The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6423 INTRODUCTION TO BIOMEDICAL IMAGING SCIENCES

Credits: 10

Course Description Including Aims

This course aims at providing students an introduction to the physical and engineering aspects of the medical imaging modalities such as 2D projection X-ray, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Ultrasound (US). The general imaging characteristics, such as spatial resolution, signal to noise ratio, and intensity discretization, are introduced first, and the supportive concepts, such as filtering and Fourier transform, are briefly reviewed. Next, the physical principles of the image formation in each of these modalities are studied and mathematically formulated from a system modelling point of view. The effect of the various system parameters in the imaging process is discussed, and several medical applications is introduced. A supportive lab work is available to help the students get hands on the practical sides of the trainings. The course is designed to achieve the following aims:

1. To provide an introduction to biomedical imaging techniques, familiarizing students with its physical and mathematical principles.

2. To show that imaging has practical limitations with regard to its resolution, signal strength and sensitivity, and that, given images, solutions of inverse problems are usually sought.

3. To review the basic theoretical concepts from signals and systems point of view and link those concepts to specific applications in biomedical imaging.

4. To familiarize the students with the suitability of each modality for various medical imaging applications involving heart, bone, soft tissues, etc.

5. To aspire the interest of the students in imaging science as an important health monitoring technology, and initiate their critical thinking about the existing technology.

Detailed Syllabus

Image characteristics and reviews of basics: (10 hours, W1-W5)
- Spatial Resolution, point spread function, modulation transfer function
- Data acquisition, A/D converters, dynamic range, sampling
- Fourier transform, image filtering
- Filter back propagation and sinograms

X-ray planar imaging and Computed Tomography: (10 hours, W6-W10)
- X-ray tube structure and energy spectrum, photoelectric and compton scattering

- Linear and mass attenuation factor
- X-ray instrumentation: detectors, collimator, anti-scatter grid
- Computed Tomography and its instrumentation
- CT image reconstruction, filter back propagation
- Clinical applications of CT

Ultrasound imaging: (8 hours, W11-W14)

- Wave propagation, acoustic impedance, absorption, and attenuation
- US Instrumentation, mechanical/phased array transducers
- Clinical scanning A/B/M modes
- Doppler ultrasound to measure flow velocity
- Clinical application of US

Magnetic Resonance Imaging: (8 hours, W15-W18)

- Magnetization and its interaction with the protons in body
- Effect of radiofrequency pulse on magnetization
- Faraday induction and MR signal detection
- Free induction decay and relaxation times
- Image acquisition, phase and frequency encodings
- K-Space and MRI image reconstruction
- MRI instrumentation: magnet design, coil arrays
- Clinical application of MRI

Lab Work

Representation of the digital images: pixels, discretization, signal to noise ratio (2 hours)
Convolution and point spread function (2 hours)
Fourier transform and image filtering (2 hours)

Time Allocation

36 lectures in weeks 1 to 18.

Pre-requisites

Engineering Mathematics, Signals and Systems, Probability and Statistics.

Assessment

Final examination: 3 out of 4 questions (75%), 4 short course works at the end of each chapter (20%), lab and class activity (5%).

Recommended Books

N. B. Smith and Anderw Webb	*Introduction to Medical Imaging*	Cambridge
Paul Suetens	*Fundamentals of Medical Imaging*	Cambridge

Objectives

By the end of the unit a successful student will be able to:

1. Describe the physical principles of image data acquisition using the modalities studied during the semester.
2. Describe the reconstruction principles employed in each modality.
3. Describe the representations and properties of digital images.
4. Understand how biomedical imaging is used in biological and medical research.
5. Model the imaging process as a mathematical linear system whose response is computed through a convolution.
6. Critically evaluate the articles from the peer-reviewed biomedical imaging.
7. Distinguish the fundamental differences between various imaging modalities when a particular body organ is considered for imaging.

Outcome Code Supporting Statement

On successful completion of this module, students will be able to:

Outcome Code	Supporting Statement
SM1f1	Derive mathematical equations that underpin some of the medical image reconstruction techniques (e.g. filtered back propagation).
SM2m	Describe how random variations in the pixel intensities can be modelled as additive random variables drawn from certain probabilistic distributions (e.g. Poisson distribution).
SM6m	Demonstrate a working knowledge on physics of X-Ray generation, and its interaction with the protons in the human body.
EA1m	Use inverse Fourier transform to compute an MRI image from its k-space data.
ET6m	Show an awareness of the health risks of an excessive exposure to X-ray and hence the importance of limiting the latter when imaging a patient.
SM2fl	Distinguish the difference between the various imaging modalities and consider their limitations when scanning a moving organ (thus being aware of motion artefact issue).
D1fl	Apply filtered back propagation techniques to reconstruct tomographic images from a limited number of projection (and hence from an incomplete data).