Retraining of Fossil Fuel Mining Area Workforce for Modern Industry
REMARKER

Project Results

Output 4: Re-training Course for Robotics

Contents

Description

Robots are machines that have interested the general population throughout history. In general, they are machines or devices that operate automatically or by remote control. They are complex and useful systems that have been employed in industry for several decades. As technology advances, the capability and utility of robots have increased dramatically. Today, robots assemble cars, weld, fly through hostile environments, and explore the harshest environments from the depths of the ocean to the cold and dark environment of the Antarctic, to the hazardous depths of active volcanoes, to the farthest reaches of outer space. Robots take on tasks that people do not want to perform. As the global marketplace demands higher quality goods and lower costs, factory floor automation has been changing from separate machines with simple hardware-based controls, if any, to an integrated manufacturing enterprise with linked and sophisticated control and data systems. For many organizations, the transformation has been gradual, starting with the introduction of programmable logic controllers and personal computers to machines and processes. However, for others, the change has been rapid and is still accelerating.

The main aim of Output 4 is to develop the structure and specification of retraining module supporting pieces of training in the field of power electronics. The course is aimed at different target groups: employees of manufacturing plants, mainly operators of advanced machines, such as robots, automats, cells/machines for automated assembly, teachers / trainers / consultants in the field of automation and robotics, technicians, and also students.

1 Analysis of the curriculum in the field of Robotics

In this section curriculum in the field of Robotics at partner universities is presented. Both bachelor and master courses are taken into account. Aims, outcomes, and descriptions are collected and structured. Content of the lectures is provided for further analysis. Moreover, the dedicated literature and references is presented.

1.1 Tallinn University of technology (TalTech)

1.1.1 Bachelor studies

Course code	ATR0030
Course title in Estonian	Robotitehnika
Course title in English	Robotics
ECTS credits	6.0
Assessment form	Examination
Teaching semester	autumn - spring
Lecturer	Madis Lehtla, Valery Vodovozov
Course aims	The teaching /learning aims are following: - to develop an understanding of robots as universal machines to help people work in abnormal or dangerous conditions or to expand limits of human cognition; - to deepen an understanding of connections between different areas of engineering like mechanical and electrical engineering, informatics, and integration of knowledge in robotics and industry automation; - to develop knowledge for a system integrator, like analysis and comparison of competitive solutions and skills for targeted use of robots and robot systems; - to develop awareness of ethical problems of modern robotics development.
Learning outcomes in the course	A student shall acquire: - knowledge of historical developments of robots as universal machines and automata and skills of their classification on the basis of design, application field or level of a control system; - knowledge about the construction of robot manipulators and design and control principles of robot's control systems; skills to describe mathematically kinematics tasks of robots; - knowledge about components used in robotics and skills to select and apply needed components for the composition of a robot manipulator or a control system; - skills to calculate the load of robot drives and to select and apply a motor or a control unit required in a robot drive; - skills to program and use industrial robots for automation of production processes; - knowledge about software packages of virtual robotics and skills to use them for the development of new robot systems.
Brief description of the course	Robotics as the part of bionics. Nature and applications of the bionics. Nature and construction of robots. Control functions of the robots. Mathematical modelling of manipulators. Model-based control of robots. Construction of manipulators: series and parallel link kinematics of manipulators, co-ordinate systems of the robots, position, velocity and acceleration vectors of robots, co-ordinate transformation, direct and reverse kinematical transformations,

	trajectory planning and motion control functions, transportation, transferring and orientation of work pieces. Robot's drives: pneumatic, hydraulic and electric drives, drives structure and components, drive controllers, digital control of drives, digital regulators and filters, load and motor characteristics, flexibility, backlash, friction and compliance effects in drive control, drive motors, converters and sensors, energy consumption of drives. Control systems of robots: software for drive control, programming and teaching of robots, programming languages, robots in flexible manufacturing systems (FMS), higher levels in control hierarchy of robots, man-machine interface (MMI), fuzzy logic control of robots, shape and object identification and recognition, environment perception, intellectual control of robots. Etichal and social aspects of bionics and robotics.
Study literature	1) T. Lehtla. Robotitehnika. TTÜ, Tallinn. 2008. 2) Introduction to robotics: mechanics and control (3rd Ed.) / John J. Craig, Harlow: Pearson Education, c2014, 374 p
Daytime study: weekly hours	4.0
lectures	2.0
practices	1.0
exercises	1.0
Session-based study workload (in a semester):	64.0
lectures	32.0
practices	16.0
exercises	16.0
Course description	http://ois2.ttu.ee/uusois/subject/ATR0030
Content of lectures	1) Introduction to robotics. 2) Frames in robotics. 3) Manipulators kinematics. 4) Robots statics. 5) Dynamics of robots. 6) Control system of robots. 7) Software of robots. 8) Sensors of robots. 9) Actuators of robots. 10) Electrical drives of robots. 11) Robot tools. 12) Robotic communication platforms. 13) Mobile robots. Part 1. 14) Mobile robots. Part 2. Positioning, runaway planning, navigation. 15) Application of industrial robots. 16) Summary and example tasks.

1.1.2 Master studies

Course code	EEM0080
Course title in Estonian	Kaasaegne robotitehnika
Course title in English	Advanced Robotics
ECTS credits	6.0

Assessment form	Examination
Teaching semester	spring
Lecturer	Valery Vodovozov
Course aims	1. To give deep knowledge about advanced robots, respective hardware control systems and software systems used to control robots. 2. To give practical skills in utilizing robot control systems and respective sensors for solving real industrial problems. 3. To give knowledge developing smart and self-learning algorithms to control autonomous and cobolt robots. 4. To give knowledge and skills for integrating advanced robots into production processes and to orient in robotics future trends.
Learning outcomes in the course	A student passed the course: - has knowledge about advanced robots, respective hardware control systems and software systems used to control robots; - has practical skills in utilizing robot control systems and respective sensors for solving real industrial problems; - has knowledge developing smart and self-learning algorithms to control autonomous and cobolt robots; - has knowledge and skills for integrating advanced robots into production processes and to orient in robotics future trends.
Brief description of the course	Robotics foundations. Advanced robot structures and respective development trends. Robot sensing and perception, visual servoing and multisensor data fusion. Object manipulation and grasping. Telerobotics, VR and AR robotics applications. Mobile and distributed robotics. Behaviousr based systems. Field and service robotics. Autonomous transport robots, UAS, UGV and UUV systems. Intelligent autonomous systems. Developing robot autonomy and autonomy exercises. Medical and domestic robotics. Use of AI and machine learning in robotics. Human-centered robotics. Safety and social aspects of robots. Robotics regulations and standards. The course contains practical course work where the students have to develop a smart control system for a robot to solve a practical task.
Daytime study: weekly hours	 4.0
lectures	1.0
Practices	2.0
exercises	1.0
Session-based study workload (in a semester):	 64.0
lectures	16.0
practices	32.0
exercises	16.0
Course description	http://ois2.ttu.ee/uusois/subject/EEM0080
Content of lectures	1) Basic concepts of robotics. 2) Robot models and coordinate transforms. 3) Actuators and tools for object manipulation and grasping. 4) Control and sensing systems. 5) Software for autonomous robots and robots. 6) Mobile robotics. 7) Artificial intelligence in robotics.

1.2 Silesian University of Technology (SUT)

1.2.1 Bachelor studies

Course code	Es1-O6-V
Course title in English	Robots and Manipulators
ECTS credits	4.0
Assessment form	Test
Teaching semester	autumn
Lecturer	Damian Krawczyk PhD
Course aims	Basic knowledge on theory of robotics, principle of operation for industrial robots, programming robots.
Learning outcomes in the course	1. Knowledge of the basic design of industrial robots and their practical use. 2. Knowledge of basic technical parameters describing industrial robots. 3. Ability to write programs for industrial robots performing basic handling tasks. 4. Ability to create and analyze kinematic structures of manipulators to simulate their workspace. 5, Ability to implement simple navigation algorithms for mobile robots. 6. Teamwork skill to solve a task of practical use of an industrial robot.
Study literature	1) J.J. Craig: Introduction to Robotics. Mechanics and Control, Pearson Education 2005. 2) S. Y. Nof: Handbook of industrial robotics, Wiley, 1999.
Daytime study: weekly hours	 3.0
lectures	2.0
Practices	1.0
exercises	0.0
Session-based study workload (in a semester):	 45.0
lectures	30.0
practices	15.0
exercises	0.0
Content of lectures	1)Definitions of robot, manipulator and other basic concepts of robotics. Classification and review of robotic applications. 2) Construction and components of industrial robots. Construction of industrial robots (drives, transmissions, sensors, grippers). 3) Applications of industrial robots. Safety in industrial robotic systems. 4) Industrial robot as part of industrial automation system. Kinematic diagrams of robotic manipulators. 5) Description of the position and orientation of objects in three-dimensional space. 6) The concept of the number of degrees of freedom. Matrix of rotation. 7) Homogeneous transformation. Spatial descriptions (representations, operators).

	8) Forward and inverse kinematics for robot manipulators. Speeds and static forces. 9) Robot task scheduling (block world). 10) Fundamentals of mobile robotics.

1.2.2 Master studies

Course code	Es2-ELEN-18o-II
Course title in English	Control and Navigation of Mobile Robots
ECTS credits	3.0
Assessment form	Test, evaluation of laboratory, seminar reports
Teaching semester	spring
Lecturer	Maciej Sajkowski PhD eng., Tomasz Stenzel PhD eng.
Course aims	Obtaining by the student skills and competence in the field of classification, principles of operation, properties, applications, methods of analysis, selection methods, simplified design and measurements of the mobile robots, with particular emphasis on specialized control systems, navigation and sensors and software, as well as the rules for using datasheets and application notes and preparation of technical documentation (reports) of performed test or research.
Learning outcomes in the course	Student is able to: - know the structure and properties and rule of operation of control systems for mobile robots; - know the methods of planning the route of the mobile robot, the robot-representation of the environment and the characteristics of these methods as a tool to solve complex engineering tasks in the field of navigation of mobile robots; - acquire and integrate critically evaluate information from technical literature and databases IEEE in order to draw the appropriate conclusions and reasoned opinions; - develop a report on the laboratory and seminar topics taking into account the conducted experiments in the field of control and navigation of mobile robots with a discussion of the results; - use route planning methods for mobile robot and representation of the robot environment to formulate and solve engineering tasks simple problems and research issues; - formulate and solve tasks related to the control and navigation of mobile robots, integrate knowledge of robot kinematics, sensor technology and route planning - using a systemic approach taking into account the aspects of man machine interaction; - formulate and using certain computationally- simulation environment, test hypotheses related to the modeling methods of control and navigation of mobile robots; - carry out modifications to the control method of the existing wheeled and walking robot.
Study literature	1) Feng L., , Borenstein J., Everett H. R.: Where am I: Sensors and Methods for Mobile Robot Positioning, Technical Report UM-MEAM-94-21, University of Michigan, Ann Arbor, MI, December, 1994. 2) Jones J.L., Flynn A.M., Seiger B.A.: Mobile robots. Inspiration to implementation, A.K. Peters, 1999.

	3) Laumond J.-P., Ed. : Robot Motion Planning and Control, Springer, 1998. 4) Spong M.W., Vidyasagar M.: Robot dynamic and control, John Wiley and Sons, Inc, 1989.
Daytime study: weekly hours	3.0
lectures	1.0
Practices	1.0
exercises	0.0
project	1.0
Session-based study workload (in a semester):	45.0
lectures	15.0
practices	15.0
exercises	0.0
project	15.0
Content of lectures	1) Robotics - basic concepts and definitions. 2) Classification of robots. Intelligence and autonomy of robots. 3) Positioning and logic control. Reactive control and planned control. 4) Kinematic diagrams of walking robot. 5) Control systems for mobile robots. 6) Sensors and sensory systems and their role in autonomous systems. Short-range sensors (tactile and proximity). Sensors for robot orientation. 7) Odometry sensors, gyro sensors and their design. 8) The design of the sonar sensor system. 9) Applications in automation and robotics. 10) Orientation in space. 11) Algorithms for working out decisions in a changing environment of mobile robot. 12) Incremental navigation and navigation using external signs. 13) Methods of route planning for mobile robot. 14) Knowledge representation of robot-environment system. 15) Artificial intelligence in robotics.

1.3 University of West Bohemia (UWB)

1.3.1 Bachelor studies

In UWB bachelor’s studies consist of two courses.

System and Models

Course code	KKY/SM
Course title in English	Systems and Models
ECTS credits	4.0
Assessment form	Examination, individual presentation at a semester
Teaching semester	Spring
Guarantor	Prof. Ing. Miloš Schlegel, CSc.
Lecturer	Doc. Ing. Václav Černý, Ph.D., Prof. Ing. Miloš Schlegel, CSc.
Tutorial lecturer	Doc. Ing. Václav Černý, Ph.D., RNDr. Jana Königsmarková, Ing. Jiří Mertl, Ph.D., Ing. Miroslav Mertl, Ing. Tomáš Myslivec

Course aims	The aim of the course "Systems and Models" is to give an introduction to the subject of modeling and simulation of processes,machines and natural systems for analysis and control purposes. Two approaches for linear and nonlinear model building are used- first-principles models and system identification. These approaches are illustrated on the examples of thermal, electrical,mechanical and mechatronic systems. The properties such as stability, controllability and observability of systems and methods ofsimulation are also considered. Widely accepted tools for simulation like Simulink, Sim-Mechanics and Modelica are used forillustration purposes. Finally, the brief introduction to model based control is provided.
Learning outcomes in the course	Knowledge – knowledge resulting from the course: - have knowledge of the basic techniques of modeling dynamic systems; - have introductory knowledge of the theory of linear time-invariant dynamic systems; - characterize the concepts of state, stability, observability, control ability of the system; - have knowledge of linear state feedback design methods. Skills – skills resulting from the course: - create mathematical models of real systems; - computer simulate dynamic systems; - design simple feedback systems; - apply MATLAB/SimMechanics resources.
Study literature	1) Přednášky předmětu "Systémy a modely" (Miloš Schlegel) - portal.zcu.cz
Daytime study: weekly hours	 4.0
lectures	2.0
Practices	2.0
exercises	0.0
Session-based study workload (in a semester):	 52.0
lectures	26.0
practices	26.0
exercises	0.0
Content of lectures	1) Introduction (process model, system feedback). 2) Mathematical tools to describe natural phenomena (differential equations, integral transform, signal and bond graphs). 3) Systems with concentrated parameters (simple electrical and mechanical systems). 4) System with distributed parameters (thermal systems). 5) Methods of making models based on the first principles (Newton-Euler, d'Alembert-Lagrange, bond graphs). 6) Model identification (method of least squares, parametric and nonparametric methods). 7) Properties of linear and nonlinear systems (the state of equilibrium, linearization, stability, controllability, observability,decomposition of the system).

	8) Examples of models (the double inverted pendulum, flexible systems) and simulation (Simulink, Sim-Mechanics, Modelica). 9) Change the dynamic properties of the system by feedback (Evensova method, modal control). 10) Micro-electro-mechanical systems.

Microelectromechanical. Systems and Sensors

Course code	KKY/MSS
Course title in English	Microelectromechanical. Systems and Sensors
ECTS credits	3.0
Assessment form	Examination
Teaching semester	Spring
Guarantor	Prof. Ing. Pavel Karban, Ph.D.
Lecturer	Prof. Ing. Pavel Karban, Ph.D.
Tutorial lecturer	Prof. Ing. Pavel Karban, Ph.D., Doc. Ing. David Pánek, Ph.D., Ing. Iveta Petrášová
Course aims	The aim of the course is to introduce students with the basic concepts of MEMS technology. In the illustrative examples, they will learn basic physical principles used to convert electrical energy to mechanical. They will also gain insight into the construction of the most commonly used sensors. Students will also learn about mathematical models of electrical, magnetic and thermal field and their application in specific problems.
Learning outcomes in the course	Knowledge – knowledge resulting from the course: - explain basic physical parameters used in MEMS applications; - explain the physical principles of energy conversion on typical examples. Skills – skills resulting from the course: - to work with a computer program for the analysis of electromagnetic phenomena and coupled problems; - to explain basic physical principles of microactuators.
Daytime study: weekly hours	3.0
lectures	2.0
Practices	1.0
exercises	0.0
Session-based study workload (in a semester):	39.0
lectures	26.0
practices	13.0
exercises	0.0
Content of lectures	1) Microsystem structures, basic physical principles of energy conversion, actuators and sensors, MEMS. 2) Basic production processes, interconnection of control, action and sensors. 3) Micromanipulators on electrostatic principle, possible applications. 4) Micromanipulators on piezoelectric principle, possible applications.

	5) Micromanipulators on electro-thermal principle, possible applications. 6) Micromanipulators on magnetic principle, possible applications. 7) Special designs, switches, optical mirrors, polymer-based actuators. 8) Sensors of mechanical quantities and their applications, tension and pressure sensors. 9) Electrochemical sensors for gases and liquids. 10) Special sensors using graphene and nanotubes. 11) Microgenerators of electricity, energy harvesting. 12) Modeling and simulation of actuators. 13) Modeling and simulation of sensor.

1.3.2 Master studies

Course code	KEV/LRS
Course title in English	Linear Control System
ECTS credits	4.0
Assessment form	Examination
Teaching semester	Spring
Guarantor	Ing. Martin Goubej, Ph.D.
Lecturer	Ing. Martin Goubej, Ph.D.
Tutorial lecturer	Ing. Martin Goubej, Ph.D.
Course aims	The purpose of the course is to ensure that student should- get an overview of automatic control problems, structures of control systems and basic types of dynamic and non-dynamic controllers.- be able to analyse a real regulation problem, to formulate requirements on the quality of regulation in time and frequency domains- use and apply proper methods for the design of continuous and discrete controllers-analyse non-linear dynamic systems and apply basic control principles to non-linear dynamic systems.
Learning outcomes in the course	Knowledge – knowledge resulting from the course: - to use mathematical-physical modeling methods; - to identify a system model based on an experiment; - to formulate requirements for the behavior and properties of the regulatory process while respecting the limitations. Skills – skills resulting from the course: - to create a mathematical model of a real system by mathematical-physical modeling or identification based on measurements; - to choose the optimal method for solving a given task of designing a control circuit; - to verify the functionality of the controller design, or to propose a variant solution; - to solve partial problems associated with the control of non-linear systems.
Daytime study: weekly hours	 4.0
lectures	3.0
practices	1.0
exercises	0.0

Session-based study workload (in a semester):	39.0
lectures	30.0
practices	9.0
exercises	0.0
Content of lectures	1) Basic control problems, quality limitations. 2) Continuous and discrete control systems, sampling theorem and signal reconstruction. 3) Discrete models of continuous linear dynamical systems. 4) Mathematical models, data-driven system identification. 5) Set pointcontrol, tracking problems, disturbance attenuation, 1DoF and 2DoF controllers. 6) Basic types of controllers. 7) Frequency and timedomain design methods, pole-placement. 8) State observers, dynamical compensator. 9) Non-linear dynamical systems, harmoniclinearization. 10) Ljapunov's stability theory.

1.4 University of Applied Science Mittelhessen (THM)

1.4.1 Bachelor studies

Course title in English	Robotics
ECTS credits	7.0
Assessment form	Examination
Teaching semester	spring
Lecturer	Prof. Dr. Diethelm Bienhaus, Prof. Dr. Thomas Glotzbach
Learning outcomes in the course	Professional Skills: The students can... - list the basic characteristics of automation technology and classify robotics within them; - describe the basic structure of an industrial robot; - report on general methods for path control and programming of robots; - report on the basic procedures for determining robot positions and kinematic transformations; - present introductory knowledge on mobile robotics and distinguish it from stationary robotics. Social Skills: The students can... - explain exercises to each other and solve complex mathematical problems in a group; - present and discuss exercises and own results on the blackboard; - work together on real tasks in the accompanying practical course. Self-competence: The students can... - independently review and deepen the contents of the lecture notes; - improve their understanding of mathematical descriptions by means of illustrative tasks;

	- apply theoretical knowledge to real tasks in the practical course.
Brief description of the course	Robotics: Introduction to structure and basic functionalities of stationary and mobile robots.
Study literature	1) Brillowski, K.: Einführung in die Robotik, Shaker-Verlag Weber, W.: Industrieroboter, Methoden der Steuerung und Regelung, Hanser. 2) Craig, J.J.: Introduction to Robotics, Mechanics and control, Pearson Prentice Hall. 3) Tsai, L.-W.: Robot Analysis, The mechanics of serial and parallel Manipulators, John Wiley& sons. 4) Paul, R.P.: Robot Manipulators: mathematics, programming and control, MIT Press. 5) Snyder, W.E.: Computergesteuerte Industrieroboter, VCH-Verlag. 6) Siegert, H.J., Bocionek, S.: Robotik: Programmierung intelligenter Roboter, Springer Verlag. 7) Jones, J.L., Flynn, A.M.: Mobile Roboter, Addison-Wesley. 8) Hertzberg, J., Lingemann, K., Nüchter, A.: Mobile Roboter, Springer Vieweg. 9) Ichbiah, D.: Roboter - Geschichte, Technik, Entwicklung, Knesebeck Verlag.
Daytime study: weekly hours	6.0
lectures	3.0
Practices	2.0
exercises	1.0
Session-based study workload (in a semester):	90.0
lectures	42.0
practices	32.0
exercises	16.0
self-learning	114.0
Content of lectures	1) Short introduction to automation 2) Introduction to robotics 3) Path control 4) Programming of robots 5) Kinematics. 6) Mobile robots.

1.4.2 Master studies

Course title in English	Advanced automation - robotics
ECTS credits	5.0
Assessment form	Examination
Teaching semester	autumn/spring
Lecturer	Prof. Dr. Graubner, Swen
Learning outcomes in the course	The students… −describe the design and function of mobile and stationary robots; −select components for the construction of automated systems; −apply appropriate concepts for navigation and motion sequences; −apply coordinate transformations and kinematic transformations between reference systems; −design, calculate and program robot motion sequences;

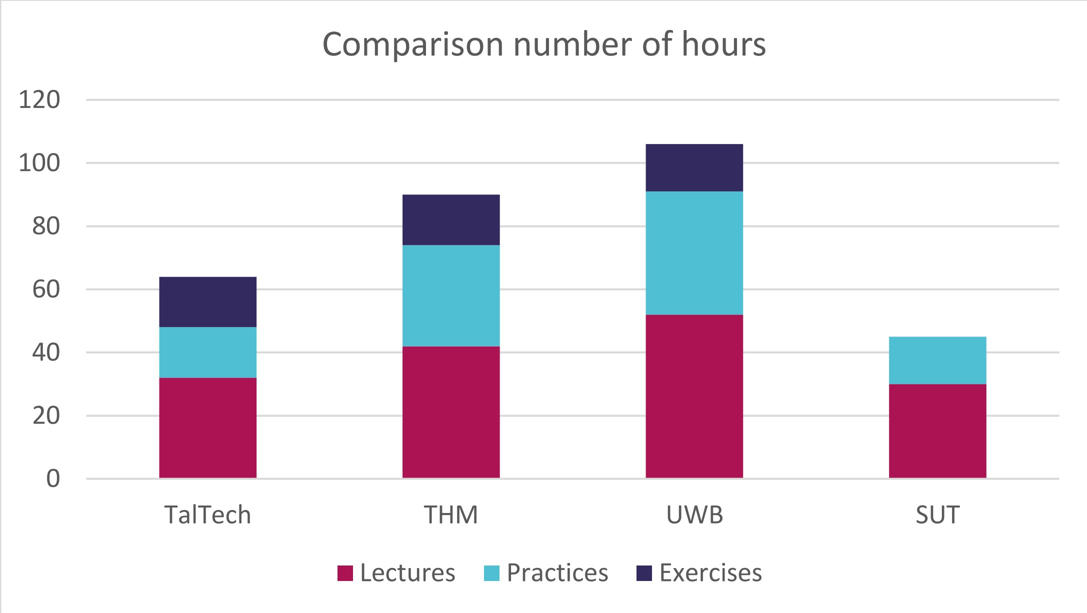
	−consider constraints in human-robot interaction and recognize safety issues when dealing with robots; −can explain current trends in robotics.
Brief description of the course	Basic and advanced robotics, coordinate transformations, kinematics, forward and backward transformations, path parameterization, robot programming, human-robot interaction.
Study literature	Appropriate recommendations will be made as part of the course
Daytime study: weekly hours	 4.0
lectures	0.0
Practices	2.0
exercises	2.0
Session-based study workload (in a semester):	 150.0
lectures	0.0
practices	30.0
exercises	30.0
self-learning	90.0
Content of lectures	1) Structure and basic function of mobile and stationary robots. 2) Selection of sensors, drives, transmission elements and controls for robots. 3) Electrical, hydraulic and pneumatic power supply in automation. 4) Coordinate transformations, forward and backward kinematics. 5) Planning of processes, mapping, navigation, trajectory calculation. 6) Robot programming. 7) Teaching and self-learning systems. 8) Human-machine interaction, haptics and operational safety. 9) Current trends in automation.

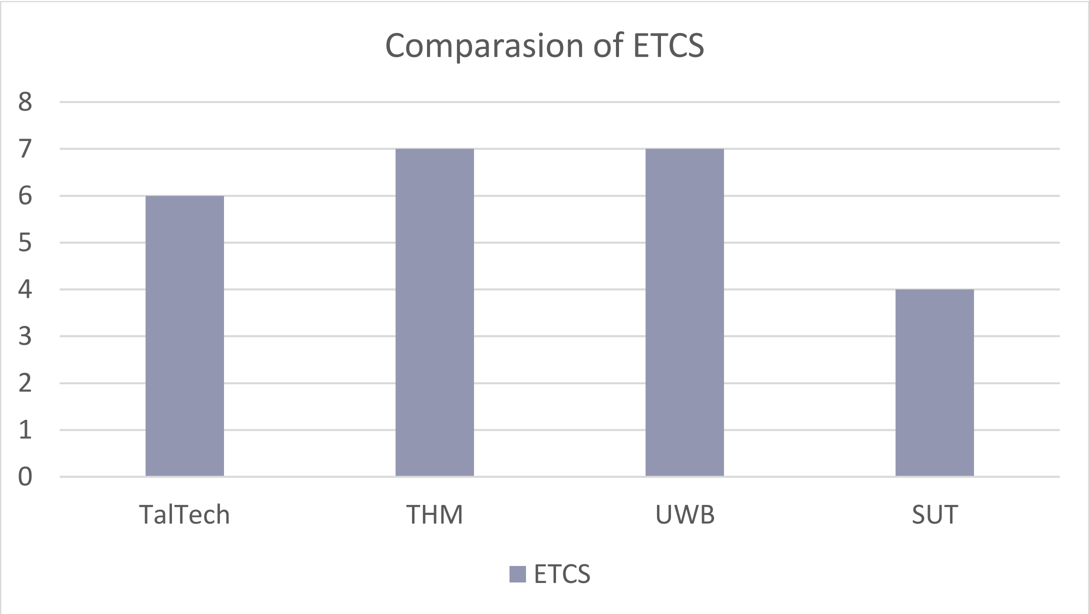
2 Comparison of robotics curricula

2.1 Bachelor studies

Comparison of the courses consists of two parts: the first part shows the difference between the workload of the courses (in the hours in a semester); the second part presents similar topics in electrical drives courses between universities and topics are special in each program.

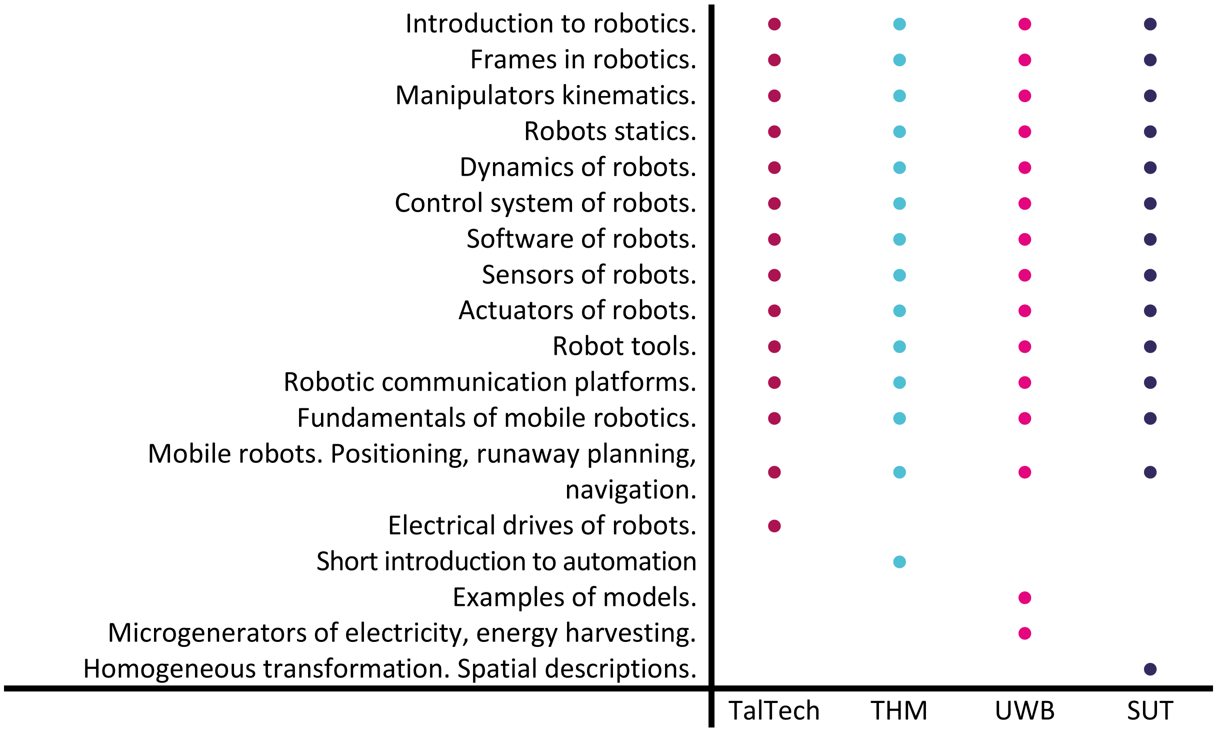
	TalTech	THM	UWB	SUT
Number of hours in semester	64	90	91	45
lectures	32	42	52	30
practices	16	32	39	15
exercises	16	16	0	0
ETCS credits	6	7	7	4





As seen from the graphs the bigger value of the study hours in the UWB, the smaller the SUT. TalTech, THM and SUT have study hours for exercises. The number of lecture hours in TalTech and SUT is similar, however, UWB is bigger two times. Study hours for practices are similar between TalTech and SUT, THM and UWB also have similar study hours for practices. UWB having two courses for robotics for bachelor's studies. The ETCS in THM and UWB are similar. Smallest ETCS in SUT. The average value of ETCS is 6.

Topics



Based on the comparison of topics between universities, possibly to make the next conclusion:

1. The common topics between universities introduction to robotics; frames in robotics; manipulators kinematics; robots statics; dynamics of robots; control system of robots; software of robots; sensors of robots; actuators of robots; robot tools; robotic communication platforms; fundamentals of mobile robotics; mobile robots; positioning, runaway planning, navigation.

2. In TalTech additional tech electrical drives of robots.

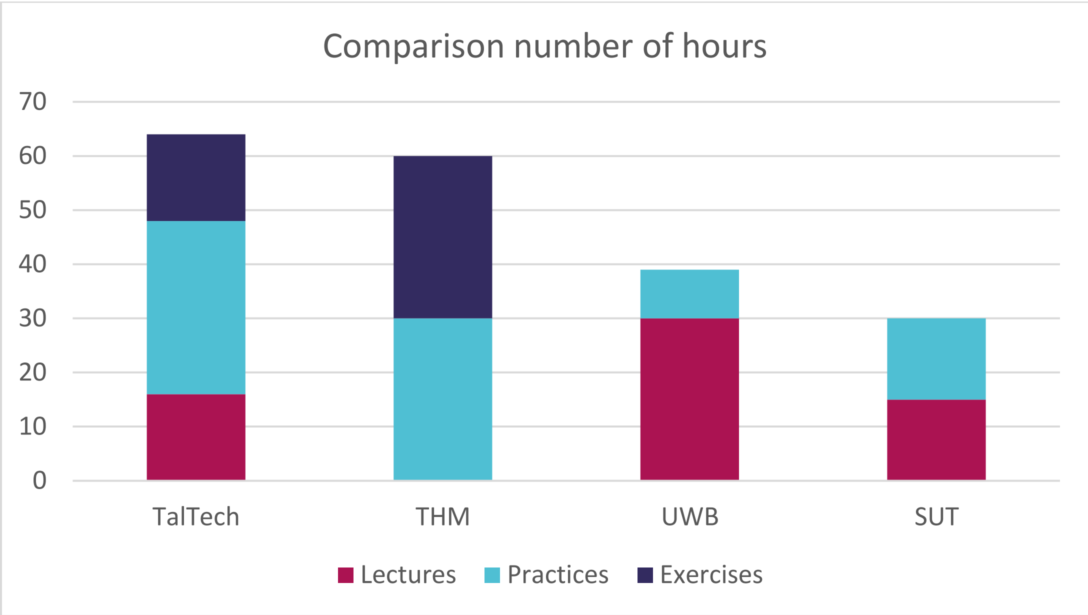
3. In THM additional teach short introduction to automation.

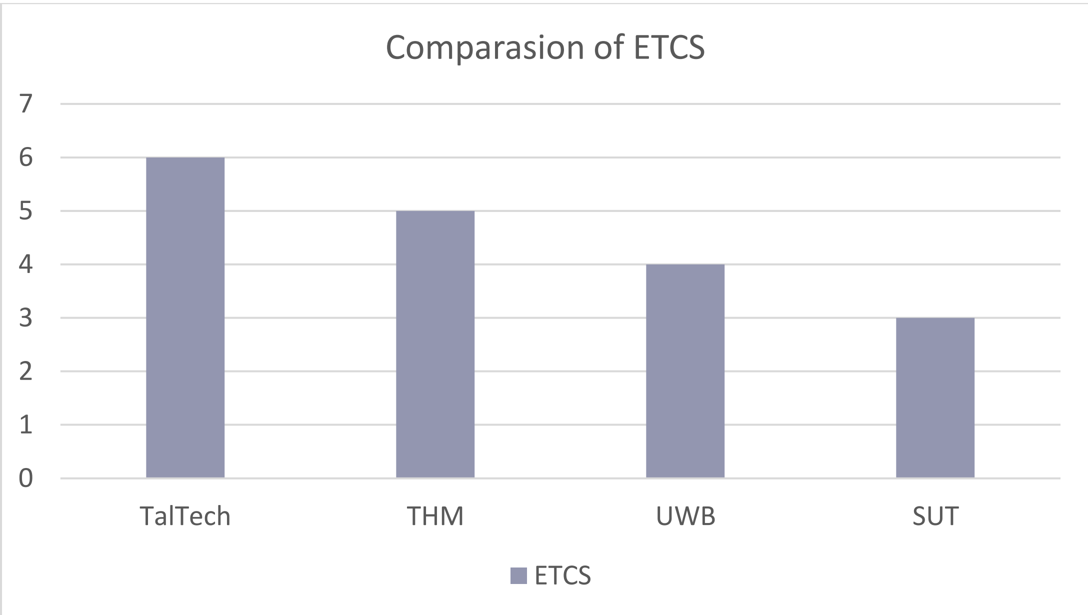
4. In UWB additional teach examples of models; microgenerators of electricity, energy harvesting.

5. In SUT additional teach homogeneous transformation. Spatial descriptions.

2.2 Master studies

	TalTech	THM	UWB	SUT
Workload:	64	60	39	30
lectures	16	0	30	15
practices	32	30	9	15
exercises	16	30	0	0
ETCS credits	6	5	4	3

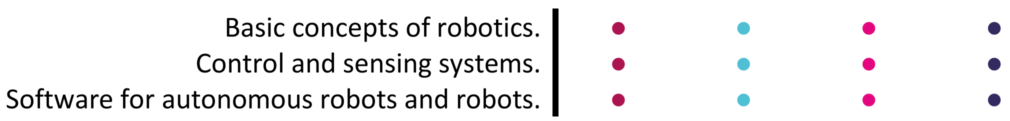




As seen from the graphs the bigger value of the study hours in the TalTech, the smaller the SUT. THM doesn't have study hours for master's studies for lectures. TalTech and THM have study hours for exercises. Number hours for lectures the same in TalTech and SUT, in UWB lectures bigger than in other universities. The number hours for practices the same in TalTech and THM, smallest hours of practices in UWB.

The ETCS is different in the universities. The bigger ETCS in TalTech, the smallest ETCS in SUT. The average value of ETCS is 4.5.

Topics



	TalTech	THM	UWB	SUT
Mobile robotics.	●	●	●	●
Artificial intelligence in robotics.	●	●	●	●
Robot models and coordinate transforms.	●		●	●
Actuators and tools for object manipulation and grasping.	●	●		
Current trends in automation.				
Frequency and timedomain design methods, pole-placement.			●	
State observers, dynamical compensator. Ljapunov's stability theory.			●	
Sensors and sensory systems and their role in autonomous systems. The design of the sonar sensor system.	●	●		●
Knowledge representation of robot-environment system.				●

Based on the comparison of topics between universities, possibly to make the next conclusion:

1. The common topics between basic concepts of robotics; control and sensing systems; software for autonomous robots and robots; mobile robotics; artificial intelligence in robotics.

2. In UWB additional teach frequency and time domain design methods, pole-placement; state observers, dynamical compensator. Ljapunov's stability theory.

3. In SUT additional teach knowledge representation of robot-environment system.

4. The common topic in TalTech, UWB and SUT is the robot models and coordinate transforms.

5. The common topic in TalTech and THM is Actuators and tools for object manipulation and grasping.

6. The common topic in TalTech, THM, and SUT is sensors and sensory systems and their role in autonomous systems. The design of the sonar sensor system.

3 Curricula for re-training course for robotics

Based on the comparison of the course programs of the universities participating in the project, the following course program of robotics is proposed:

Course title in English	Re-training course for robotics
ECTS credits	1.25
Assessment form	Examination
Teaching semester	autumn - spring
Course aims	The teaching /learning aims are following: - to develop an understanding of robots as universal machines to help people work in abnormal or dangerous conditions or to expand limits of human cognition; - to deepen an understanding of connections between different areas of engineering like mechanical and electrical engineering, informatics, and integration of knowledge in robotics and industry automation; - to develop knowledge for a system integrator, like analysis and comparison of competitive solutions and skills for targeted use of robots and robot systems; - to develop awareness of ethical problems of modern robotics development.
Learning outcomes in the course	A student shall acquire: - knowledge of historical developments of robots as universal machines and automata and skills of their classification on the basis of design, application field or level of a control system; - knowledge about the construction of robot manipulators and design and control principles of robot's control systems; skills to describe mathematically kinematics tasks of robots; - knowledge about components used in robotics and skills to select and apply needed components for the composition of a robot manipulator or a control system; - skills to calculate the load of robot drives and to select and apply a motor or a control unit required in a robot drive; - skills to program and use industrial robots for automation of production processes; - knowledge about software packages of virtual robotics and skills to use them for the development of new robot systems.
Brief description of the course	Robotics as the part of bionics. Nature and applications of the bionics. Nature and construction of robots. Control functions of the robots. Mathematical modelling of manipulators. Model-based control of robots. Construction of manipulators: series and parallel link kinematics of manipulators, co-ordinate systems of the robots, position, velocity and acceleration vectors of robots, co-ordinate transformation, direct and reverse kinematical transformations, trajectory planning and motion control functions, transportation, transferring and orientation of work pieces. Robot's drives: pneumatic, hydraulic and electric drives, drives structure and components, drive controllers, digital control of drives, digital regulators and filters, load and motor characteristics, flexibility, backlash, friction and compliance effects in drive control, drive motors, converters and sensors, energy consumption of drives. Control systems of robots: software for drive control, programming

	and teaching of robots, programming languages, robots in flexible manufacturing systems (FMS), higher levels in control hierarchy of robots, man-machine interface (MMI), fuzzy logic control of robots, shape and object identification and recognition, environment perception, intellectual control of robots. Etichal and social aspects of bionics and robotics.
Session-based study workload (in a semester):	32.0
lectures	32.0
practices	0.0
exercises	0.0
Content of lectures	1) Introduction to robotics. 2) Frames in robotics. 3) Manipulators kinematics. 4) Robots statics. 5) Dynamics of robots. 6) Control system of robots. 7) Software of robots. 8) Sensors of robots. 9) Actuators of robots. 10) Robot tools. 11) Robotic communication platforms. 12) Fundamentals of mobile robotics. 13) Mobile robots. Positioning, runaway planning, navigation. 14) Artificial intelligence in robotics. 15) Robot models and coordinate transforms.

4 Conclusion

Based on the provided outputs, it can be concluded that there are several common topics among universities in the field of robotics. These shared topics include the introduction to robotics, frames in robotics, manipulator kinematics, robot statics, dynamics of robots, control systems of robots, software for robots, sensors of robots, actuators of robots, robot tools, robotic communication platforms, fundamentals of mobile robotics, mobile robots, positioning, path planning, and navigation. These areas provide a solid foundation of knowledge in robotics across different educational institutions.

Additionally, each university offers additional teachings that focus on specific aspects within the field of robotics. TalTech emphasizes the electrical drives of robots, providing students with specialized knowledge of drive systems used in robotics. THM offers a short introduction to automation, enhancing students' understanding of the automation aspects related to robotics. UWB expands the curriculum by teaching examples of models, microgenerators of electricity, and energy harvesting, showcasing the practical applications and emerging trends in the field. SUT provides teachings on homogeneous transformation and spatial descriptions, allowing students to explore advanced concepts related to robot transformations and spatial representations.

There are also several common topics that emerge between universities. TalTech, UWB, and SUT share a common topic in robot models and coordinate transforms, highlighting the significance of understanding and manipulating coordinate systems in robotics. TalTech and THM share a common topic in actuators and tools for object manipulation and grasping, indicating the shared focus on robotic manipulation capabilities. Furthermore, TalTech, THM, and SUT share a common topic in sensors and sensory systems, emphasizing the role of sensors in autonomous systems, with SUT specifically focusing on the design of the sonar sensor system.

Overall, the combination of common foundational topics and specialized teachings in specific areas ensures that students receive a comprehensive education in robotics. This diverse curriculum equips them with the necessary knowledge and skills to design, control, and operate robots across various applications. The collaboration between universities in covering common topics fosters a cohesive understanding and promotes the exchange of ideas and expertise in the field of robotics.