X-ray imaging

F. Grüner
Röntgen’s first “medical imaging”
System-specific image processing

Adaptive auto-windowing algorithm
Basic principles

X-ray absorption/phase **contrast** imaging

X-ray fluorescence

Signal ("tumor is light source")
refractive index is written as \( n = 1 - d + i\beta \)

d and \( \beta \) as a function of energy in keV for biological tissue
absorption vs phase contrast imaging

different contrast generation

http://www.medphys.ucl.ac.uk/research/acadradphys/researchactivities/pci.htm
different contrast quality

http://www.medphys.ucl.ac.uk/research/acadradphys/researchactivities/pci.htm
- high resolution voxel models of breast
- created from CT-scans of anatomical breast specimens
- voxel size: 60 x 60 x 60 µm³
- segmentation in different tissues:
  - adipose
  - glandular
  - skin

- using brilliant undulator radiation: beam geometry, spectral angular flux,...
- simulation of absorption and scattering processes with Geant4-Software-Toolkit
absorption imaging: contrast reduction

Balance in imaging processing

Object detail

Surrounding structures
0.2 mGy average glandular dose at $\sim 10^{11}$ photons
absorption imaging: contrast enhancement

- geometrical limitation of radiation (aperture)
- anti-scatter grid ideal: focused anti-scatter grid

Anti- Scatter grid is placed directly on the film/screen-film-system/detector
a) Frequency of examinations

- CT: 8%
- Thorax: 11%
- Skeleton: 32%
- Others: 12%
- Dental: 37%

b) Collective effective dose from medicine

- CT: 60%
- Angiography/Intervention: 19%
- Others: 8%
- Skeleton: 10%
- Thorax: 3%
absorption imaging: applied dose

criterion = signal-difference-to-noise ratio versus averaged-glandular dose

analytical model

simulation for 3 different breast models → requires tunable source
absorption imaging: applied dose

Typically used number of photons in clinical systems

Together with MAP-AG Florian Gruener

Transmission of Main Absorber \( p \) minimum is always at ca. 20% transmission through main absorber

Together with Felix Schöfer, Schöfer et al. in prep.
Lung perfusion dual energy CT, courtesy of LMU

With especially designed „monoenergetic“ radiation low dose individualised medicine will be developed together with MAP II.

- New diagnostic tool
- at least two scans
- high dose
- registration problems
- non-optimal image information due to overlapping spectra
- Limitations for suitable markers
A sampling of dual energy scans demonstrating clinical application to:
- gout detection and quantification
- kidney stone characterization
- tendon/ligament differentiation.
• Differentiation between tissue structures
  - most notably between **malign** and **benign** carcinomas by
  • different scatter intensity caused by change in the collagen structure of malign tissue
  • different scatter distribution

→ Differentiation between malign and benign tissue without the need for biopsy would be a great benefit

Image of scatter distribution in tumour
X-ray fluorescence imaging

Using H2O with 100μg/ml Gold

e.g. 100 keV incident, 69 keV Au line
fluorescence imaging: experiments
Figure 8. Reconstructed GNP distribution and location within the PMMA phantom using experimental data shown in figure 7.
fluorescence imaging: background

max. sensitivity at 1mGy / 5mm pixel / CNR=5 ~ 10µg/ml ~ 100 times more sensitive than transmission-CT

(simulation by B. Müller, HZM/MAP)
Physicists’ impacts

- **new methods:**
  - phase-contrast with low-brilliance sources
  - absorption/x-ray fluorescence with high-brilliance sources

- **pushing the limits:**
  - dose reduction
  - lowering the concentration of contrast media
  - enhancing the sensitivity
  - enforcing personalized medicine

- **cooperations** between medicine and physics:
  - possibly comparative studies between UKE and my group (magnetic particle imaging vs X-ray fluorescence imaging)
  - new detectors for medicine (Erika!!)