# Course Package

## Biorobotics – Q3 + Q4

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| Name module | Biorobotics - Q3 + Q4 |
| Educational programme | MSc Biomedical Engineering |
| Period | Second semester (quartiles Q3 + Q4) |
| Study load | 30 ECTS |
| Coordinator | J. Huttenhuis |

| **Biorobotics** | | | |
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| **Quartile 1** | **Quartile 2** | **Quartile 3** | **Quartile 4** |
| | | **Software Development for Robotics 202200108** (5 EC) | **Identification of Human Physiological Systems 201700071** (5 EC) |
| | | **Human Movement Control 191150480** (5 EC) | **Biomechatronics 201200133** (5 EC) |
| | | **Biomechanics of Human Movement 201800156** (5 EC) | ***Electives: choose 5 EC*** |
| | | | **Soft Robotics – 202000248** (5 EC) |
| | | | **System Identif. Parameter Estim. and ML – 202200111** (5 EC) |
| | | | **Early HTA during Med. Device Development - 202001580** (5 EC) |
| | | | **Design Flexible and Soft Robotic Systems – 202000040** (5 EC) |

<u>Required preliminary knowledge:</u> Basic programming knowledge in a C-like language (variables, functions, loops, pointers); Mathematics: Signals and Systems; Biorobotics: Multibody Dynamics & Control, Biomedical Signal Analysis; Multibody Dynamics & Control, Biomedical Signal Analysis; Dynamical Systems: Dynamics 1, Systems Analysis; Mechatronic Design: Dynamics 2, System and Control Engineering 1; Being fluent in MATLAB programming; Bachelor Technical Medicine or equivalent; Bachelor Mechanical, Electrical, Advanced Technology or Biomedical Engineering; The use and properties of Complex Numbers; The use and properties of Matrices; Some basic knowledge of Differential Calculus, Integration Calculus; Some basic knowledge of (ordinary) Differential Equation; Some basic knowledge of Elements and Physical Phenomena in the Electrical Domain, including voltage, current, resistor, capacitor and coil; Mechanics (kinematics and statics); Linear algebra; Basic strength of materials; Previous experience with Solidworks or other CAD software.

*The modules are tentative and subject to change. Please check* <u>the website</u> *regularly.*

# Quartile 3

**202200108 - Software Development for Robotics**

This course has two parts:

- Part I: Generic software concepts: on software concepts such as object-oriented programming, data structures, algorithm efficiency, and multithreading.
- Part II: Component-based software development for robot control: on writing software for controlling robots, using a combination of robot-software libraries (ROS2) and model-driven robot-software development (i.e., automatically generated code), to be implemented on a simulated robotic system.

Homework assignments yield hands-on experience for both parts. Weekly tutoring sessions are scheduled for support with the homework assignments. The programming language used in this course is C++.

**191150480 - Human Movement Control**

Different neuromuscular systems are involved in the control of human movement. These systems include the different sensory systems (visual, proprioceptive, vestibular), the central nervous system and the muscles. This course discusses the role of the separate systems and their interactions in motor control with an emphasis on integration of sensory information, postural control and control and adaptation of reaching movements. Obtained knowledge can be applied in the development of treatments and assessment methods for diagnosis in neurology and (neuro)rehabilitation. In this course student will obtain knowledge about the physiological and computational mechanisms involved in movement control through lectures and self study and will learn to make use of engineering skills/tools in assignments and a practical to better understand the importance of the different involved processes.

Regarding the required background skills and knowledge, you should be able to

- Make a free body diagram of a particular system including all forces and moments working on the system
- derive the equations of motions for a particular system,
- linearize a nonlinear differential equation around an operating point
- transform the different representations of a linear time invariant (LTI) system in each other (differential equation, state space, transfer function),
- know how the Bode Diagram and step response of standard LTI systems (integrator, differentiator, time delay, 1st order system) look like,
- indicate the effect of mass, damping coefficient and spring constant of a mass-spring-damper system on the response of this system in the time and frequency domain,
- know how relative damping, the system gain and eigen frequency can be recognized in a time and/or frequency response,
- determine the stability of a system using the Bode diagram/Nyquist diagram and poles and zeros.

**201800156 - Biomechanics of Human Movement**

The course will teach you to record movement data in a real movement analysis lab. It will then teach how to use such data to generate introduce forward dynamics and inverse dynamics formulations for the simulations of the composite neuro-musculo-skeletal system. Inverse dynamics formulations will include static optimization techniques where the contribution of individual muscle-tendon units to joint actuation is resolved by using pre-defined optimization criteria and reflexive rules so that the emerging muscle-actuated movement tracks experimental joint mechanics or shows agreement with joint mechanics normative values. Forward dynamics formulations will include EMG-informed musculoskeletal modelling. Synthesis of human movement will be introduced via dynamic optimization. The significance of these approaches for studying human machine physical interaction and for controlling assistive devices online (i.e. artificial limbs and exoskeletons) will be especially stressed. Hands-on programming training for this course will rely on existing modelling frameworks available at the University of Twente as well as on modelling software including CEINMS (https://simtk.org/projects/ceinms), OpenSim (https://simtk.org/projects/opensim). This will be applied in 1 laboratory excursion, 1 written test and three group-based programming assignments.

This will be applied in one written exam and three hands-on assignments. The written examination determines for 40% and each of the three assignment determine for 15% of the end mark, i.e. 45% across all three assignments. Reading tests will be performed contributing to a total 15% of the final grade. The exam focuses on understanding of theoretical concepts; practical skills are assessed by the assignments. NOTE: A minimum grade of 5.5 at the written exam is required to pass the course. Also, in order to pass the course, you have to submit results for all the assignments.

## Quartile 4

**201700071 - Identification of Human Physiological Systems**

Distorted physiological control systems underlie various impairments in motor control, respiration and cardiovascular function. For instance, a hyperactive control loop to regulate muscle length is the underlying cause for spasticity. Clinicians are perfectly able to see that something is wrong and can use available clinical scales to quantify the severity of the impairment or disability. However, they are much less able to see what is wrong. System identification techniques make it possible to characterize the distorted physiological control systems for various conditions in a standardized way. In this course, we will cover different approaches and techniques to be able to identify a linear system. The addressed topics vary from correlation functions, identification in the frequency and time domain, open and closed loop system identification, perturbation signal design and parameter estimation and optimization. In the course we will focus on distorted human motor control. Yet, the learned methods and techniques can be applied to a wide range of physiological and technical systems.

**201200133 – Biomechatronics**

The human motor system consists of a sensory system, a controller (the central nervous system), an actuation system and a mechanical system (skeleton and passive tissues). In people with neuromuscular disorders parts of the motor system do not function adequately. The goal of the course Biomechatronics is to present concepts for the support of the affected human motor system.

The following topics will be addressed: description of the human motor system as a controlled dynamic system; dynamic system description of the physiological sensory system; physiological motor control; impairments of the human motor system and resulting disabilities and handicaps; artificaial motor control for supporting the impaired motor system; orthoses and prostheses; artificial sensors and derivation of information from physiological sensors; artificial actuation; user interface; examples of support systems for human motor control.

**Electives: choose 5 EC**

**202000248 - Soft Robotics**

he Soft Robotics course discusses the design, fabrication, materials and characterization methods of soft robotic systems, as a new generation of robots with physically flexible-bodies and electronics.

The intrinsic flexibility of soft robots make them potentially a great solution for adaptable and safe interaction with their user and environment. However this flexibility also compels the need for new generation of actuators, sensors and fabrication techniques and design tools. This course will discuss the state-of-the-art fabrication techniques and design of soft actuators, sensors and smart structures with their technical features, characteristics and limitations. Bioinspiration and embodied intelligence as short-cut solutions for arriving to an optimal and smart design will also be introduced.

This course includes several practical sessions in which students practice how to use non conventional materials and techniques to realize robots that are highly adaptable and safe with their user and environment. With in the course projects students develop soft robots for different and wide range of applications such as adaptive manipulation, surgical robotics, werable robotics, search and rescue,

Some of the last year practical results can be find in the soft robotics lab YouTube channel: https://www.youtube.com/@softroboticslabuniversityo5458

**202200111 - System Identification with Parameter Estimation and Machine Learning**

In everyday control or optimization practice, one requires the model of the corresponding system that is to be improved or controlled. As a system or its components cannot be always accurately described by physics-based principles, one aims at identifying a robust mathematical model, i.e. the parametrized linear/nonlinear function of the state, that can accurately describe the system dynamics. This is known as system identification. As both the system model and its parameters are assumed to be unknown, they are estimated given measured (input)-output data. In this manner, the discrepancy between the behaviour of the model and the real system is reduced. In general such an estimation can be achieved by a classical system identification/parameter estimation approaches, or by use of newly developed machine learning algorithms. In this course both of these approaches will be tackled, as well as their similarities and differences discussed.

Topics of this course are: The selection of the model structure, parameter estimation and the design of identification experiments for that purpose. One part of the course will be focusing on the system identification problem by considering a limited number of standard model structures for linear systems. In addition, attention will be paid to a more general parameter estimation in the time and frequency domain. Nonlinear systems will be also tackled such that their corresponding parametrization has a physical meaning.

**202001580 - Early Health Technology Assessment during Medical Device Development**

The rate of biomedical innovation development is rapidly increasing. However, while many biomedical innovations may have the potential to revolutionize healthcare and the healthcare system, only a fraction of all innovations actually reach the market and (clinical) practice. This is partially caused by the strong focus on feasibility and performance during early development stages. Potential applications, expected impact on, for example, patient health outcomes and healthcare costs, and the barriers for subsequent implementation, are largely under-investigated. This course addresses the need and methods for structured early assessment of biomedical innovations during development. Particular attention is paid to methods for measuring and analysing expected health and economic outcomes, determining stakeholder preferences for health outcomes and for the process of care, and identifying barriers and facilitators for implementation in combination with scenarios for potential use. Structured application of these methods can boost the impact and value of biomedical engineering efforts by creating awareness of the context innovations are assessed and judged in, and the requirements of stakeholders that need to be met for successful future implementation.

**202000040 - Design of Flexible and Soft Robotic Systems**

The course will cover basic concepts in robot mechanics such as statics and kinematics of serial chain robots and mechanisms.

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

The use of software to model such systems will also be demonstrated. Mechanical aspects of robotic systems will be analyzed using Finite Element software, along with methods of theoretical analysis using energy methods.

The use of flexible elements and soft materials within robots will be detailed. Actuation modalities for medical applications (cable-driven, magnetic fields, pneumatics) will be discussed.Methods of fabrication and prototyping using a range of materials will be examined.

Assignments will focus on modeling, analysis and design of robotic systems for biomedical application. Quizzes will focus on conceptual learning of topics covered in lectures and tutorials.

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