Rapid Generation of Preview Images for 3D MR DSA

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INTRODUCTION: Large 4D data sets are acquired in time-resolved 3D MR angiography [1]. In these exams it is desirable to receive feedback shortly after scan completion. However, 4D image reconstruction is an immense computational task. This work investigates methods that generate "preview images" of lower image quality from subsets of the acquired data. The goal is to rapidly reconstruct these moderate-quality images so that they could be used to assess the technical success of the procedure and to guide reconstruction of a subset of the high-quality images. A previous study [2] showed that images reconstructed from only the central k-space slice (Fourier projection [3]) are suitable for carotid exams. However, this method failed in regions with enhanced fat and muscle, such as in the pelvis.

METHODS: The reconstruction time is primarily due to the data transfer time for the acquired data volume and the number of computational operations. The image volume $V = N_x \times N_y \times N_z$ is reconstructed from the acquired volume $V_a = N_{x,a} \times N_{y,a} \times N_{z,a}$. Most of the computational effort in generating the images is due to the Fourier transform (FT). The required operations for an N-point FT are proportional to $N \log_2 N$. The operations (O) for a complete reconstruction are then roughly proportional to $N_{x,a} N_{z,a} N_y \log_2 N_y + N_{x,a} N_y N_z \log_2 N_z + N_y N_z N_x \log_2 N_x$.

Preview images were generated on a smaller reconstruction matrix $V' = N'_x \times N'_y \times N'_z$, where $N'_i = r_i N_i$. Figure 1 shows two 1D examples of k-space subsets used for the generation of preview images. In method A, only the central part of the k-space data is used. This corresponds to a low-pass filtered data set with decreased spatial resolution ($\Delta i = 1/k_{i,max}$). A higher spatial resolution is achieved with method B at the expense of a reduced FOV in i ($FOV_i = 1/\Delta k_i$). For our analysis, the k-space volume was reduced with methods A in k_x and k_y and with method A and B in k_z. Delineation of vessels can be further improved by magnitude subtraction (MS) of a pre-contrast mask in image space or complex subtraction (CS) in k-space [4].

RESULTS AND DISCUSSION: The contrast $C = (S_a - S_t) / S_t$ between the signal S_a in the artery and the signal S_t from tissue was analyzed for varying reduction coefficients on a pelvis exam (second injection; $V_a = 312 \times 144 \times 24$). The correct aspect ratio was maintained by keeping $r_{xy} = r_x = r_y$. Fig. 2a shows a MIP image from the fully reconstructed data set. Signal is lost in some vascular segments with Fourier projection ($N'_z = 1$) and MS (Fig. 2b). CS suppresses the background (Fig. 2c) but without loss of vascular segments. Vessel conspicuity is enhanced as N'_z is increased (Fig. 2d). Method B further increases the contrast (Fig. 2e). The delineation of vessels from the background improves with higher spatial resolution, because partial volume effects are minimized in z. Aliasing introduces no artifact in the MIP image. An acceptable image was observed for $V' = 128 \times 192 \times 4$ (Fig. 2f), which required only 0.5% of the operations and 4.6% of the data transfer, yet displays the key features of the fully reconstructed image (Fig. 2a).

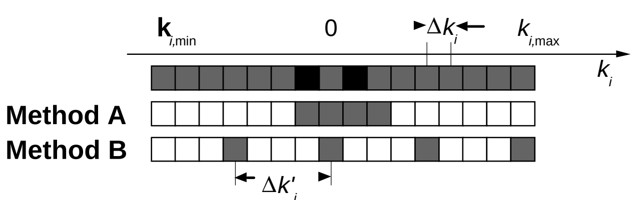

Fig. 1: *Sampling schemes for low-pass filtered (A), and reduced FOV acquisition (B) with $N_{i,a} = 16$ and $N'_i = 4$.*

Table 1: *Parameters and contrast measures for Figure 2.*

Fig. 2	Image Size, V'	Method	V'_a/V_a	O'/O	C
a	512×384×48	A; CS	100 %	100 %	9.2
b	512×384×1	A; MS	4.2 %	2.0 %	–
c	512×384×1	A; CS	4.2 %	2.0 %	1.8
d	512×384×4	A; CS	16.7 %	8.6 %	2.4
e	512×384×4	B; CS	16.7 %	8.6 %	4.2
f	128×96×4	B; CS	4.6 %	0.5 %	3.4

Figure 3 shows variations in the number of operations and the contrast as a function of the reconstruction parameters. For all r_{xy} and r_z, method B had an equal or larger contrast compared to method A. Good contrast per reconstruction time (O'/O) was obtained for $r_{xy} = 0.25$ and $r_z = 0.1$ to 0.5.

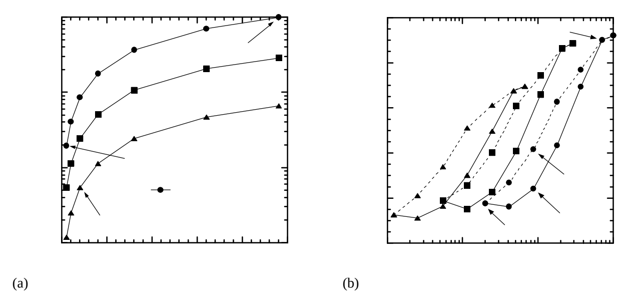

Fig. 3: *(a) O'/O vs N'_z and (b) C vs O'/O for CS data. Labels refer to images shown in Figure 2. Symbols in (b) are as defined in (a). Solid and dashed lines in (b) refer to methods A and B, respectively.*

CONCLUSIONS: We demonstrated methods that generate acceptable preview images in a fraction of the time of a full reconstruction. Fourier projections with CS have sufficient quality in most cases. When background tissue is a problem, k-space reduction in all dimensions is a flexible scheme which can improve image quality. These schemes allow interactive reconstruction on various computers by trading-off image quality for reconstruction speed.

REFERENCES

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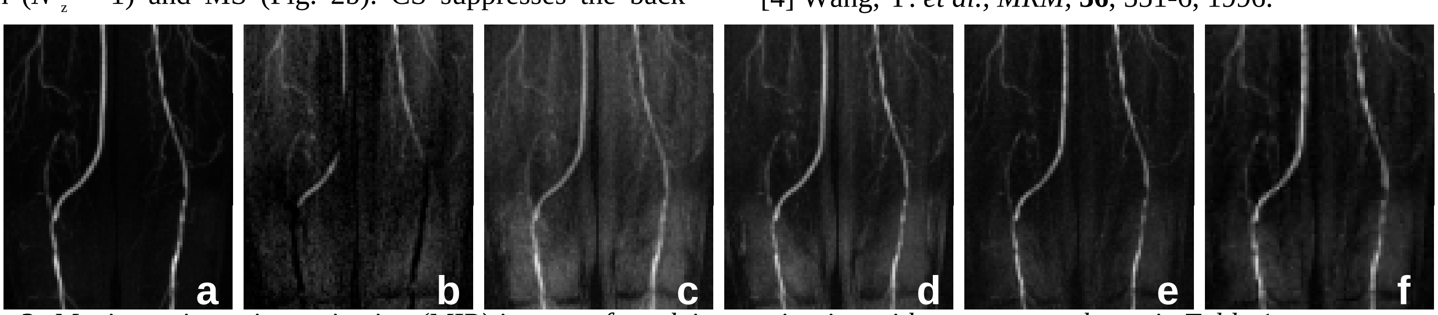

Fig. 2: *Maximum-intensity projection (MIP) images of a pelvis examination with parameters shown in Table 1.*