Fan-beam Projection Image Acquisition using MRI

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Introduction

Motivation:

- Real-time image acquisition for interventional MRI.
- Possible with MRI:
  - Fast acquisition of parallel projection images.
  - Lack of perspective distortion similar to X-ray fluoroscopy.

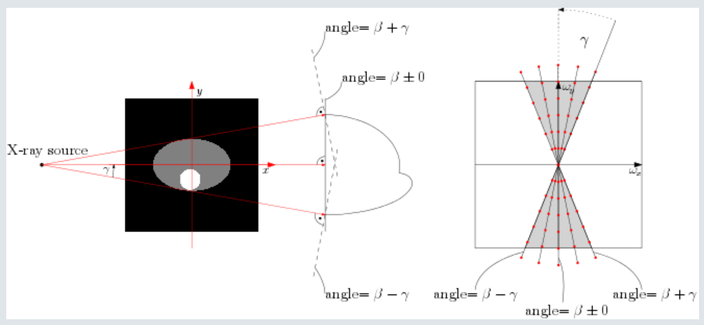

Figure 1: Fan-beam projection in Fourier space.

Idea:

- Using the Fourier-Slice theorem to identify the section of the k-space to which a fan-beam projection is contributing.
- Using the MRI to sample only this section and create a fan-beam projection.

Goal:

- **Create fan-beam projections with MRI using a minimal number of parallel projections.**

Materials and Methods

➢ **Fan-beam projection in Fourier space:**

- According to the Fourier-Slice theorem the information for a fan-beam projection lies in a wedge in Fourier Space with the fan-angle (see Fig. 1)
- Creating a fan-beam projection (see Fig. 2):
  1. Sampling this wedge by acquiring lines through the origin with the MRI followed by an inverse Fourier transform gives a stack of parallel projections.
  2. Use rebinning formulas to find the ray in the parallel projection stack:

$$\theta = \gamma + \beta$$

$$s = D_{si} \cdot \sin\gamma$$

  - where γ is the half fan-angle, β the angle between the central ray and the coordinate axis and D_{si} is the source to isocenter distance. The rotation angle of a detector acquiring parallel beam is described by θ and s is the respective pixel.
  1. Using linear interpolation to obtain the value of the fan-beam projection.

➢ **Undersampling the wedge in K-space:**

- The acquisition of one parallel projection for each fan-beam pixel is referred to as full sampling (see Fig. 3A).
  - ➢ Highly redudant data is acquired!
- Reducing the amount of acquired parallel projections:
  - ➢ Investigate undersampling factors with equiangular spacing.
  - ➢ The outer as well as the central ray are always acquired.

Evaluation on:

- A slice of an X-ray and MRI sensitive head phantom.
- A ray-driven fan-beam forward projection is used as ground-truth (GT)

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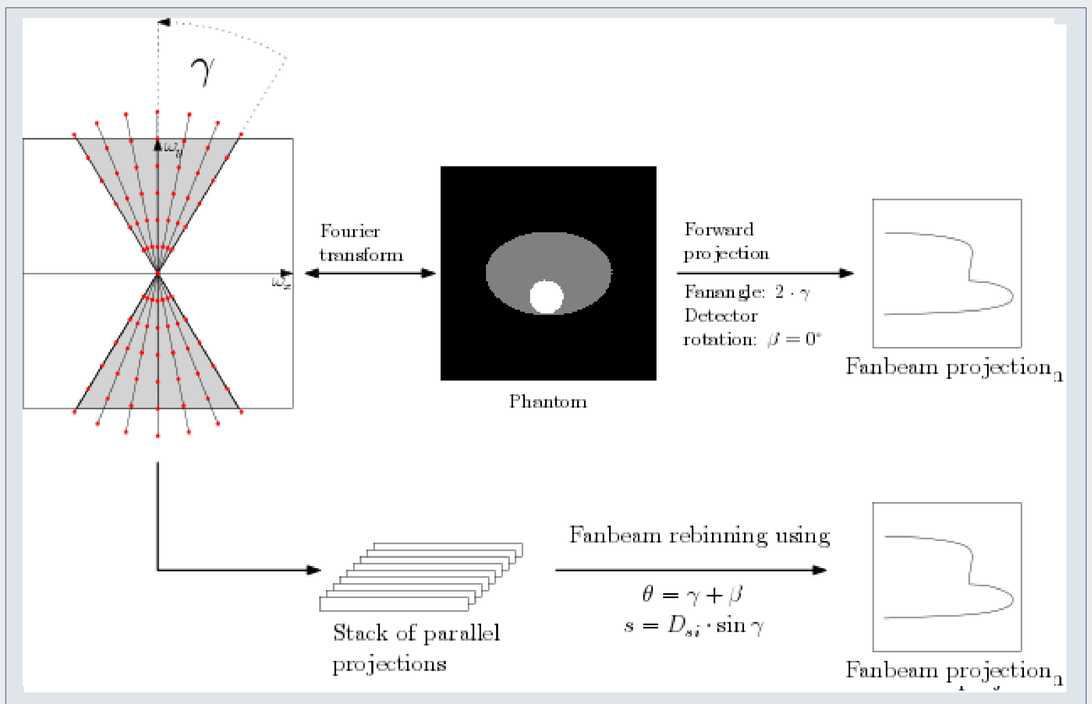

Figure 2: Fan-beam projection image acquisition method

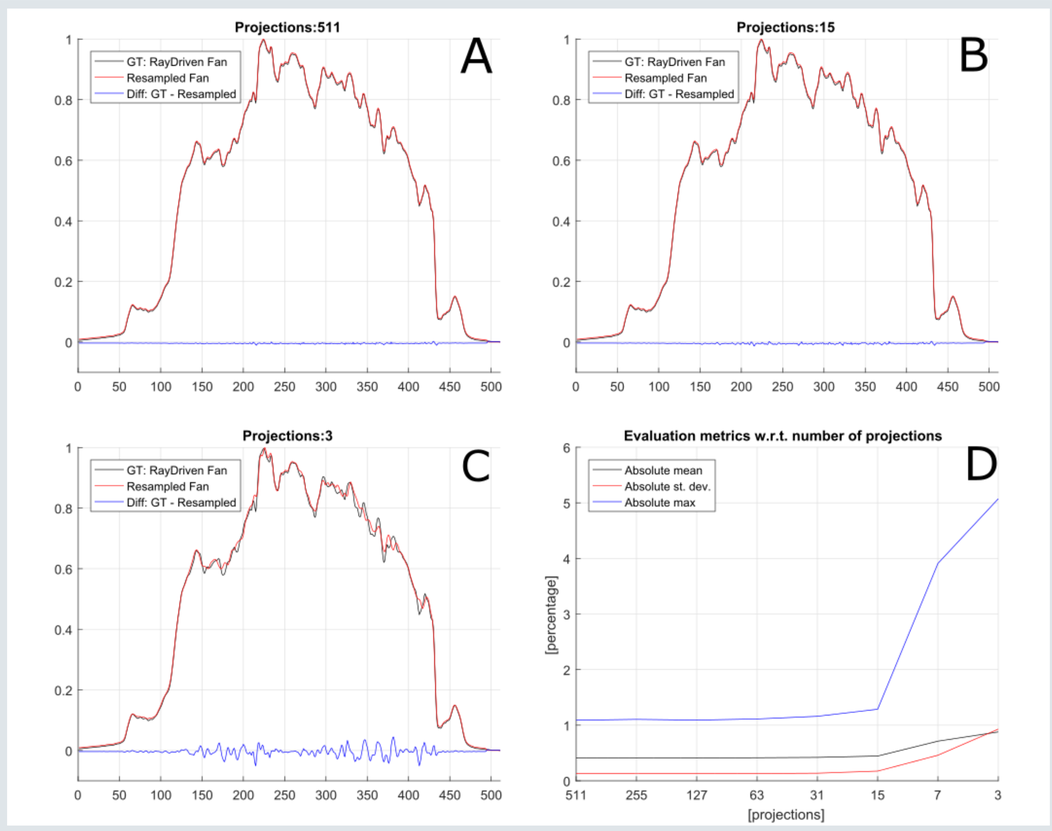

Figure 3: Fan-beam projection image acquisition with different undersampling factors.

Results and Discussion

➢ **Qualitative evaluation**: Fig. 3 shows that the resampling error is nearly constant down to 15 projections (Fig. 3B). Using fewer projections increases the error.

➢ **Quantitative evaluation**: In Fig. 3D the absolute error metrics w.r.t to the GT projection of the different undersampling factors are shown.

Conclusions

- We have shown that the MRI can acquire projection images with perspective distortion, while the k-space sampling is minimal.
- We have only investigated undersampling of the wedge using fewer parallel projections, undersampling along the line could give further improvement in acquisition time.
- Adapting the minimal k-space sampling to cone-beam enables for fast acquisition of projection images with the same perspective distortion as angiography systems.

➢ **Minimal k-space sampling allows for interventional MRI projection image acquisition.**