Complementary Filtered Backprojection - Implementation and Evaluation

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Based on the article

A New Approximate Algorithm for Image Reconstruction in Cone-Beam Spiral CT at Small Cone-Angles

Stefan Schaller, Thomas Flohr, Peter Steffen

Siemens / Erlangen-Nuremberg University

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Evolution

- two-dimensional filtered backprojection
- three-dimensional FBP (Feldkamp)
- Feldkamp with helix trajectory (Wang)
- Wang with complementary rays (Schaller)

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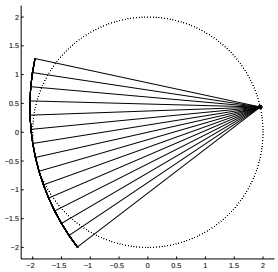
Two-Dimensional Filtered Backprojection



- Weighting and filtering

$$\tilde{p}(\alpha,\beta) = g(\beta) * p(\alpha,\beta)\cos\beta$$

- Backprojection

$$f(x,y) = \frac{2}{\pi N}\sum_{\alpha=0}^{2\pi}(\frac{R}{\hat{L}})^2\tilde{p}(\alpha,\hat{\beta})$$

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Shortcomings

- acquisition of only one slice at a time
- most X-rays never hit the detector
- time consuming to acquire a volume

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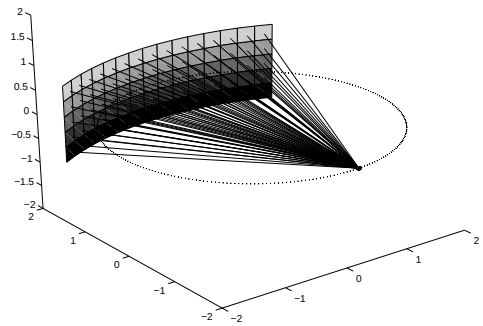
Feldkamp's Algorithm



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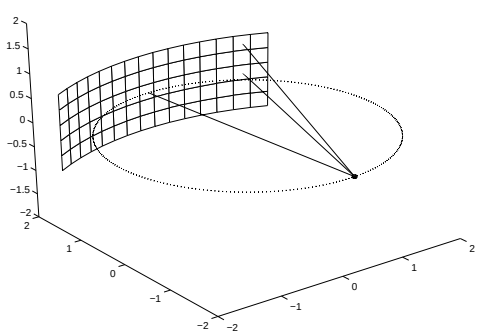

- Weighting and filtering

$$\tilde{p}(\alpha,\beta,\zeta) = \frac{R}{\sqrt{R^2+\zeta^2}} g(\beta) * p(\alpha,\beta,\zeta)\cos\beta$$

- Backprojection

$$f(x,y,z) = \frac{2}{\pi N}\sum_{\alpha=0}^{2\pi}(\frac{R}{\hat{L}})^2 \tilde{p}(\alpha,\hat{\beta},\hat{\zeta})$$

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Shortcomings

- approximate method, exact only in the central plane
- changing image quality along z-axis

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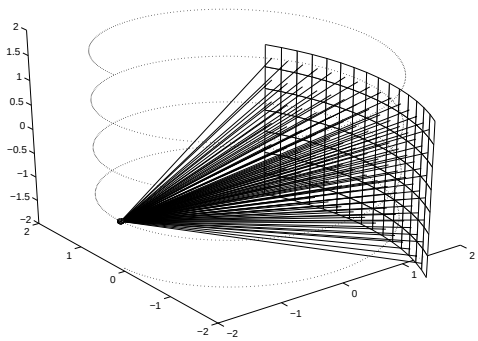
Wang's Algorithm



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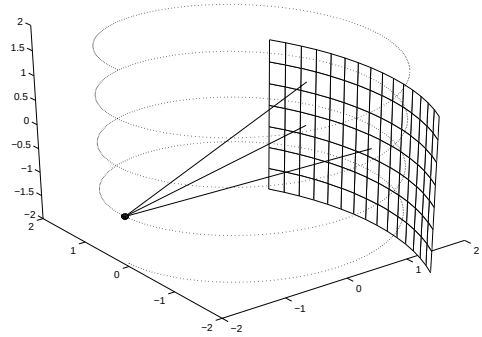

- Weighting and filtering

$$\tilde{p}(\alpha,\beta,\zeta) = \frac{R}{\sqrt{R^2+\zeta^2}} g(\beta) * p(\alpha,\beta,\zeta)\cos\beta$$

- Backprojection

$$f(x,y,z) = \frac{2}{\pi N}\sum_{\alpha_0=0}^{2\pi}(\frac{R}{\hat{L}})^2 \tilde{p}(\hat{\lambda}2\pi+\alpha_0,\hat{\beta},\hat{\zeta})$$

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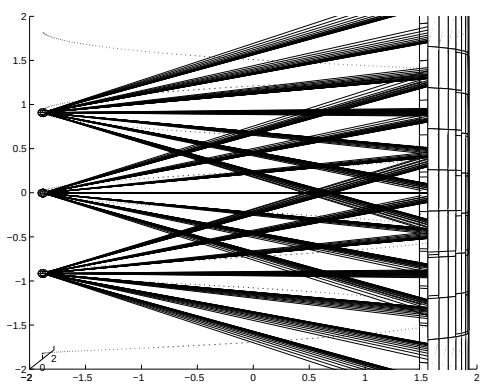
Shortcomings



- limited pitch
- not optimal interpolation

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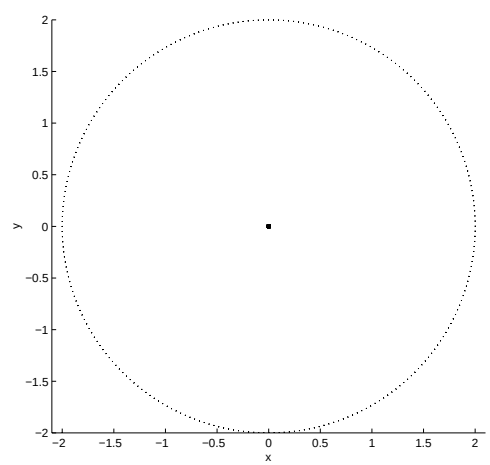
Complementary projections



$$p^c(\alpha,\beta,\zeta) = p(\tilde{\alpha},\tilde{\beta},\zeta)$$

where

$$\tilde{\alpha} = \alpha + 2\beta - \pi$$

$$\tilde{\beta} = -\beta$$

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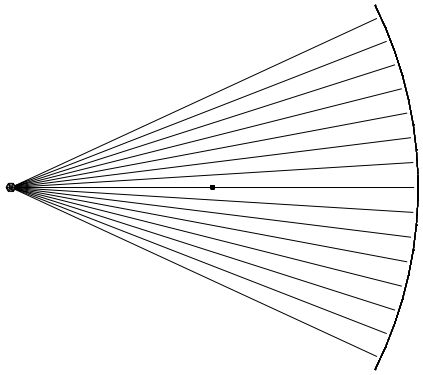
To be cut out and attached to the previous slide.



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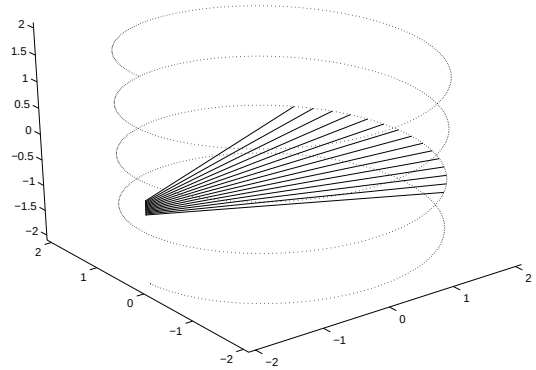
A complementary fan



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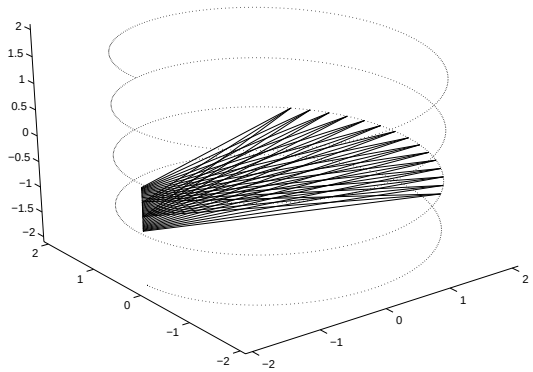
A complementary cone



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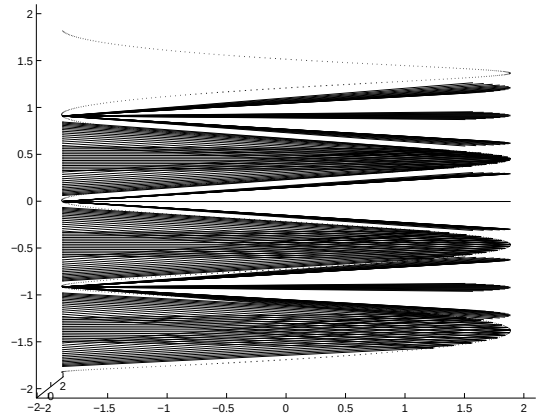
Direct and complementary cones



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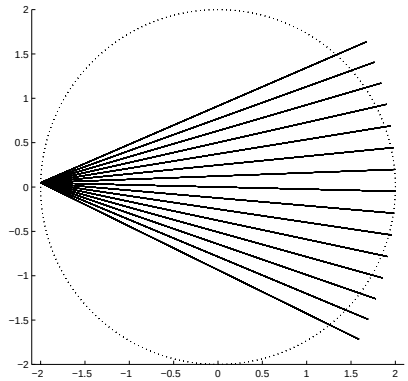
As seen from above



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Schaller's algorithm

- Weighting and filtering

$$\tilde{p}(\alpha,\beta,\zeta) = \frac{R}{\sqrt{R^2+\zeta^2}} g(\beta) * p(\alpha,\beta,\zeta)\cos\beta$$

- Backprojection

$$f(x,y,z) = \frac{2}{\pi N}\sum_{\alpha_0=0}^{2\pi}(\frac{R}{\hat{L}})^2 \times$$

$$\frac{\sum_c \sum_\lambda \sum_\zeta \tilde{p}(\lambda 2\pi + \alpha_0, \hat{\beta}, \zeta, c) h(d_z)}{\sum_c \sum_\lambda \sum_\zeta h(d_z)}$$

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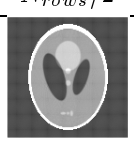
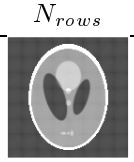
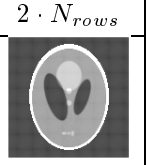
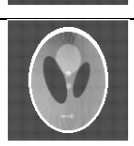
N_{rows}, cone-angle	Pitch		
	$N_{rows}/2$	N_{rows}	$2 \cdot N_{rows}$
7, $\pm 1.6°$			
31, $\pm 6.9°$			
63, $\pm 13.8°$			

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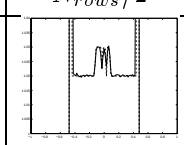
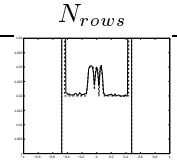
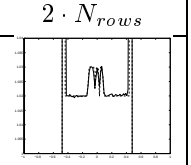
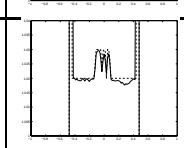
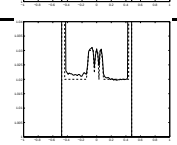
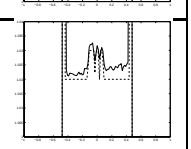
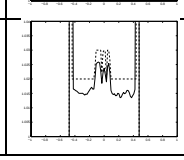
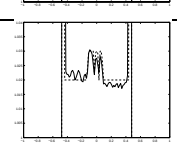
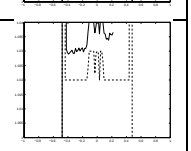
N_{rows}, cone-angle	Pitch		
	$N_{rows}/2$	N_{rows}	$2 \cdot N_{rows}$
7, $\pm 1.6°$			
31, $\pm 6.9°$			
63, $\pm 13.8°$			

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Shortcomings

- only for small cone-angles ($< \pm 1.2°$ according to Schaller)
- computationally expensive
- perhaps too complex interpolation

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