High resolution 3D imaging using multiple oblique view acquisitions

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Introduction Conventional 3D MR imaging typically uses 3D Fourier encoding acquisitions and/or 3D Fourier transform based reconstruction. However, for high resolution 3D imaging using these methods, SNR can be a limiting factor along with side effects such as ringing with Fourier based reconstruction. Here, we propose an alternative 3D high resolution imaging method where multiple 2D acquisitions are performed using a variable oblique-view pulse scheme. An image-based reconstruction is performed using an iterative back projection process thereby enabling flexible tradeoffs between SNR and resolution.

Methods The proposed pulse scheme can be understood as acquiring images projected on to the z-plane from tilted subject views along user defined angles($\tan\theta_n = G_{SS\_add_n}/G_{RO}$) as shown in Fig. 1. This kind of sequence was already introduced as view angle tilting (VAT) with optimal Gz gradient for some applications such as chemical shift correction [1] and metal artifact correction [2]. In the k-space perspective, this sequence acquires kz data according to additional Gz gradient. Subsequently, the acquired data sets can be reconstructed as 3D images. 2D images are acquired by changing the amplitude of additional Gz gradient along the angles and are reconstructed as 3D using an image based iterative back projection algorithm in Fig. 2. By modifying the transform function T in the iterative back-projection algorithm [3], we can reconstruct 3D images appropriately suited to the acquired 2D images. Simulations were performed on the analytic phantom images for proof of concept. MR images were obtained on Siemens 3T Tim Trio scanner using an agar filled vascular wax phantom and in vivo. A spoiled gradient echo sequence was modified by incorporating the proposed sequence. Comparisons were performed against a conventional 3DFT GRE sequence with almost same scan time of acquiring total 2D images. The scan parameters were TR = 22ms, TE = 8.1ms, resolution = 1.0 x 1.0 mm^2, slice thickness 10.0 mm and the number of angles = 17 from -80º to 80º with 10º interval. The thickness of reconstructed images was 0.625mm which was same as 3D SPGR images. The in-plane resolution was changed for in vivo study to 2.0 x 2.0 mm^2.

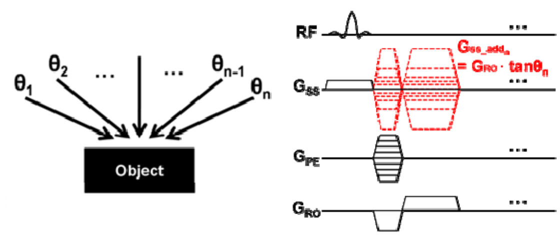

Figure 1. The proposed pulse sequence diagram. The dotted parts were modified.

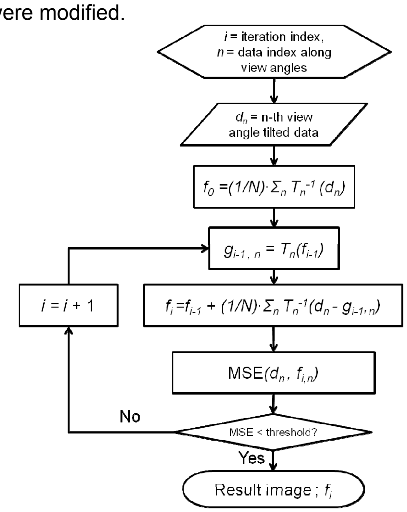

Figure 2. A flow diagram of iterative back projection reconstruction algorithm.

Results and Discussion Figure 3 shows the wax phantom built for the experiment mimicking a vessel and acquired 2D images along tilting angles (-80 to 80, interval 10). Figure 4 shows the simulation results using an analytical phantom image. The blurring of the initial images was gradually removed along the number of iterations (Fig.4d). Reconstructed images of phantom (Fig.5) and in vivo (Fig.6) experiments show comparable results as standard 3DFT GRE approach and the SNR of reconstructed images were much higher than that of 3D SPGR images. Additionally, since the reconstruction algorithm is an image based approach, ringing effects that occur in FT based reconstruction did not appear and the aliasing effects around the first and last slices of 3D imaging also did not appear. However, there were some drawbacks and limitations. The reconstructed images had minor contrast distortions in upper and lower slices. Also, blurring effects were not perfectly removed. These drawbacks could be solved by further optimizing the reconstruction algorithm. In addition, the range of the view angles should be large to get better reconstructed images. However, this means that the amplitude of Gz, which is limited by the hardware, needs to increase for increased view angle.

Conclusion An image based 3D reconstruction method using multiple 2D oblique view projection images is described. The sequence can be useful for increasing SNR in high resolution 3D imaging. The method can be applied to not only GRE sequences but also to spin echo based sequences as well. However, it has some drawbacks and limitation - residual blurring, contrast distortions and gradient limitation. In the future work, the reconstruction algorithm should be optimized.

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References [1] Cho et al., Med. Phys., 15, 1988 [2] Lu et al., MRM., 62:66–76, 2009 [3] Park et al., IEEE Sig. Proc. Mag., 21, 2003

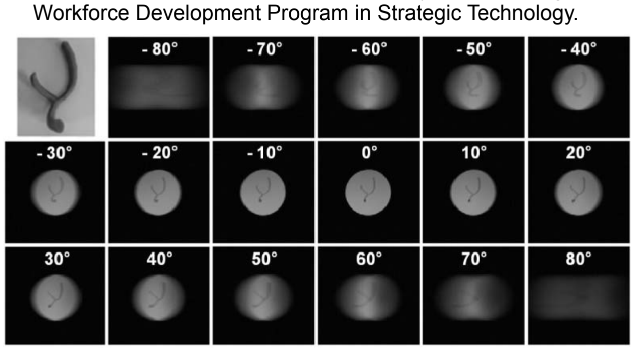

Figure 3. A picture of wax phantom and acquired images using proposed pulse sequence. (17 images, from -80° to 80° interval 10°)

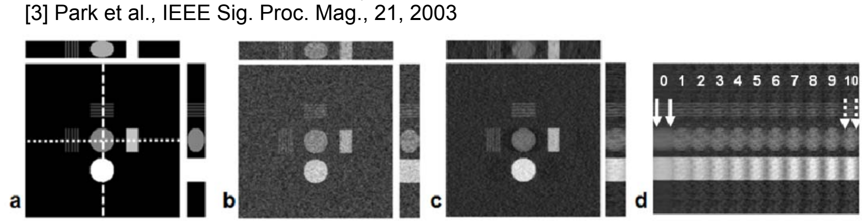

Figure 4. Simulation results. a) 3D analytic phantom without noise. b) 3DFT image with Gaussian noise. c) Reconstructed image using proposed method with the same noise as in b. Upper and right part of a, b and c are coronal view along dotted line and sagittal view along dashed line. d) Sagittal view along each iteration (numbered). The blurring (solid arrows) were removed along the number of iterations (dotted arrows).

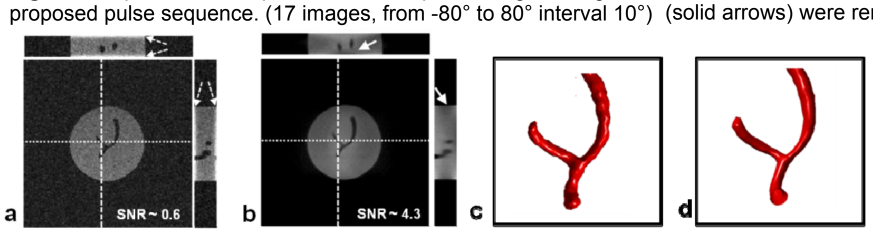

Figure 5. Phantom results. a) 3DFT SPGR images, b) Reconstructed images using the proposed method. Dotted arrows designated 3DFT aliasing around first and last slices. The reconstruction errors and residual blurring were indicated by solid arrows in b. c) and d) are 3D rendering images of a and b, respectively.

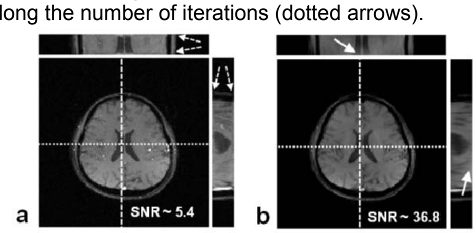

Figure 6. In vivo results. a) 3DFT SPGR images. b) Reconstructed images using the proposed method. Dotted arrows designated 3DFT aliasing around first and last slices. The reconstruction errors and residual blurring were indicated by solid arrows in b.