Compressed Sensing with Compressed Channels

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Introduction

In MRI, imaging using receiving coil arrays with a large number of elements is an area of growing interest. With increasing channel numbers, longer reconstruction times have become a significant concern. Channel compression [1] has been proposed to reduce the processing time. However, the degree of channel compression is limited by the need to avoid significant signal loss. In this work, a novel technique called flexible virtual coil (FVC) is proposed for faster channel-by-channel compressed sensing [2, 3]. The fundamental aspect of the proposed method is to use all acquired data, instead of only the data from compressed channels, in the final reconstruction. Using *k-t* FOCUSS [3] and a 32-channel cardiac coil as specific examples, the proposed method was 5 times faster than the conventional channel compression technique, while achieving better image quality.

Theory

The difference of the proposed method from conventional channel compression technique is to use relative sensitivity maps to include all acquired data in the final reconstruction. Figure 1 shows the flow chart of the proposed FVC scheme. The part in dashed line is the same as existing channel compression technique [1]. However, FVC only applies channel-by-channel compressed sensing to a selected number of virtual source channels, which are linear combinations of the original channels. . An optimal combination scheme is then applied to compressed sensing results to generate a composite image I_{FVC}. The relative sensitivity maps S^j_{FVC} (*j* is the count of channels, *j*=1, …, N_c) are the sensitivity maps of each combined channels relative to I_{FVC}. Once I_{FVC} and S^j_{FVC} are given, then image of each combined channel can be approximated by $S^j_{FVC} \times I_{FVC}$. By inserting the partially acquired data into the inverse Fourier transform of these approximated images, the set of reconstructed *k*-space of all channels is derived. This set of full *k*-space data is used for the final reconstruction. For *k-t* FOCUSS, the temporally invariant term (i.e., direct-current or DC) can be used for the relative sensitivity map calculation. DC is the average of *k*-space along the time direction, which is a full *k*-space. Since all acquired data are used for final reconstruction, the loss of signal due to channel compression will not happen even if only a few channels are used in FVC.

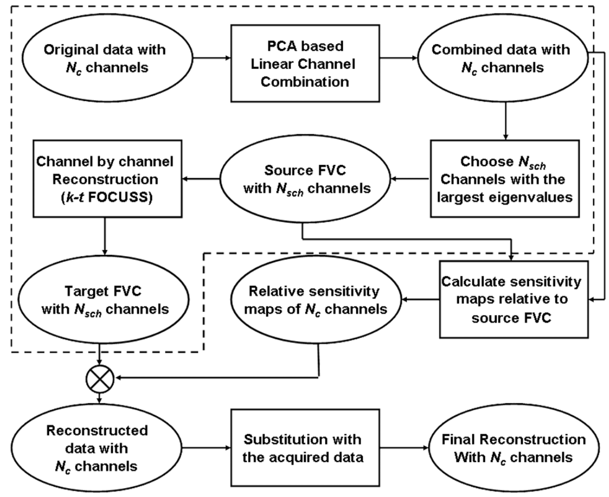

Fig. 1. Flow chart of the proposed flexible virtual coil method. The flow chart in dashed lines is the conventional channel compression scheme.

Methods and Results

Using a 32-channel cardiac coil (Invivo Corp., Gainesville, FL) with electrocardiography (ECG) gating, one set of cardiac cine data was acquired on a Philips 1.5 T system (Philips, Best, The Netherlands). A healthy volunteer was scanned using a balanced TFE sequence in a single 23s-long breath-hold. The acquisition parameters were FOV 320×320 mm^2, matrix size 192×190, heartbeats per acquisition 38, phase encodes per segment 5, number of phases 30, TR 3.4 ms, TE 1.72 ms, flip angle 60°, and slice thickness 8 mm. Fully acquired data were artificially down sampled with net acceleration factor 4. The method proposed in Ref. [1] was used for region of interest (ROI) optimized channel combination. In the proposed FVC *k-t* FOCUSS, only the channel with the largest eigenvalue was processed by *k-t* FOCUSS. All other 31 combined channels were reconstructed using relative sensitivity maps and insertion of partially acquired data. All methods were implemented using the Matlab programming environment, and were processed on an xw4100 HP workstation with two 3.2 GHz CPUs and 2 Gb RAM. Figure. 2 shows the results. The reconstruction time for Figs. 2a, 2c, and 2e was 68, 315, and 741 seconds respectively. The root mean square error (RMSE) of these images was 6.0, 22.3, and 5.1% respectively.

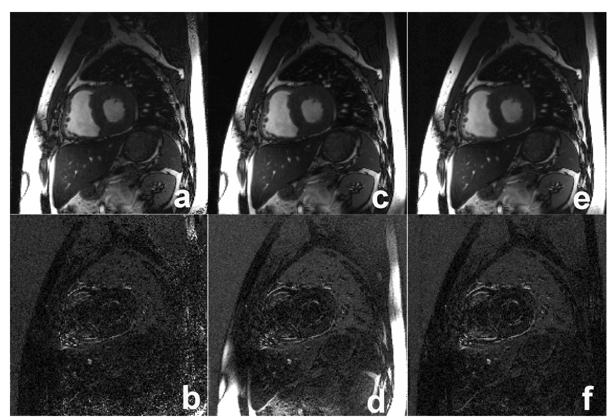

Fig. 2. Images reconstructed at net acceleration factor 4 with single channel FVC (a-b), conventional channel combination method with 12 compressed channels (c-d), and all 32 channels (e-f). The second row shows the difference maps (brightened 5 times) to the reference images.

Discussions and Conclusion

In FVC *k-t* FOCUSS, only one channel was processed by *k-t* FOCUSS. On the contrary, the conventional channel compression technique with 12 combined channels and the method without channel compression processed 12 and 32 channels by *k-t* FOCUSS. Hence, FVC *k-t* FOCUSS was 4.6 and 10.9 times faster than those two methods. Moreover, because the 20 combined channels with smaller eigenvalues were abandoned in the conventional channel combination technique, significant loss of signal can be observed (Fig. 2d). FVC *k-t* FOCUSS solved the problem (Fig. 2b) using relative sensitivity maps. In conclusion, the proposed FVC scheme can significantly reduce the reconstruction time of channel-by-channel compressed sensing, while preserving image quality.

References : [1] Huang F., et. al. MRI 2008; 26(1):133-141.[2] Lustig M. , et. al. MRM 2007;58:1182-1195. [3] Jung H. , et. al. MRM 2009;61:103-11