A Simple Fast Method of Gibbs Ringing Artifact and Noise Reduction with Edge Enhancement Using Low-pass, Band-pass, and High-pass K-Space Windowing Functions

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Introduction: Gibbs ringing artifacts reduction has been one of the very basic subjects in MRI imaging, which attracted a sizeable literature proposing many different algorithms. The commonly used *k*-space low-pass filtering method blurs out fine image details and reduces general edge definition. One the other end, the much more elaborate Gegenbauer reconstruction [1], and the "total variation (TV)" constrained data extrapolation and other extrapolation methods [2-3] (similar to anisotropic diffusion, which is popular in CT) are complex and iterative, tend to be slow, and tend to produce carton-like result with piece-wise constant compartments, which does not look natural for MR because of the fine gradation nature of the general soft tissue contrast.

Method: We propose a simple, fast, and rather straightforward method for simultaneous ringing and noise reduction plus edge enhancement, based on multiplying the raw *k*-space data with low-pass (LP), band-pass (BP), and high-pass (HP) windowing functions separately, and combining the results in image space, as illustrated in Figure 1. All the *k*-space windowing functions have been optimized, with the shape of the BP filter selectively picking up the edges from a carefully controlled range of mid-range spatial frequencies, to enable an edge mask of exact edge thickness after thresholding and feathering, and to match the active edge enhancement range of the HP Laplacian sharpening mask. Slow image domain convolution operations, such as these used in the commonly used Canny edge detectors, are avoided, since we are not interested in pixel thin edges, but rather a region around them. The sharpening mask is added back to the LP smoothed image through the edge mask.

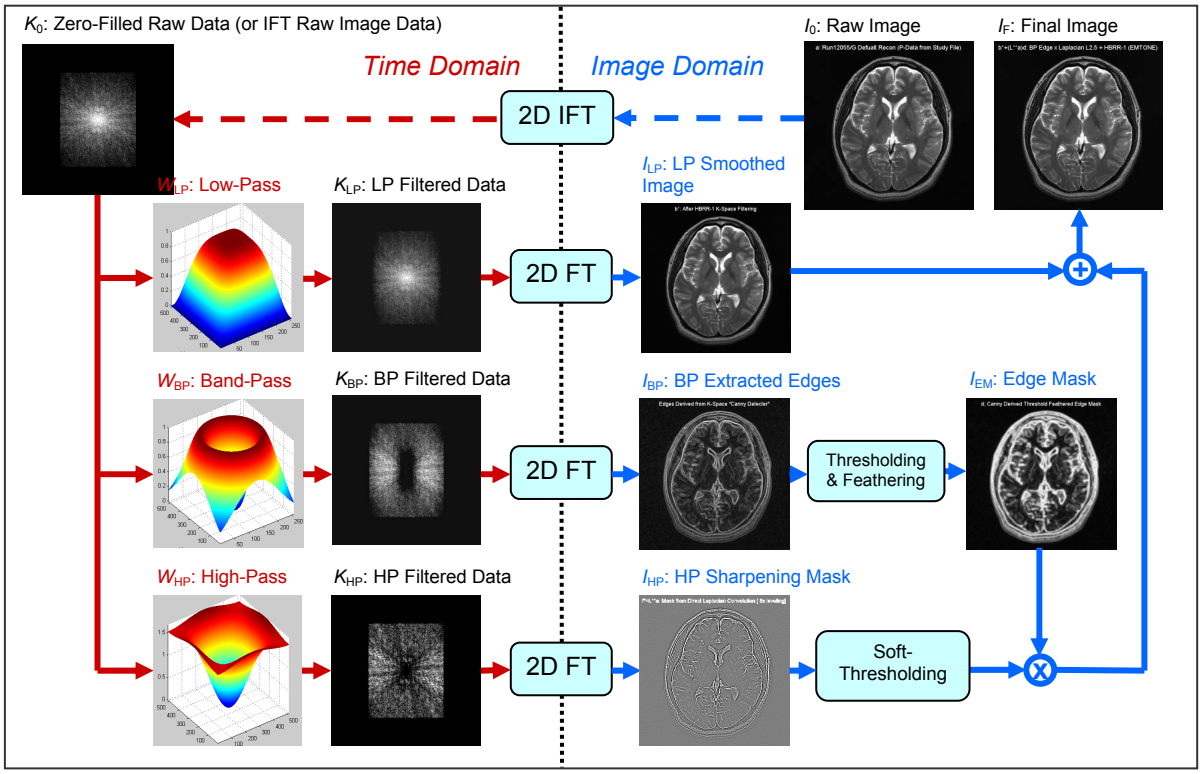
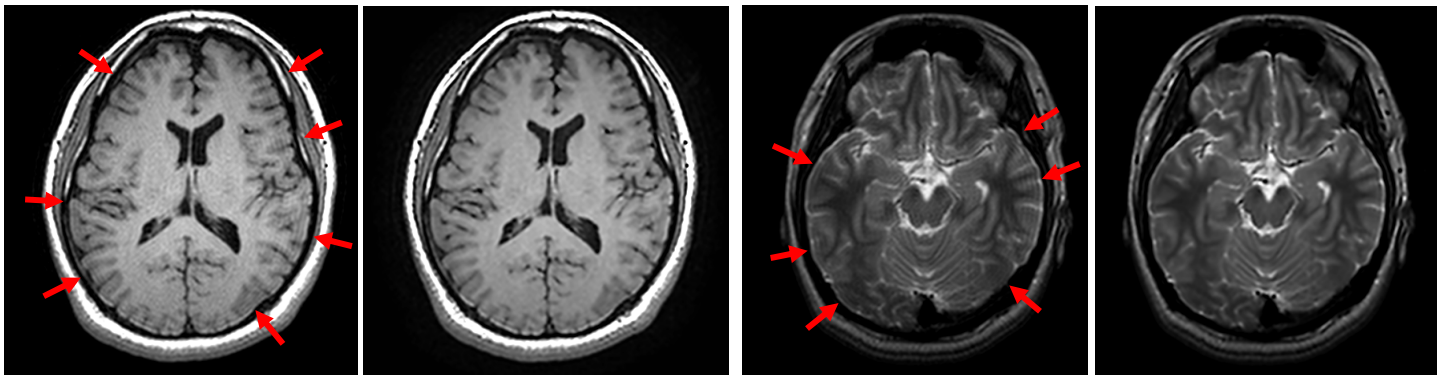


Figure 1: Illustration of the proposed algorithm with matching low-pass, band-pass, and high-pass *k*-space windowing functions. The use of a band-pass frequency domain filtering for edge region extraction is the key new feature of the method.

Figure 2 (below): Samples of T1- and T2 -weighted brain scan MR images before (left side of each image pair) and after (right side) processing with the proposed method.

Results: Demonstrated in the examples in Figure 2, we found the proposed method efficient in removing ringing artifacts and noise from both low-resolution and high-resolution MRI images, while at the same time enhancing edge delineation and fine detail conspicuity. The overall processed image quality betters that from many more complicated methods in the literature, and from some of the commercially available filter packages, while the simple algorithm runs much faster.



References:
[1] Amartur, S. & Haacke, E.M., **JMRI 1**: 307-317 (1991). [2] Amartur, S., Liang, Z.-P. & Haacke, E.M., **JMRI 1**: 721-724 (1991).
[3] Archibald, R. & Gelb, A., **IEEE Trans. Med. Imag. 21**: 305-319 (2002).
[4] Block, K.T.; Uecker, M. & Frahm, J., **Int. J. of Biomed. Imag.**: ID 184123 (2008).