Medical Imaging: X-Rays and ultrasound

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This course introduces you to two of the most commonly used medical imaging techniques: X-ray imaging and Ultrasound. The course will introduce basic concepts concerning how both X-rays and ultrasound are generated, how these interact with matter and how images are formed and analysed.

The course is worth 3 ECTS and consists of 11 hours of lectures 2 hours of matlab-based workshops (one on X-ray tomography and one on ultrasound).

This course has a sister course, covering the other major medical imaging modalities (Nuclear diagnostics and MRI).

Aims:
To provide students with a general overview of how physical principles are to generate contrast in modern medical imaging using X-rays and ultrasound. Students should gain an appreciation of the physical factors determining the resolution, speed and sensitivity of imaging modalities including X-ray imaging, X-ray computed tomography and ultrasound.

Objectives:
After attending the course, students should be able to:

X-ray imaging:
• explain how x-rays are produced for medical imaging applications and the factors affecting the x-ray spectrum
• discuss the factors affecting the performance of an x-ray tube and calculate its performance in a given situation
• explain the main x-ray tissue interactions and discuss how these lead to image contrast and dose to the patient
• calculate the attenuation of x-rays or gamma-rays in a given situation
• calculate the energies of the interacting particles for each x-ray matter interaction in a given situation
• explain the main techniques used for the detection and recording of x-ray images
• discuss the main factors limiting the resolution of an x-ray image and be able to calculate the resolution of an x-ray imaging system in a given situation
• recall what fluoroscopy is and how it is achieved
• discuss desirable properties for x-ray contrast agents
• recall what is meant by signal to noise ratio and contrast to noise ratio in an image and be able to explain and calculate these parameters

X-ray tomography
• explain how an x-ray computed tomography (CT) dataset is acquired and discuss the various parameters affecting its performance
• recall and apply the Central Slice Theorem
• explain the process of filtered back projection for CT image reconstruction and discuss modifications such as the Hann or Shepp-Logan filters
• recall and discuss the main differences between the different generations of x-ray CT instrumentation

**Ultrasound**
• recall the basic mechanical properties of tissues that govern the behaviour of acoustic waves
• define the term acoustic impedance
• calculate ultrasound wave peak particle displacement amplitude, peak particle velocity and intensity
• explain and discuss scattering, reflection and attenuation of sound waves in tissue
• calculate ultrasound attenuation in a given situation
• calculate ultrasound reflection and transmission coefficients for a plane wave incident on a boundary
• explain the key components of an medical ultrasound scanner and discuss the main parameters defining its performance
• discuss the compromises inherent in the design and construction of ultrasound transducers
• calculate parameters required for the active element, matching layer and backing layer
• describe and discuss the process of image acquisition and image formation in ultrasound imaging
• calculate the resolution of an ultrasound system in a given situation
• calculate the maximum imaging depth, imaging speed and data rates of an ultrasound system in a given situation
• discuss common ultrasound image artefacts and propose ways they can be reduced