Analytical Reconstructions of Regions of Interest in Medical Imaging

Kévin Polisano

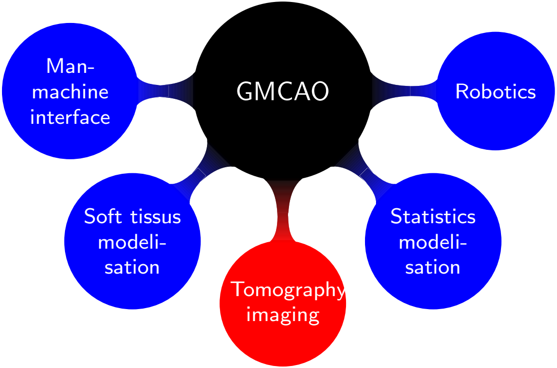
Supervised by :
Laurent Desbat

09/18/2012

Contents

Introduction

Context



Clinical applications

Introduction
Topic

Surgivisio
Surgical Vision reloaded

What is the topic of this intership ?

- To discover the field of Computed Tomography Imaging
- To improve the current way of reconstruction of images
- To reduce the X-ray exposure by decreasing the trajectory of the scanner around the patient
- To implement a first version in Matlab which could be reused then by Surgivisio

Introduction
Topic

Surgivisio
Surgical Vision reloaded

What is the topic of this intership ?

- To discover the field of Computed Tomography Imaging
- To improve the current way of reconstruction of images
- To reduce the X-ray exposure by decreasing the trajectory of the scanner around the patient
- To implement a first version in Matlab which could be reused then by Surgivisio

Introduction
Topic

Surgivisio
Surgical Vision reloaded

What is the topic of this intership ?

- To discover the field of Computed Tomography Imaging
- To improve the current way of reconstruction of images
- To reduce the X-ray exposure by decreasing the trajectory of the scanner around the patient
- To implement a first version in Matlab which could be reused then by Surgivisio

Introduction
Topic

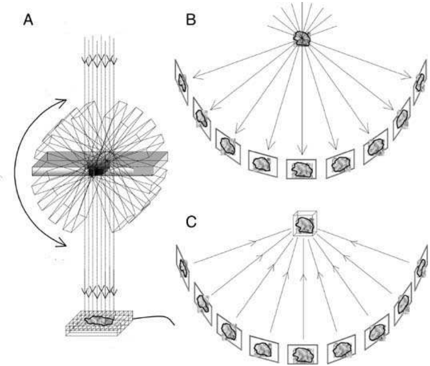
Surgivisio
Surgical Vision reloaded

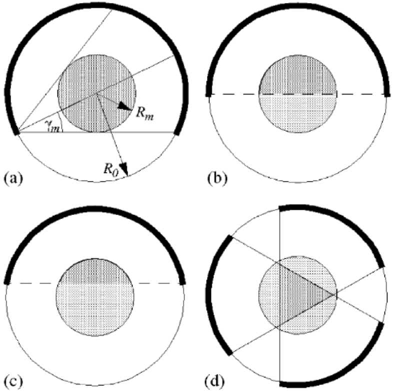
What is the topic of this intership ?

- To discover the field of Computed Tomography Imaging
- To improve the current way of reconstruction of images
- To reduce the X-ray exposure by decreasing the trajectory of the scanner around the patient
- To implement a first version in Matlab which could be reused then by Surgivisio

Introduction

Principles of tomography

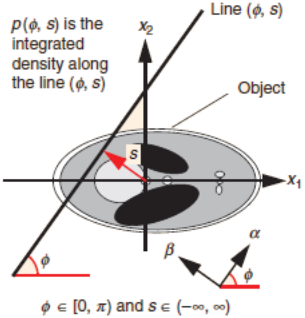




Contents

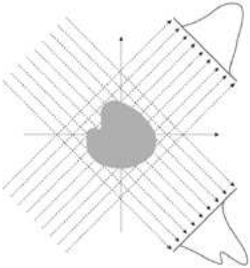
Mathematical formulation

Projection



Projection

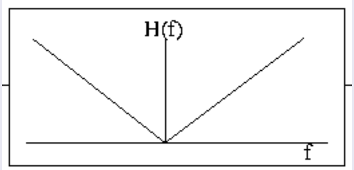
$p(\phi, s) = \int_{-\infty}^{\infty} f(r\alpha + s\beta) dr \text{for } \phi \in (0, \pi), s \in (-\infty, \infty)$



Mathematical formulation

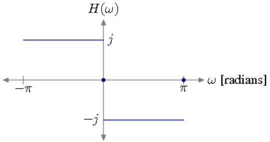
Filters applied to projections

Ramp filter



$$p_R(\phi, .) = p(\phi, .) * r$$
$$R(\sigma) = |\sigma|$$

Hilbert filter



DTFT of the ideal discrete Hilbert transform filter for $-\pi < \omega \leq \pi$

$$p_H(\phi, .) = p(\phi, .) * h$$
$$H(\sigma) = -j.sign(\sigma)$$

Mathematical formulation

Filtred backprojection

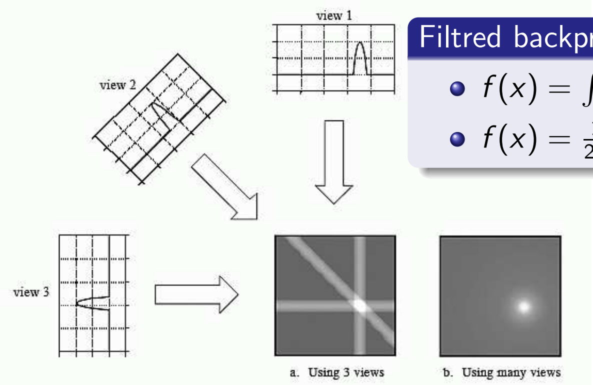


FIGURE 25-16
Backprojection. Backprojection reconstructs an image by taking each view and *smearing* it along the path it was originally acquired. The resulting image is a blurry version of the correct image.

Filtred backprojection

- $f(x) = \int_0^\pi p_R(\phi, s)_{|s=x\cdot\beta} d\phi$
- $f(x) = \frac{1}{2\pi} \int_0^\pi \frac{\partial p_H}{\partial s}(\phi, s) d\phi$

Parallel geometry problems

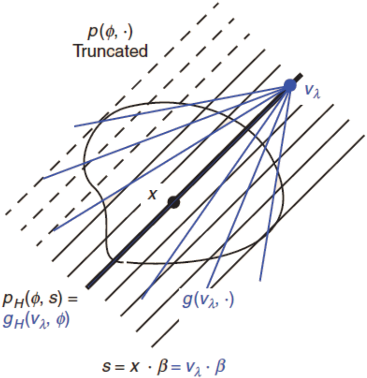
Some problems with parallel geometry

- The X-ray source doesn't cast parallel beams
- The parallel formulas require all projections $p(\phi, s)$
- This geometry is not adapted to data truncation

Work flow

- To adopt a new geometry called fanbeam geometry
- Rebinning truncated parallel projections into fanbeam
- To apply Hilbert equality to evaluate $p(\phi, s)$

Fanbeam geometry
Projection and Hilbert equality



Projection

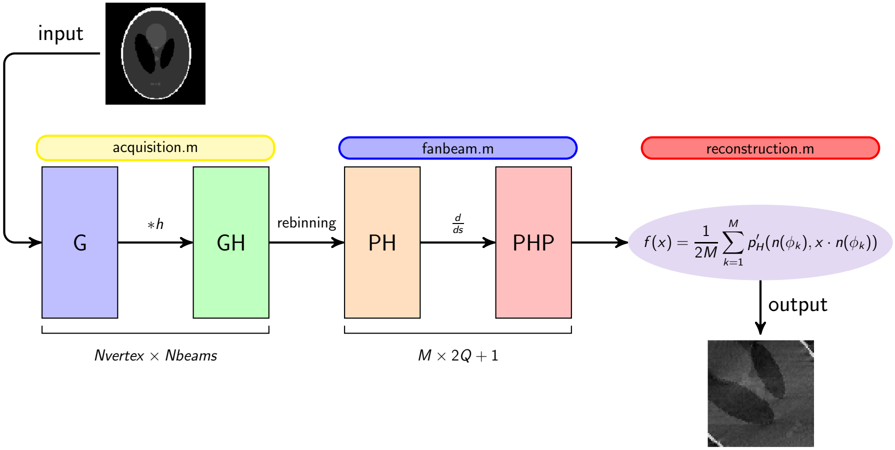
$$g(\lambda,\phi) = \int_0^\infty f(v(\lambda) + l\alpha)dl$$
$$\alpha = (\cos\phi, \sin\phi)$$
$$\beta = (-\sin\phi, \cos\phi)$$

Hilbert equality

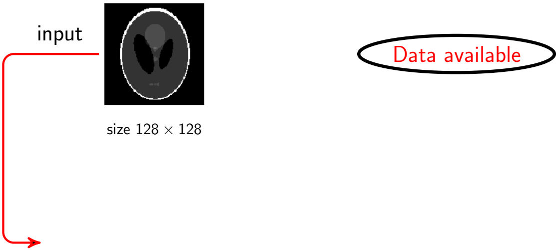
$$p_H(\phi, s) = g_H(v_\lambda, \phi), s = v_\lambda \cdot \beta$$

Contents

Global vision of the architecture



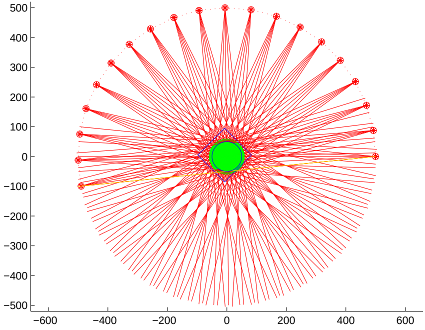
Focus on the CT imaging process
acquisition.m



size 128 × 128

Focus on the CT imaging process

acquisition.m

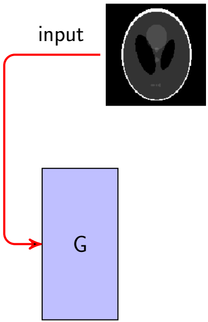


Data required

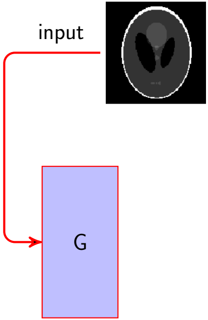
- image's position
- $Rtraj = 150$
- $Nvertex = 512$
- $Nbeams = 1024$
- $\gamma_m = arcsin(\frac{FOV}{Rtraj}) \simeq 20^\circ$
- $FOV = 50$
- integrale discretization=256

Focus on the CT imaging process

acquisition.m



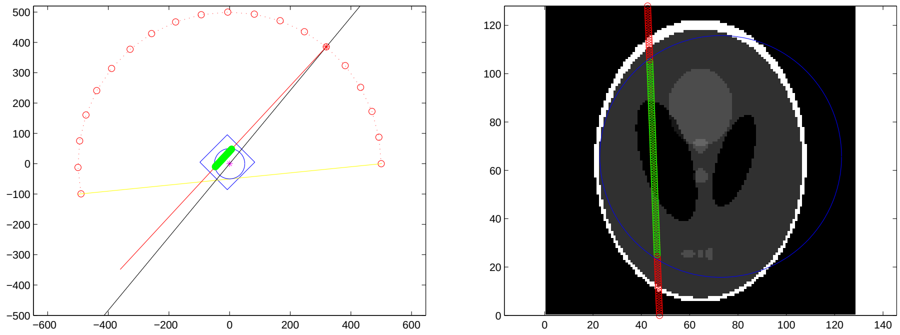
Focus on the CT imaging process
acquisition.m



Calculation of $g(\lambda_i, \alpha_j)$

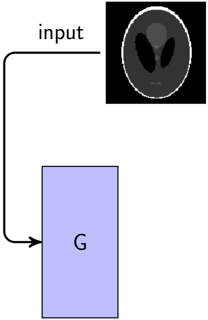
Focus on the CT imaging process

acquisition.m



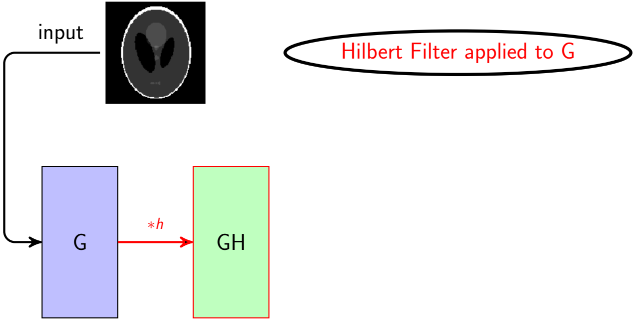
Focus on the CT imaging process

acquisition.m



Focus on the CT imaging process

acquisition.m

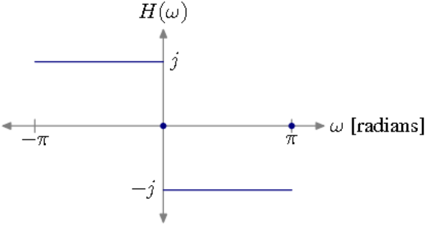


Filtered projections

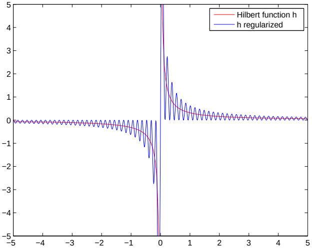
acquisition.m

Numerical problems

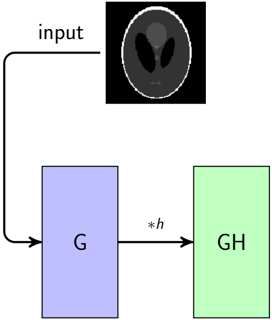
- Calculation of $g_H = g * h$ unstable around zero
- Solution $\Longrightarrow$ regularization



DTFT of the ideal discrete Hilbert transform filter for $-\pi < \omega \leq \pi$

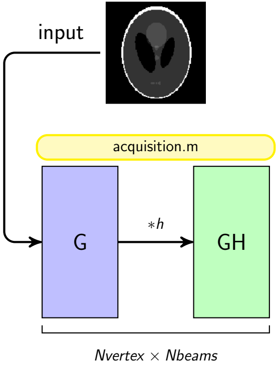


Focus on the CT imaging process
fanbeam.m

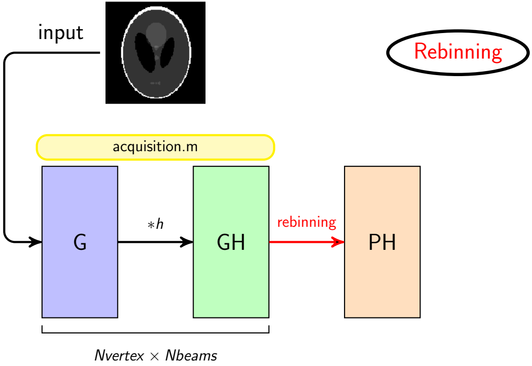


Focus on the CT imaging process

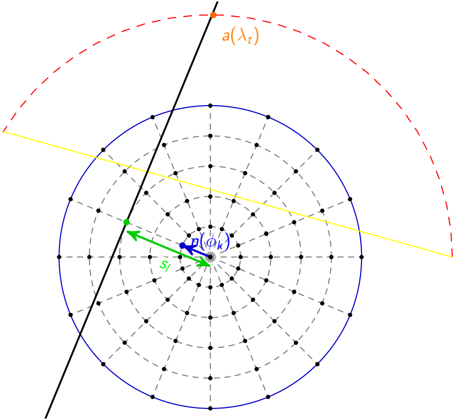
fanbeam.m



Rebinning : fanbeam geometry to parallel geometry
fanbeam.m



Rebinning : fanbeam geometry to parallel geometry
Discretized plan

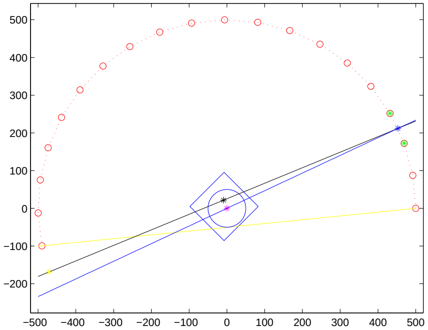


Discretization

- $\phi_k = k\frac{\pi}{M}, k = 0..M-1$
- $s_l = l\frac{RROI}{Q}, l = -Q..Q$
- $Q = 512$
- $M = 1607$

Rebinning : fanbeam geometry to parallel geometry

The rebinning method step by step

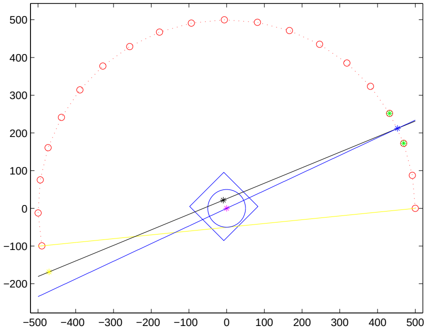


Steps

1. Intersection $a(\lambda_t)$ of $(n(\phi_k), s_l)$ with path
2. Determine the angle α_t between two lines
3. Give a bound of $\lambda_i \leqslant \lambda_t \leqslant \lambda_{i+1}$ and $\alpha_i \leqslant \alpha_t \leqslant \alpha_{i+1}$

Rebinning : fanbeam geometry to parallel geometry

The rebinning method step by step

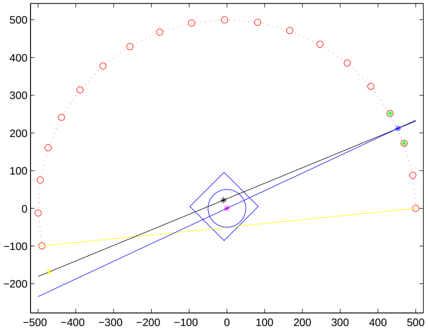


Steps

1. Intersection $a(\lambda_t)$ of $(n(\phi_k), s_l)$ with path
2. Determine the angle α_t between two lines
3. Give a bound of $\lambda_i \leqslant \lambda_t \leqslant \lambda_{i+1}$ and $\alpha_i \leqslant \alpha_t \leqslant \alpha_{i+1}$

Rebinning : fanbeam geometry to parallel geometry

The rebinning method step by step

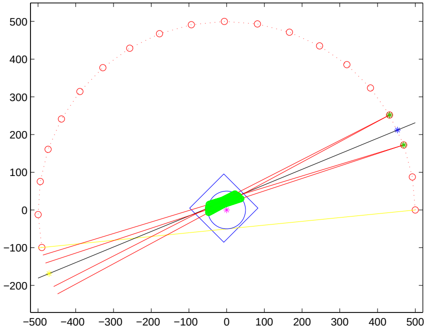


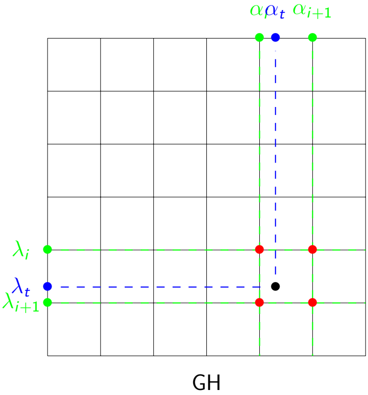
Steps

1. Intersection $a(\lambda_t)$ of $(n(\phi_k), s_l)$ with path
2. Determine the angle α_t between two lines
3. Give a bound of $\lambda_i \leqslant \lambda_t \leqslant \lambda_{i+1}$ and $\alpha_i \leqslant \alpha_t \leqslant \alpha_{i+1}$

Rebinning : fanbeam geometry to parallel geometry

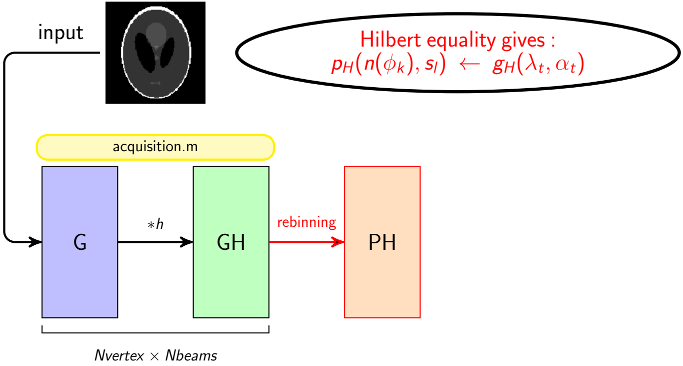
Bilinear interpolation of $g_H(\lambda_t, \alpha_t)$





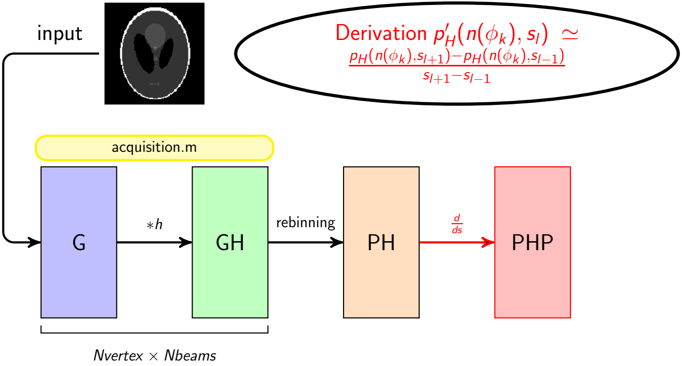
Rebinning : fanbeam geometry to parallel geometry

fanbeam.m



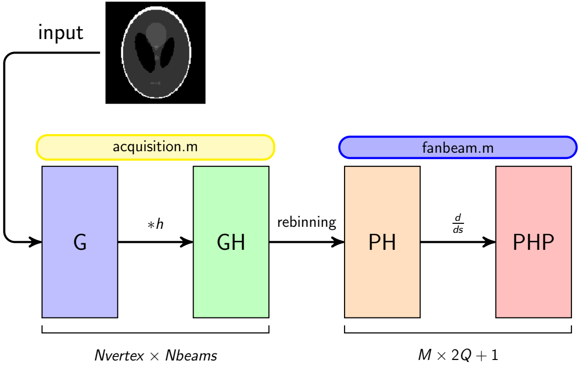
Rebinning : fanbeam geometry to parallel geometry

fanbeam.m



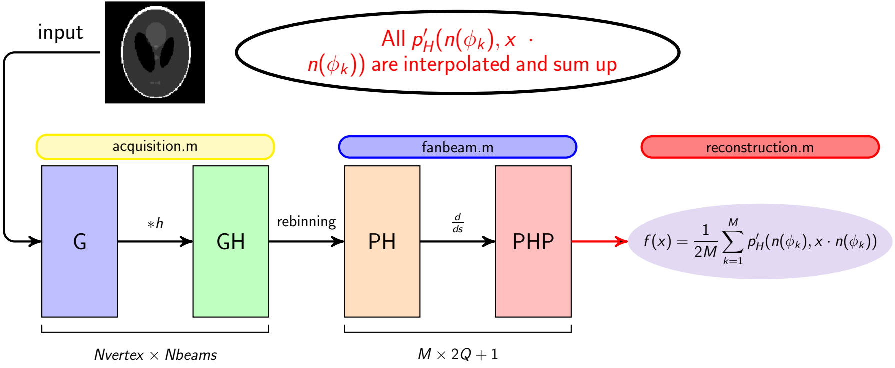
Rebinning : fanbeam geometry to parallel geometry

fanbeam.m



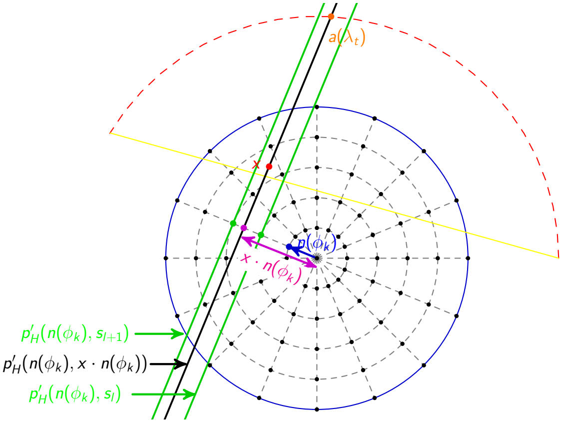
Reconstruction

reconstruction.m



Reconstruction

Interpolation



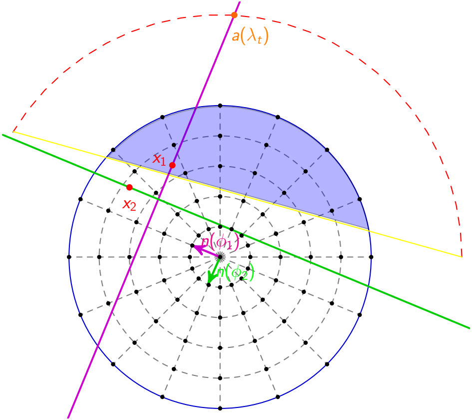
Linear interpolation

$$y = x \cdot n(phi_k)$$

$$p'_H(n(\phi_k), y) \simeq \frac{(y - s_l)}{s_{l+1} - s_l} p'_H(n(\phi_k), s_{l+1}) + \frac{(s_{l+1} - y)}{s_{l+1} - s_l} p'_H(n(\phi_k), s_l)$$

Reconstruction

Condition of accurate reconstruction

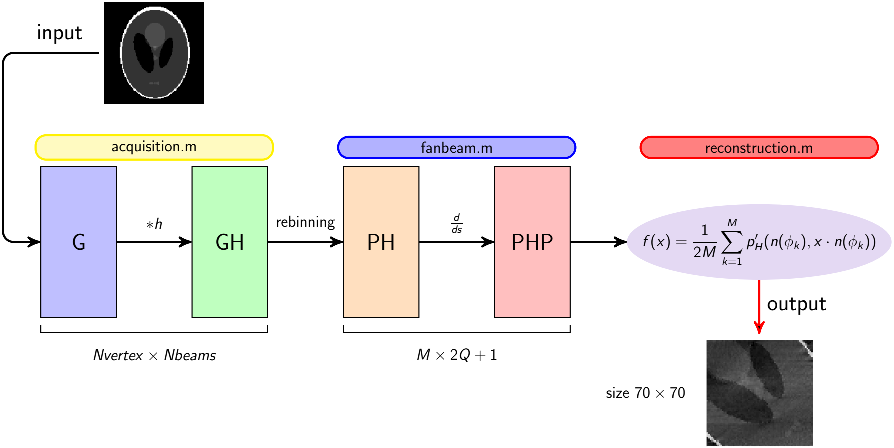


Fanbeam data condition

The point x can be reconstructed from complete fanbeam projections provided a fanbeam vertex can be found on each line passing through x

Reconstruction

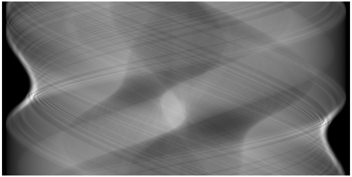
reconstruction.m

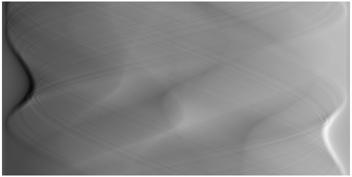


Contents

CT imaging results

acquisition.m : sinogram and filtred sinogram



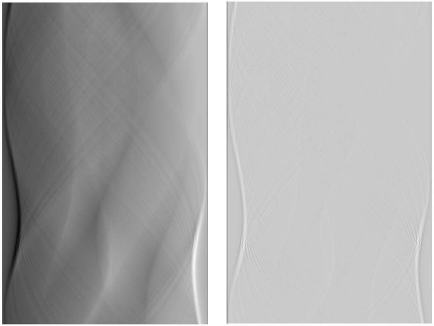


Fanbeam measures

- On the top the sinogram $G = (g(\lambda_i, \alpha_j))_{i,j}$
- On the bottom the filtred sinogram after applying the Hilbert filter h, $GH = (g_H(\lambda_i, n(\alpha_j)))_{i,j}$

Rebinning results

fanbeam.m : PH and PHP visualization

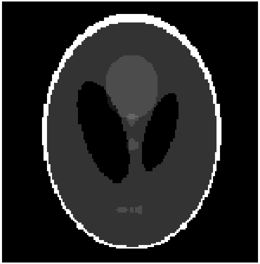


Parallel geometry

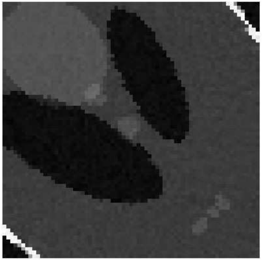
- On the left
  $PH = (p_H(n(\phi_k), s_l))_{k,l}$
- On the right
  $PHP = (p'_H(n(\phi_k), s_l))_{k,l}$

Reconstruction results

reconstruction.m : reconstructed image display



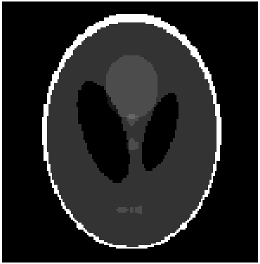
Original image

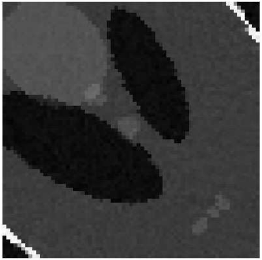


Reconstructed image

Reconstruction results

reconstruction.m : reconstructed image display



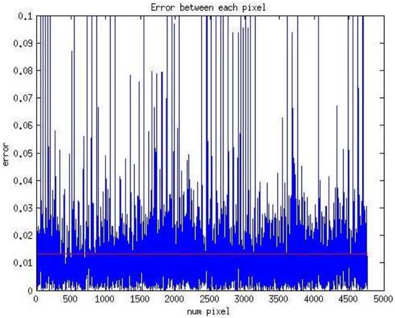


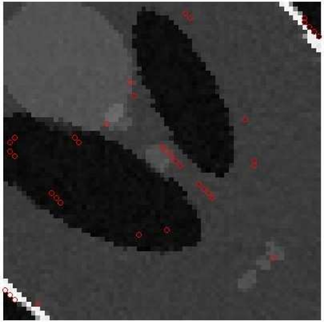
Original image

Reconstructed image

Reconstruction results

Error calculation





mean/pixel	standart deviation	quadratic	max	$> 10^{-1}$
$1,33.10^{-2}$	$2,6.10^{-2}$	2, 01	0, 62	38/4900

Contents

Conclusion
Personal record

Scientific point of view

- Discover of a new field of science applied to health
- Learn a new mathematical theory and its recent advances
- Fight against numerical problems
- Acceleration of the execution of programs

Human point of view

- Pluridisplinary within research teams
- Partnership with companies
- Business dimensions

Conclusion

Future improvements

Improvements

- Report will be use to teaching aid
- C++ implementation, real time
- Adaptation of this algorithm in 3D reconstruction
- Extent to fanbeam truncated data $\Rightarrow$ virtual fanbeam
- Integration in Surgivisio's softwares

Thank you for your attention