Reconstruction with Prior Information for Dynamic MRI

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Introduction

Prior-information driven techniques are based on the idea that one should be able to acquire fewer data points given some degree of prior information about the object being imaged. Prior-information driven techniques include the keyhole method [1], broad-use linear acquisition speed-up technique (BLAST) [2], etc. All these methods copy prior K-space information, and often lead to a smoothly varying view of the dynamic area. Reconstruction with Prior information for Dynamic MRI (RPID) utilizes both prior information in K-space and in image space, the prior information in image space being used as an iterative correction to the prior K-space data.

Method

Assume K_i is the ith set of acquired K-space data in a sequence of dynamic images, K_1 is fully accquired, all others are under-sampled. Let D_i be the region in K-space where K_i has some value (i.e., where data was sampled). D_i is called the dynamic area, the corresponding static area S_i is the set of positions where K_i has no value (when i is not unity). Hence K_1 and the correspondence image I_1 will be used as prior information with the static background area b chosen from I_1. Let K_i^n, $n = 1,2,3...$, be the n^{th} iterative approximation for K_i with I_i^n its corresponding image and I_{ib}^n the background data from I_i^n (with values in D_i set to zero). Let K_i^t represent the unknown fully sampled K-space we wish to approximate. Eq. 1, with FFT being the Fast Fourier Transform operator, follows from these definitions. Eq. 2 follows directly from Eq. 1. Since I_i^t is unknown, Eq. 2 can not be directly applied to obtain K_i^t. Fortunately, at the background area b, I_i^t should be nearly identical to I_{1b}, hence I_{1b} can be used to approximate I_i^t at b. Then also assuming I_i^t and I_i^n are close in value on D_i we obtain Eq. 3, an iterative correction to K_i^n. The constraint of Eq. 4 is added since we do not wish to change the values of the actual scanned data. Eq. 5 represents the starting point of the iteration using the actual under-sampled K-space data. The number of iterations may be terminated in 2 or 3 loops generating the iterative result K_i^{ir}. In order to take advantage of the prior K-space information, the final static area of the K-space, K_i^a, is defined as the weighted average of iterative result $K_i^{ir}(S_i)$ and prior static K-space data $K_1(S_i)$, with α_i in Eq. 6 being a weight. Combining equations (3-6), the flow chart in Figure 1 demonstrates the proposed method.

$$K_i^t - K_i^n = FFT(I_i^t - I_i^n) \quad (1)$$

$$K_i^t = FFT(I_i^t - I_i^n) + K_i^n \quad (2)$$

$$K_i^{n+1} = FFT(I_{1b} - I_{ib}^n) + K_i^n \quad (3)$$

$$K_i^{n+1}(D_i) = K_i(D_i) \quad (4)$$

$$K_i^1 = \begin{cases} K_i & ,D_i \\ 0 & ,S_i \end{cases} \quad (5)$$

$$K_i^a = \begin{cases} K_i & ,D_i \\ \alpha_i K_i^{ir} + (1-\alpha_i)K_1 & ,S_i \end{cases} \quad (6)$$

References

[1] Suga, M., et al., JMRI 10:778-783, 1999.
[2] Tsao, J., et al., Magn Reson Med 46: 652-660, 2001
[3] Huang, F., et al., submitted to ISMRM, 2004.

Results and Discussion

Figure 2 shows results for Cardiac Images collected by a 1.5 T GE system (FOV 280 mm, matrix 160×120, TR 4510 ms, TE 2204 ms, flip angle 45°, Slice thickness 6 mm, number of averages 2) through Fast Imaging Employing Steady-State Acquisition (FIESTA) with a GE 4-channel cardiac coil. Breath-holds ranged from 10-20 seconds. There were 20 images per heartbeat. For reconstruction, only the 1st image utilized the full K-space. Reconstruction for all the other images used the center 20% of K-space. Weights α_i were chosen through a Gauss distribution in order to give less weight to K_i^{ir} when there was little change in the dynamic area from the reference image I_1. The time required for processing all 20 images via RPID was 7.98 seconds using a PC with a 1GHz CPU and 1 Gb RAM. The reference image is reconstructed with a fully sampled K-space. The proposed RPID method works for arbitrarily shaped dynamic areas of K-space. RPID has fewer errors in the image's dynamic area than keyhole has with a comprable degree of background error. This method can be easily combined with parallel imaging techniques to improve the reconstruction quality. For example, the dynamic K-space area can be scanned with equal spacing and several extra ACS lines, then LIKE [3] may be applied to interpolate the missing lines before applying the RPID method for final recontruction.

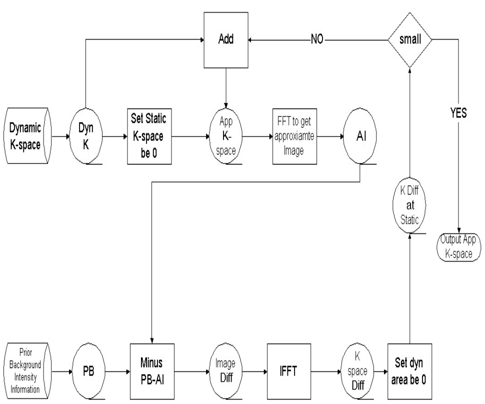

Fig 1.The flow chart of RPID

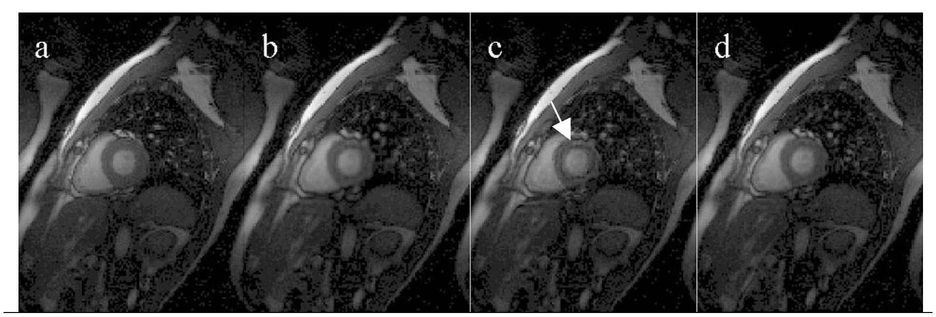

Fig 2. Some results of RPID for Cardiac images. Each image uses the same gray scale. a) reference of the 9th image; b) reconstructed result of the 9th image by RPID, the relative error is 10.56%; c) reconstructed result of the 9th image by keyhole, the relative error is 11.11%, the arrow shows the obvious error; d) reconstructed result of the 9th image by RPID with LIKE, the relative error is 10.07%