A brief overview of medical imaging using Ultrasound, MRI, X-ray CT, and PET

Yakov Keselman

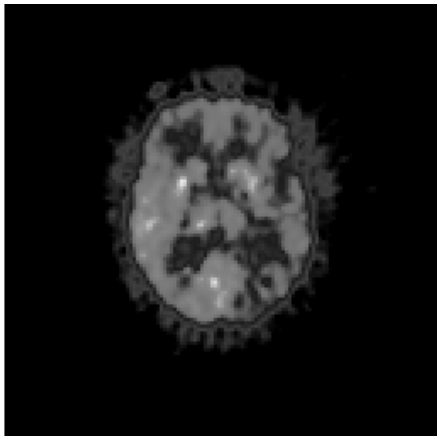
School of CTI
DePaul University

Based on slides by
Dr. S. J. Doran
Department of Physics
University of Surrey

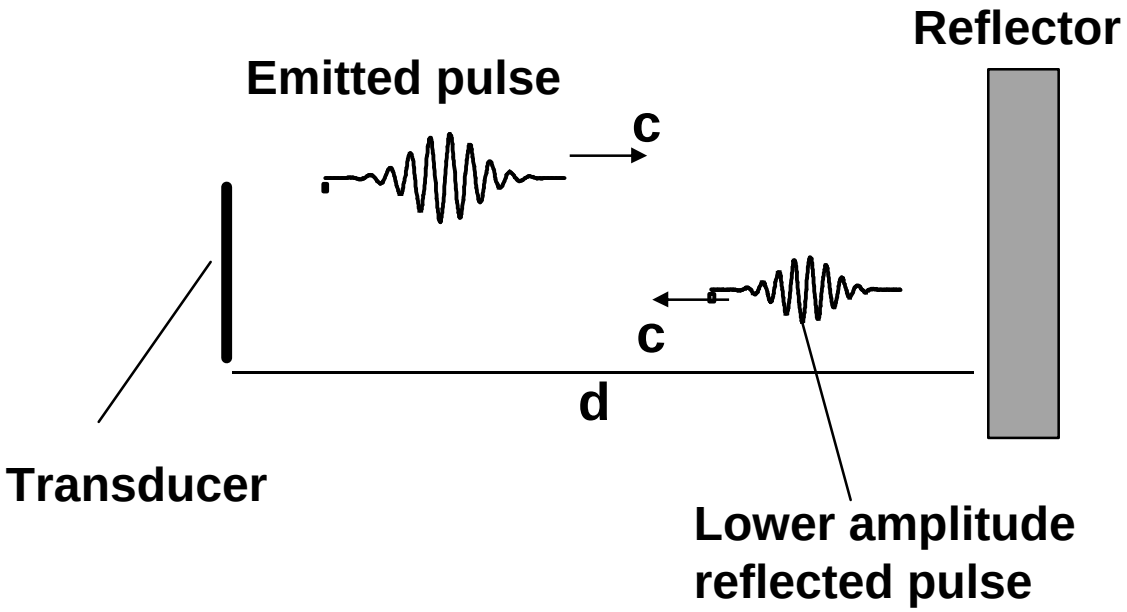
Different imaging methods reveal different features

- Ultrasound maps the *reflection and attenuation* of sound
- MRI maps the *distribution and "environment"* of water molecules in the body
- X-ray CT maps the *attenuation* of X-rays
- PET maps the distribution of *radioactively labeled* compounds

- "Understanding" the resulting images automatically (by computer) is highly challenging



Basic Principles of Diagnostic Ultrasound



- Based on ultrasound reflection and attenuation coefficients
- Position calculated using equation d = ct/2

Use of Ultrasound in Obstetrics

5.5 Weeks

6 Weeks

Data source : Joseph Woo

Use of Ultrasound in Obstetrics

18 Weeks

19 Weeks

Data source : Joseph Woo

Use of Ultrasound in Obstetrics

Bi-parietal diameter

The distance between the two sides of the foetal head

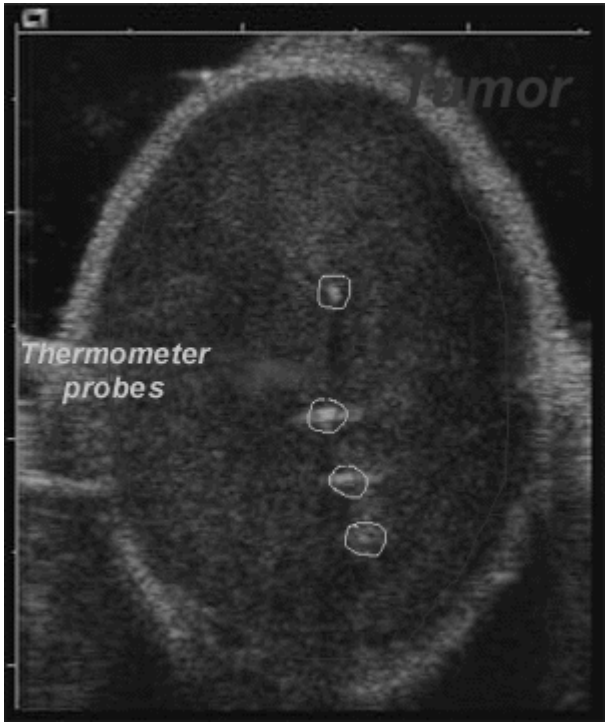
Length of femur

Femur: the long bone of the thigh

Measurements of foetus *in utero*

Data source : Joseph Woo

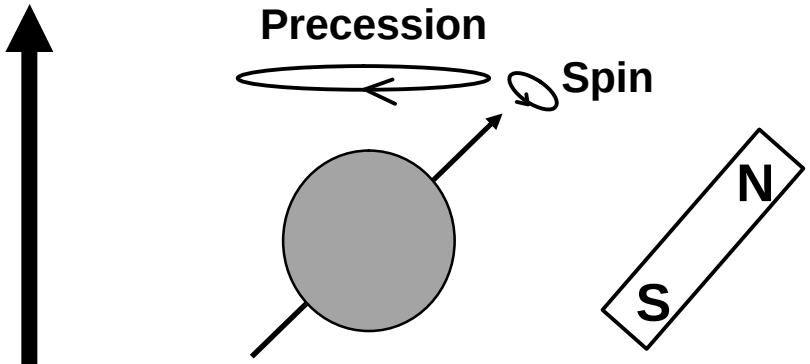
Segmenting Ultrasound Images



Method: deformable models

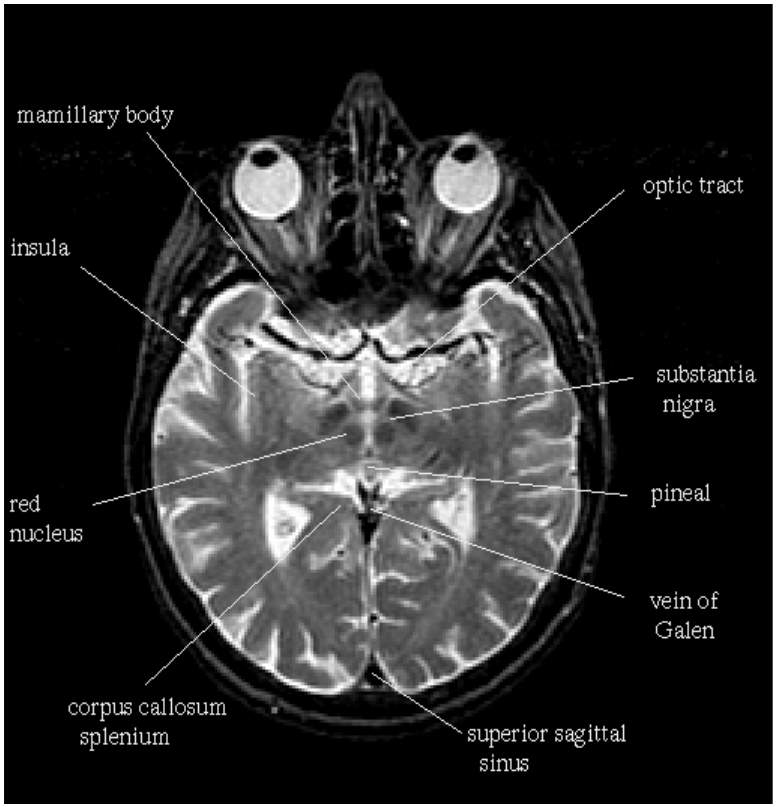
Source: www.ubmi.cvut.cz/aktivity/ultrazvuk/ivan/main.html

Basic Principles of MRI



- In a magnetic field, spinning nuclei *precess* at the Larmor frequency.
- The spin-up and spin-down nuclei have different energies.
- Transitions between levels lead to emission of photons, which we can detect.

The Human Brain as seen by MRI



Data sources : Left - The Whole-brain Atlas, K. A. Johnson and J. A. Becker, Harvard; Right - SMIS UK Ltd.

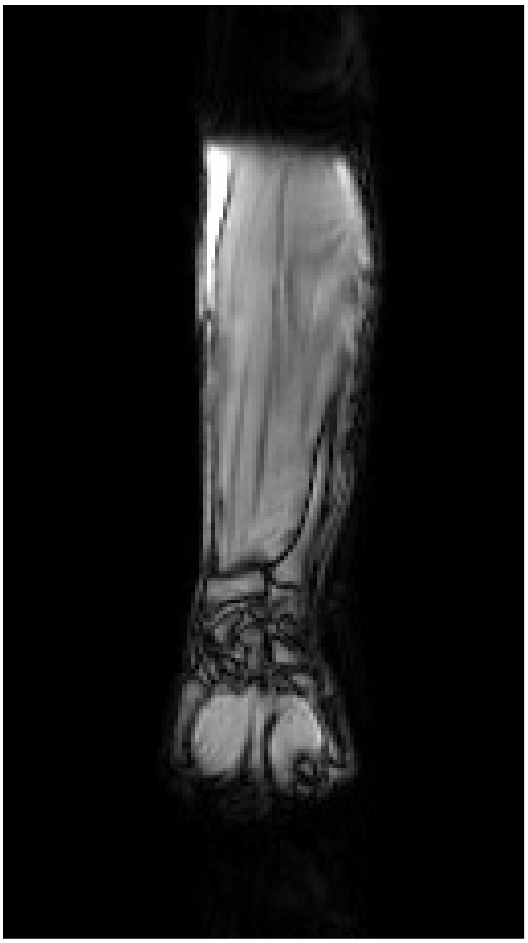
MRI can image much more than just the brain ...

Knee

Knee (close up, different patient)

Data source : SMIS

MRI can image much more than just the brain ...



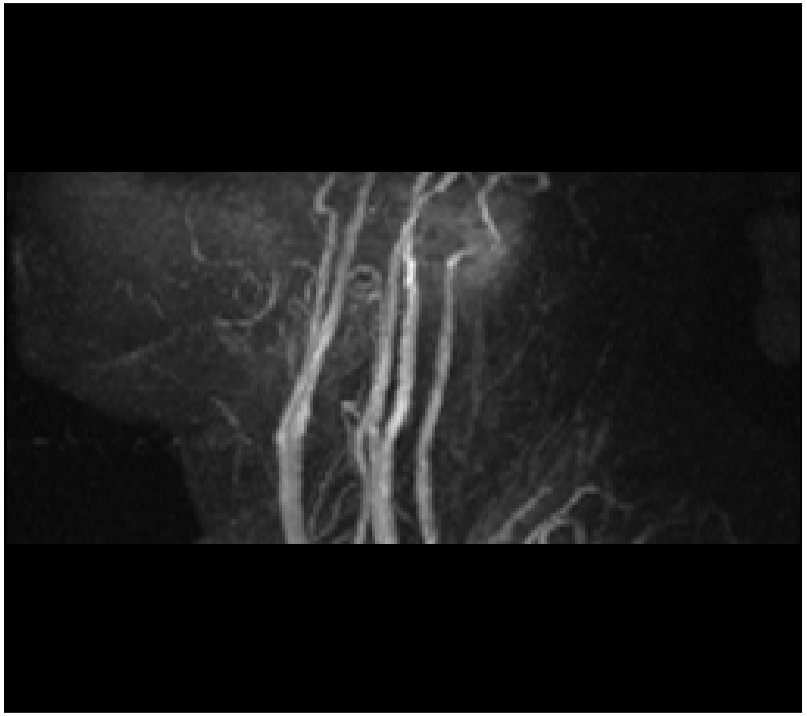
Arm, wrist and hand

Lumbar spine

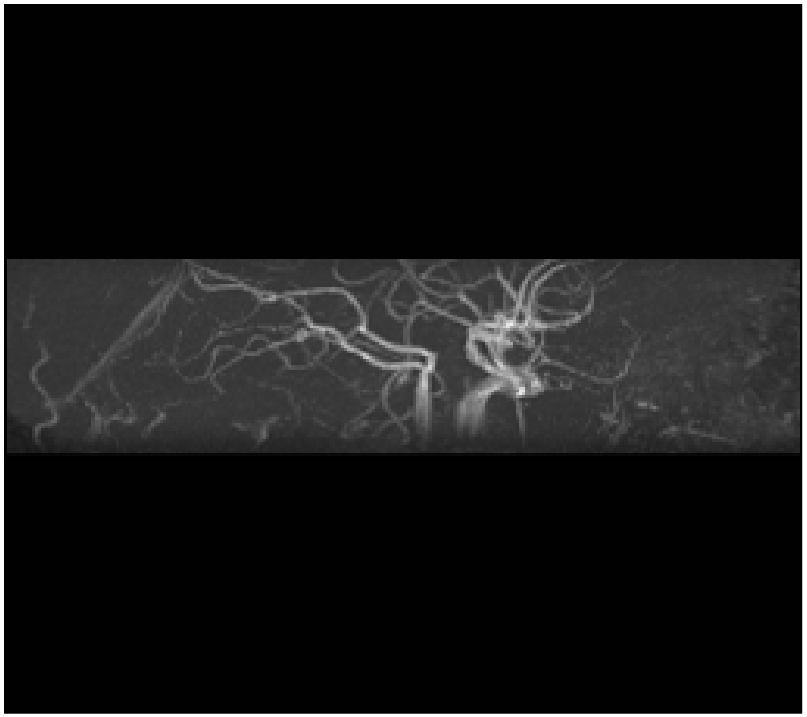
Chest region

Data source : UoS, SMIS

Magnetic Resonance Angiography



Neck

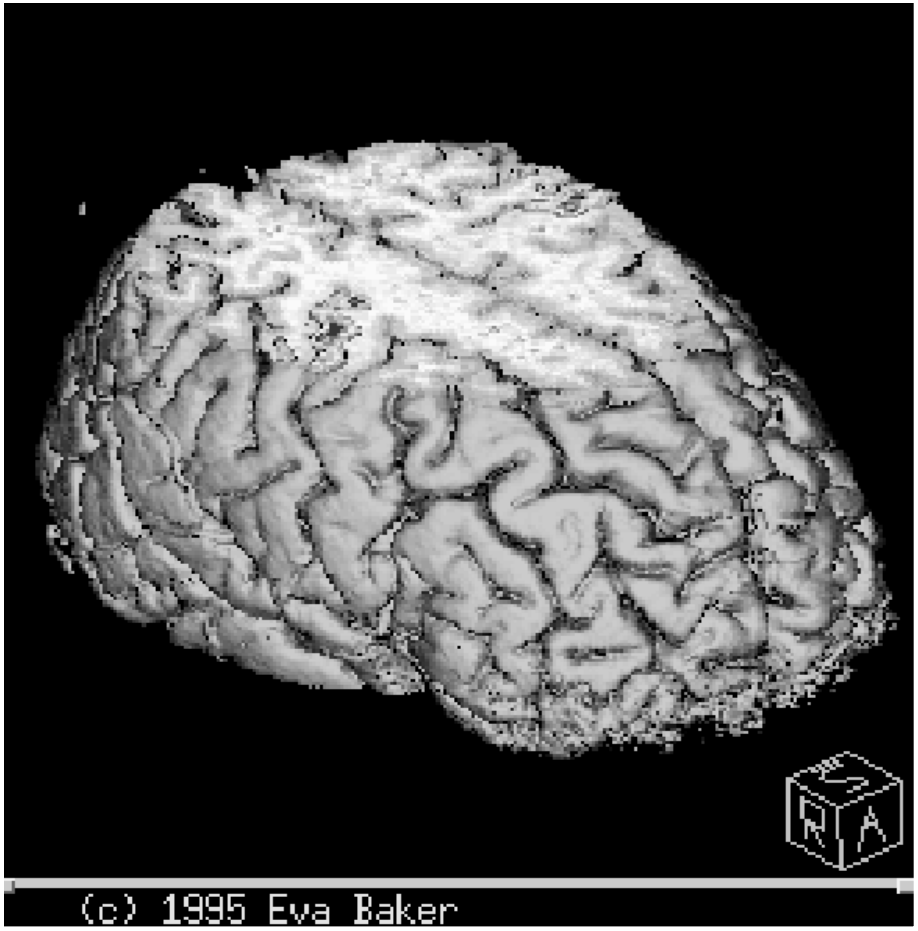


Small part of head

MRI can also be used to visualize patterns of blood vessels. In these pictures, the image has been sensitized to *movement*, in this case the movement of blood inside veins and arteries.

Data source : The Whole-brain Atlas, K. A. Johnson and J. A. Becker, Harvard

Functional Imaging

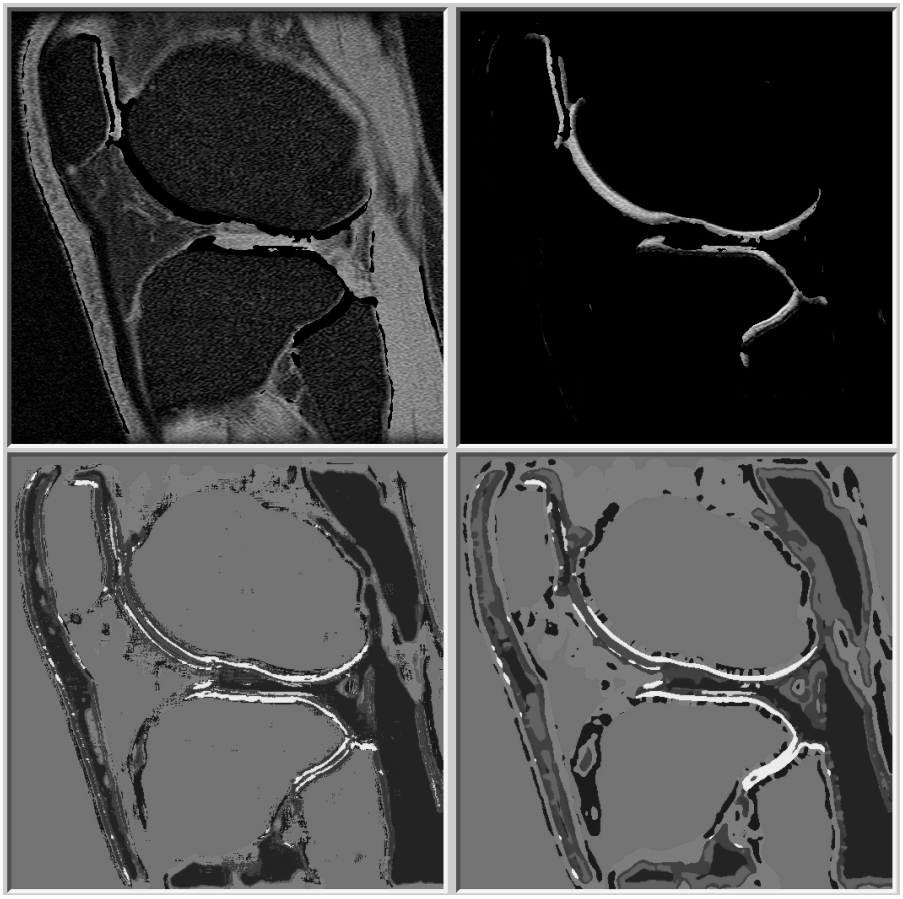


Functional MRI (fMRI) is the “hottest” topic in MRI for many years. If we acquire one image of the brain in a resting state, followed by another with the brain “stimulated” in some way, we can compare the two. Any regions which are different correspond to areas of brain activation.

The image is a 3-D picture of a human brain, which has been “sliced” in the computer to reveal the interior at a particular level in the brain (white and grey). Superimposed on this are colored regions, which correspond to the activated areas of the brain.

Data source : UW Madison MRI Center

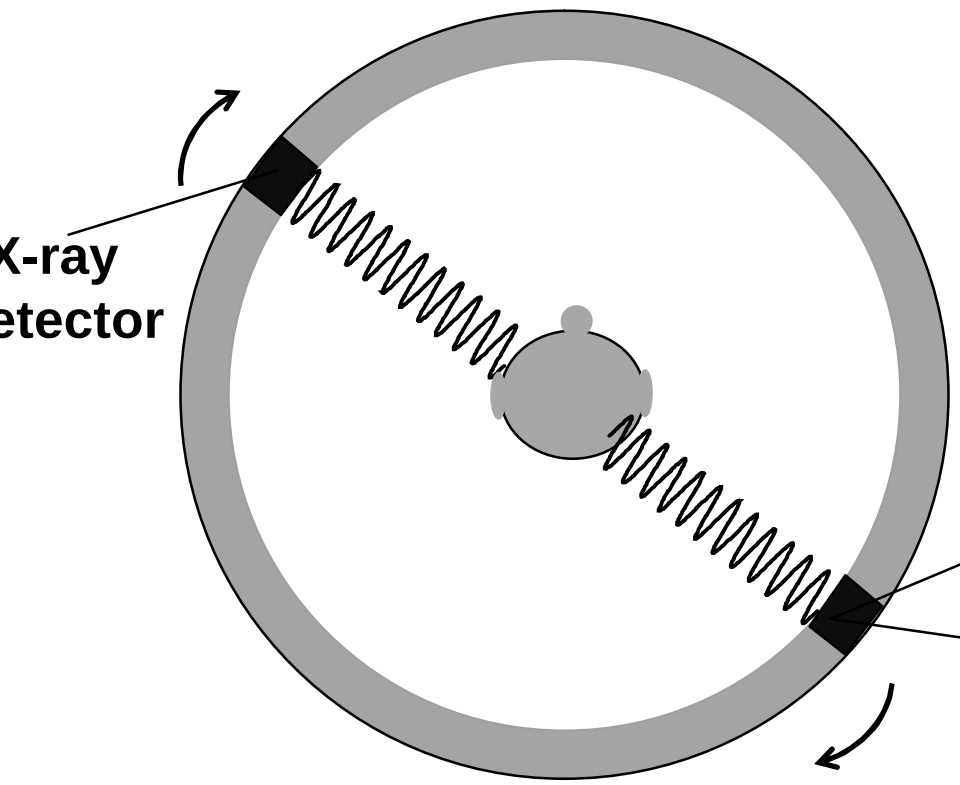
Segmenting MRI Images



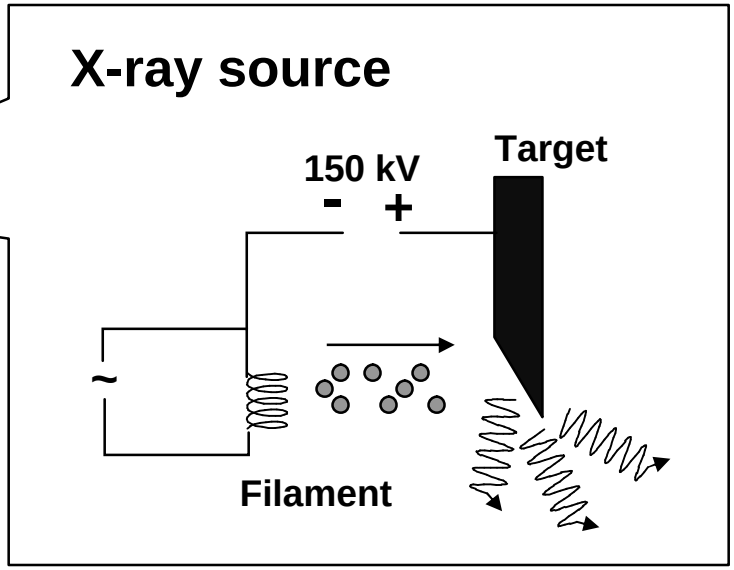
Method: texture-based classification

Source:
www.debonet.com/Research/Segmentation/

Basic Principles of X-ray CT



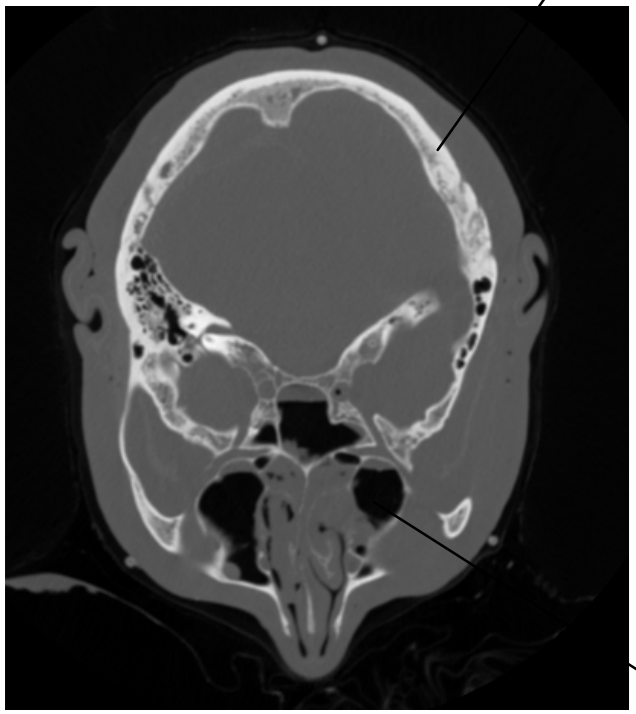
- A standard tube produces X-rays with an energy of approximately 150 keV.
- The X-ray focal spot scans across and around the patient.
- The technique measures the X-ray attenuation coefficient of the different tissues in the body.

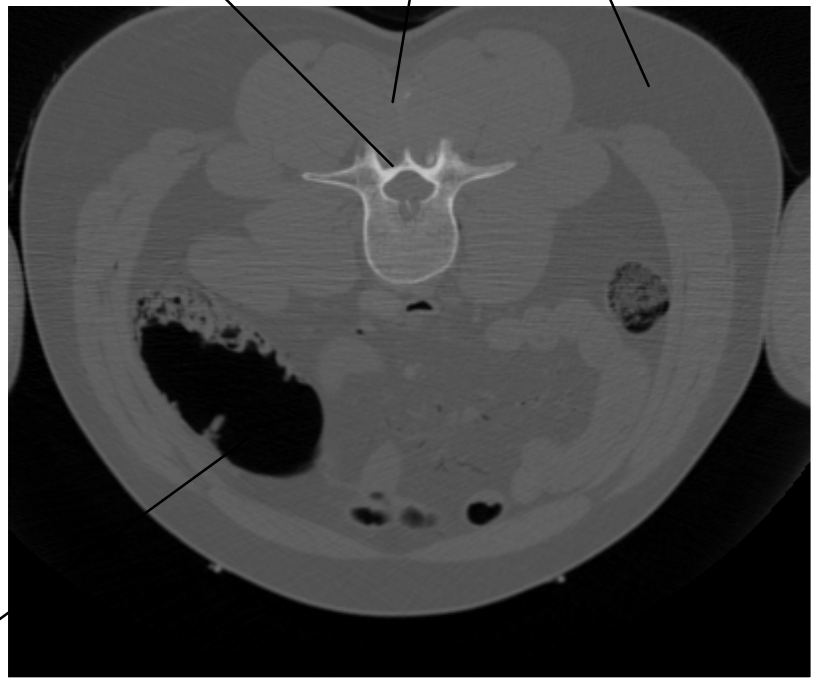


X-ray CT Pictures of the Head and Abdomen

Bone shows up bright

Different densities of tissue give inter-mediate results

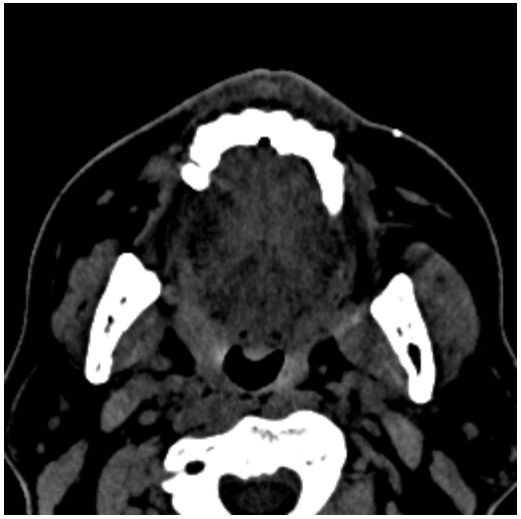


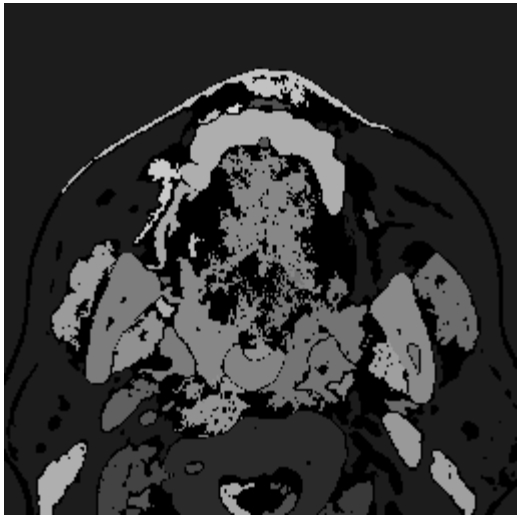


Air is dark

Segmenting CT Images

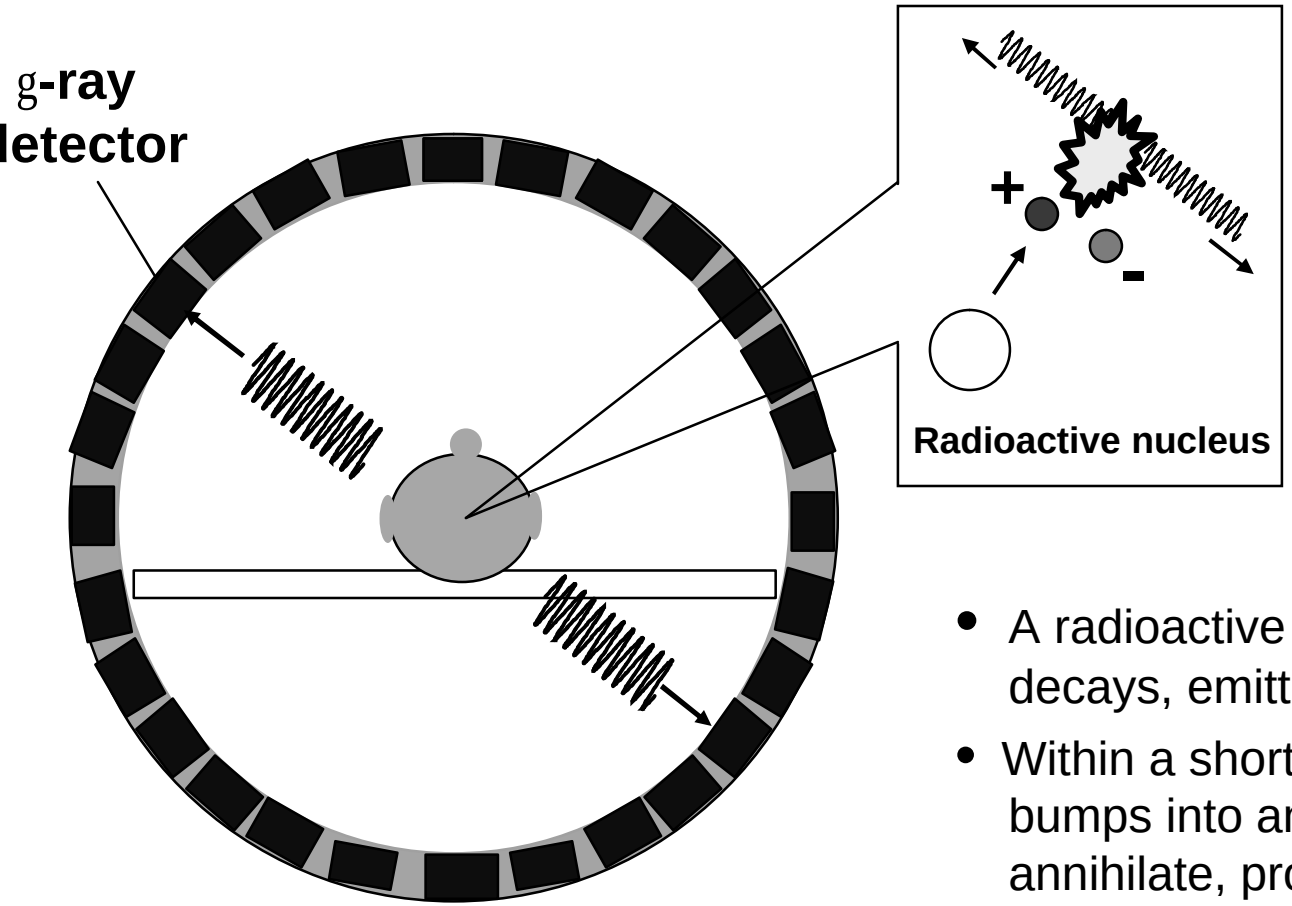
Source:
www.cs.bgu.ac.il/~multimed/textures/html/results52.htm/





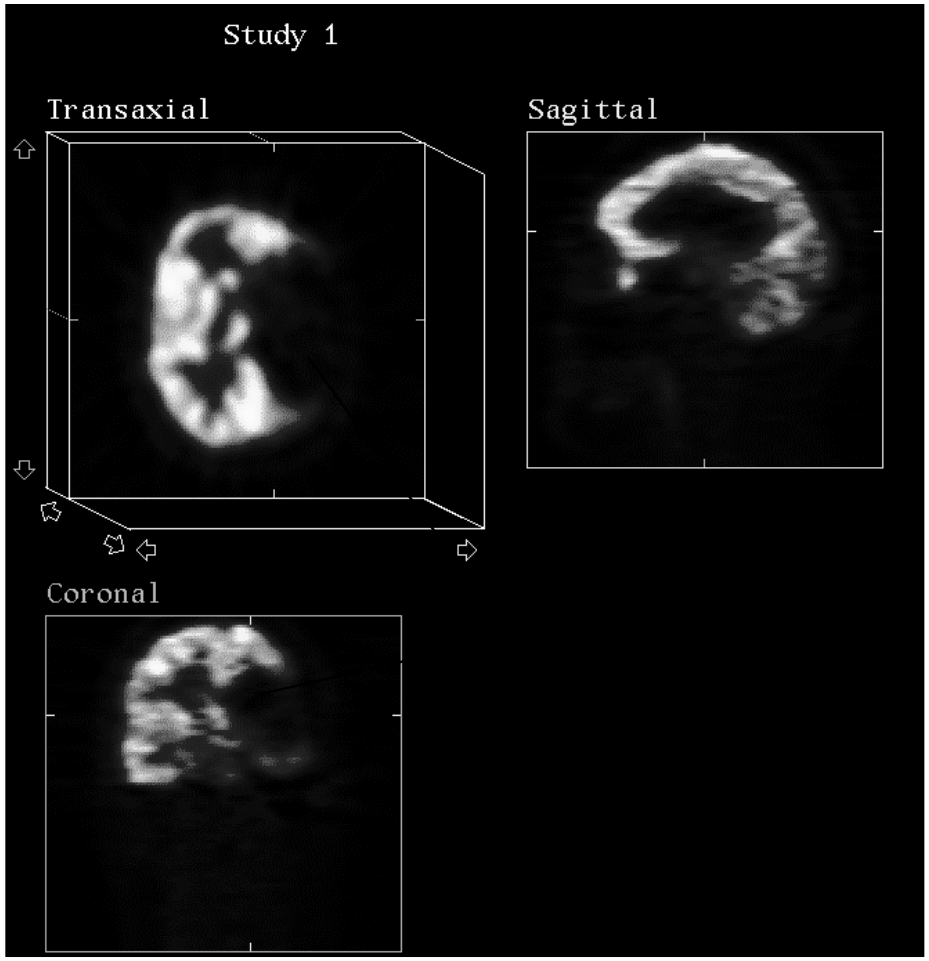
Source:
www.cse.ohio-state.edu/ volviz/Images/segment.html

Basic Principles of Positron Emission Tomography



- A radioactive isotope is injected and decays, emitting a β^+-particle.
- Within a short distance, the β^+-particle bumps into an electron and the two annihilate, producing a pair of γ-rays.
- By detecting and reconstructing where the γ-rays of come from, we can measure the location and concentration of radio-isotope

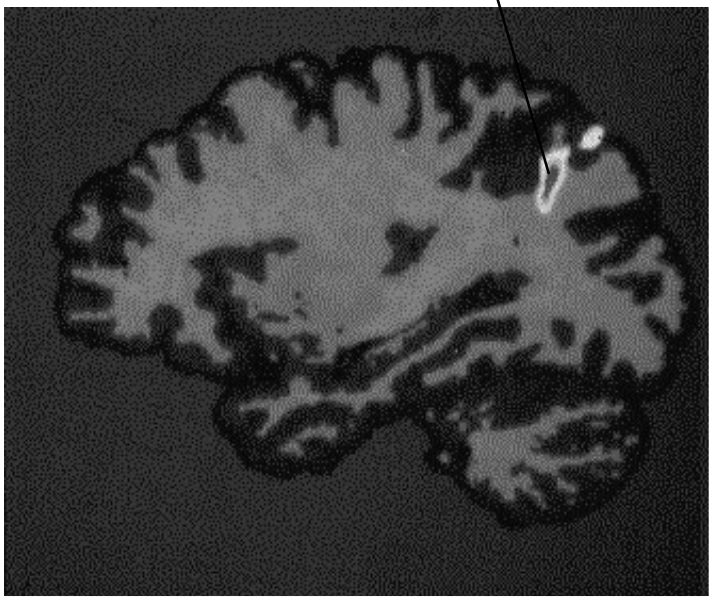
Two Typical PET Studies



FDG Study of Patient with Stroke

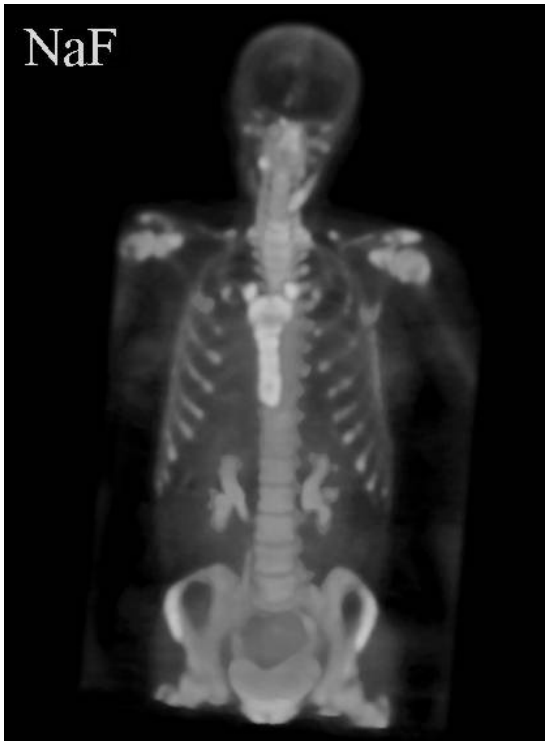
The highlighted region shows which
part of the brain (the parietal lobe) was activ
during a visual stimulation task.

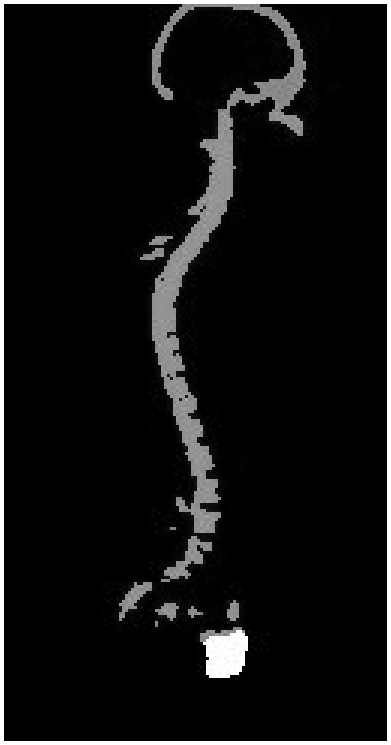
Data source: CVVC, Psychology Dept., Durham Un



FDG “Brain Activation” Stud

Segmenting PET Images



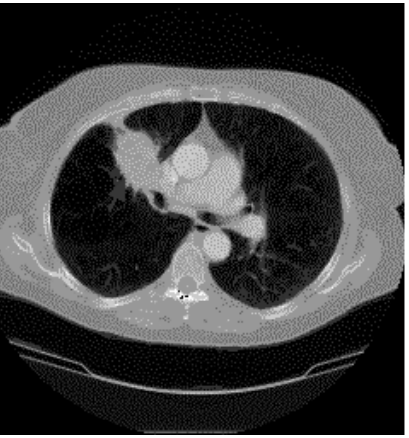


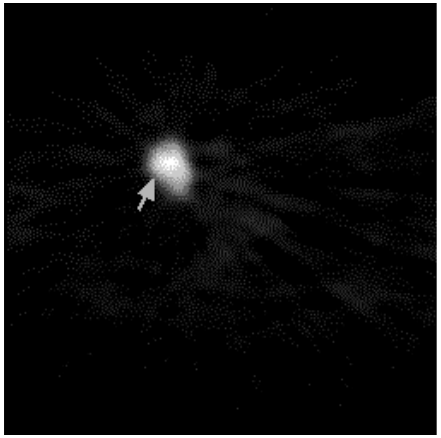
Method: region growing starting from region seeds

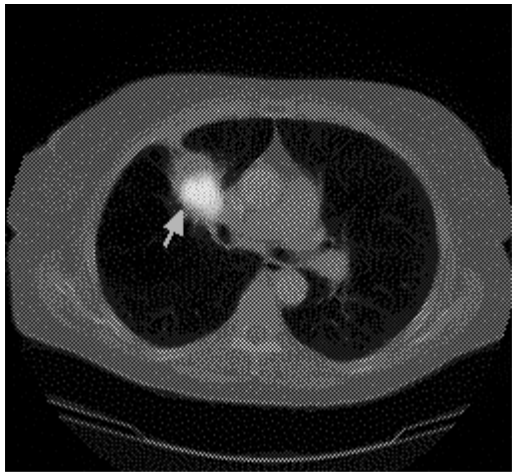
Source: www.creatis.insa-lyon.fr/menu/ivolumique/segmentation/segregro-cmu/index-us.html

Image Fusion — Combining Modalities

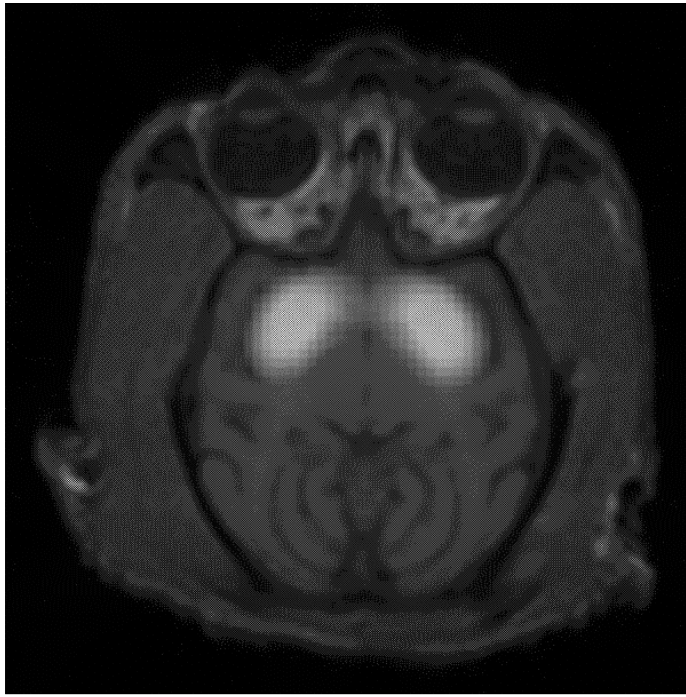
Clinical Study - Lung Tumor







Research Study MRI + PET



Location of Dopamine Receptors

Data source: Bowman Gray School of Medicin

Conclusion

- There are many different ways of imaging the human body, based on different physical principles (acoustics, magnetism, nuclear and particle physics).
- The different methods tell us different things.
- The challenge of “understanding” the resulting imagery automatically remains, despite years of research activity.