

BENG 100 Frontiers of Biomedical Engineering
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Chapter 12

SUMMARY

- The technology to image inside the body and at a microscopic scale has greatly evolved and has significantly enhanced our ability to diagnose and treat disease providing an array of imaging modalities each with strengths and weaknesses.
- X-ray and CT imaging provided the first true windows into the body enabling the visualization of internal structure.
- Ultrasound imaging is fast, portable and cheap providing dynamic images of structure and velocity.
- Nuclear medicine allows the imaging of function within the body using radioactive compounds to quantify physiologic changes in disease.
- Microscopy has matured in the last hundred years with fluorescence and confocal imaging enabling the visualization of structure and function at the microscopic scale and in three dimensions.
- Endoscopy literally brings a camera into the body to image internal structure for diagnostic and surgical applications.
- Magnetic resonance imaging is the most versatile modality providing structure and function in a programmable way.
- Computer processing of images is essential for the formation and quantification of images, improving their appearance and enabling the measurement of anatomy and function.

KEY CONCEPTS AND DEFINITIONS

coincidence detection – a method for simultaneously detecting two signals at the same time.

computed tomography (CT) – a medical imaging method that utilizes x-rays to image internal structures of an object by compiling a series of two-dimensional cross-sections to create three dimensional images through computer technology.

contrast – the relative change in intensity (from dark to bright or vice versa) between two neighboring regions in an image.

contrast agent – a material that is injected during imaging, such as a barium sulfate or iodine, to make a particular tissue more visible during radiological imaging tests.

cyclotron – a type of particle accelerator used to produce radioactive substances by

alternating electric fields to add energy to sub-atomic particles.

digital – a method of storing information electronically through the use of the binary language, or an array of numbers, typically “1” and “0”.

Doppler effect – a change in the apparent frequency or wavelength of a wave due to a change in the distance between a source and an observer.

electronic collimation – an optical device used in a PET camera consisting of channels of lead that only allow penetration of gamma rays that originated directly in line with the channel.

electron microscopy – the use of a microscope with the ability to magnify very small objects by deflecting a beam of electrons with electromagnets.

endoscope – a tubular optical instrument used during surgery to illuminate the organs of the body through the use of fiber optic cables.

endoscopy – the use of fiber optic cables in a flexible tube (an endoscope) to light the internal organs of the body for examination or to treat a condition.

energy window – a defined range of energies in which photons are counted to obtain a gamma image.

fiber optics – thin flexible fibers made of glass that are used to transmit images or signals in the form of light at high speeds with little signal loss.

field of view – the area that has been or can be imaged through an optics device.

fluorophore – Certain molecules that have the ability to emit light at a particular wavelength after they are exposed to light of a specific, shorter wavelength.

functional magnetic resonance imaging (fMRI) – a non-invasive imaging procedure that uses radio waves and a magnetic field to image the changes that occur in the brain due to blood flow and cognitive thinking.

gamma camera – a device used in the medical field to scan patients that have been injected with radioactive materials and to produce images of the radioactivity.

half-life – the time that it takes for half of the atoms of a radioactive element to decay.
iodine-131 (^{131}I) – a radioisotope of iodine, also called radioiodine, used in nuclear medicine for both imaging and therapy.

Larmor frequency – The frequency at which a magnetic nucleus can be excited proportional to the strength of a magnetic field.

linear filtering – a process to enhance an image by determining a new value for a pixel from the sum of the products of the corresponding elements.

magnetic resonance imaging (MRI) – a computer generated method of medical imaging for producing cross-sectional images of internal organs and tissues through the use of radio waves and magnetic fields.

modalities – the different types of methods used in imaging.

Magnetic resonance spectroscopy (MR) – a method of imaging human tissues and organs into 3D computer generated images to study their chemical composition.

noisiness – the difference between a true value and a measured value that can distort a signal

oxygen-15 – A radioisotope of oxygen with a half-life of 2.04 commonly used in the studies of respiratory function and in positron emission tomography.

piezoelectric crystal – a special type of crystal used to generate ultrasound that will vibrate in response to an electrical signal, or driving voltage, and can also induce a voltage after receiving a vibration.

pixel – the smallest unit of a digital image that can be displayed and manipulated.

positron emission tomography imaging (PET) – a nuclear medical imaging technique used to produce three dimensional images of the body through the decay of radioisotopes.

projection – a shadow of a three-dimensional object created on a plane.

radioactive molecules – molecules that are unstable and spontaneously decay to release radiation energy.

real time – Recording structure and dynamic function from rapidly moving tissues, such as a beating heart, and visualizing them at the same speed in which they happen.

refraction – the change in direction a path light travels as it passes from one medium to another.

registration – the process of aligning images into one coordinate system to better define or compare them.

refractive index – the ratio of the speed of light traveling through a vacuum to the speed of light traveling through a particular substance.

resolution – a measure of how much detail can be seen in an image.

resonant frequency – the frequency at which a material naturally vibrates.

sample – the process of drawing a group from a larger population and using it to estimate the characteristics of the population as a whole.

segmentation – the process of identifying smaller structures, such as organs and cells, in images
signal-to-noise ratio – in imaging, the ratio of signal (activity) to error in the signal (noise) which is usually expressed in decibels.

single photon emission computed tomography (SPECT) – a brain imaging technique in nuclear medicine where gamma rays are used to produce 2D image slices of radioactive drugs in the body, that are converted to 3D through computer reconstruction.

spin – the movement of an electron around its axis in a clockwise or counterclockwise direction.

superconducting – the process of conducting electric current at very low temperatures in materials with no resistance.

technetium-99m – a man-made gamma ray emitting element with a half-life of 6 hours used in medical diagnostic studies.

Tesla – SI unit used to describe the density of a magnetic field.

total internal reflection – complete reflection of light at the boundary between two different media at an angle greater than the critical angle.

tracers – radiopharmaceuticals used in nuclear medicine that are ingested, inhaled, or injected to track the movement of a substance through the body.

ultrasound imaging - the propagation of high frequency sound waves (2-13 megahertz) through tissue to record the structure and dynamic function of rapidly moving tissues, such as a beating heart or a developing fetus, at the same speed in which they happen.

unsharp masking – the process of increasing the sharpness of an image through computer manipulation by subtracting out a blurred version of the image to enhance detail.

QUESTIONS

1. A patient comes into the emergency room having been shot by a shotgun. What kind of imaging would you do in order to find the metal pellets so that they can be removed?
2. Imagine a SPECT image of a subject with no radioactivity injected but with a number of capsules filled with radioactivity attached to their skin. These are called “fiducial markers” and can be used for image registration if their locations can be accurately determined. What would the histogram of this image look like? Describe a method of localizing the markers.

PROBLEMS

1. In Doppler ultrasound, given a flow of X meters/second, using a Y MHz transducer, what is the largest angle to the flow that would give a change in frequency of 5%?
2. If your detector measures 250 gamma photons every second from a radioactive sample governed by a Poisson distribution, how long do you need to measure to get a signal to noise ratio of 10?
3. You must design an optical fiber for endoscopy. If you use glass with a refractive index of 1.5 for the cladding, what refractive index do you need for the core in order to achieve a critical angle of 60° ?
4. Design an image processing filter that will give high values for thin bright horizontal lines in the image.