Reconstruction of Undersampled Dynamic Images Based on Time Frame Registration

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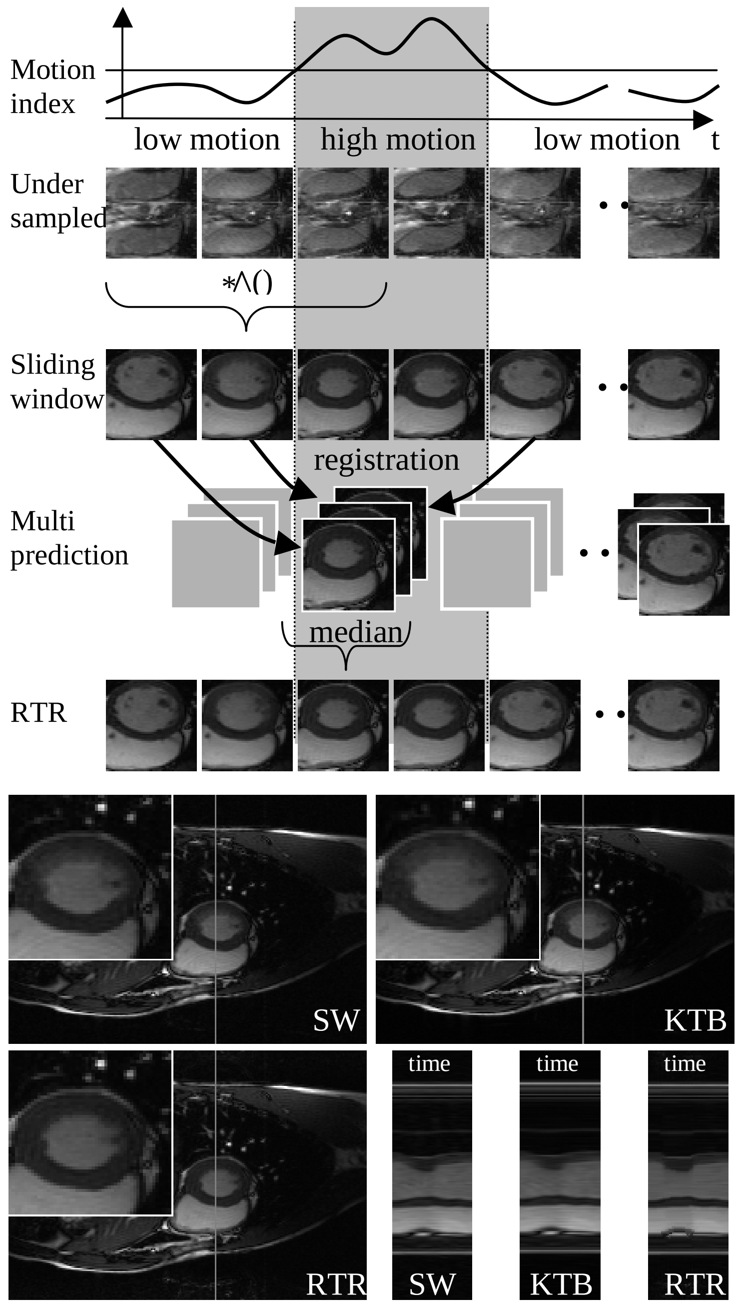
Introduction. Partial acquisition of *k*-space can be used in speeding up cardiac MR imaging. The missing *k*-space data can then be filled, by exploiting the object information redundancy in space and/or time. Several methods have been proposed to do this: partial Fourier [1], reduced field of view [2], keyhole [3], time averaging [4] or unaliasing by Fourier encoding (UNFOLD) [5]. Recently Tsao et al. [6] proposed a technique, *k-t* BLAST (KTB), that uses a skewed under-sampling pattern together with training data and regularized reconstruction for further increasing the acquisition speed whilst eliminating aliasing. All these techniques can produce temporal or spatial blurring in the reconstructed images, in particular when the algorithms operate in the Fourier domain.
We propose a technique for Reconstruction using Temporal Registration (RTR) that exploits the redundancy of information in the object domain by the means of predicting the time frames, while ensuring consistency with the sampled data. By using an average of the frames where there is little motion we obtain a clear (un-blurred) image which is used to predict the images for all frames, thus reducing blurring, especially in the frames with a large degree of motion.

Method. Let M_U be the under-sampled data in the k_x-t domain (missing samples are zero). The RTR method involves four stages: (1) An initial estimate, M_T, is obtained convolving M_U, in time, with a triangular function. This “sliding window” (SW) operation filters the temporal frequency. (2) A motion index is computed by the energy of the time derivative of m_T, , in pixels of high time variance. (3) A prediction is done by registering the set of the closest low motion frames to every frame in m_T (using a simple sliding block correlation, a la MPEG). A median filter is applied to this set of registered images to obtain m_P. (4) Finally, the differences with M_U are added to the reconstructed object, M_P in the k_x-t domain to match the acquired samples M_U.
To test the proposed reconstruction, we acquired a fully sampled 2D breath-hold retrospectively gated SSFP cine short axis slice (matrix 256x160, 50 time frames) using a 5 element synergy cardiac coil in a Philips Intera 1.5T. We simulated under-sampled data by only using one every five profiles, with a skewed k_x-t pattern as proposed in [6]. The same under-sampled data was also reconstructed with KTB (11 profiles for training).



Results and discussion. All three reconstruction methods, SW, KTB and RTR, have low Mean Absolute Errors compared to the fully sampled data (0.52%, 0.65% and 0.52%, respectively). As expected the SW reconstruction has a noticeable aliasing artifact. RTR reconstructs well-defined edges in space and time with no aliasing, as seen in the images right. Other advantages include easy applicability to non-cartesian *k*-space sampling, and unlike KTB there is no need for training data and does not make assumptions about image motion being restricted to small parts of the field of view. One disadvantage is the additional computational load, mainly used for the registration algorithm. This technique can easily be applied to 3D acquisitions.

Conclusion. We have proposed a method for reconstructing under-sampled dynamic images that uses the information redundancy from frame to frame to predict the missing *k*-space samples. The advantages of this technique over others are that it does not introduce blurring in space or time, and that it is easily applicable to non-cartesian sampling of *k*-space.

References. [1] McGibney et al. MRM 30,1 (1993); [2] Hu et al. MRM 31,6 (1994); [3] van Vaals et al. JMRI 3,4 (1993); [4] Xiang et al. JMRI 2,6 (1992); [5] Madore et al. MRM 42,5 (1999); [6] Tsao et al. MRM 50,5 (2003)