Channel Compression and Denoising

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Introduction: With the advent of partially parallel imaging (PPI) techniques, the demand for multiple channel coils has increased drastically, thereby increasing the reconstruction time and computer memory requirements. Considerable work has been done in the field of hardware channel compression [1,2] and lately the software implementation of channel compression [3,4]. Here, we describe the key advantages of the latter and how it can be used as a denoising technique for PPI as well as non-PPI techniques. The primary advantages of software channel compression are that it reduces the computation/reconstruction time and the memory requirements of the scanner without affecting the image quality much. It was shown in [3, 4] that the g-factor and parallel imaging capabilities of a coil are not significantly affected even by aggressive channel compression. It is known that in the straight square root of sum of squares (SSoS) reconstruction of MR data, in regions of low signal intensity, increased number of channels implies more noise, thereby changing the image contrast. Here, we also present channel compression to be an efficient denoising technique in that it helps to reduce the noise bias in the image.

Methods: Channel compression is achieved by performing principal component analysis (PCA) on the raw k-space data obtained from the scanner and extracting the combination matrix accordingly. It is an inherent property of the PCA is to concentrate the useful information into fewer channels, and the amount of information is described by the Eigen values so obtained. Hence, this was used as a criterion for determining how many channels need to be discarded to denoise the image. In our case, it was determined that all channels with Eigen values less than 1% of the maximum would contribute just noise and hence that many channels were left unused. Data were acquired using the 32 channel cardiac coil (Invivo Corporation, Gainesville) on a 3.0T TIM Trio scanner (Siemens Medical Solutions, Erlangen, Germany), using a standard turbo-FLASH sequence with an acquisition matrix of 118x384. Using the criterion of rejecting channels with less than 1% of the maximum Eigen value, we reduced the data from 32-channels to 12 channels.

Results: Figure 1(a) shows the reference 32 channel image – with our region of interest (ROI) defined by the green box encompassing the heart. The red box illustrates the region over which the signal mean and standard deviation were computed for the SNR. The blue line through the image illustrates the line profile obtained across the image that is shown in figure 4. Figures 1(b) and 1(c) show the standard square root of sum of squares (SSoS) image of the original 32-channel dataset, and the compressed 12 channels data. From the difference map (Figure 2), it can be seen that there is no signal loss and the difference is just noise at ROI. The SNR, computed as the ratio of the mean of the signal region in the ROI placed in the heart to that of the standard deviation of values in the same region is shown in Table 1. Also, the effect of this channel reduction technique on PPI capabilities of the coil was investigated. A reduction factor of 3 was simulated and g- factor maps computed for both cases. Figures 3(a) and 3(b) show the g-factor maps obtained for the case of 32 and 12 channels respectively. The mean g-factor values computed in the chosen ROI (heart) are also shown in Table 1. Figures 4(a) and (b) illustrate the line profiles through the images obtained using 32 and 12 channels across the whole image and the zoomed ROI respectively.

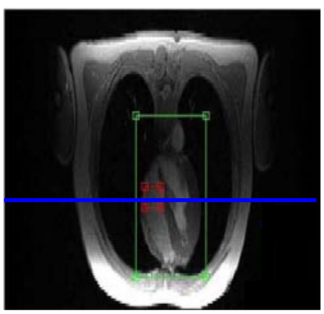

Fig. 1(a) Reference image showing the ROIs for SNR and the g-maps.

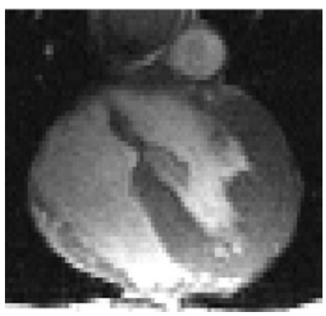

Fig. 1(b) SSoS of 32 channel data

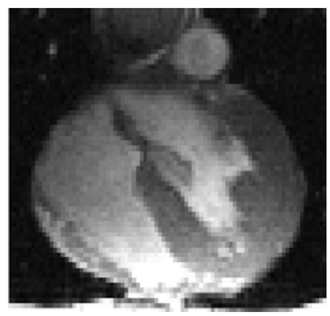

Fig. 1(c) SSoS of 12 channel data

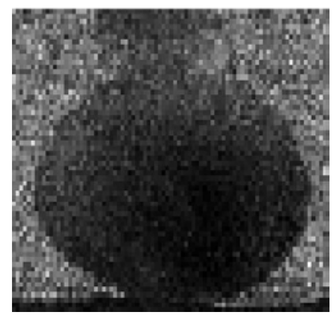

Fig. 2 Difference image between 1(b) and 1(c)

Table 1. Table showing SNR, std. g-map values

	32	12
SNR	7.164	7.684
g-map (mean over green ROI)	1.6086	1.9567

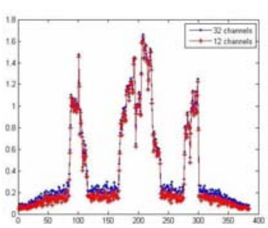

Fig. 4(a) Line Profile: whole image

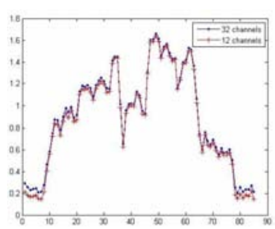

Fig. 4(b) Line Profile: ROI

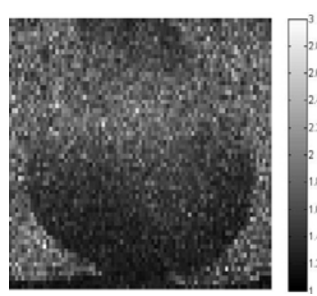

Fig. 3(a) g-map:32 channels (R=3)

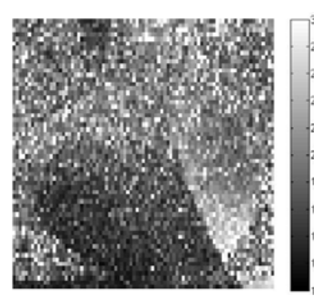

Fig. 3(b) g-map:12 channels (R=3)

Conclusion & Discussion: The results clearly indicate that the channel compression technique can be used effectively to denoise an image without losing the image signal and the parallel imaging capabilities much. From the line profiles in Figure 4 and the SNR value obtained, it can be verified that the channel compression technique can definitely improve the SNR obtained in low intensity regions and can eliminate a big noise bias in them. The number of channels to reduce to however needs to be determined by setting a threshold on Eigen values obtained from PCA. Overall, an efficient way to denoise and reduce the memory and computation time requirements for multiple channel data is presented.

References: [1] King S.B. et al. Proc. ISMRM, p.712, 2003. [2] Gotshal U. et al. Proc. ISMRM, 2004. [3] Huang F. et al. Proc. 27th Annual International Conference of the IEEE-EMBC, p.1190, 2005. [4] Vijayakumar S. et al. Proc. of the 9th Annual meeting of SCMR, p. 251-252, 2006.