Introduction to Medical Imaging

Lecture 1: Overview

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Overall Concept

object → imaging device → data → imaging algorithm → reconstructed cross-sectional image
Imaging Modalities Overview

CT

MRI / fMRI

Nuclear

PET

Ultrasound

X-ray

magnetic spin

metabolic tracer X-ray emission

sound waves
Anatomic vs Functional Imaging

<table>
<thead>
<tr>
<th>Person alive</th>
<th>Person dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI scan</td>
<td>anatomical information</td>
</tr>
<tr>
<td>PET scan</td>
<td>functional information</td>
</tr>
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bright spots = high brain activity

An MRI scan shows you that you have a brain
A PET scan shows that you use it
History: X-Rays

Wilhelm Conrad Röntgen

- 8 November 1895: discovers X-rays.
- 22 November 1895: X-rays Mrs. Röntgen’s hand.
- 1901: receives first Nobel Prize in physics

An early X-ray imaging system:

Note: so far all we can see is a projection across the patient:
History: Computed Tomography

The breakthrough:

- acquiring many projections around the object enables the reconstruction of the 3D object (or a cross-sectional 2D slice)

CT reconstruction pioneers:

- 1917: Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.
- 1963: Allan Cormack publishes mathematical analysis of tomographic image reconstruction, unaware of Radon’s work.
- 1972: Godfrey Hounsfield develops first CT system, unaware of either Radon or Cormack’s work, develops his own reconstruction method.
- 1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.
Computed Tomography: Concept

more:
Computed Tomography: Past and Present

Image from the Siemens Siretom CT scanner, ca. 1975
- 128x128 matrix.

Modern CT image acquired with a Siemens scanner
- 512x512 matrix
3D Visualization

Reconstructed object enables:

- Enhanced X-ray visualization from novel views:

- Maximum Intensity (MIP) visualization:

- Shaded object display:
More Visualizations
Aortic Stent and Arterial Vessels
Cartotid Stenosis
Virtual Medicine

Virtual colonoscopy, endoscopy, arthroscopy
Virtual therapy and surgery planning
Training platform
History: Ultrasound

1942: Dr. Karl Theodore Dussik,
  • transmission ultrasound investigation of the brain

1955: Holmes and Howry
  • Subject submerged in water tank to achieve good acoustic coupling

1959: Automatic scanner, Glasgow
  • Image of normal neck
  • Twin gestation sacs (s) and bladder (B).
Ultrasound: Present

3D Ultrasound

Intravascular ultrasound

Doppler ultrasound
1946: Felix Bloch (Stanford) and Edward Purcell (Harvard) demonstrate nuclear magnetic resonance (NMR)

1973: Paul Lauterbur (Stony Brook University) published first MRI (Magnetic Resonance Imaging) image in Nature.
  • receives the Nobel Prize in Physiology or Medicine in 2003

Late 1970’s: First human MRI images conceived

Early 1980’s: First commercial MRI systems available

1993: Functional MRI in humans demonstrated
MRI Concept

MRI measures the effects of magnetic properties of tissue

- these effects are tissue-specific
- also specific to blood perfusion / oxygenization (functional MRI)

MRI is very versatile (but also more expensive than CT)
MRI Applications

Cardiac MRI

• measures the distortion of “tags” to assess motion of the heart tissue

Diffusion Tensor Imaging

• measures the diffusion of water
• allows the tracking of nerve fibers in the brain (white matter)
Functional MRI

- allows to assess brain activity during certain tasks
- valuable for brain functional studies, but also for surgery planning and diagnosis
MRI Applications

MR Spectroscopy

• measures the distribution of chemicals in each “voxel” of the brain
MRI Applications

MR Angiography

- magnetizes the bolus of blood, enhances vessels
- similar effects to X-ray angiography, but non-invasive
MR Microscopy

- can resolve volumes of down to 50 mm$^3$ (clinical MR does 1mm$^3$)
- use for small animal experiments (in place of destructive histology)
Most historical data and some images were taken from a similar presentation by Dr. Thomas Liu, UC San Diego

Other images are due to (list not complete):

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