Image Reconstruction of Low SNR Images from Large-N Arrays

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Introduction

The number of receive channels used for parallel reception has increased from 4 or 8 receivers to 32 on many clinical scanners and as many as 96 for experimental systems. This order-of-magnitude level increase was motivated by the desire to increase image sensitivity and improve the acceleration capability of parallel acquisition. While accelerated imaging reconstructions make use of the detailed coil sensitivity profiles and correlations of the array elements, un-accelerated imaging commonly relies on the Sum-of-Squares (SoS) combination method. The SoS method is favored due to its computational simplicity and good performance in most cases.[1] However, it has been pointed out that optimal combination of the receiver data with the SoS method requires that the measured image intensity of an array element is a good approximation of the expected coil sensitivity profile and that this assumption is violated for low SNR data.[1,2] However, previous simulations of this effect utilized the relatively low number of receive channels available at the time, where the SoS method did not give drastically degraded results. In this work, we simulate the SNR penalty for SoS combination in low SNR images using noise maps and coil sensitivity data obtained from 8, 23, and 90 channel head arrays [3] by comparing the SoS method to combination based on a coil sensitivity map. We find that the noise amplification of the SoS method within a low SNR object increases significantly with the number of array elements and the penalty is maximum near the array elements. The spatial variations in the noise levels also become larger with more channels and weighted reconstruction. With the 90 channel arrays, use of measured coil sensitivity profiles can improve the SNR of low sensitivity regions by up to a factor of 3. For cases where coil sensitivity cases are not available, we test a modified version of the SoS method which also improves performance in low SNR data from large arrays.

Methods

MR Imaging was performed on a Siemens Avanto 1.5T system (Siemens Medical Solutions, Erlangen, Germany) using the body RF coil for excitation and three different head array coils (8, 23 and 90 channels) for reception. Complex coil sensitivity profiles and coil noise maps were obtained from each channel in a head shaped phantom. The noise maps were acquired with zero flip angle excitation. To show the effect of SoS and weighted reconstructions on low SNR data, a data set was generated by fabricating a head-shaped "object" with low signal intensity and known contrast features. Each channel's expected view of the object was modeled by multiplying the object by that channel's measured sensitivity profile and adding the measured noise seen by that channel. The modeled data was then reconstructed with both a SoS combination and a reconstruction where each channel's data was weighted by the measured coil sensitivity profile and then summed (sensitivity weighted reconstruction). [4] The procedure was performed for both a low SNR model (SNRmax ~ 4) and for a zero SNR model (no signal). The latter highlights the considerable spatial variations in the noise map for the sensitivity weighted reconstruction.

For cases where the coil profiles are not available, an improved SoS scan can be achieved by multiplying each coil's data by a smoothed version of itself. Thus the coil sensitivity profile at a given location is not approximated by the received image intensity at that location (which is corrupted by noise), but by a spatially smoothed version which provides a higher SNR estimate. This method (with 8mm Gaussian kernel) was compared to the conventional SoS method.

Results and Conclusion

Figure 1 shows the noise distribution maps (zero SNR object) and profiles for the 8ch, 23ch and 90 channel phased array coils reconstructed with both the SoS and sensitivity weighed reconstruction. The differences in noise distributions and levels increase with increasing number of array elements. For the 90 channel array, sensitivity weighted reconstruction shows similar noise levels to SoS in the center of the head (where all coils contribute with roughly equal weighting) but nearly 3 fold improvements in noise levels near the array. This reflects amplified noise in the SoS reconstruction; the SoS method emphasizes the receiver channels which happen to experience the largest statistical noise fluctuation rather than the receivers with the highest detection sensitivity at that location. The modified SoS method is able to improve visualization of contrast features compared to the standard SoS method, but is not as effective as the sensitivity weighted reconstruction.

Figure 2 shows reconstructions of the low SNR model object for the 8, 23 and 90 channel arrays. The conspicuity of the low contrast grid pattern in the object is improved in all cases with the sensitivity weighted reconstruction with larger improvements for the larger arrays. In cases of low image SNR, the increasing penalty of the SoS reconstruction significantly reduces the sensitivity advantages from larger N arrays. Figure3 shows the modified SoS method for the 90ch array.

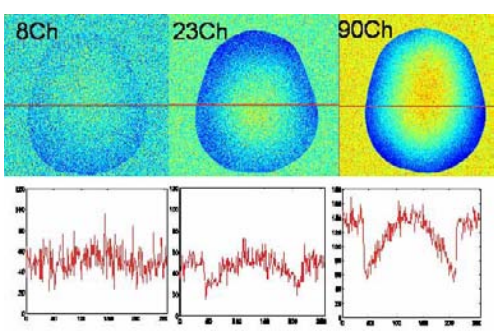

Figure 1. Top: Noise distribution in combined images from the zero SNR data and profiles at location shown. Regions outside the phantom are comparable to the SoS reconstruction since no coil map information is present. The gain in SNR from weighted recon is about 3-fold in the cortex (90ch array).

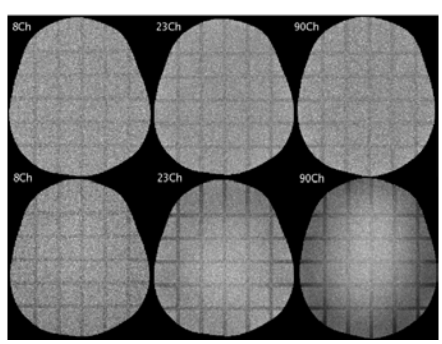

Figure 2. Reconstruction from the 8, 23, and 90 channel array using Sum-of-Squares (top row) and sensitivity weighted reconstruction method (bottom) on the low SNR images.

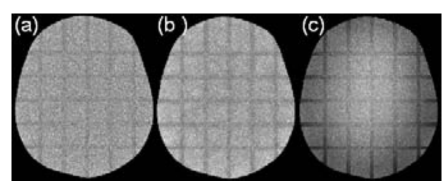

Figure 3. Reconstruction from the 90ch array using a) SoS, b) modified SoS and c) sensitivity weighted reconstruction method.

References: 1)Roemer P.B.,et al, MRM,16:192-225, 1990, 2)Constantinides C.D.,et al, MRM, 38:852-857, 1997, 3)Wiggins, G.C.,et al, ISMRM,p679, 2005, 4)Wright S.,et al, NMR in Biom.,10:394-410,1997.**Acknowledgements:**NIHP41RR14075,MIND Institute.