# Deliverable D2.1 Master programme structure and content design

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This document includes a detailed list of the topics of interest being subject of the master course program. Specifically, the document outlines the program content being common to both of the profiles and detail medical and engineering study plans. This took into account the specific priorities of Uzbekistan in terms of specialists trained within higher education, based on the demand and need for them within the economy and within other areas of public life.

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**Master programme in Computer systems for medicine**

The Master programme will be implemented on a two-year (4 semesters) basis.

## Experimental tools to be made available to the Uzbek universities

Teaching activities will rely on the following specific equipment planned to be installed at UZ universities:

|  |  |
| --- | --- |
| Motion capture system | System with 4 cameras |
| Force platform | Digital force platform |
| Virtual reality platform | Virtual reality system |
| Electromyography system | 10-channel wireless configuration system |
| Postural training platform | 4-channel postural training plate |
| Biofeedback system for clinical and home rehabilitation | Wearable sensor nodes and applications |
| Research system for rehabilitation | Research system for rehabilitation |

## Disabilities to be studied

For evaluation or improvement

|  |  |
| --- | --- |
| Musculo-skeletal disorders | Physical and cognitive impairment |
| Neurological disorders |

## Knowledge to be acquired for a rehabilitation Master specialization

|  |  |  |
| --- | --- | --- |
| General topic | Subjects | Already acquired in ICT Bachelor |
| Instrumentation | Sensors | Basics on sensors’ physics |
| Electronic measurement | OK |
| Analog to digital conversion | OK |
| Data collection and storage | OK |
| Data protection and ethics | - |
| Processing | Image | OK |
| Signal | OK |
| Virtual reality | A bit |
| Human machine interface | - |
| Biomechanics | Biomechanics | - |
| Mechatronics | Mechanics, | - |
| Sensors | OK |
| Actuators | OK |
| Automatic control | OK |
| Micro-controllers | OK |
| Programming | OK |
| Medical needs | Musculo-skeleton disorders | - |
| Neuro-sensori motor disorders | - |
| Market needs and economics | Market needs and regulations | - |
| Product development | - |
| Economics | - |
| English language | OK ? |

## Topics for a Master programme designed for engineering students

|  |
| --- |
| Introduction to musculo-skeleton disorders |
| Introduction to neurological disorders |
| Overview of state-of-the-art rehabilitation systems |
| Working principles of sensors in rehabilitation systems |
| Protection of personal data, regulation and ethics |
| Biomechanics |
| Mechanics |
| Physical human-machine interaction |
| Virtual reality |
| Human-machine interface HMI |
| Development of rehabilitation systems, market needs and economics |
| Mandatory units in Uzbek Masters (500 hours) |

## Topics for a Master programme designed for medical students

|  |
| --- |
| Selected units of medical Master |
| Extended version of  Overview of state-of-the-art rehabilitation systems |
| Development of rehabilitation systems, market needs and economics |

## Course modules requiring training the Uzbek teachers

|  |  |  |
| --- | --- | --- |
| Topic | Experimental system | Place |
| Vision | Motion capture system | Paris & Sannio |
| Sensors, biomechanics | Force platform | Paris & Sannio |
| Postural biofeedback platform | Lisbon |
| Computer science | Virtual reality platform | Paris |
| Electronic measurement | Electromyography system | Sannio |
| Research system for rehabilitation | Lisbon |
| Mechatronics | Postural training platform | Paris |
| Musculo-skeleton disorders |  | Vilnius & Plovdiv |
| Neurological disorders |  | Vilnius & Plovdiv |

# Unit descriptions

# Background knowledge

The following units correspond to knowledge that should be acquired before starting the Master.

* Analog to digital conversion
* Automatic control
* Digital signal processing
* Electronic measurement
* Image processing
* Micro-controllers
* Modelling and analysis of dynamic systems
* Numerical methods
* Object-oriented programming
* Physics of sensors
* Signals and systems

**Analog to digital conversion**

European credits: 3

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 12 |
| Tutorials | 10 |
| Practical work | 8 |
| Project |  |
| Other |  |

Objective:

Principles and techniques for analog to digital conversion

Content:

* Definition of an A/D conversion, quantization, sampling, resolution, quantization noise …
* Characteristics of an A/D converter: resolution, range, sampling frequency, conversion rate, integral and differential nonlinearities, signal to noise and distortion ratio, effective number of bits …
* Architectures for A/D conversion: flash ADC, sub-ranging ADC, pipeline ADC, folding ADC, successive approximation ADC, ramp ADC, sigma-delta ADC … comparison between architectures (resolution, speed, power consumption …)
* Enhancement techniques: oversampling, self-calibration, anti-aliasing filters ...

Background:

* Fundamentals on electronics: amplifiers, filters, digital functions

**Automatic control**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 12 h |
| Tutorials | 10 h |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

The aim of this course is to provide the basic knowledge for the study, characterization and synthesis of controlled systems. To this end, the unit relies on knowledge of the study of signals and systems and complements it in order to allow students to formalize the general concepts of automatic control (closed loop, error, accuracy, rapidity of a system). Special attention is then paid to the synthesis of analog controllers, illustrated with examples of concrete physical systems. Finally, students are introduced to the numerical implementation of control laws, requiring interfacing a digital corrector with a continuous time system. Thus, the basic principles of the discrete control are presented, as well as the basic tools allowing to implement a digital controller.

The discovery of these fundamental theoretical notions will also rely heavily on the experimental implementation of continuous and discrete closed-loop systems during sessions of practical work.

Content:

* Mathematical modelling of physical systems

Block diagram, transfer function, associate laws

* Reminders on signals and continuous time systems

Temporal description (standard answers, convolution),

Frequency description (Laplace transform, transfer function, frequency response)

* Time domain and frequency domain analysis of system behaviour

Impulse and step response, Bode, Nyquist and Nichols diagrams

* Continuous Time Controlled Systems

Principle and objectives of feedback control

Stability, precision, time performance of closed-loop systems

* Design of analog controllers

Frequency approach, integral lead-lag and PID controllers

* Towards the discrete control

Sampling

Correction of an analog system by a digital controller (analog/digital, digital/analog conversion, and modelling)

Elementary methods of discretization of an analog corrector (simple temporal equivalences, recurrence equation)

Background:

* Signals and systems

**Digital signal processing**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 18 h |
| Tutorials |  |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

This course concerns the digital signal processing, provides students with some basic concepts of digital processing going from digital filtering to the realisation of systems. These are essential to correctly understand problems related to images and sounds processing, communicating systems, sensors and their modelling.

Content:

* Reminders on sampling
* Z Transform
* Discrete Fourier Transform
* Description of numerical filters
* Classification of numerical filters: finite and infinite impulse response filters (FIR and IIR)
* Analysis of numerical filters
* Stability of numerical filters
* Temporal and frequency responses of numerical filters
* Synthesis of numerical RIF and RII filters

**Electronic measurement**

European credits:

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 15 |
| Tutorials | 10 |
| Practical work | 5 |
| Project |  |
| Other |  |

Objective: Understanding requirements of an electronic conditioning chain

Content:

* Elements of an electronic conditioning chain: transducers, amplifiers, filters, A/D converter
* Noise in the conditioning chain: signal to noise ratio, noise factor, noise Bandwidth, Friis formula, quantization noise in A/D converters. Noise measurement.

Background:

* Fundamentals on electronics. Passive elements, transistors.

**Image processing**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 14 h |
| Tutorials |  |
| Practical work | 16 h |
| Project |  |
| Other |  |

Objective:

This course aims to give to students with basic tools of image processing required for computer vision. It presents a complete set of processing techniques. Several applications are presented through theoretical and practical courses.

Content:

* Introduction
* Images presentation
* Enhancement and restoration
* Noise reduction
* Mathematical Morphology
* Contours detection
* Region segmentation
* Perspective transformations

**Micro-controllers**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 12 h |
| Tutorials | 6 h |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

The aim of this course is to provide students with the foundation for programming embedded microprocessors and microcontrollers for the development of applications in control of digital systems.

Content:

* Micro-controllers: design and drivers, programming by interrupt, example in motor control
* DSP: design, signal processing in real-time on DSP, example in digital signal processing
* Applications: digital control, closed-loop systems

**Modelling and analysis of dynamic systems**

European credits: 6 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 24 h |
| Tutorials | 24 h |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

This course is interested in modelling the dynamics of robotic systems. It addresses fundamental notions as spatial geometry, kinematics, cinematic-static and dynamics of multi-body systems. This unit is based on numerous examples of robotic systems at consider many practical examples with practical works using the dynamic simulation software ADAMS.

Content:

* Reminders of kinematics of the mechanical systems
* Mechanical transmissions
* Application of the general theorems of the mechanics
* Equations of the movement by the general theorems
* Theorem of d’Alembert and equations of Lagrange
* Multipliers of Lagrange of constrained systems
* Orthogonal projection on pseudo-velocities
* Analytical and numerical resolution of the equations of movement
* Systems equilibrium and stability analysis
* Simulation

Background:

* Basics in mechanics

**Numerical methods**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 6 h |
| Tutorials |  |
| Practical work | 24 h |
| Project |  |
| Other |  |

Objective:

This course introduces the students to the finite difference method and the finite elements method. These methods allow to numerically solve partial differential equations and are used for simulation in various domain of engineering: continuum mechanics, meat transfer, electromagnetism …

Content:

* Introduction to the finite differences methods, practical examples: 1D transfer equation, 1D diffusion equation
* Introduction to the finite element method, practical examples: electrostatic sensor, joule heating

**Object Oriented Programming**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 16 h |
| Tutorials | 16 h |
| Practical work | 8 h |
| Project |  |
| Other |  |

Objective:

This course aims to present the essential elements of object-oriented programming (could be using Java or C++) and its specific environment for object-oriented design and programming,

Content:

* The basic concepts of object-oriented programming: objects, classes, methods constructors, inheritance, overloading and redefinition, encapsulation
* The packages of basic and graphics toolkit (Swing classes)
* The management of events
* Applets and the Internet
* Threads and synchronization

Background:

* Programming

**Physics of sensors**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 18 h |
| Tutorials | 8 h |
| Practical work | 4 h |
| Project |  |
| Other |  |

Objective:

Sensors are nowadays encompassing emerging technologies that prevail in the world in which we live. The course aims at presenting fundamental knowledge in the general area of sensors. As the course is devoted to future actors of the industrial and/or economic world, it also addresses applications relying on sensor-based industries to review current developments in the field.

Content:

* The introductory chapter reveals fundamentals of sensors: common features, appropriate readout electronics, economical criteria, examples of complete sensor systems, etc.
* Part A deals with temperature sensors (thermocouples, metal-based resistance thermometers, thermistors) as well as humidity sensors (psychrometer…).
* Part B is devoted to sensors whose response relates to mechanics: displacement, speed, force, acceleration, fluid pressure, etc.
* Part C presents radiation sensors (photo-detectors, bolometers, pyroelectric detectors) on the one hand and magnetic sensors (e.g. Hall effect probe) on the other hand.
* Part D examines some electrochemical and biological sensors.

**Signals and systems**

European credits: 6 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 24 h |
| Tutorials | 24 h |
| Practical work | 16 h |
| Project |  |
| Other |  |

Objective:

This course allows the acquisition of fundamental knowledge for the study of signals and systems, which are essential for the subsequent study of signal processing, system identification and control techniques. The different modes of representation, temporal and frequential, are addressed for both analog and digital systems.

Content:

* Definition of systems and signals

Concept of system and properties: invariant, causal, linear/nonlinear, continuous/discrete

Signal definitions and properties: deterministic/random, periodic/aperiodic, continuous/discrete, real/complex, stationary/non-stationary

Signal operations: inter and auto correlation functions

Test signals: Dirac pulse, gate, step, ramp, sine ...

Definitions: impulse response, index response ...

* Frequency analysis of signals: time / frequency duality

Reminders: Fourier series (periodic signal), Fourier transform (aperiodic signal)

Energy and power of a signal: spectral density, temporal windows

* Modelling a system and analysing its response

Time domain: convolution product, temporal responses to test signals, use of the Laplace transform, transfer function

Frequency domain: definition, use of Fourier series, complex gain, representation in the Bode diagram, output signal spectrum, filtering concept

Application to amplitude modulation

* Some systems to very well know

Order 1 system: impulse response, step response, transfer function, Bode diagram

Order 2 system: impulse response, step response, transfer function, Bode diagram

Association and cascading of systems of order 1 and 2 - Construction of the Bode diagram

* Discretisation of an analog system:

Analog/digital conversion: sampling - Shannon's theorem - quantification

Digital/analog conversion: control block

Discrete transfer function, recursion equation, Z transform, discrete Fourier transform

Analysis of simple discrete systems

Background:

* Fourier transform
* Laplace transform

# Specialized knowledge

The following units correspond to knowledge that should be acquired during the Master.

* Biomechanics
* Controlling robotic systems
* Designing mechatronic systems for rehabilitation
* Development of medical systems and evaluation
* Image processing for human analysis
* Introduciton to physiology and physiopathologie
* Locomotor devices
* Multi-modal perception
* Physical human-machine interaction
* Programming rela-time systems
* Regulation of medeical devices
* Safety and acceptability in rehabilitation systems

Elena ??

* Introduction to musculo skeleton disorders
* Introduction to neuro-sensori motor disorders

**Basics of biomechanics**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 22 h |
| Tutorials | 8 h |
| Practical work |  |
| Project |  |
| Other |  |

Objective:

To provide the bases in biomechanics necessary to the understanding of the phenomena encountered in he immobile apparatus, immobile and in motion.

Content:

* Reminders of functional anatomy (skeleton, joints, ligaments, muscles, nervous system)
* Organization of the simple movement
* Monoarticular movement
* Multi-articular motion
* Examples of segmentation
* Anthropometry
* Distribution of body mass
* Joint and ligament mechanical stops
* Muscular action
* Organization of a complex movement
* Various types of redundancy (geometric, kinematic, dynamic)
* Identification of muscle activity

**Controlling robotic systems**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 18h |
| Tutorials |  |
| Practical work | 12h |
| Project |  |
| Other |  |

Objective:

This course introduces the methods for mechanical modelling, analysis and control of robotics systems. It aims at giving to the students the possibility of beginning in complete autonomy the resolution of certain number of elementary problems of robotics as the configuration description, the generation of trajectories, the dynamic control as well as of being capable of analysing the behaviour of mechatronic systems from the point of view of their properties of kinemato-static transmission, their static and dynamic balance.

Content:

* Kinematic description and parametric representation of systems
* Homogeneous transformations
* Direct and inverse geometrical
* Laws of transmission of movement
* Resolution of the kinematic problems
* Generation of articular and Cartesian trajectories
* Position, force and impedance control

Background:

* Automatic control
* Modelling and analysis of dynamic systems

**Designing mechatronic systems for rehabilitation**

European credits: 6 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 40 h |
| Tutorials |  |
| Practical work | 20 h |
| Project |  |
| Other |  |

Objective:

The objective of this course is to apply mechatronic design to the specific area of physical rehabilitation. The point of view of physical medicine and rehabilitation is first presented with the description of therapeutic needs with respect to altered motor functions and performances of the patient. The second part considers how to measure these motor performances for, in one hand diagnostic quantification and in the other hand for the design of mechatronic systems for rehabilitation. The last part of the course is devoted to the design of these specifics systems that can physically assist the movement of a patient and eventually apply corrective forces. This part is based on examples and case studies.

In addition, visit and practical works will be held in hospitals dedicated to the rehabilitation and to better understand the potential use and real use of high technology systems in rehabilitation protocols.

Content:

* User needs
* Link to Biomechanics aspects
* Motor function evaluation
* Overview of state-of-the-art rehabilitation systems
* Aspects of the interactive robot design (case studies)
* Sensor fusion for the control of robots that are in physical interaction (impedance control …)

Background:

* Automatic control
* Biomechanics
* Multimodal perception

**Development of medical systems and their evaluation**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 30 h |
| Tutorials |  |
| Practical work |  |
| Project |  |
| Other |  |

Objective:

This course gives the general principles of clinical research and statistical basic tools.

Content:

* Clinical trials methodology and protocol design
* Data Analysis, Biostatistics
* Engineers, designers and technicians’ collaboration methodology
* Evaluation of a medical product
* Certification principles and regulations
* Life of the product

Background:

* Statistics

**Image processing for human analysis**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 30 h |
| Tutorials |  |
| Practical work |  |
| Project |  |
| Other |  |

Objective:

The objective of this course is to provide students with image processing tools required for any real application based on vision and, more particularly, for applications centred on the human. This course addresses several issues to present all the steps of image processing system. Several applications such as human detection or motion estimation will be proposed during tutorials.

Content:

* Introduction
* Presentation of images
* Images filtering
* Mathematical Morphology
* Edge detection
* Human detection with background subtraction
* Motion estimation
* Basis of tracking

Background:

* Image processing

**Introduction to physiology and physiopathology**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 22 h |
| Tutorials | 8 h |
| Practical work |  |
| Project |  |
| Other |  |

Objective:

Provide up-to-date knowledge in the field of physiology and pathophysiology of the body's major functions

Content:

Physiology and physiopathology of the

* musculoskeletal system
* cardiovascular system
* respiratory system
* digestive system
* neuro-sensory apparatus
* urogenital apparatus..

**Locomotor devices**

European credits: 3

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 36 h |
| Tutorials |  |
| Practical work |  |
| Project |  |
| Other |  |

Objective: present and understand technological solutions for orthopedic pathologies

Content:

* Anatomy and physiology of locomotor system, trauma pathologies.
* Biomaterials for orthopaedics.
* Orthopedic devices: prosthesis and orthosis
* Prosthesis design.
* Implantation and interaction with living matter. Fixing techniques and materials.
* Imaging for prosthesis design. Sizing tools and techniques.

**Multi-modal perception**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 18 h |
| Tutorials |  |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

The objective of this course is to present to students the sensors and tools useful for the development of rehabilitation systems and the human state estimation. Various types of sensors like force sensors, accelerometers or motion capture systems will be introduced. Their use in human pose (or gesture) tracking system will be presented too. As a generality, the human state is not directly measured by sensors but has to be estimated from the measures. This course will also focus on state estimators like the Kalman filter and its extensions or the particle filter.

Content:

* Sensors: force sensors, accelerometers, EMG, motion capture
* Estimation theory: bias, covariance, efficiency, asymptotic properties, classical estimators (least square, maximum likelihood,….) and state estimators for stochastic systems : Kalman filter, extended Kalman filter, unscented Kalman filter, particle filter,….
* Sensors fusion

Background:

* Physics of sensors

**Physical human-machine interaction**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 22 h |
| Tutorials |  |
| Practical work | 8 h |
| Project |  |
| Other |  |

Objective:

Being able of properly handling the specific constraints pertaining to the design and control of robotic devices aimed at physically interacting with a human being.

Understanding how they can be used in a motor rehabilitation protocol.

Content:

The course focuses on those robots that are more and more used for rehabilitation purpose, i.e. that can physically assist the motion of a human being and eventually apply corrective forces. It will be divided in three main parts.

* Firstly, a 10 hour series of lectures will focus on design. It will start by an exhaustive overview of the state of the art in rehab robotics, which will also cover the medical aspects such as protocol definition, pathology description, motor learning fundaments, etc. This series will then cover the kinematics, statics and dynamics aspects of the interactive robot design, all based on elementary biomechanics, as well as the most popular actuation solutions.
* Secondly, an 6 hour series of lectures will introduce the problems and solutions encountered in force control of robots, in a conventional way. Attached to this part will be a 4 hour lab.
* Finally, a 6 hour series of lectures will focus on current tendencies of anthropocentric robot control, i.e. robot control methods explicitly accounting for human being models in their controller, with, again, a 4 hour lab.

**Programming real-time systems**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 12 h |
| Tutorials | 2 h |
| Practical work | 12 h |
| Project |  |
| Other |  |

Objective:

This course will provide an understanding of real-time embedded systems with key modelling concepts and fundamental programming aspects of multithreaded applications running with real-time operating systems currently used in rehabilitation robotics.

Content:

* Introduction to real-time operating systems
* Tasks and kernel objects (semaphores, message queues, etc)
* Scheduling, synchronization and communication
* Timer services
* I/O subsystem
* Exceptions and interrupts

Background:

* Programming

**Regulation of medical devices**

European credits:

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures |  |
| Tutorials |  |
| Practical work |  |
| Project |  |
| Other |  |

Objective: Understanding hospital environment and medical regulation and steps to develop a medical device

Content:

* Hospital environment and actors: physicians, pharmacists, nurses, buyers, technical staff...
* Constraints on medical devices: disinfection and sterilisation processes
* Waste collection
* Galenic forms
* Classes of medical devices: definitions, constraints, regulations.
* Step for development of a medical devices: regulation, standards, certification organisms …
* Comparison of local procedure and European (CE) and american (FDA) procedures.

**Safety and acceptability in rehabilitation systems**

European credits: 3 ECTS

Course components:

|  |  |
| --- | --- |
| In class work | Total time |
| Lectures | 30 h |
| Tutorials |  |
| Practical work |  |
| Project |  |
| Other |  |

Objective:

This course examines several central aspects with respect to the safety and the acceptability of assistive and rehabilitation technologies. Risk management concepts and techniques for the development of medical robots and more particularly rehabilitation robots are explained. Developing equipment and devices that are well accepted by potential users is a central question in rehabilitation. The engineering aspects here are only a part of the issues to be considered at the design stage, the human factors and the impact of the potential robotic aids in the users’ life are to be carefully analysed.

Content:

* Definition and application of basic concepts for risk management: risk, harm, safety, hazard, hazardous situation, safety integrity, safety integrity level, etc.
* Risk analysis methods (Fault Tree Analysis, Failure Mode Effects and Criticality Analysis, HAZOP,etc.) based on system modeling
* Risk reduction techniques for medical robots (Hardware and software fault avoidance techniques, fault tolerance mechanisms, etc.)
* Acceptability and ergonomy of the assistive technologies.
* Relationship between Assistive Technology and Inclusive Design.

Background:

* State-of-the-art rehabilitation systems