MR-projection imaging with perspective distortion as in X-ray fluoroscopy for interventional X/MR-hybrid applications

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Purpose

Hybrid X/MR-devices are promising for interventional applications (e.g. intravasculature) exploiting the high frame-rate of X-ray imaging and the contrast variety of MRI [1]. Standard cone-beam fluoroscopy exhibits perspective distortion due to the projection onto the detector. In contrast, MRI data are sampled point-wise with a high flexibility in k-space. Synthesis of both modalities might be achievable through X-ray-like MR projections. Here, we demonstrate initial experiments yielding MR-fan-beam views without the need of time consuming 3D acquisition.

Methods

Principle: According to the Fourier-slice theorem, fan-beam views can be obtained from k-space projections covering the fan-angle of the X-ray system [2]. Using this idea, we are able to synthesize fan-beam projections from multiple parallel MR projections spanning the respective angles.

Measurements: 2D MR projections were acquired with a gradient-echo sequence by omitting slice selection in view direction. The projection angle was swept from -6° to 6° in steps of 0.1°. 2D/3D acquisitions were performed with a volunteer and a head phantom at 1.5T (Aera, Siemens Healthineers, Erlangen) within 3.8 s / 14:20 min at 1 mm resolution and TE/TR/flip-angle = (3/6/9/12) ms / 15 ms / 8°.

Analysis: Measured 2D-projections and resampled fan-beam views were compared to a ground truth obtained through parallel/fan-beam forward projection of the 3D image data, respectively.

Results

2D MR projections approach the ground truth for short TE<3 ms, where the projections should ideally match the line integral of the relaxation-weighted proton density (**Figure 1**). Signal voids occur due to dephasing with increasing TE. Perspective distortion as seen in fan-beam X-ray can be generated from MR projections (**Figure 2**). Only a small number of angular views is sufficient (error below 10% with 3 projections).

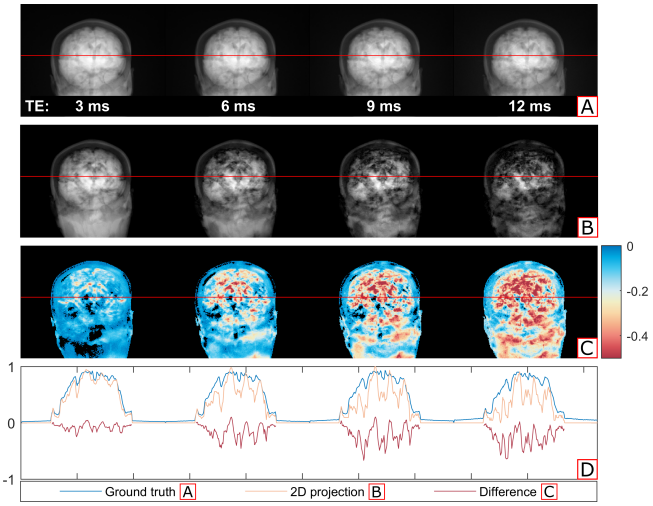

Figure 1: *Phantom measurement: Magnitude projections of 3D-scan at different TE (A), measured 2D-projections (B), difference (C), and line plots through A-C (D).*

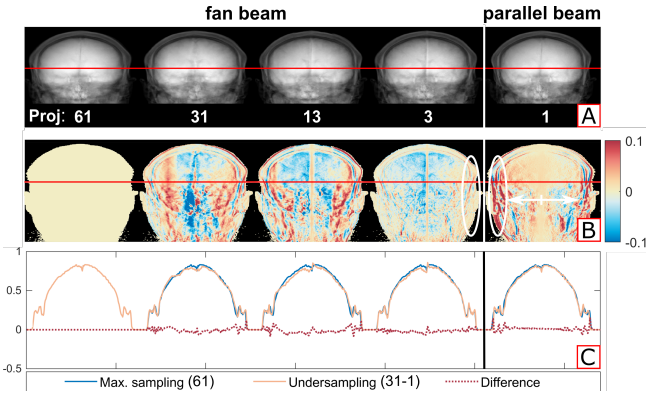

Figure 2: *Fan-beam views of the volunteer (A) with different numbers of base projections (61-3) and parallel-beam projection (1), difference to the highest sampling number 61 (B), and line plot depicting the difference (C). For the parallel beam (1), the error relative to a fan-beam projection increases proportional to the distance to the center (white arrows) whereas for the fan-beam reconstruction (3) the deviation stays below 10 % (white ellipses).*

Conclusions

We demonstrate an acquisition and reconstruction scheme for MR data enabling straightforward transfer to X-ray data. This enables image fusion of both modalities during an intervention without time-consuming and error-prone transformations. In future, the implementation of dedicated magnetization preparations can tailor the image contrast to the application at hand.

Acknowledgements

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References [1] R. Fahrig et al. JMRI. 2001. [2] C. Syben et al. IGIC 2017.