

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
			<i>Electives: (3 of the 4)</i>
			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.

Please note, choose 3 subjects to have 15 EC

Electives: (3 of the 4)

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

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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

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

Lecture 1: course introduction and basics of signal processing useful for medical acoustics (Guillaume)
Content:

Course introduction

Formulate the goal of the course

Course concept: why we need to pass by all these elements (= 8 lectures)?

What will you learn?

Signals

Fourier transform and fft

Fourier filtering

Bandwidth VS signal duration

interpolation

Cross-correlation

Hilbert transform

SVD filtering

List of useful matlab/python functions

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What you get out of the colstructure:

At the end of this first course and associated tutorial/homework,

You understand the logic in the construction of the course and see how the pieces fit together as a whole.

You can explain why each part is necessary to be able to create an ultrasound image.

You can use the basic processing functions essential to ultrasound imaging. You can explain what they are used for and why.

you can practically implement these functions in Matlab and have a library of the essential Matlab function that you will use throughout the course (and beyond, as these functions are widely used).

Lecture 2: ultrasound (physics) (Guillaume)

Content:

- Wave: the different waves, definition, frequencies and dispersion relation

- Wave equation

- Acoustic impedance

- Intensity VS pressure

- Reflection, transmission, refraction

- Attenuation

- Scattering (the different types of scattering)

- Non-linear propagation

What you get out of the colstructure:

After this lecture, you can distinguish between the types of wave, and know which waves are used in medical ultrasound.

You know the relation dispersion that characterizes acoustic waves and the difference between pressure and intensity (This is a critical point).

You understand which tissue/material properties are important for ultrasound and what their impact is on ultrasound propagation.

You understand the origin of reflection and scattering and explain the difference. You can manipulate the basic relations that describe the reflection or transmission of a wave across an interface.

You can explain the difference between the linear and non-linear effects, and know the impact of the non-linear effects on the ultrasound wave, both in time and in the Fourier domain.

Lecture 3: transducers (Michel)

Content:

- Single element transducers

 - The main characteristics (what you read on it: frequency, diameter, focal distance, etc...)

- Focused and unfocused transducers

- Near and far field

 - The different transducer arrays

- The different transducer type and the working principles

 - Piezos:

 - Piezo ceramics

 - Piezo polymers

 - Capacitive transducers

 - Cmut

 - Pmut

 - Matching layers and acoustic lenses

What you get out of the colstructure:

After this lecture, you can explain the technologies used in transducer to emit and receive waves. You can explain what the differences are between the technologies and describe their field of application.

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You understand how clinical probes (arrays) are made, their composition and the role of the different structural elements. You can reason based on the superposition of the sources that are each of the elements. You can give an overview of the resulting specific artifacts present in clinical scanners.

Lecture 4: beamforming (Chris)

Content:

- Beamforming in emission
- Plane-wave VS traditional B-mode (multibeam)
- System resolution
- Effect of pulse length
- Delay/sum for image reconstruction

Beamforming in receive/ synthetic aperture

What you get out of the colstructure:

You can use an array to produce any wave shape that might be needed in ultrasound imaging.

You can explain the difference between the standard B-mode imaging and plane-wave imaging and you understand the concept of each and the advantages and inconvenient of both

You know and can explain the physical resolution of the systems, both in the axial and in the lateral directions and how in changes with frequency and with the choice of the probe.

You can perform the basic delay/sum technique for reconstructing an ultrasound images from the RF time series recorded by the transducer elements.

You can explain the concept of beamforming in receive and of synthetic aperture and understand how they can improve image reconstruction.

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,

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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.