

# ELG7173 – Topics in signal Processing II Computational Techniques in Medical Imaging

## Topic #1: Intro to medical imaging

# Medical Imaging Classifications

- n Measurement physics
  - ⌘ Send Energy into body
  - ⌘ Send stuff into body
- n Imaging Algorithms
  - ⌘ Mathematical approach
- n Type of activity
  - ⌘ Anatomical imaging (static images)
  - ⌘ Functional imaging (dynamic images)
- n and medical perspectives ...

# Medical Imaging Classifications

- n **Measurement physics**
  - ⌘ Send Energy into body
  - ⌘ Send stuff into body
- n **Imaging Algorithms**
  - ⌘ Mathematical approach
- n **Type of activity**
  - ⌘ Anatomical imaging (static images)
  - ⌘ Functional imaging (dynamic images)
- n **and medical perspectives ...**



# Medical Imaging Technologies

- n Send energy into the body and watch what comes out
  - ✧ Electromagnetic radiation
  - ✧ Sound
- n Send stuff into the body which later releases energy and watch that
  - ✧ Nuclear Medicine



# Medical Imaging Technologies

- n Send energy into the body and watch what comes out
  - ✧ Electromagnetic radiation
  - ✧ Sound
- n Send stuff into the body which later releases energy and watch that
  - ✧ Nuclear Medicine

# Send Energy into the body

## n Electromagnetic Energy

- ✧ X-rays, CT
- ✧ MRI
- ✧ Microwave Imaging
- ✧ Photon Migration Tomography

## n Electrical Current

- ✧ Electrical Impedance Tomography

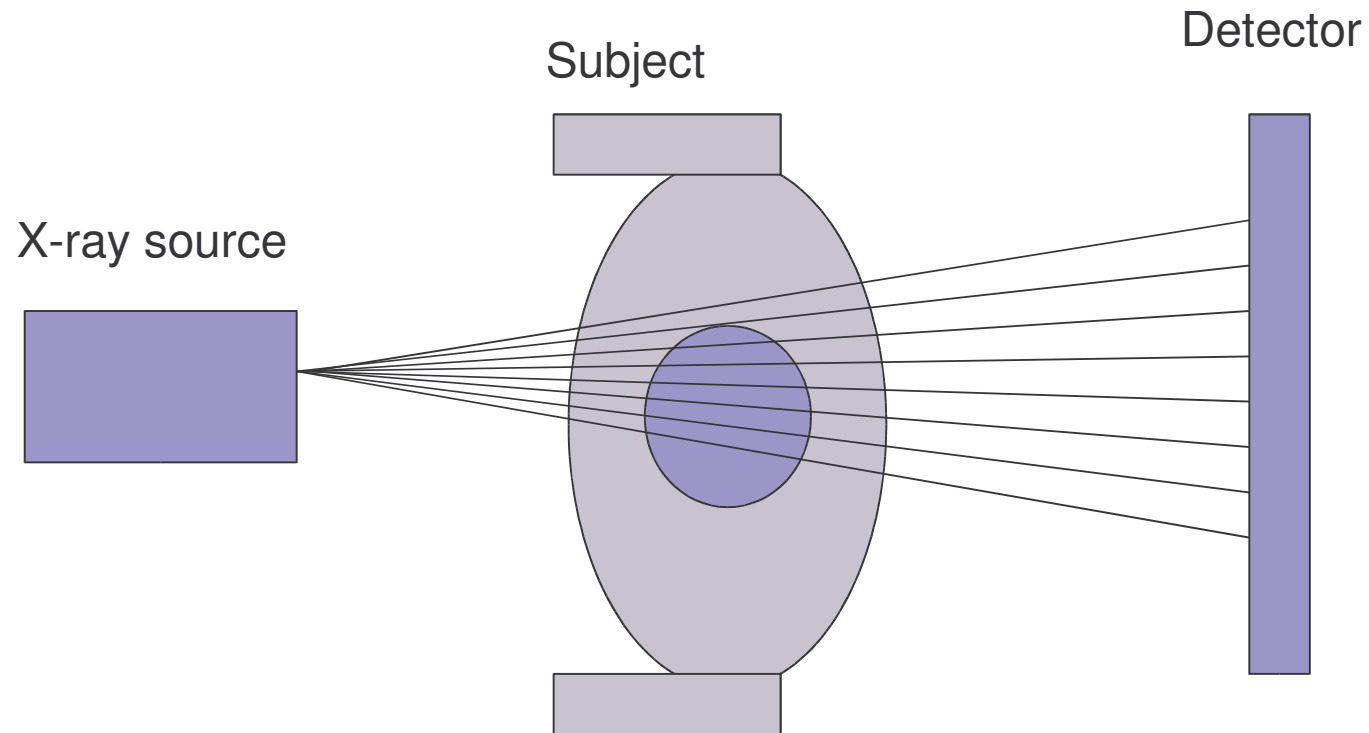
## n Magnetic Fields

- ✧ Magnetic imaging
- ✧ Eddy Current imaging

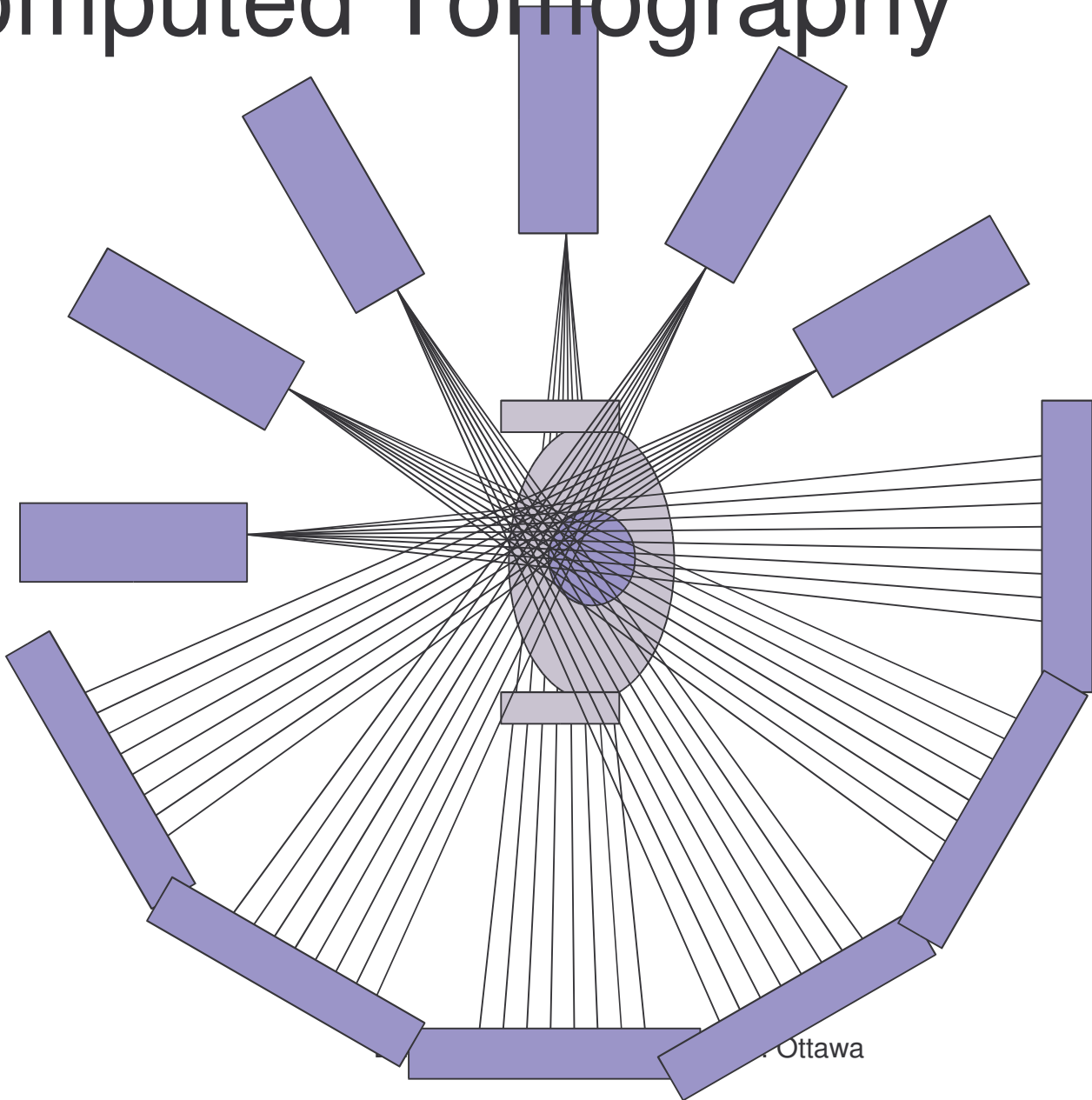
## n Vibration

- ✧ Ultrasound
- ✧ Sonoelastometry

# X-rays

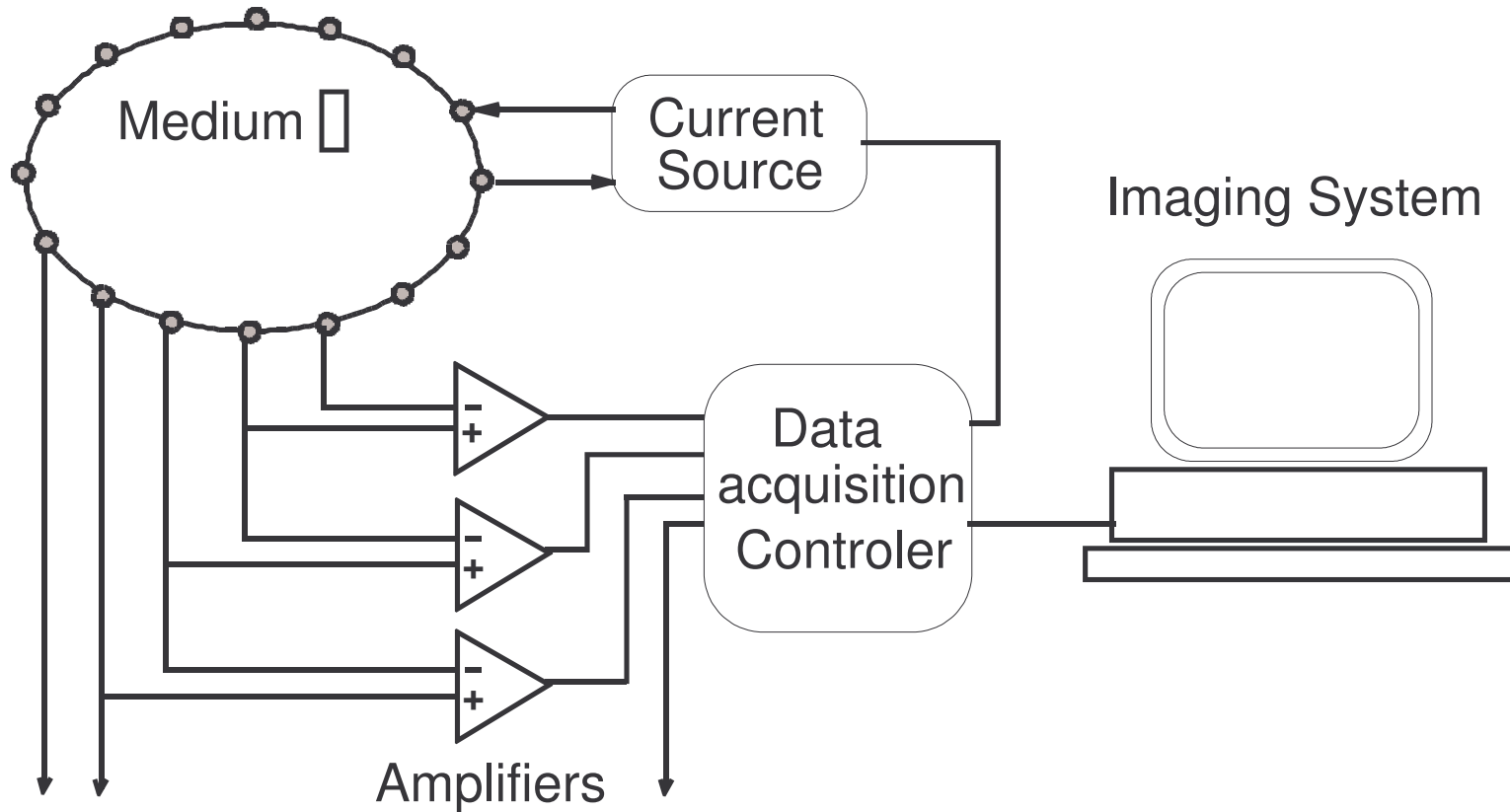


# Computed Tomography





# Electrical Impedance Tomography





# Medical Imaging: History

- n Röntgen discovers X-rays (1895)
  - ⌘ Beam of X-rays is directed through the patient onto film
  - ⌘ Non-quantitative
  - ⌘ Soft tissue is darker than bone
  - ⌘ First Physics Nobel prize (1901)
- n Within 12 months 1000 papers published

# X-ray technology pre 1950's

- n Faster imaging (seconds). Early exposures required 20 minutes
- n Contrast agents (1910s) – radioopaque materials in GI tract gave significant improvement
- n Angiography – arterial contrast agent
- n Other instrumentation improvements, but no breakthroughs in physics
- n Most development done by medical community

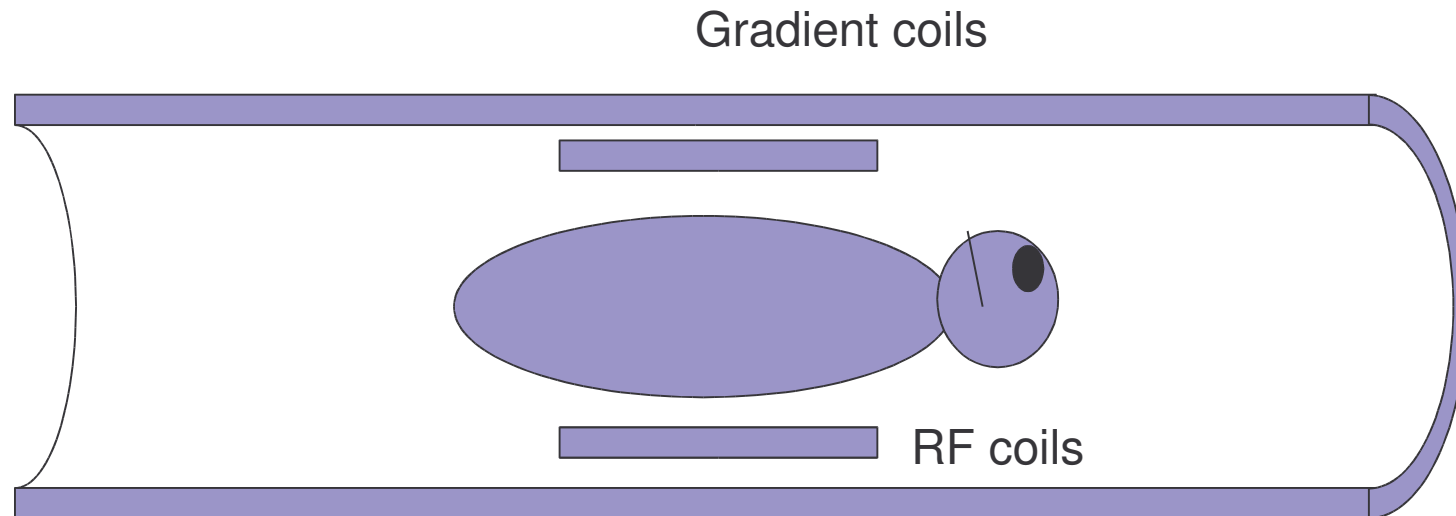
# Computed Tomography

- n G. Hounsfield (1972) based on work of A. Cormack. Nobel Prize 1979 medicine
  - ✧ Cross sectional image is *computed* from X-ray projections
  - ✧ Most revolutionary idea in medical imaging since Röntgen – took medical imaging into the engineering world.
  - ✧ Imaging becomes *quantitative*
  - ✧ Images are no longer directly from data. *Counter-intuitive* processing is required.
  - ✧ Inspired similar approaches in MRI, PET, etc.

# Magnetic Resonance Imaging

- n MRI is politically correct name. was Nuclear magnetic resonance (NMR)
- n NMR invented as a spectrographic technique.
  - α F.Block and E.Purcell (Nobel physics 1952)
- n NMR extended to imaging in 1970's
- n Initially slow (minutes) now millisec
- n Uses radio waves, not ionizing radiation, thus no risk of tissue damage

# Magnetic Resonance Imaging



# Ionizing Radiation for imaging

Microwave	MHz ( m )	Ultrasound, MRI
UHF	GHz ( mm )	Microwave imaging
Visible	1 eV (100 nm)	Photon Migration Tomography
Soft X ray	100 eV (nm)	X-ray (film, CT)
Gamma ray	10 keV	Scintillation, SPECT
Gamma ray	1 MeV	PET

# Ultrasound

- n Image is formed from scattered echo
- n Clinical ultrasound derives from Navy sonar technology from WWII
- n Advantage: No ionizing radiation
- n Disadvantages
  - ⌘ Only useful for soft tissue characterization
  - ⌘ Mathematics is very different + not as well systematized





# Medical Imaging Technologies

- n Send energy into the body and watch what comes out
  - ✧ Electromagnetic radiation
  - ✧ Sound
- n Send stuff into the body which later releases energy and watch that
  - ✧ Nuclear Medicine

# Send stuff into the body

## n Nuclear Medicine

### ✧ EM radiation (gamma rays):

- n SPECT: single photon emission computed tomography

- n Anger camera

### ✧ positrons:

- n PET: positron emission tomography

### ✧ Compounds which release

## n Exotic stuff ... but not yet widely used

### ✧ Magnetic beads – magnetic twisting cytometry

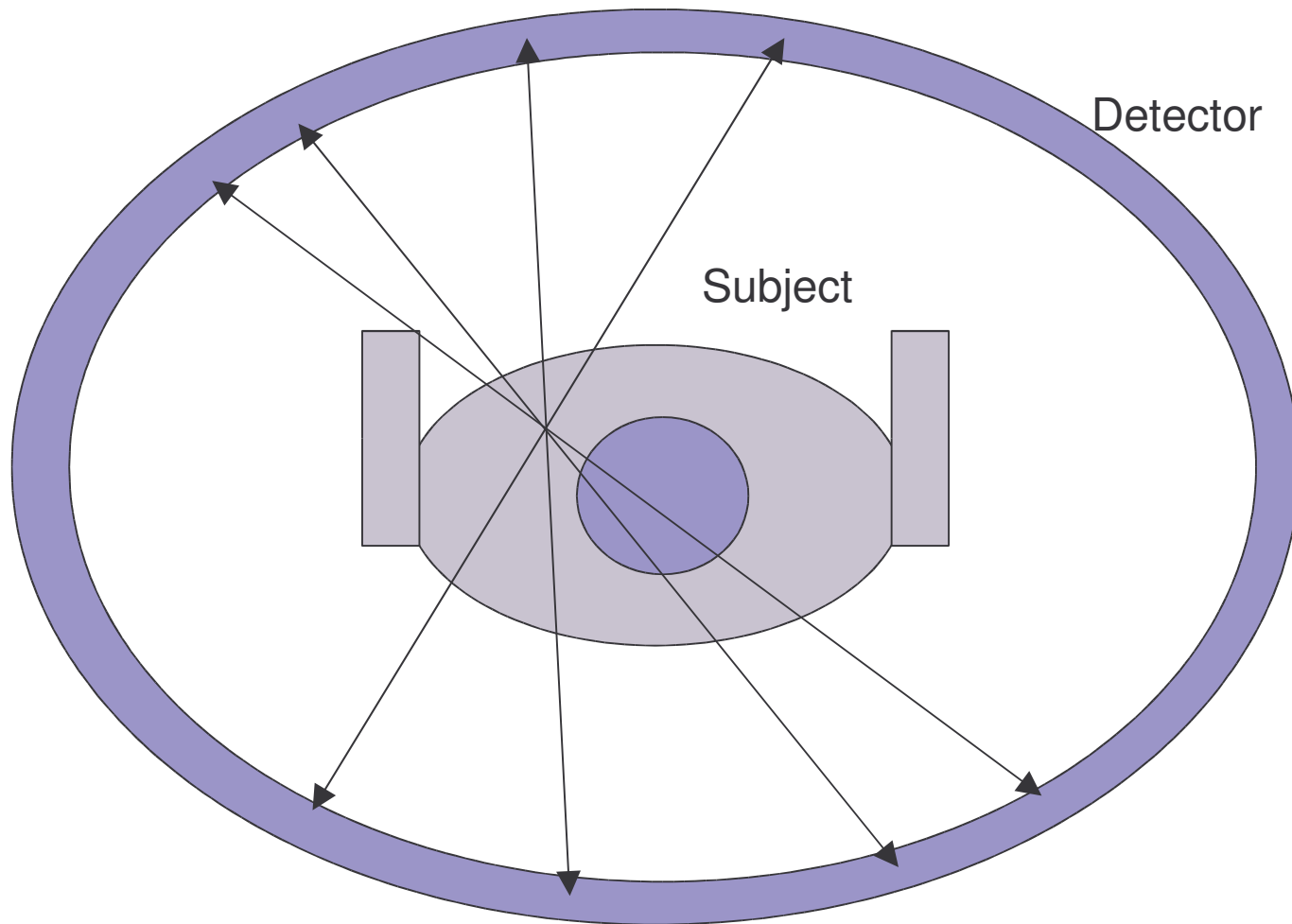
# Nuclear medicine

- n Natural radioactivity (Becquerel, 1896)
- n Polonium (P + M Curie , 1898)
  - ⌘ Shared 3<sup>rd</sup> Nobel Prize Physics (1903)
- n Term “nuclear medicine” from 1950’s where I-131 used as a tracer for brain tumors

# Nuclear Medicine

- n Functional imaging technique
  - ⌘ You don't get a picture of the anatomy, only of the areas to which the tracer goes
  - ⌘ View *physiological function* , *functional metabolism*
- n Much research complex tracers: attach radioactive molecule to compound of interest

# PET



# Medical Imaging Classifications

- n Measurement physics
  - ⌘ Send Energy into body
  - ⌘ Send stuff into body
- n **Imaging Algorithms**
  - ⌘ **Mathematical approach**
- n Type of activity
  - ⌘ Anatomical imaging (static images)
  - ⌘ Functional imaging (dynamic images)
- n and medical perspectives ...

# Algorithms

2D and 3D projection reconstruction	Parallel-beam
	Fan / cone beam
Iterative / Matrix Method	Algebraic Reconstruction Technique
	Max. Likelihood / Max. A Posteriori / Bayesian reconstruction
Fourier Reconstruction	Direct Fourier Reconstruction Direct Fourier Imaging (MRI)