A method to combine multi NEX diffusion weighted images using Homomorphic filter

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[Target audience] audience who are interested in diffusion and liver imaging.
[Purpose] Tissue movements from respiration, cardiac, and peristaltic motion during diffusion gradient can cause signal loss, which often leads to local overestimation of ADC map. The movements are hard to model or predict, and combined use of gating can result in extremely long scan time in scans such as intra voxel incoherent motion. To reduce signal loss, maximum intensity projection, weighted averaging or weighted multiplication methods have been proposed[1]. These post processing methods are simple and efficient; however the final images cannot achieve pixel intensities higher than acquired raw images. To overcome such limitation, we introduce a new image combining method with homomorphic filtering (H-MSW). In this work, homomorphic filter[2] is applied within the regions with high signal variation during multiple NEX acquisitions, then magnitude squared weighted averaging is applied to combine the homomorphic filtered images. We investigated the feasibility of the proposed method and compared with conventional multi NEX combination methods.
[Methods] Simulation study: A simulation study was performed by applying 2D Gaussian signal loss to a spin echo EPI image at 25 random locations. For each location, 2D Gaussian modulation was applied four times with random scaling factors in order to mimic the nature of signal loss during multi NEX free breathing diffusion acquisition. The simulated data was combined using conventional averaging, magnitude squared weighted averaging (MSW), and the proposed homomorphic filtered magnitude squared weighted combination (H-MSW) method. All methods were implemented using MATLAB (Mathworks, Natick, MA).
Volunteer study: Free breathing diffusion weighted images were acquired on a single volunteer five times on a GE 1.5T scanner (GE Healthcare, Waukesha, WI). For each acquisition, b=1000 s/mm^2, single direction (3 in 1), 4 NEX, TR 7s, TE67.9ms were used, while saving individual NEX images. After applying three NEX combination methods to the volunteer data, ADC maps were calculated. The ADC standard deviation maps were calculated from five repetitions for each processing method.
[Results] In simulation study, the average NRMSE (Normalized Root Mean Squared Error) was found to be 12.4% in conventional averaging, 9.14% in magnitude squared weighted averaging, and 8.29% in the proposed H-MSW method. Figure 1 shows the simulation results. In volunteer study, standard deviation was found to be reduced significantly near left upper area of liver, which often suffers diffusion signal loss due to cardiac motion. Figure 2 and 3 show volunteer experiment results.
[Discussion] The simulation result indicates that the proposed H-MSW combination method can improve image quality over conventional averaging and magnitude squared weighted averaging. The proposed method does not distinguish diffusion signal loss from other slowly varying signal inhomogeneity such as surface coil intensity variation or dielectric artifacts. Therefore, a pre-processing to reduce such non-uniformity may be necessary. In order to minimize confusion with pathology induced signal loss, the homomorphic filtering process is limited to the areas with high temporal variation. The proposed method used addition instead of multiplication of modulation function to preserve SNR level, which may reduce the tissue contrast within the filtered region. The proposed method did not degrade overall image quality in all slice locations both in simulation data and in vivo data.
[Conclusion] A new image combination method for multi NEX diffusion acquisition was implemented. By simulation and in vivo experiment, it was shown that the new method can improve the accuracy and reproducibility of diffusion weighted imaging.
[References] **1**.Li et al., Smart combination: A technique for reducing cardiac motion induced signal loss in diffusion-weighted liver imaging. Proc. Intl. Soc. Mag. Reson. Med. 20 (2012)
2.Lim, Two-dimensional signal and image processing, Prentice Hall, 1990

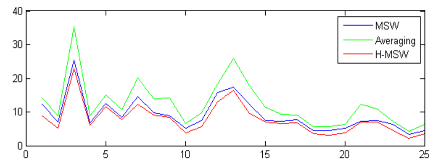

Figure 1. *Simulation result*: NRMSE (%) for all 25 simulated signal loss locations. The average NRMSE was found to be 12.4% using conventional averaging, 9.14% in magnitude squared weighted averaging, and 8.29% in the proposed H-MSW method.

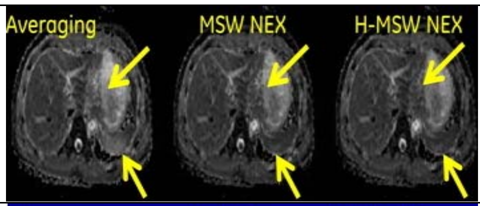

Figure 2*. In vivo experiment :* ADC maps from each method.The over estimation of ADC in left liver dome (upper arrows) and spleen (lower arrows) are observed in conventional averaging method.

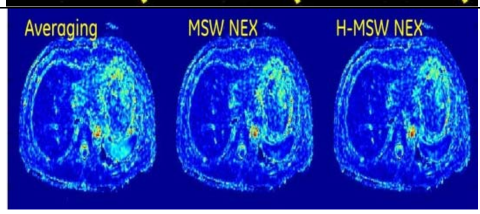

Figure 3*. In vivo experiment :* standard deviation map of ADC maps from each method. The proposed method reduced standard deviation significantly over conventional averaging and magnitude square weighted averaging.