Course Package

Biorobotics – 2A + 2B

Name module	Biorobotics - 2A + 2B
Educational programme	MSc Biomedical Engineering
Period	Second semester (block 2A + 2B)
Study load	30 ECTS
Coordinator	J. Huttenhuis

Biorobotics			
block 1A	**block 1B**	**block 2A**	**block 2B**
		Human Movement Control - 191150480 (5 EC)	**Identification of Human Physiological Systems - 201700071** (5 EC)
		Elective (2 out of 3): **Biomechanics of Human Movement** (5 EC)	**Biomechatronics - 201200133** (5 EC)
		System Identification and Parameter Estimation - (5 EC) **Design Principles for Precision Mechanisms 2 -** (5 EC)	**Optimal Estimation in Dynamic Systems - 191210920** (5 EC)

Required preliminary knowledge: Bachelor's level on Systems and Control, Dynamics, and Mechanics. *More information will be available shortly.*

191150480 **Human Movement Control (2A)**
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.

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

Elective (Choose 2 out of 3):

- 201800156 **Biomechanics of Human Movement (2A)**

  The course will introduce forward dynamics and inverse dynamics formulations for the simulation 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), and the AnyBody Modeling System™ (https://www.anybodytech.com/software/ams). This will be applied in 1 written test and three group-based programming assignments.

- 191131700 **System Identification and Parameter Estimation (2A)**

  In system modelling the choice of the model structure plays an important role. This model structure specifies the mathematical expressions to describe the system and the parameters that are considered to be relevant . By setting correct values for the parameters, it is possible to optimise the agreement between the behaviour of the model and system.

  Topics of this course are: The selection of the model structure, parameter estimation and the design of identification experiments for that purpose. One part is about so-called system identification, where mathematical models are used. Usually the parameters do not have a physical meaning. The focus is on a limited number of standard model structures for linear systems. In addition, attention will be paid to more general parameter estimates in time and frequency domain. Nonlinear systems are also tackled and the parameters usually have a physical meaning.

- 191131360 **Design Principles for Precision Mechanisms 2 (2A)**

  This course gives insight in the conceptual design of precision mechanisms used in products, tools and equipment. Characteristic to all precision systems is the high level of determinacy required. Predictable and reproducible behavior are key-qualities that can only be achieved when mechanics and control systems (if present) are carefully designed and robust to disturbances. Their mechanical design is the subject of this course. The insight in precision mechanisms enables the student to recognize problem areas, generate design alternatives and make the appropriate choices. Considerable attention will be paid to details, because these can be crucial and decisive for the quality of the design. Important principles for precision mechanism design which will be focused on during the course are: Designing for light and stiff mechanisms, exact kinematic constraint design, design of low-hysteresis mechanisms and designing precision manipulators.

201700071 **Identification of Human Physiological Systems (2B)**

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 (2B)**
The course Biomechatronics presents concepts for the support of the motor control function in persons with neuromuscular disorders. Topics include: clinical need, models and selection of actuation, sensor fusion, interaction control and stability, human machine interfaces, wearable exoskeletons, prosthesis, and rehabilitation robotics.

191210920 **Optimal Estimation in Dynamic Systems (2B)**
The course addresses the following problem: How to estimate the dynamic quantities in a physical process given the data from a sensory system? Although the applications are wide: (ranging from production processes, water management, orbit determination, telecommunication and so on), the course will concentrate on robotic applications: navigation and tracking. Especially, the SLAM problem will be addressed. SLAM = simultaneous localisation and mapping, e.g. a mobile robot that has to navigate within an unseen environment. The course will familiarise the student with methods for the estimation of state variables in dynamic systems. The course starts with an introduction of the topic 'parameter estimation' which is the fundament for state estimation. After that, the estimation paradigm will be embedded in a dynamic framework. For linear-Gaussian systems this leads to the well-known Kalman filter which is an online estimation method. An extension of the Kalman filter makes it applicable to offline estimation, and to prediction. For nonlinear dynamic systems, the so-called 'extended Kalman filter' is a suboptimal solution which only works well if the nonlinearities are not severe and the disturbances are Gaussian. Another estimation method is the 'particle filter'. This method is generally applicable, and is optimal, but it is computationally intensive. An important aspect of the course is bringing a theoretical concept to a practical solution. Students that attend this course will design an estimator for a given navigation process. Various estimation methods (e.g. Kalman, extended Kalman, particle filtering) will be tested and evaluated with a tracking and SLAM problem. Matlab is used as a development platform.