Course Package

Imaging & In Vitro Dagnostics – Q3

Name module	Imaging & In Vitro Dagnostics – Q3
Educational programme	MSc Biomedical Engineering
Period	First quartile of the second semester – Q3
Study load	15 ECTS
Coordinator	J. Huttenhuis

Imaging & In Vitro Dagnostics			
Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
		Deep Learning for 3D Medical Image Analysis 202100107 (5 EC)	
		Medical Acoustics 193542070 (5 EC)	
		AI- and Image-guided Robotics: From Theory to Medical Applications 202400681 (5 EC)	

Required preliminary knowledge: Linear Algebra; Calculus; Probability Theory; Basic programming experience in Matlab or (preferably) Python; Machine Learning; Knowledge of Differential Equations and Numerics.

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
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 practical skills to address commonly occurring medical image analysis problems. Main topics include:

- The medical imaging pipeline and common image analysis problems
- Convolutional neural networks and transformer models 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

The modules are tentative and subject to change. Please check the website regularly.

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.

202400681 - AI- and Image-guided Robotics: From Theory to Medical Applications

This course is designed to equip students with a foundational understanding of cutting-edge technologies in robotics, medical imaging, and artificial intelligence, all within the context of clinical applications. It offers a unique interdisciplinary approach, blending engineering principles with medical sciences to explore the latest advancements in surgical technology, robotic systems, imaging techniques, and AI-guided interventions. Students will gain a deep understanding of the engineering behind these innovations, from robotics and sensing technologies to the integration of AI in clinical workflows. The course also emphasizes hands-on experience in research methodologies, preparing students to apply their knowledge directly to real-world medical and surgical settings.

Throughout the course, students will develop strategies for implementing modern clinical workflows enhanced by robotic and mechatronic assistance, ensuring they are prepared to contribute to the future of healthcare. This course is ideal for those looking to bridge the gap between engineering and medicine, fostering skills that will drive innovation in the rapidly evolving field of surgical technology.

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