Introduction to Medical Imaging

Lecture 1: Overview

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Overall Concept

- Object
- Imaging device
- Imaging algorithm
- Data
- Reconstructed cross-sectional image

Imaging Modalities Overview

- CT
- MRI / fMRI
- Nuclear
- 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>MRI scan</td>
</tr>
<tr>
<td>PET scan</td>
<td>PET scan</td>
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Bright spots = high brain activity

An MRI scan shows 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

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
Slice Viewer

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

Ultrasound: Present

image of normal neck

3D Ultrasound

Intravascular ultrasound

Doppler ultrasound
History: MRI

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

**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 mm³ (clinical MR does 1 mm³)
- use for small animal experiments (in place of destructive histology)

Credits

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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