

TomAS - Tomographic Algorithms and Ultrasound Simulation¹

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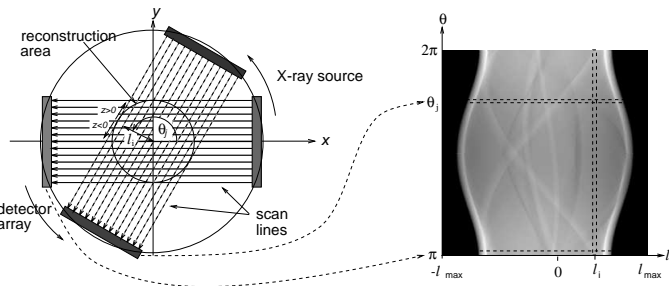
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Tomographic Algorithms

Ultrasound Simulation

Simulation of scan process

- Scan geometry (parallel or fan beam)
- Radon transform $\int_{-\infty}^{\infty} f(\sqrt{\ell^2 + z^2}, \phi(z)) dz$
- Error sources
 - scatter, noise, motion, ...

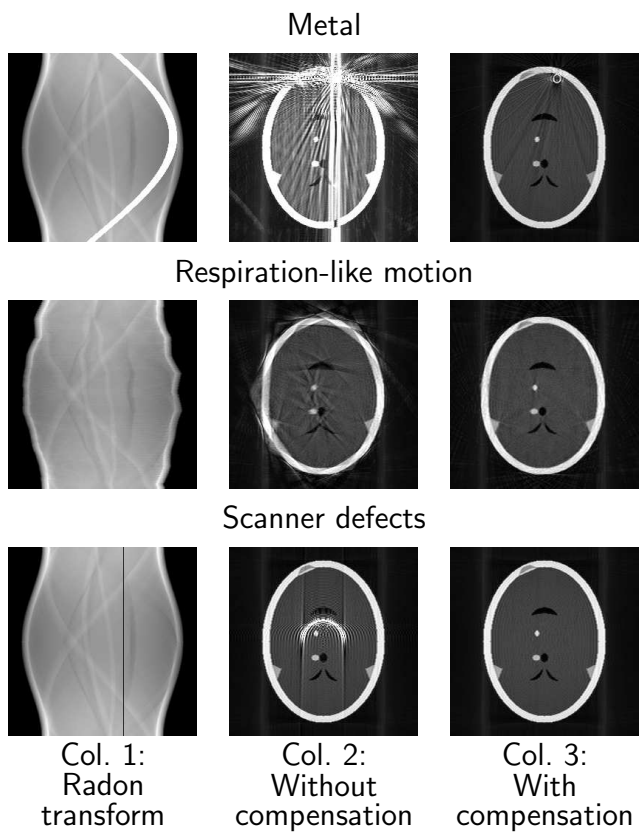


Reconstruction methods

Estimate density distribution from measured Radon transform.

- Algebraic reconstruction $f^* \approx \mathcal{R}^{-1} \cdot g$
- Filtered backprojection $-\frac{1}{2\pi} \cdot \mathcal{B} \mathcal{H}_l \mathcal{D}_l$
- Fourier method $\mathcal{F}_2^{-1} \mathcal{F}_1$
- Convolution method $\mathcal{B}(g * q)$
- Rho filtered layergram $\mathcal{F}^{-1} r \cdot \mathcal{F} \mathcal{B}$

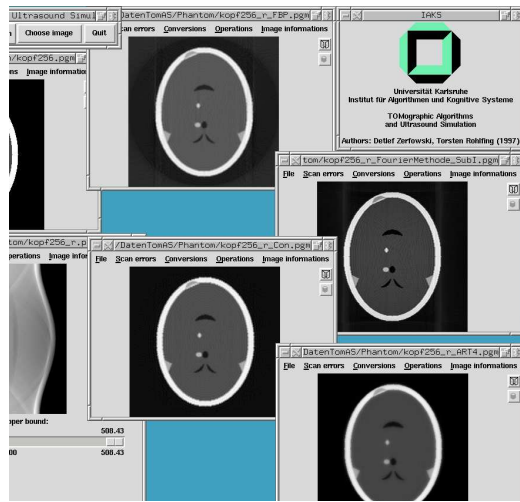
Simulated artifacts and image enhancement



- Reduction of metal artifacts
- Motion compensation
- Compensation for missing data
- Denoising

Sophisticated graphical user interface

- Intuitive window based appearance
- Suitable for educational purposes
- Implementation in C++ and Tcl/Tk
- Handling of various image formats



Phantom generation

- 3D phantom description language
 - Geometric primitives like ellipsoids, boxes, cylinders, etc.
 - Rotation, translation, copying, composition by adding or overwriting, etc.
 - Set operations for US-simulation: Union, intersection and complement
- Arbitrary phantom data sets (e.g. images, volume data sets) for CT-simulation

Signal transforms and operations

- Elementary operators
 - Normalization
 - Transforms of coordinate system
 - Pointwise operators (e.g. additive, multiplicative)
 - Crop and embedding operators
 - Contrast enhancement by range restriction
- Conversion between data types
 - Complex data \longleftrightarrow real data
- Signal transforms
 - Multi dimensional FFT
 - Multi dimensional wavelet transforms
 - Threshold operators on subbands for denoising or compression
 - Convolution and filter operations

Model of wave propagation

- Partial differential equation

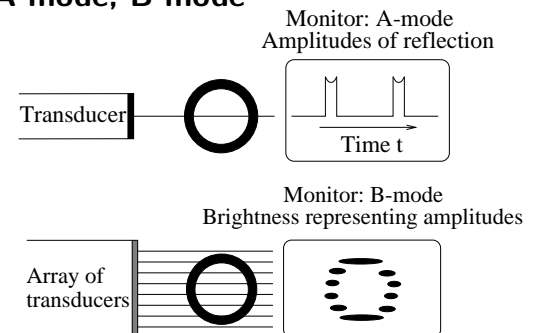
$$\nabla^2 \psi(\vec{x}, t) = \frac{1}{c^2} \left(\frac{\partial^2 \psi(\vec{x}, t)}{\partial t^2} + \underbrace{\mu c \frac{\partial \psi(\vec{x}, t)}{\partial t}}_{\text{decay}} \right)$$

- Finite differences

- Iterative approximation by 4D computational stencil.
- Frequency and minimal phase velocity determine spatial sampling.
- Spatial sampling and maximal phase velocity determine resolution in time.

Simulated scan modes

- A-mode, B-mode

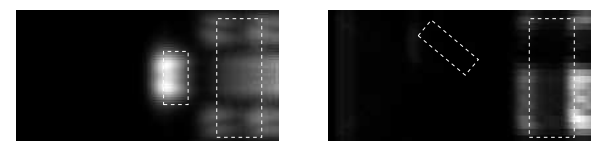


- Ultrasound tomography possible

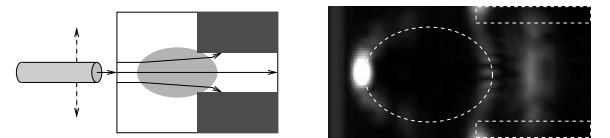
Simulated physical effects

- Linear B-scans performed in a simulated 3D volume

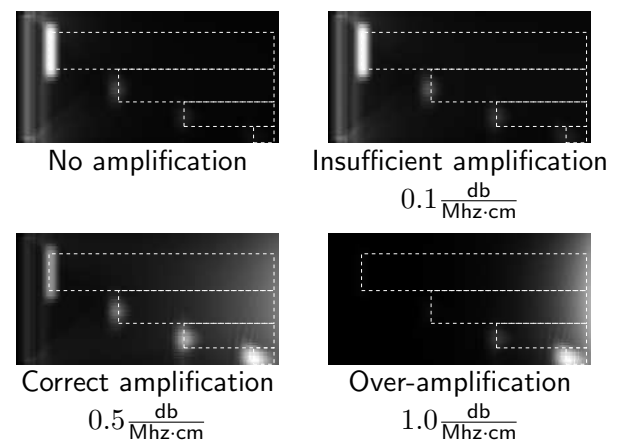
Orthogonal and non-orthogonal reflection



Sedimentation



Compensation of decay



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