جامعة محمد بن زايد للذكاء الاصطناعي
MOHAMED BIN ZAYED UNIVERSITY OF ARTIFICIAL INTELLIGENCE

Core Courses Syllabi

HC701 - Medical Imaging: Physics and Analysis

Title	Medical Imaging: Physics and Analysis
Code	HC701
Loading	4 Credit-hours
Prerequisites	Familiarity with Python programming, high-school physics
Catalog Description	This course provides a graduate-level introduction to the principles and methods of Medical Imaging, with thorough grounding in the physics of the imaging problems. This course covers the fundamentals of X-ray, CT, MRI, Ultrasound, and PET, imaging. In addition, the course provides an overview of 3D geometry of medical images and the two classic problems in analysis of medical images: segmentation and registration.
Goal	This PhD course aims to inculcate a deeper understanding of the fundamentals of Medical Imaging and its analysis. The course introduces the physics behind various imaging modalities such as x-ray, CT, MRI, Ultrasound, and PET and presents an overview of the 3D geometry relevant to medical image analysis from the perspective of solving registration and segmentation problems.
Content	Course covers: **(I)** Medical imaging modalities: X-ray, CT, MRI, Ultrasound, PET, **(II)** Medical image analysis: geometry, ITK toolkit, registration, and segmentation
Recommended Textbooks	The Essential Physics of Medical Imaging, J. Bushberg, J. Anthony Seibert, E. Leidholdt, J. M. Boone, Lippincott, Williams, & Wilkins (3rd edition).
Recommended References & Supplemental Material	1. ITK User Guide V4.13, https://itk.org/ItkSoftwareGuide.pdf 2. SimpleITK Jupyter Notebooks: http://insightsoftwareconsortium.github.io/SimpleITK-Notebooks/

Typical Week-wise Teaching Plan (3 lectures per week)

	Overview of the course
1	**Introduction to Medical Imaging and Image Analysis** **Lecture** • Clinical motivation • What is an image? • Image geometry: origin, direction, spacing, etc • Image transformation: rigid, affine, composition • Rotation matrix, quaternion, and versor • Medical imaging file formats: DICOM, NIFTI, NRRD, etc. **Lab** • Introduction to ITK-SNAP **Assessment Items** • Assignment 1 handed out
2	**Image Analysis Basics** **Lecture** • Introduction to ITK toolkit • Image quality – resolution, PSF, SNR, CNR • Loading and displaying an image • Image interpolation • Resampling and transforming an image **Lab** • Transform and resample an image using ITK • Modify image metadata using ITK
3	**Fundamentals of Human Anatomy** **Lecture** • Musculoskeletal System • Neuroanatomy • Splanchnology **Lab** • Demonstration of anatomical models in class
4	**Radiation Basics** **Lecture** • X-ray production • Radiography basics • X-ray absorption, dosage, and safety limits • Interaction of particles with matter **Lab** • Calculation of X-ray absorption **Assessment Items** • Assignment 1 due at the end of the week • Assignment 2 handed out

	Overview of the course
5	**Mammography and Fluoroscopy** **Lecture** • Mammography systems • Compression, scattered radiation, and magnification • Fluoroscopic imaging chain components and modes of operation • Dosimetry, patient safety, and regulatory requirements **Lab** • Discuss angiography and applications
6	**Computed Tomography (CT)** **Lecture** • CT Systems designs • Modes of CT acquisition • CT reconstruction • Image quality in CT • Safety around CT scanners • CT Contrast agent **Lab** • Hospital visit: acquiring CT scan of a CT phantom under various settings **Assessment Items** • Assignment 2 due at the end of the week • Assignment 3 handed out
7	**Radiotherapy** **Lecture** • Ionizing particles • Radiotherapy machines: LINAC, Proton therapy, Brachytherapy • Dose calculation and delivery techniques **Lab** • Demonstration of radiotherapy treatment planning
8	**Magnetic Resonance Imaging (MRI)** **Lecture** • Introduction to MRI physics • Magnetic fields, nuclear magnetic characterisation • Image weighting, decay rates, and contrasts • Safety around MRI scanners **Lab** • Demonstration of simulations on signal decay and contrast mechanisms **Assessment Items** • Assignment 3 due at the end of the week • Assignment 4 handed out

	Overview of the course
9	**Magnetic Resonance Imaging** **Lecture** • MR signal, encoding, and image formation • Image acquisition: time, quality, and associated trade-offs • Basics of pulse sequences **Lab** • Demonstration of MRI image simulator under various settings
10	**Magnetic Resonance Imaging** **Lecture** • Signal from flow: perfusion and diffusion • Diffusion tensor imaging • MRI artifacts • MRI contrast agent **Lab** • Hospital visit: acquiring MRI of an MRI phantom using multiple sequences
11	**Nuclear Imaging** **Lecture** • Radiation detection and measurement • Focal plane tomography • SPECT and PET • Dual modality imaging: SPECT/CT, PET/CT, PET/MRI **Lab** • Demonstration of co-registration issues in dual-modality imaging **Assessment Items** • Assignment 4 due at the end of the week • Assignment 5 handed out
12	**Ultrasound** **Lecture** • Interaction of ultrasound with matter • Ultrasound system design: transducer, detector, beam properties • 2D and 3D imaging: time, quality, artifacts • Doppler ultrasound • Acoustical power delivery and biosafety **Lab** • Hospital visit: imaging abdominal organs using ultrasound

	Overview of the course
13	**Image Registration** **Lecture** • Registration introduction: translation and rotation • Rigid and affine registration • Initializing registration: moments matching, sampling pose on spheres • Nonlinear registration models **Lab** • Using ITK, ANTS, and Elastix for linear and nonlinear registration • Registration of Diffusion Tensor Images **Assessment Items** • Assignment 5 due at the end of the week • Assignment 6 handed out
14	**Image Segmentation** **Lecture** • Levelset and watersheds • Active contour • Introduction to deep learning for medical image segmentation **Lab** • Demonstration of segmentation tools in ITK-SNAP and 3D slicer
15	**Review and final exam preparation** **Lecture** • Lecture hours reserved for student questions **Assessment Items** • Assignment 6 due