging Research Centre, University of Edinburgh, Edinburgh, United Kingdom

Introduction

Dynamic imaging such as CINE cardiac MRI or MRI flow measurement is important while often time consuming. In dynamic imaging signal is collected from k-t space and it is possible to partially sample it to save scan time because generally there is spatiotemporal redundancy in real k-t space data. Quality of reconstructed images largely depends on the sampling pattern in k-t space and the assumptions used to recover the skipped data. For a general-purpose under-sampling technique without any prior knowledge of the imaged object, the k-t sampling pattern is crucial because that determines how much spatiotemporal information will be available for recovering skipped data. We noticed central parts of k-t space signal provide more information than outer parts so it should be more efficient to densely sample the central regions and sample the outer regions sparsely. Therefore we have developed a k-t variable-density under-sampling technique (ktVDUST) to increase scan speed. The k-t sampling pattern is simply customized to improve sampling efficiency and in reconstruction data of each k-space location is processed separately so the reconstruction is very fast. The technique can be easily implemented for scans with retrospective gating. It is also possible to parallelize this technique for further acceleration.

Methods

The design of the k-t sampling pattern follows two rules:

1. Central regions of k-t space are sampled more frequently than the outer regions. Number of samples for each k-space position can be customized to meet the overall acceleration target.
2. In the temporal dimension the k-t space should be sampled as evenly as possible. This means the samples of a same k-space location should be collected approximately equally spaced along the temporal cycle. For retrospective gating timing of each sample is not available but the interval between consecutive samples of a same k-space position is still in control.

In reconstruction each k-space location is processed separately. Number of temporal frequency components of the k-space position is assumed to be same or less than the number of samples collected.

Results

Prospectively gated and fully sampled mouse cardiac data (12 frames of a 256x256 slice) is used as true data for the simulations of data acquisition using retrospectively gated sampling patterns of ktVDUST and k-t BLAST [1] (Figure 1). Overall acceleration factor is 4 for both methods. In k-t BLAST central 1/8 of k-t space is fully sampled for the training data so only 1/8 k-t space is left for the dynamic data. In k-t BLAST reconstruction the data consistency equation is set up between x-f true data to be solved and the sampled data in k-t space. This equation is an equivalent of the equation in the original k-t BLAST but it is able to take retrospectively gated data as input directly. For each time frame, reconstruction error is estimated by the absolute average in a region-of-interest of the differences between reconstructed image and true image.

The reconstruction of ktVDUST took less than 1 second. For k-t BLAST it took more than 30 minutes. 4 frames of true data, results from ktVDUST and k-t BLAST are displayed in Figure 2. It is not difficult to find out there are more artifacts in k-t BLAST results than in ktVDUST frames. In Figure 3 the score of reconstruction error of ktVDUST is very close to that of k-t BLAST. There are still motion artifacts and blurs in ktVDUST results compared with true data.

Discussion

ktVDUST is similar to TRICKS [2] in sampling central k-t space more frequently. In ktVDUST k-space positions are not grouped into segments so k-t space can be sampled more efficiently. In k-t BLAST to minimize the x-f space overlap of signal the number of samples of all k-space positions are the same. With the same total number of samples ktVDUST can acquire more temporal information by spending more time on central k-space positions.

In addition to sampling pattern, quality of reconstruction results still depends on the imaged object. It is not possible to ensure in a certain acquisition the temporal information of true data is sampled as designed in the sampling pattern which is set before the scan, especially in a retrospectively gated scan. Although k-t space is sampled as evenly as possible, the samples can still happen to miss the required timing for retrieving enough information for a good reconstruction. In ktVDUST an automatic error check is added to the end of reconstruction for each k-space position to determine if a reduction of the number of temporal frequency components is necessary.

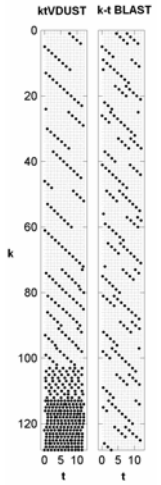

Figure 1: Upper half of the sampling patterns (retrospectively gated)

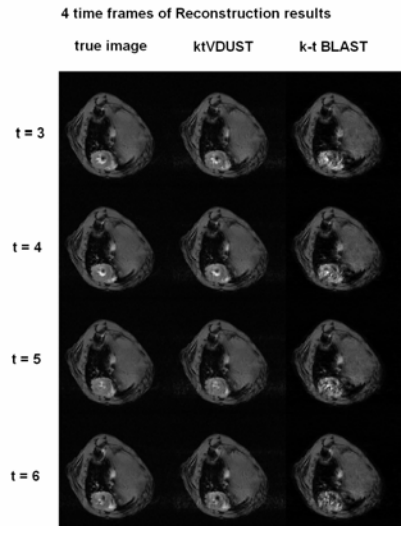

Figure 2: 4 time frames of reconstruction results

References

[1] Tsao J, et al. Magn Reson Med, 50, 1031-42. 2003.

[2] Korosec FR, et al. Magn Reson Med, 36, 345-351. 1996.

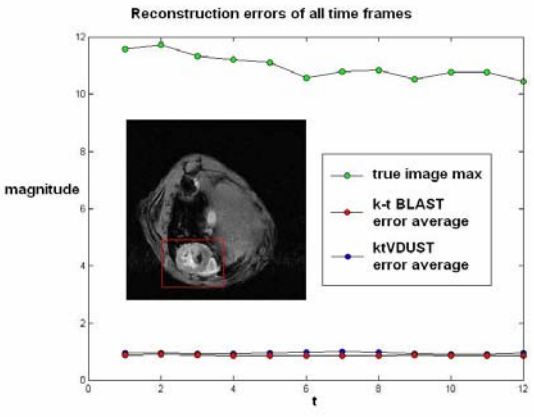

Figure 3: Reconstruction errors of different time frames