LUND UNIVERSITY

Mathematical methods and simulations tools useful in medical radiation physics

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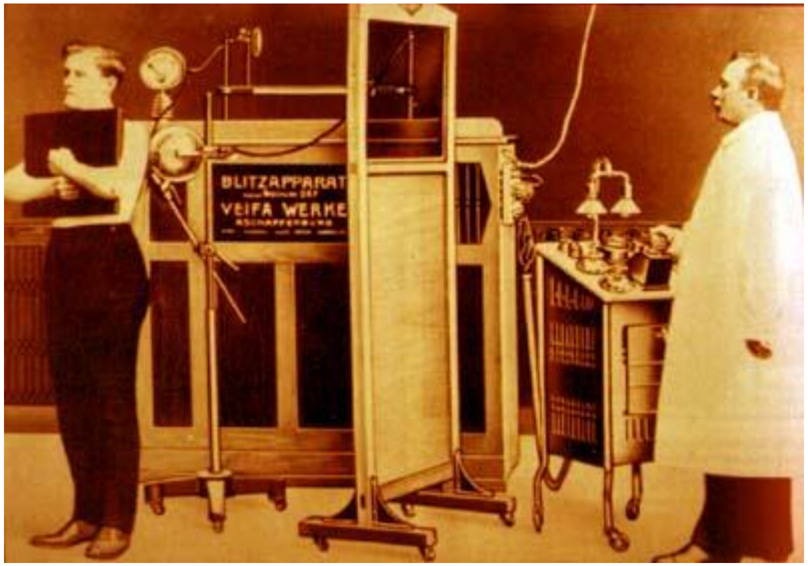
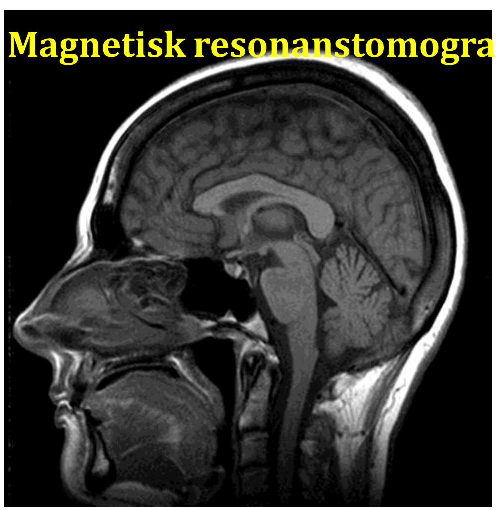
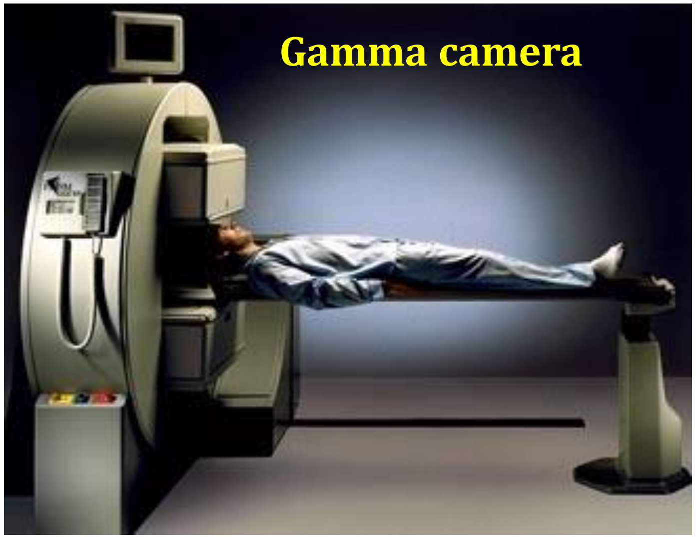
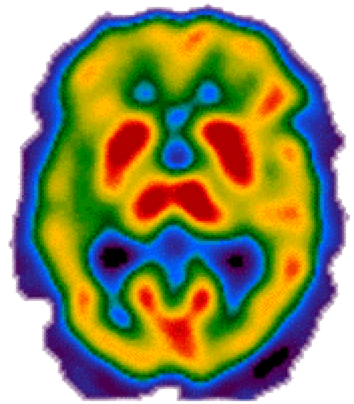
Major topic 1: X-ray investigation and MRI





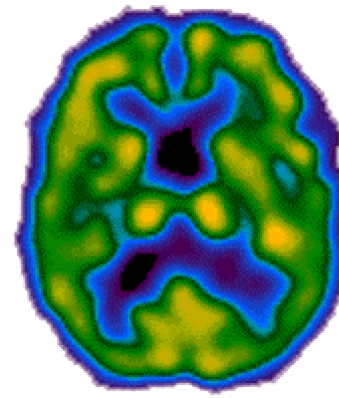
Major topic 2: Nuclear medicine for functional imaging

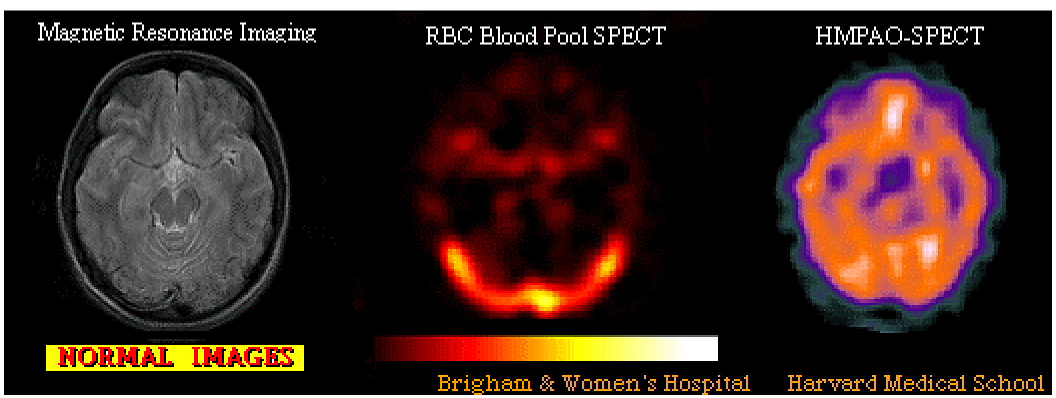




Healthy

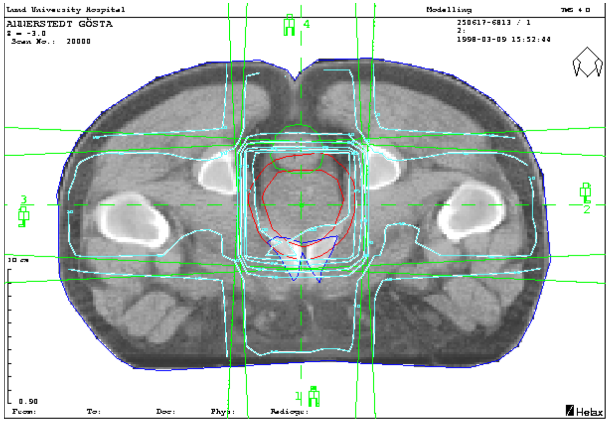
Drud-adicted brain



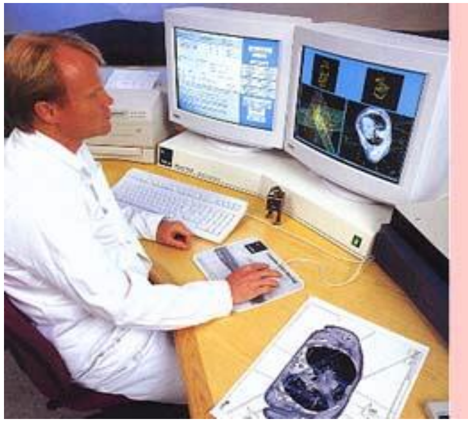


Radio-pharmaceuticals

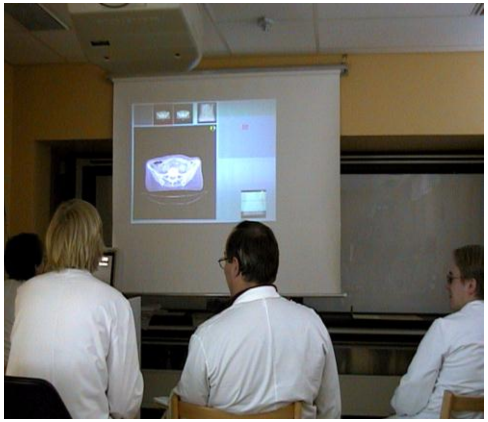
Major topic 3: Treatment of Cancer by Radiotherapy



Doseplan



Doseplaning



Discussion

Treatment

The Medical Image

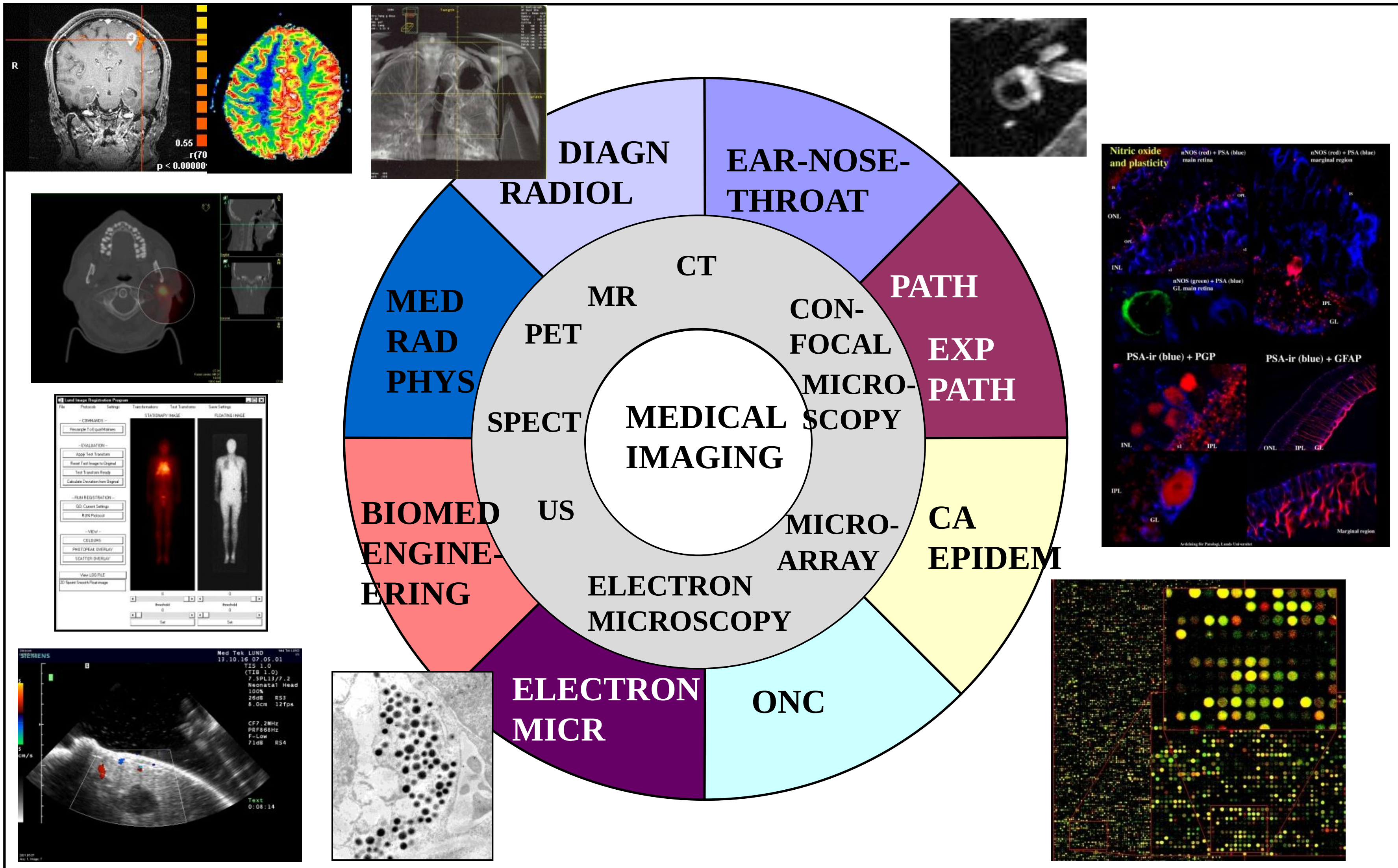
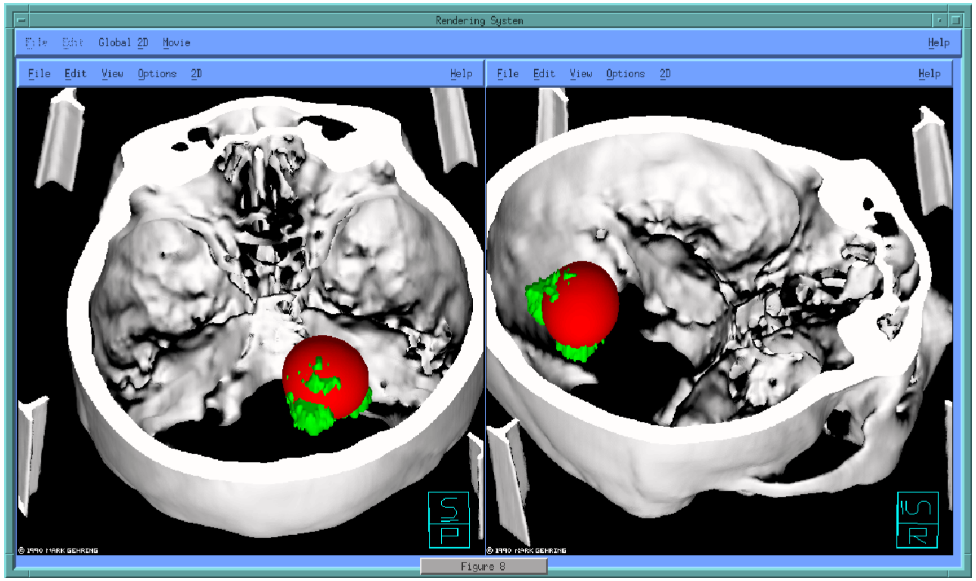
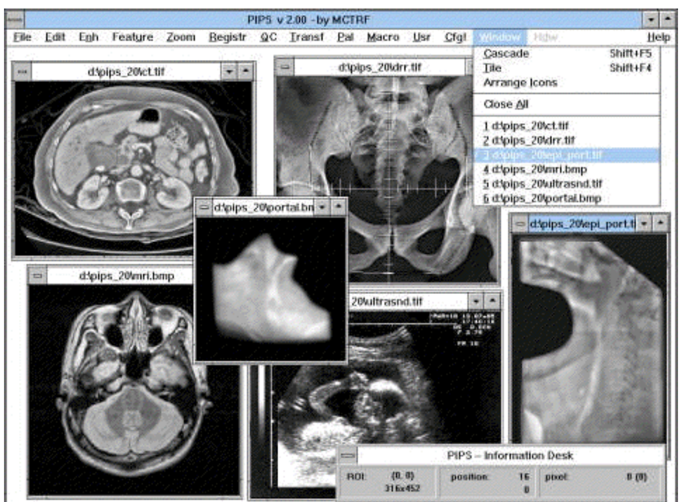
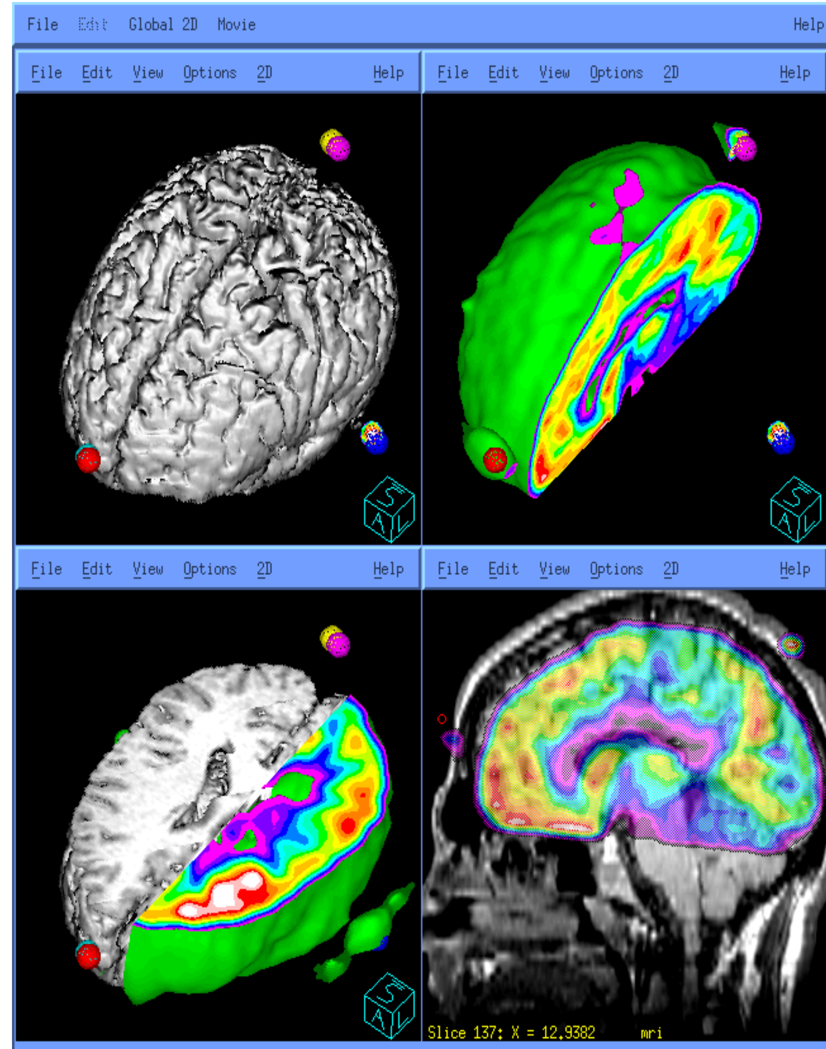


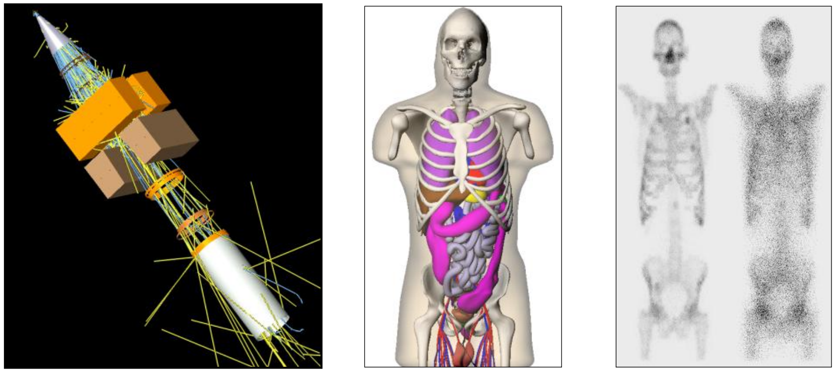
Image processing and display





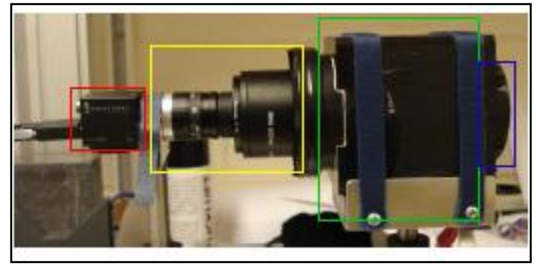


Main Research Topics at the Medical Radiation Physics

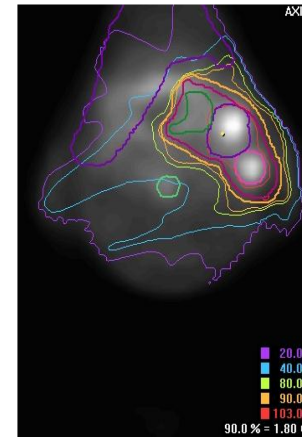


Mathematical Modeling by Monte Carlo Methods

Detector Development

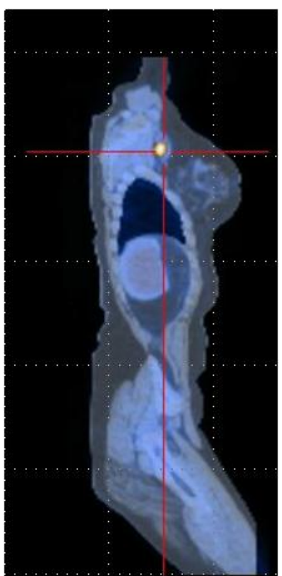


Radiotherapy and Doseplanning

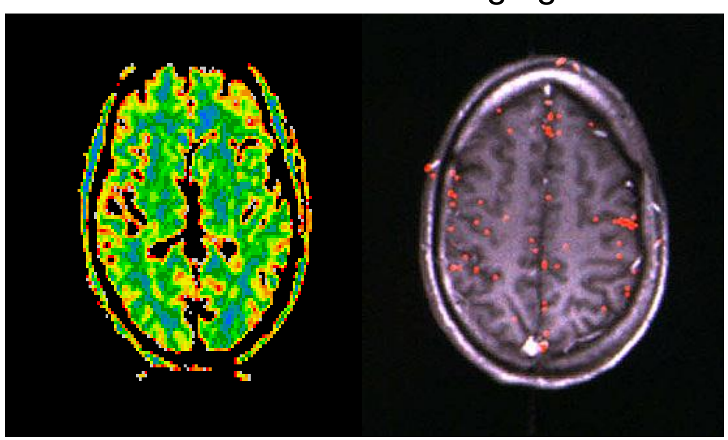


Oncology Imaging and Dosimetry

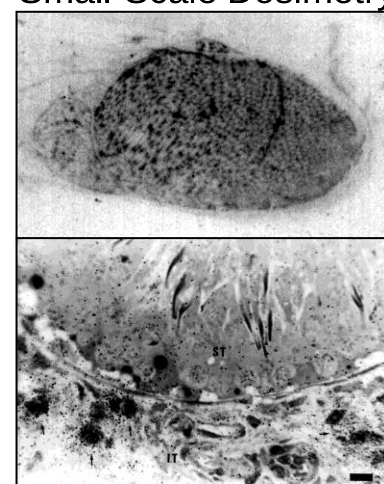
Nuclear Medicine Imaging



Functional MR Imaging



Small-Scale Dosimetry



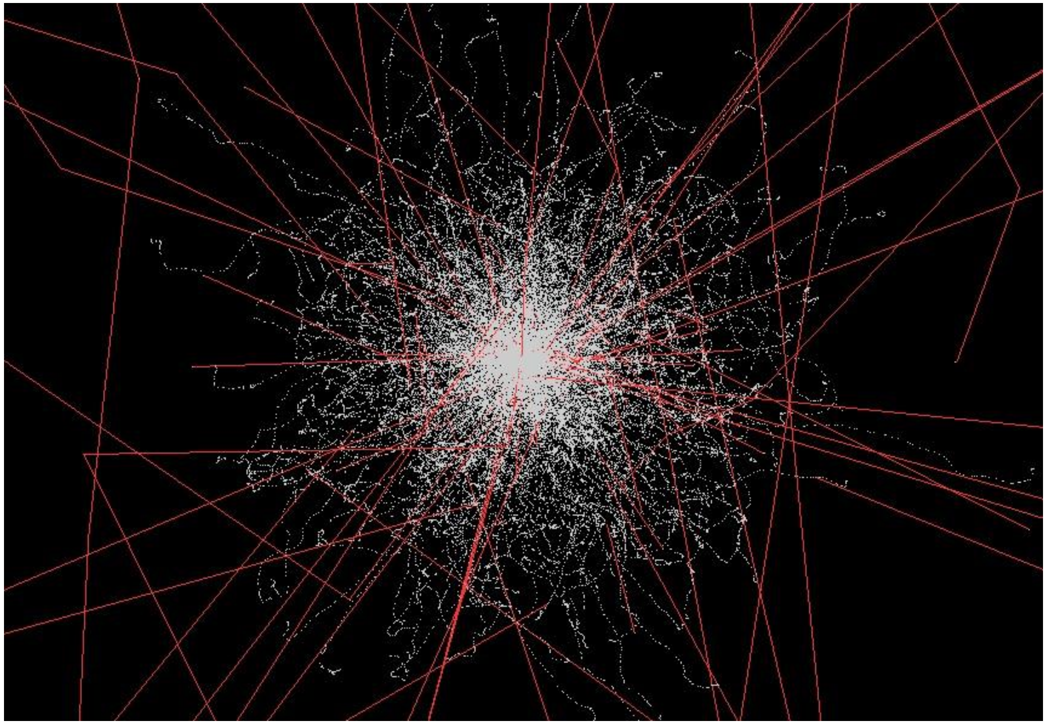
Monte Carlo Calculation

Useful in many areas of Medical Radiation Physics

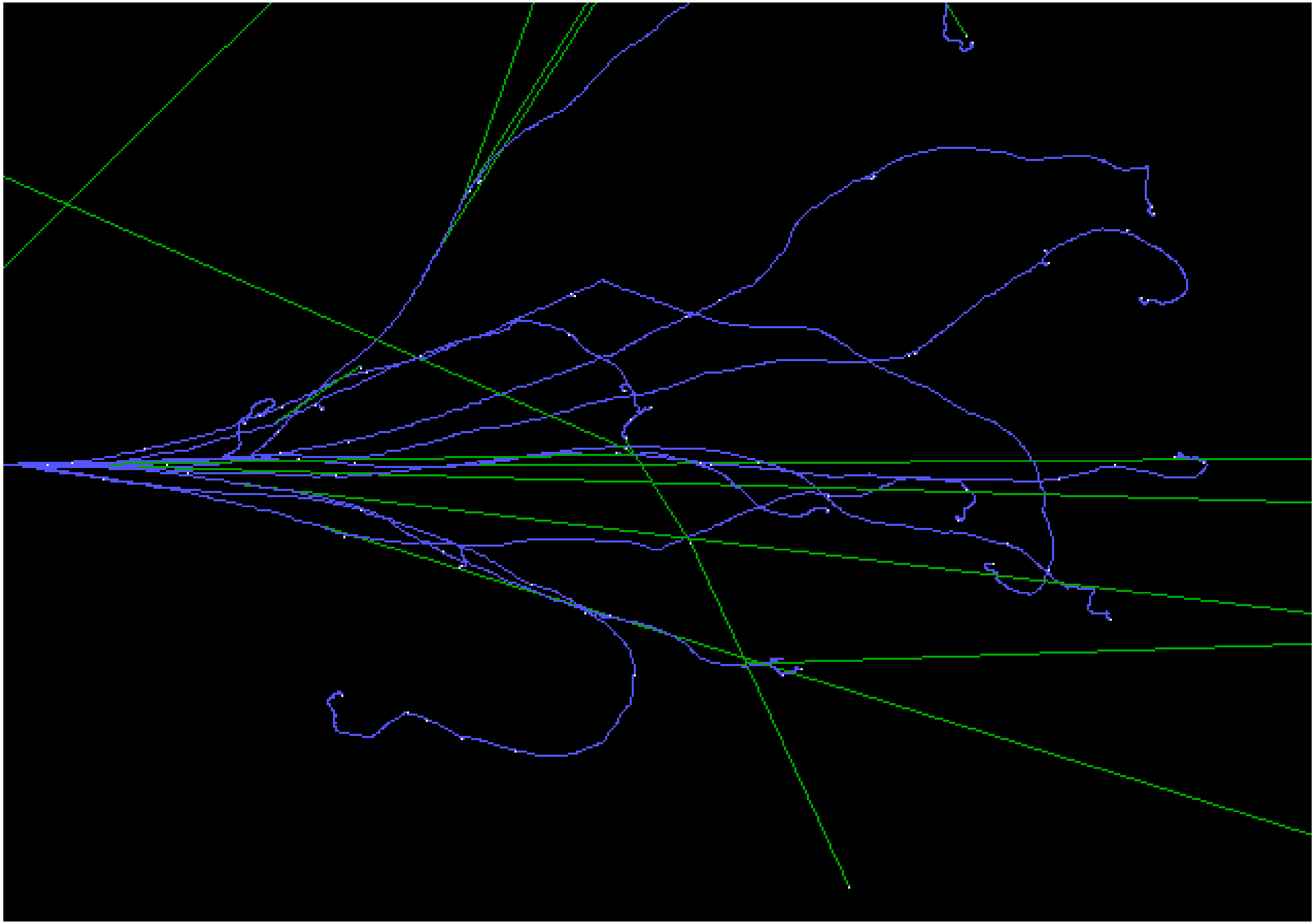
Simulates particle tracks and energy depositions

”Public Domain” programs available

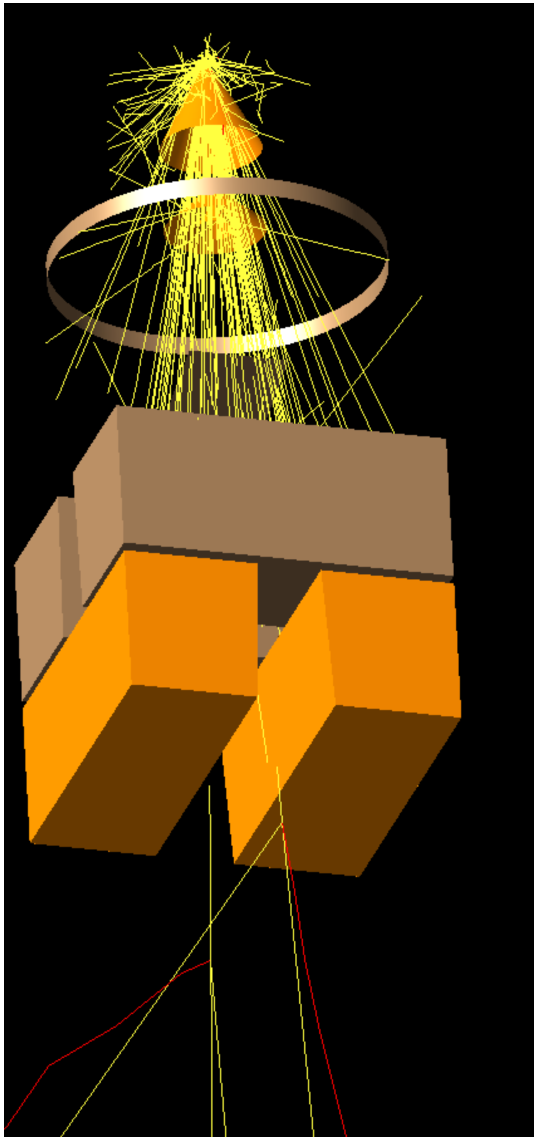
- EGS4,EGSnrc
- MCNPX
- Geant4
- Penelope
- SIMIND
- GATE
- SIMSET

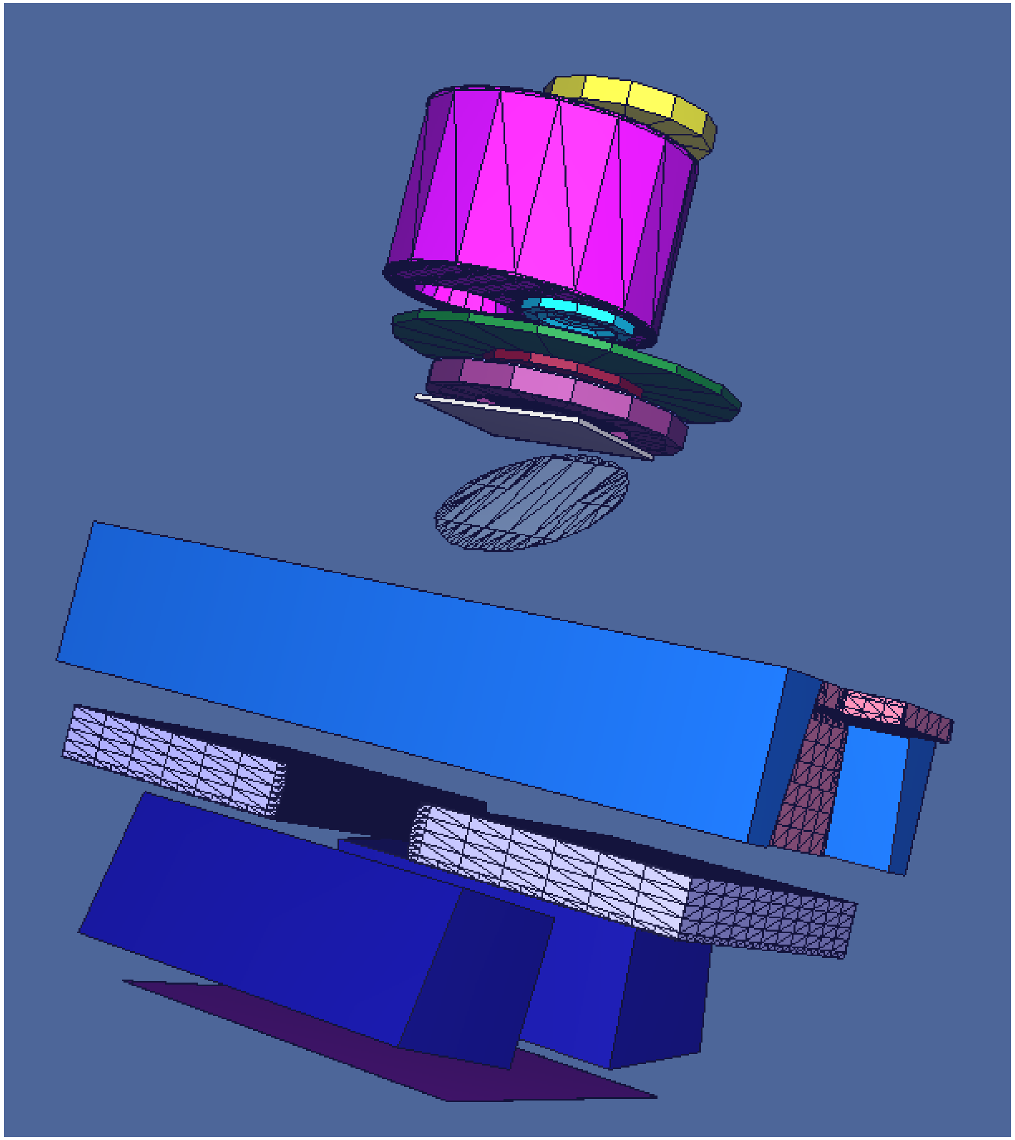


10 MeV electrons in water



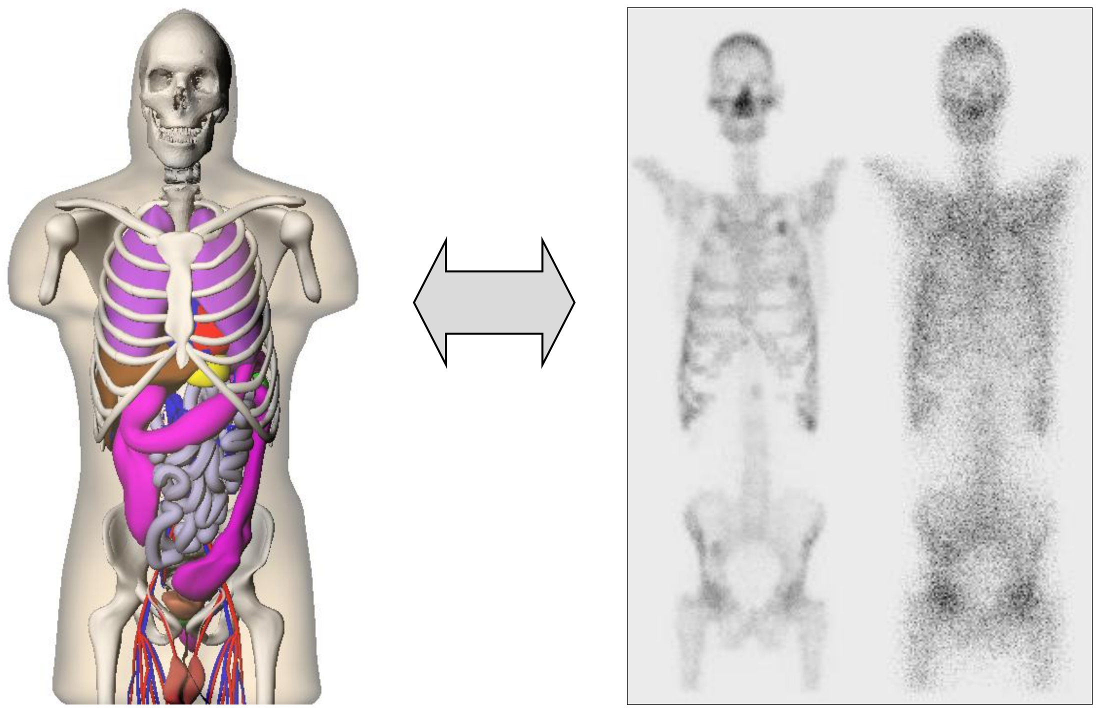
Simulation of Radiotherapy units





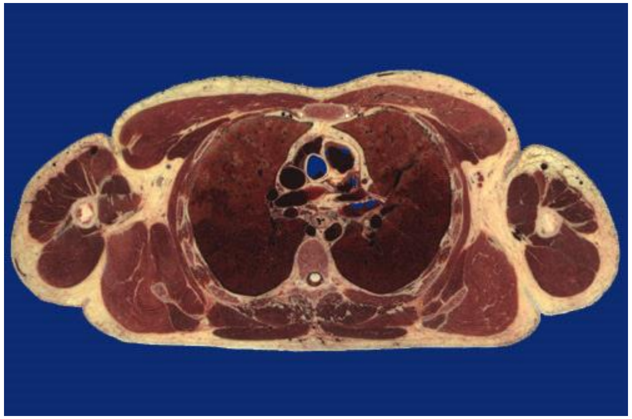
Monte Carlo simulations

Mathematical modeling of
scintillation cameras by Monte Carlo



Development of the NCAT/XCAT Male and Female Base Anatomies

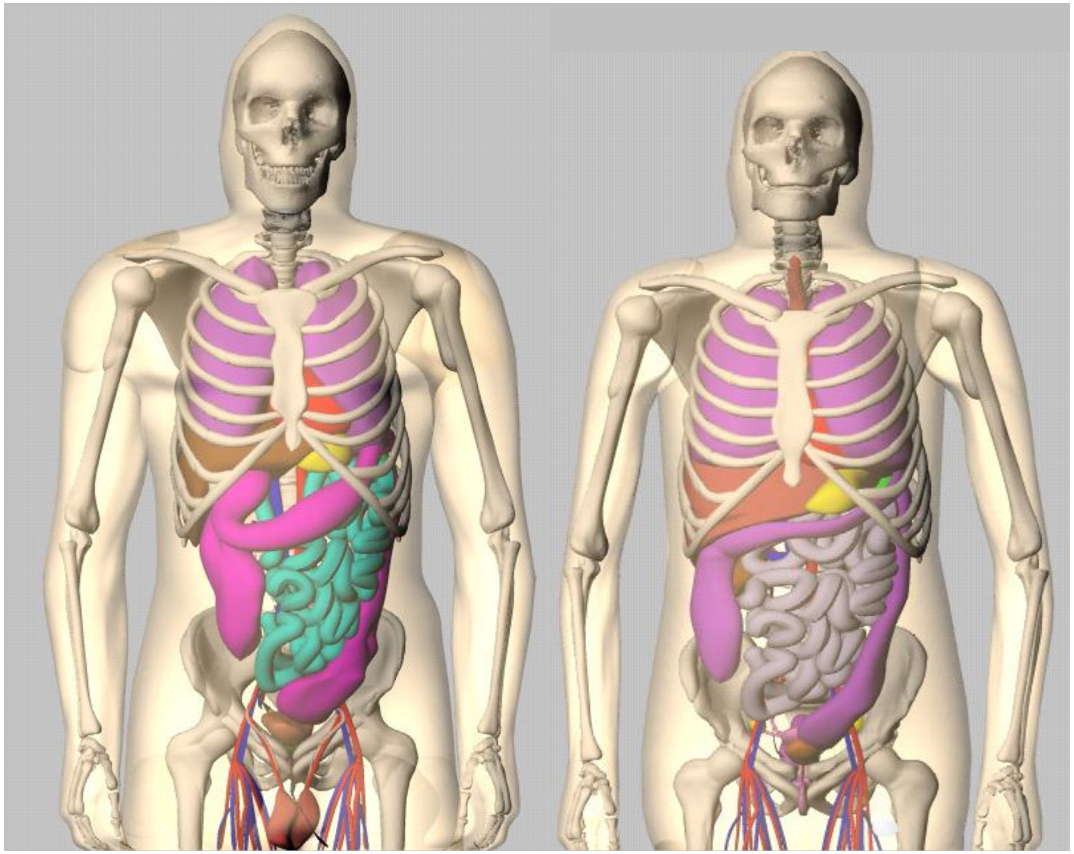
Segmented Organs From Imaging Data



Visible Male Anatomical Images

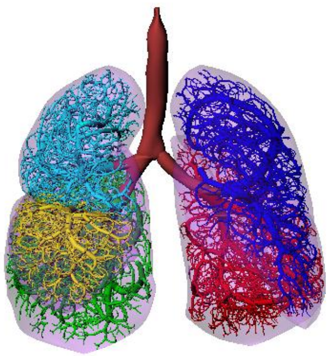
Visible Female Anatomical Images

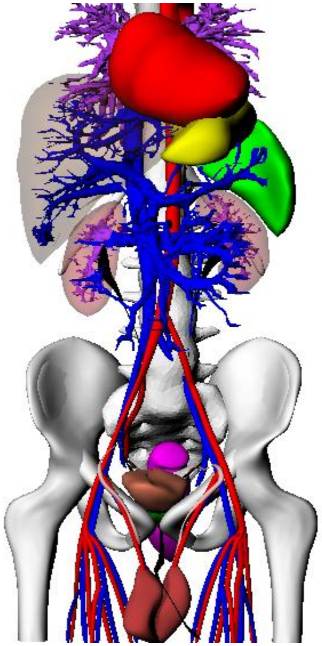
Fit 3D NURBS and Subdivision Surfaces to Segmented Organs

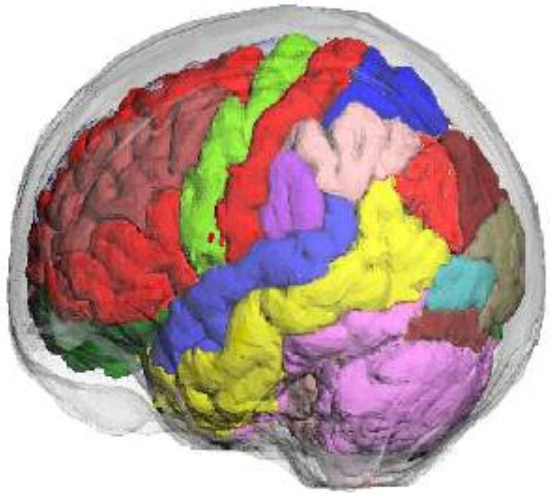


Male Anatomy Female Anatomy

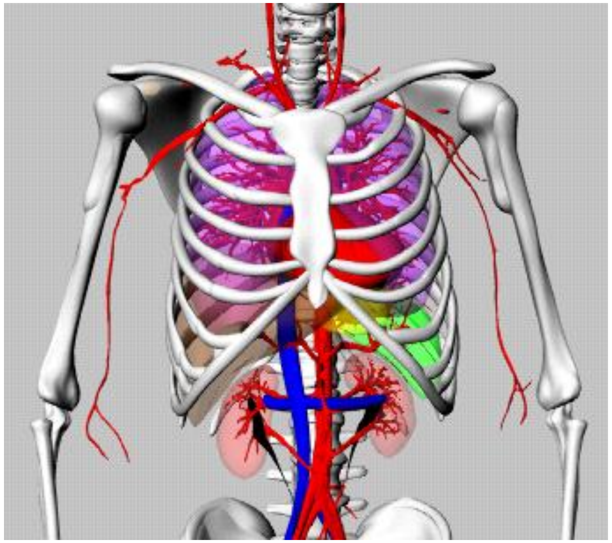
Phantom Anatomy



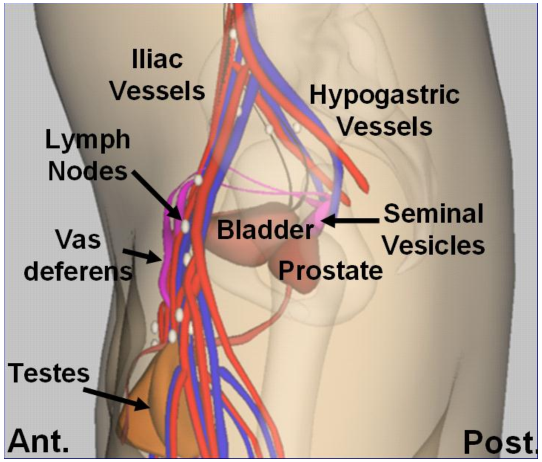




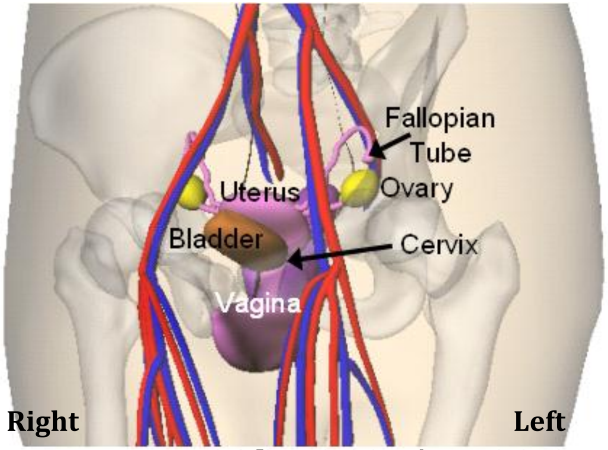
Head



Chest

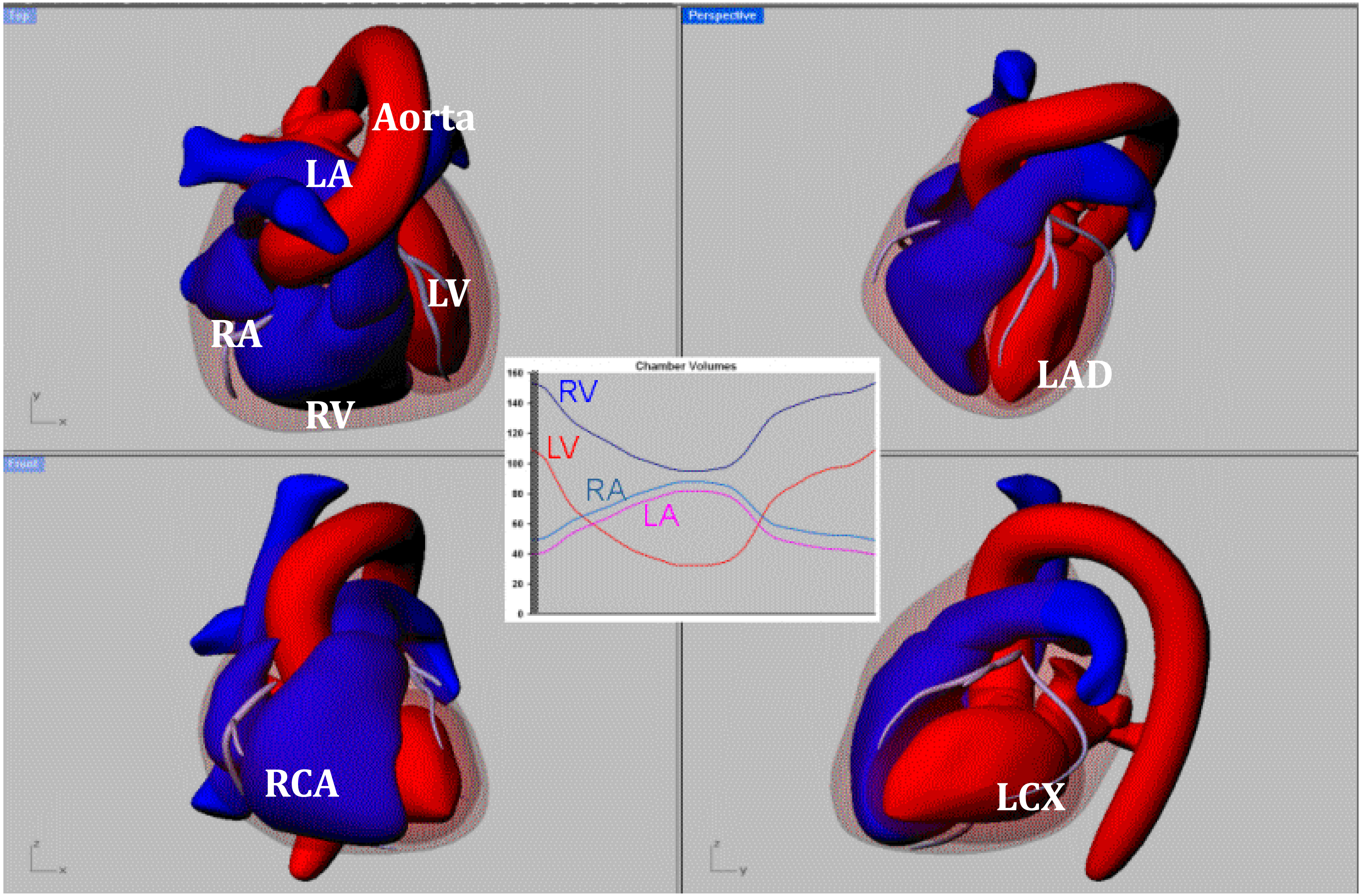


Male Abdomen



Female Abdomen

4D Beating Heart Model



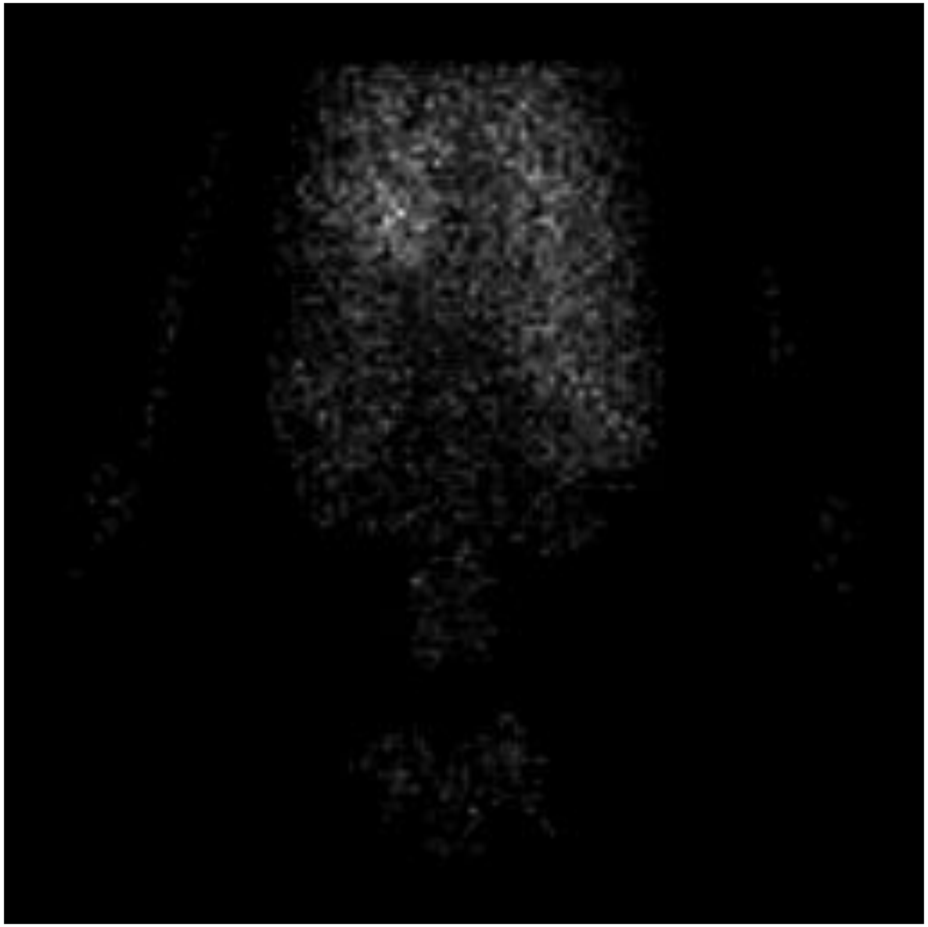
Evaluation of Renography studies

Computer phantom useful to simulate realistic

Renography

Investigare the function of the kidneys

Simulations using realistic Phantom



Voxel-/Pixel-based radiation dosimetry

SPECT/CT voxel-based dosimetry:

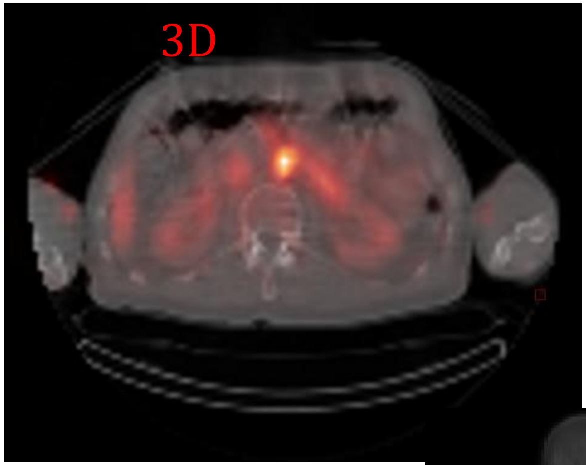
- OSEM image reconstruction with detailed corrections
- Deformable image registration of time-series of images.
- Monte Carlo based Absorbed dose calculation.

Planar whole-body pixel-based dosimetry:

- Image-based activity quantification with detailed corrections for photon interactions in the patient and camera
- Deformable image registration of time-series of images.
- Absorbed dose based on ref. data for imparted energy/decay

Both SPECT/CT and Planar based methods:

- Curve-fitting procedures.



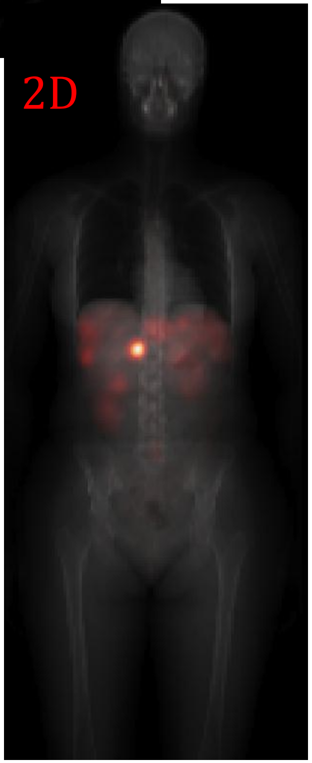
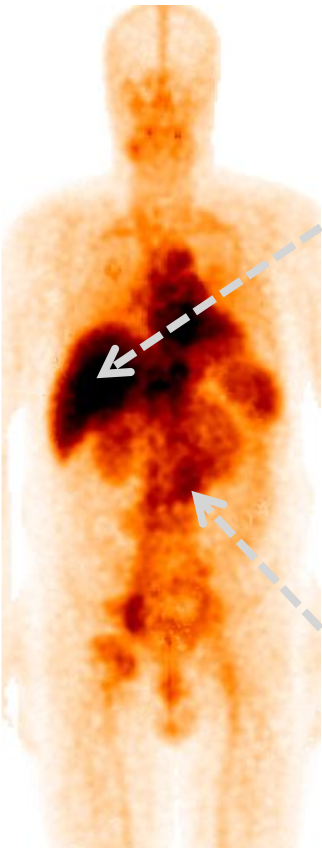
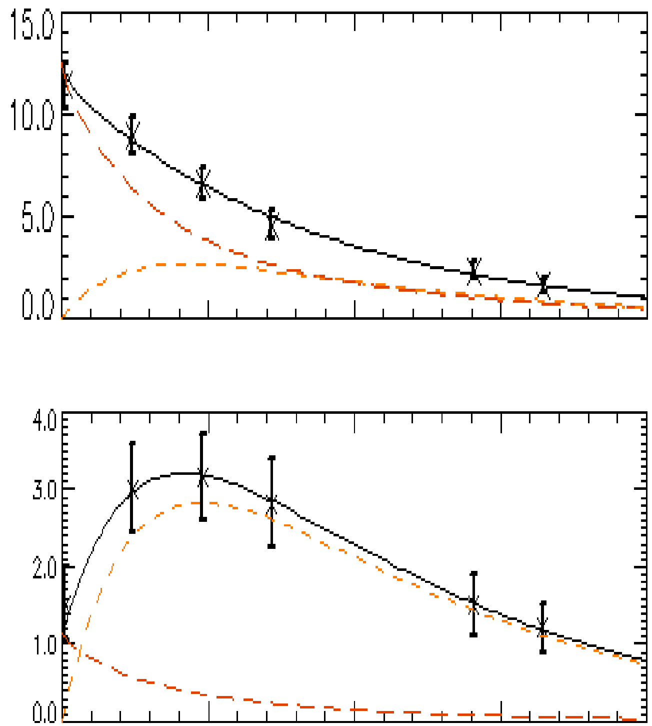


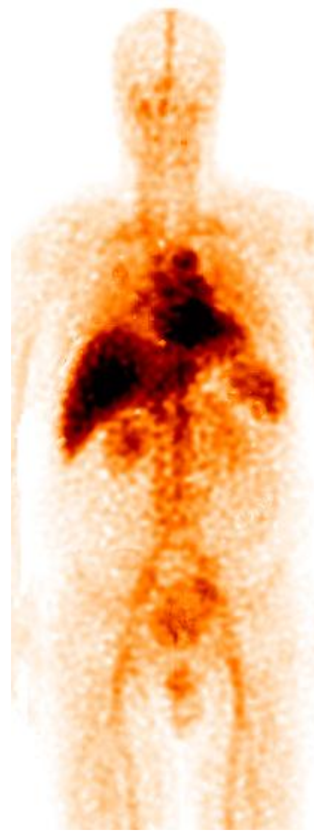
Image-based pharmacokinetic modeling

Total AUC

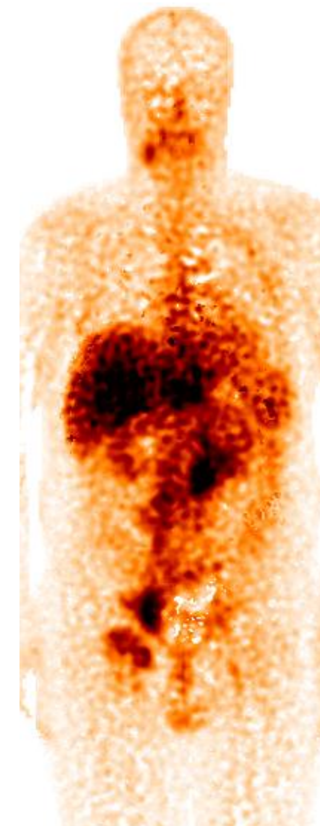




Vascular AUC



Extra-Vascular AUC

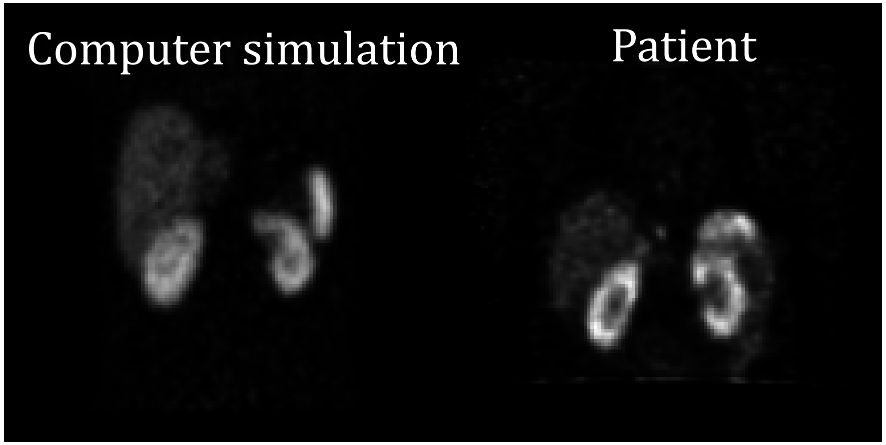


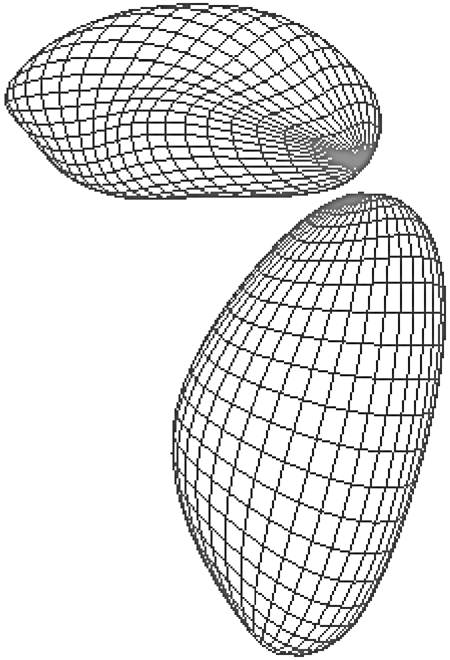
Automatic segmentation

Automatic segmentation could offer an increased reproducibility in the analysis of an image

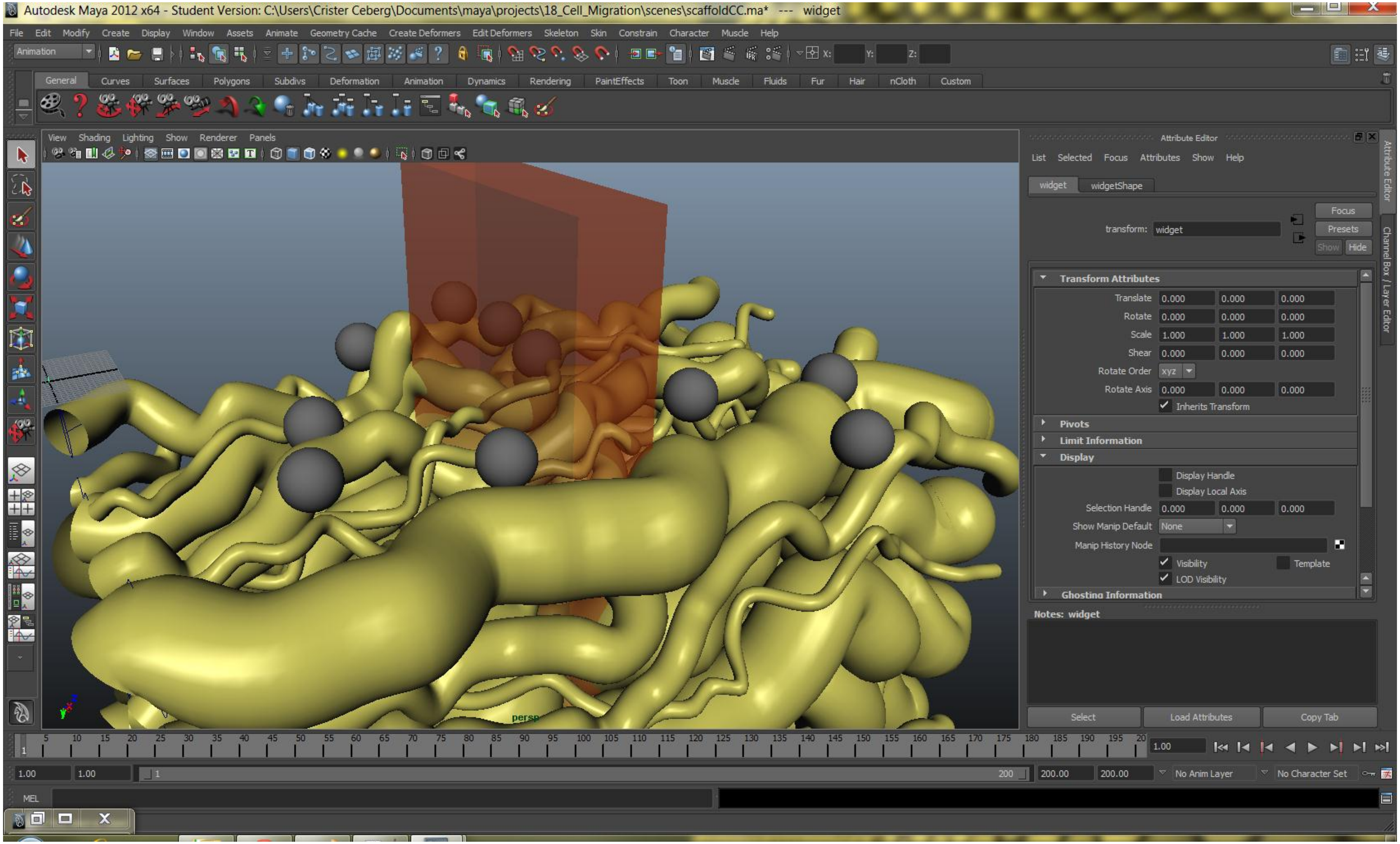
SPECT images are characterized by a poor spatial resolution and high noise levels, making segmentation difficult

Using surfaces described by Fourier descriptors



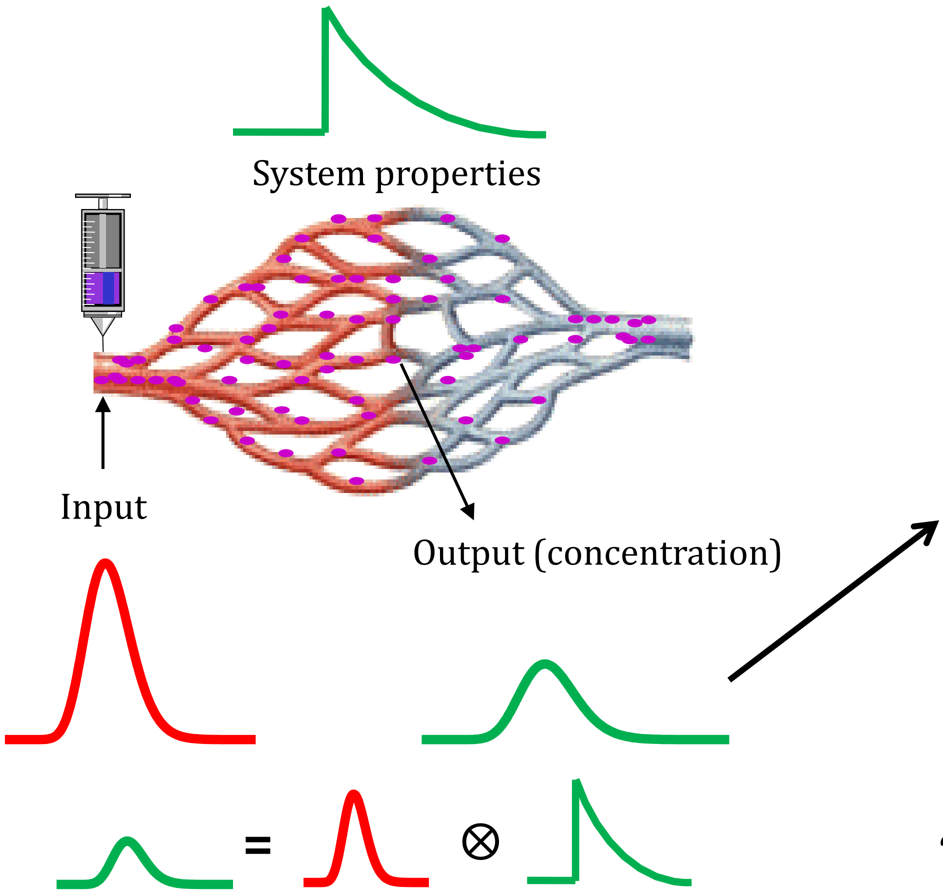


Cell migration under the influence of an external irradiation beam



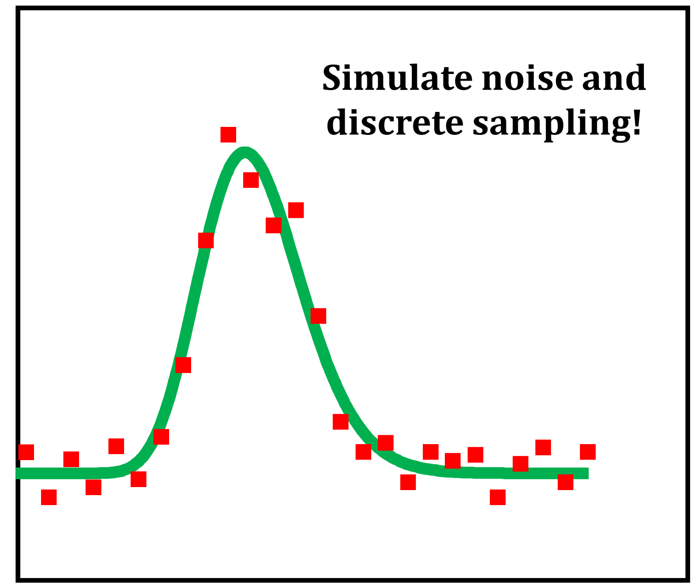
Perfusion MRI

1) Simulate the physiological system and injection



Output = Input ⊗ System

2) Simulate the experiment (imaging)



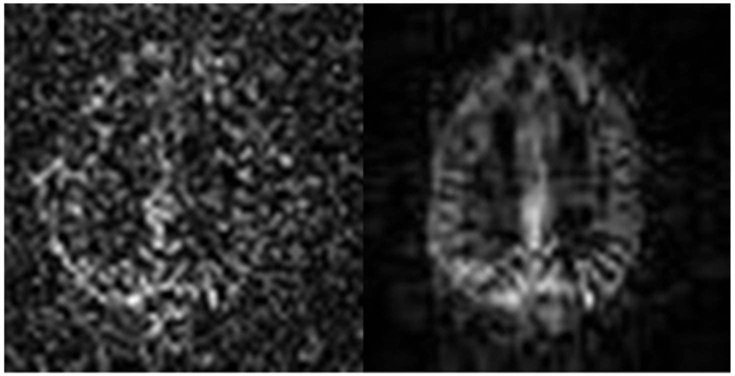
1000s of realizations

Hopefully gives answer to the question:

"Is the system properties (parameters) recoverable with our method/model/experiment?"

Image Processing and Visualisation - MRI

(1) Denoising of magnetic resonance image (MRI) data by *wavelet-domain filtering*: Application to arterial spin labelling (ASL) images for improved quantification of brain capillary blood flow (cerebral blood flow, CBF).



Unfiltered Filtrered

Fig. 1: Left: Original (unfiltered) map of cerebral blood flow. Right: Corresponding image after wavelet-domain filtering.

(4) Multidimensional velocity mapping using MRI: *Visualization* can bby displaying the velocity vector field at a given time point (Fig. 4, left) or by using streamlines, which represent the tangents of the vectors at a given time point (Fig. 4, right).

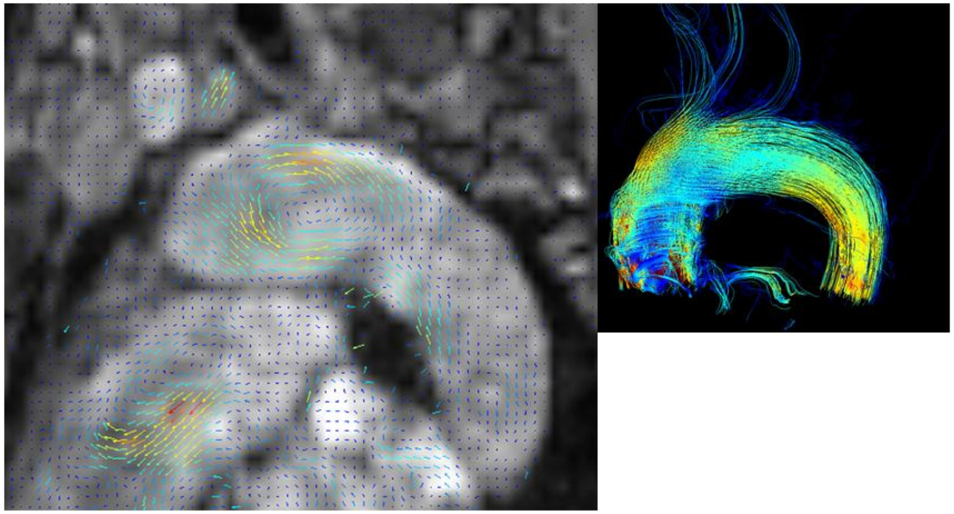


Fig. 4: Left: Aortic blood flow in healthy volunteer. This image shows the vector field at the time when blood is ejected from the heart into the aorta. Right: Streamlines in the aortic arc of a healthy volunteer, at the time when all blood has been ejected into the aorta.

Conclusion

Medical Radiation Physics

The image is essential.

1. Quantification
2. Visualisation
3. Simulation
4. Optimisation

Need to good mathematical methods and tools