Flexible Virtual Coils (FVC) for Faster Channel-by-Channel Partially Parallel Imaging

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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 for parallel acquisition, longer reconstruction times have become a significant concern. Channel compression [1], direct virtual coil (DVC) [2] and synthetic coil (ST) [3] have been proposed to reduce the processing time of channel-by-channel partially parallel imaging (PPI) techniques [4]. In this work, a technique called flexible virtual coils (FVC) is proposed to enable faster and more accurate reconstruction than these existing techniques.

Theory

A common feature of Channel-by-channel reconstruction parallel imaging techniques (e.g. GRAPPA) is to derive data on a number of target channels from a number of source channels prior to final optimal channel combination. As a result, the number of source channels (N_{sch}) and the number of target channels (N_{tch}) determine the reconstruction time. Figure 1 shows the flow chart of the proposed FVC scheme. There are two fundamental aspects of FVC that differs from existing techniques. 1) To reduce both N_{sch} and N_{tch} simultaneously, but not necessarily equally. Based on this idea, two FVCs, source FVC (with N_{sch} virtual channels) and target FVC (with N_{tch} virtual channels), are defined. This aspect is different from conventional channel compression scheme, which reduces N_{sch} and N_{tch} simultaneously and equally. It is also different from DVC/ST scheme, which does not reduce N_{sch}. The FVCs are composed of one or more virtual channels and each virtual channel is a linear combination of the original channels [1]. 2) All acquired data are incorporated into the final reconstruction by using relative sensitivity maps. In all existing techniques, only data from target FVC are used in the final reconstruction. This feature enhances the accuracy of the proposed method by using all available information. For GRAPPA [4], the relative sensitivity maps can be computed using fully-sampled auto-calibration signal.

Methods and Results

One set of head images was acquired on a Philips 3T system using a 32-channel head coil (Invivo Corp.) using T_1-weighted gradient-echo sequence (FOV 205×205 mm^2, matrix size 256×256, TR 25 ms, TE 6.3 ms, flip angle 30°, and slice thickness 5 mm). The fully acquired data set was artificially down-sampled by a reduction factor of 4 with 48 ACS lines. The net acceleration factor was approximately 2.6. For FVC based GRAPPA, the method proposed in Ref. [1] is used for channel combination. N_{sch} and N_{tch} were 16 and 6, respectively. GRAPPA reconstruction with 16 compressed channels, with DVC reconstruction (phase of DVC was experimentally chosen to minimize RMSE), and without channel compression were carried out for comparison. 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. Fig. 2 and Table 1 demonstrate the improved speed and accuracy of FVC over existing techniques.

Discussions and Conclusion

Experimental results show that FVC based GRAPPA was faster and more accurate than channel compression scheme [1]. The reason is that the proposed FVC scheme reconstructed fewer target channels, but used all acquired data in the final reconstruction. The FVC scheme was 2.8 times faster than DVC/ST scheme, and resulted in lower RMSE. This is because that the DVC/ST scheme does not reduce N_{sch}, which has a larger influence on reconstruction time than N_{tch}. Another issue of DVC/ST is the optimized definition of the phase of the DVC/ST is not known yet [2, 3]. And the accuracy of the final reconstruction can be significantly compromised due to inaccurate phase definition. Since FVC scheme uses linear combination for channel combination, it avoids the phase definition problem. In conclusion, flexible virtual coil is expected to have a major impact in reducing computation cost in parallel imaging with high-channel count coil elements.

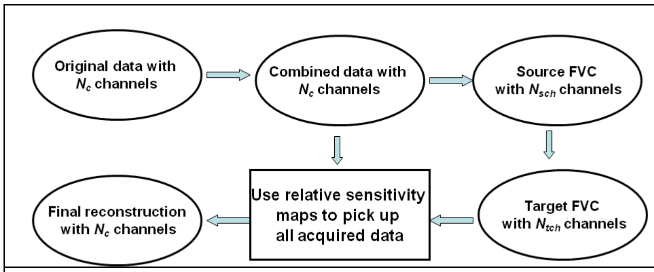

Fig. 1. Flow chart of the proposed flexible virtual coil method.

Table 1. Comparison of channel reduction schemes

	FVC	16 ch	DVC	32 ch
Rec Time in second	20	28	56	117
RMSE %	2.6	3.2	4.1	2.8

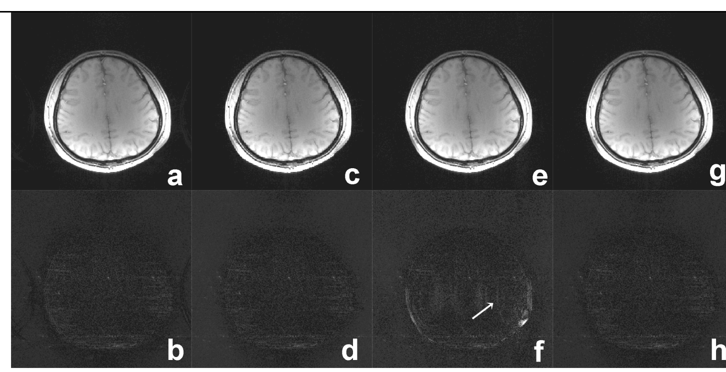

Fig. 2. Comparison of reconstruction schemes for GRAPPA with net acceleration factor of 2.6 using a 32-channel head coil. The first row shows the reconstructed image. a), c), e), and g) are reconstructions by GRAPPA with FVC (16/6 source/target virtual channels), Conventional channel compression with 16 channels, DVC, and conventional GRAPPA (no compression). The second row shows the corresponding error maps. The error maps are brightened five times.

References : [1] Huang F., et. al. MRI 2008; 26(1):133-141.[2] Beatty PJ. , et. al. ISMRM16, 2008; p8. [3] Chen W., et. al. ISMRM 16, 2008; p1296. [4]Griswold MA. , et. al. MRM 2002;47:1202-1210