Multi-Scale Digital Tomosynthesis Image Reconstruction

TSBB11 - Images and Graphics CDIO Project Course

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Introduction

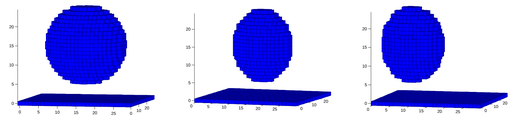
This project is a system for multi-scale tomosynthesis: reconstruction of a 3D image from a limited number of x-ray projections, from coarser to finer resolution.

Main problems to be addressed included

- Limited projection angle
- Robust reconstruction
- Computational complexity

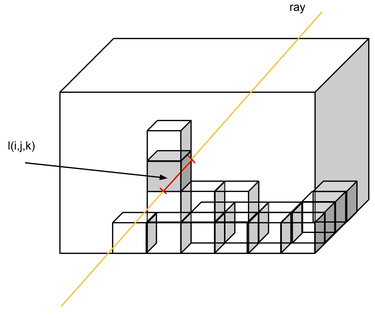
Simulation

Some examples of phantom simulation set-ups:



For each ray, the simulation software finds the total ray attenuation using Siddon's algorithm and calculates the number of detected photons according Lambert-Beer's law.
r_{ij} is the projection in pixel i,j on the detector.

$$r_{ij} = r_0 e^{-\sum_{ijk} l_{ijk} f_{ijk}}$$



intersection length of pixel i,j,k

Reconstruction

The expectation-maximization algorithm updates the attenuation per voxel, according to

$$f_j^{(n+1)} = f_j^{(n)} + \Delta f_j^{(n)}, \quad j \in \{1, 2, \ldots, N\}$$

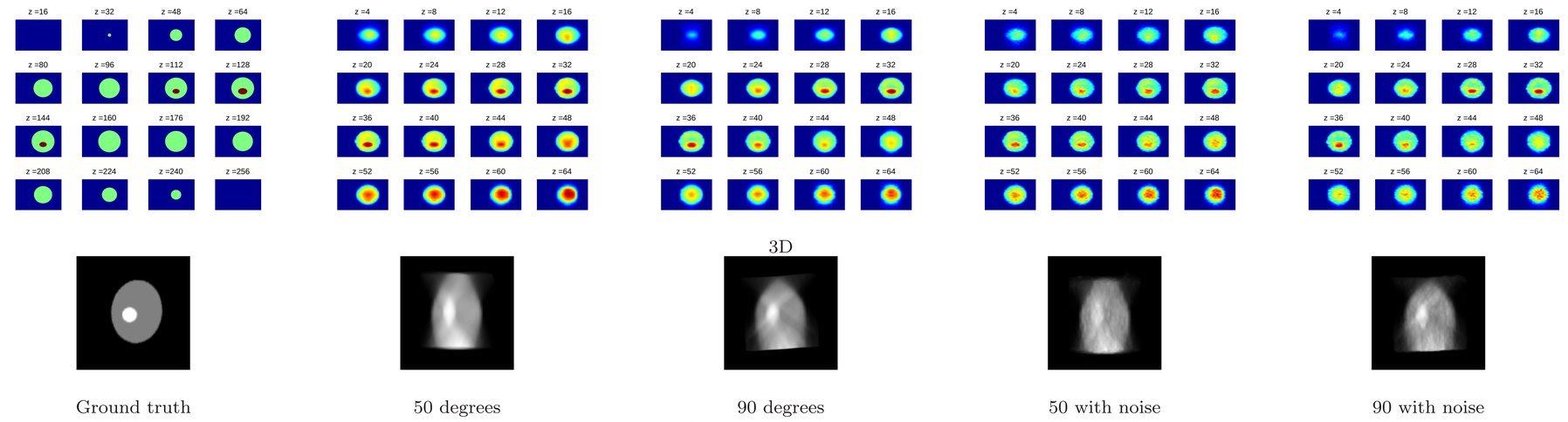
a set number of iterations, after which the attenuation map is scaled up and the process is repeated.

$$\Delta f_j^{(n)} = \frac{f_j^{(n)} \sum_{i=1}^{M} \left(l_{ij} (r_0 e^{-\langle l, f^{(n)} \rangle} - r_i \right)}{\sum_{i=1}^{M} \left(l_{ij} \langle l, f^{(n)} \rangle r_0 e^{-\langle l, f^{(n)} \rangle} \right)}$$

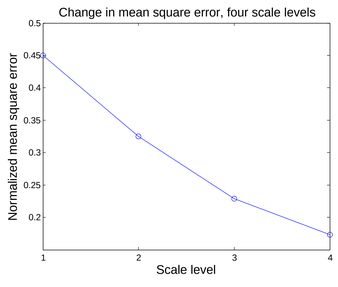
$$\langle l, f^{(n)} \rangle = \sum_{j=1}^{N} l_{ij} f_j^{(n)}$$

$f_j^{(n)}$ denotes the attenuation in voxel j at iteration n,
l_{ij} the intersection length between ray i and voxel j,
r_i the detected number of photons from ray i, and
r_0 the number of emitted photons.
$\langle l, f^{(n)} \rangle$ is the expected number of detected photons, given our attenuation map estimation.

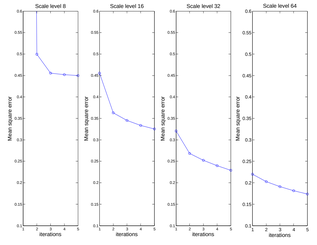
Results in-silico



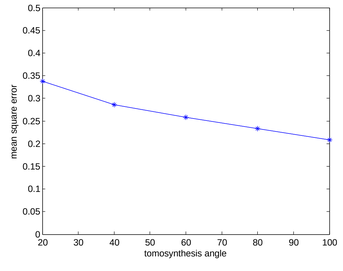
Mean square error



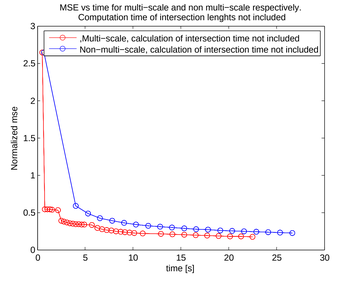
Variation with scale level



Variation with iteration



Variation with angle



Variation with time

Conclusion

- Multi-scale reconstruction yields better reconstruction, given equal computation time.
- The reconstruction improves with each iteration.
- Convergence is faster at coarser scale levels.
- With the detector sizes used in our experiments, it is possible to distinguish features enclosed in other objects of different attenuation.
- The program gives useful results despite measurement noise in the detector, which is present in real-life use.