Course Package

Imaging & In Vitro Diagnostics – 2B

Name module	Imaging & In Vitro Dagnostics
Educational programme	MSc Biomedical Engineering
Period	Second block of the second semester (block 2B)
Study load	15 ECTS
Coordinator	J. Huttenhuis

Imaging & In Vitro Dagnostics			
block 1A	**block 1B**	**block 2A**	**block 2B**
			Electives: choose 15 EC
			Biomedical Optics 193500000 (5 EC)
			Deep Learning for 3D Medical Image Analysis 202100107 (5 EC)
			Medical Acoustics 193542070 (5 EC)
			Imaging Technology in Radiology 201800114 (5 EC)

Required preliminary knowledge: Knowledge of Optics; Wave Optics; Electrodynamics; Differential, and Integral Equations; knowledge of Geometrical and Physical Optics; Basic mathematical skills, including working with Complex Numbers; Simple Differential Equations; and Fourier Transforms; and basic skills in MATLAB or Python for data processing; Linear Algebra; Calculus; Probability Theory.

Electives: choose 15 EC

193500000 - Biomedical Optics

Skin and other biological tissues scatter light, making it impossible to look directly inside the body. Still, there are many optical methods that can image structures deep under the skin e. g. by cleverly using interactions between light and tissue, by exploiting the properties of light propagation in scattering materials, or by combining light with ultrasound. In this course, you will get to know the basic theoretical models for light propagation in biological tissue, and you will learn the working principle of a large range of optical imaging methods, ranging from highly experimental approaches to devices widely used in the clinic on a daily basis. Topics include: light scattering on small particles, light diffusion and radiative transport, optical coherence tomography, photoacoustic tomography, speckle-based blood flow monitoring, optical wavefront shaping, and more. In addition to the lectures, you will perform a series of light-scattering experiments.

202100107 - Deep Learning for 3D Medical Image Analysis

In recent years, the automated analysis of medical images like computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) has been revolutionized by deep learning. This umbrella term covers a wide range of machine learning methods that optimize

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artificial neural networks to perform tasks such as image reconstruction, segmentation, or registration. It is expected that deep learning will significantly impact image-driven medical specialties like radiology, radiotherapy, pathology, and dermatology. The advent of deep learning builds on decades of research in mathematical medical image analysis, combined with strong influences from computer vision and machine learning. However, genuinely successful deep learning in medical image analysis also requires domain knowledge about the clinical problem visualized, the physics underlying image formation, and the mathematics governing image reconstruction.

This course equips students with an understanding of the relationship between key concepts in this rapidly developing field and skills to address commonly occurring medical image analysis problems. Main topics include:

- The medical imaging pipeline and common image analysis problems
- Convolutional neural networks on images and manifolds
- Deep learning for image reconstruction, segmentation, and registration
- Mathematical image analysis and its relation to deep learning
- Quantitative evaluation of medical image analysis problems
- Interpretability, explainability, and uncertainty estimation in deep learning models
- Unsupervised, semi-supervised learning, and active learning on real-world data
- Approaches to working with multi-modal imaging and clinical data

193542070 - Medical Acoustics

At the end of this course, you will know how an ultrasound image is formed, from the signal generation to the image, passing by the transducer, the wave interaction with soft tissue, the required signal processing and the utilization of a medical scanner.

This course is not a medical course and therefore does not aim at simply showing how to operate an ultrasound scanner or perform a diagnostic examination. We aim at providing you with an in-depth understanding of the imaging process in order to give you the base required to go towards research, industry, or clinical physics. The primary aim of this course is therefore to explain the in and out of ultrasound imaging. This includes the basic physics of ultrasound propagation and scattering, the working principles of a transducer and the basics of signal acquisition and processing that lead to a greyscale image. Additionally, new techniques like contrast imaging using microbubbles and functional imaging including strain and shear wave imaging will be discussed. Building on this, we will discuss the differences between the different imaging modes in ultrasound both implemented in the clinics and under development.

Overall, you are expected to explain your reasoning, in a concise but complete way. When a small derivation is required, we expect to see this derivation in its main steps. Extensive answers where the correct response is provided together with wrong elements will typically not give the full points.

During the exam, no document or computer are allowed, and only a non-programmable calculator will be allowed. The grade repartition is: exam 50%, homework, 25% and lab reports: 25%. A minimum of 5.5 at the exam is necessary to validate the course.

When acquiring an ultrasound image, all the acoustic phenomena, and processing techniques occur simultaneously, in a way that makes them difficult to isolate. The lectures are designed to address each aspect independently and explain how they interact in an ultrasound image acquisition. The homework assignments will reflect the lectures and require from You to manipulate and crystalize the concepts through exercises. These exercises will train the various important skills that you are expected to develop, and in particular the use of Matlab, basic programming skills, knowledge of the basic operations and transforms, and their implementations. The tutorials will offer supervised exercises to start manipulating the lectures concepts during 2 dedicated hours per week. The tutorials will also leave room for question regarding the lectures, previous exercises, or practicals. The practicals will show how to apply the concepts from the lectures and homeworks. The first practical will consist of a hand-on training in the ECTM on clinical ultrasound scanners and training simulators in order to provide context. Subsequently, you will use single element transducers to send and acquire the signals and observe the various acoustic phenomena that give rise to scatter, reflections, attenuation and distortions.

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201800114 - Imaging Technology in Radiology

The goal of this course is that students understand and can apply techniques that are currently used in the clinic to generate medical images from signals. Next to that they can optimize the acquisition and reconstruction of these images for specific purposes such as image quality, acquisition time or dose reduction.

It is expected from the students that they already know how to get a measurable signal from a human body using CT, PET/SPECT and MRI. The requirements on hardware to obtain signals should therefore be known. Using this course the students learn how to make optimal use of this equipment.

The lectures on radiography and fluoroscopic imaging give the student an overview of the radiographic and mammographic systems used in the clinic, as well as on fluoroscopy systems used for interventional procedures. The different clinical applications of these systems, their relation to patient dose, and the relation between image quality and the diagnostic accuracy are discussed.

In the lectures on Computed Tomography students will gain insight in the different configurations of CT systems, the techniques of image formation, image reconstruction and the influence of acquisition and reconstruction parameters on image quality. In addition, the students will learn about radiation dose in CT and the significance of dose saving strategies and radiation dose indices provided on the scanner. The translation of the technical parameters on CT and their influence on the diagnosis of patients will be enlightened by different case studies.

The PET/SPECT lectures will introduce the key aspects of nuclear medicine imaging. Radioactivity as a means of detecting functional processes inside the body and radiation protection issues will be considered. The students will also gain insight into technological basics of PET and SPECT scanners as well as into image reconstruction and quantification techniques. Typical artefacts will be presented in selected case studies.

During the MRI part of the course students will become familiar with signal encoding that makes generating images possible and the parameters that influence the resulting image quality and resolution. Next to that, students will learn how this acquisition can be described and optimized in the frequency domain. Finally, by practical sessions on an MRI scanner students will learn how to use a scanner and optimize it for a specific use.