<table>
<tr><td colspan="4">Óbuda University
Bánki Donát Faculty of Mechanical and Safety Engineering</td><td colspan="5">Institute of Mechatronics and Vehicle Engineering</td></tr>
<tr><td colspan="3">Subject title and code:</td><td colspan="3">Robotics I.
BMXRTE5BNF</td><td>Credits:</td><td colspan="2">5</td></tr>
<tr><td colspan="2">Full-Time Study</td><td>2026/2027</td><td>ac. year</td><td>I.</td><td colspan="4">semester</td></tr>
<tr><td colspan="3">The course is available at:</td><td colspan="6">Mechatronic Engineering</td></tr>
<tr><td colspan="2">Supervised by:</td><td colspan="2">Dr. István Nagy</td><td>Lecturers:</td><td colspan="4">Bence Varga</td></tr>
<tr><td colspan="3">Prerequisite (neptun code):</td><td colspan="6">Mechanics (BTXMNE2BN)</td></tr>
<tr><td colspan="9">Weekly number of lessons</td></tr>
<tr><td>Lecture:</td><td>2</td><td>Exercise:</td><td>-</td><td>Laboratory ex.:</td><td>3</td><td>Consultation</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Way of assessment:</td><td colspan="7">Exam (Writing)</td></tr>
<tr><td colspan="4">Online Consulatation (in case it’s required):</td><td colspan="5">-</td></tr>
<tr><td>Educational goal:</td><td colspan="8">The aim of the course is to provide students with up-to-date theoretical and practical knowledge of the structure, operation, modelling, and programming of industrial robots, and to enable them to apply this knowledge from an engineering perspective in automation and robotics tasks.
During the theoretical part of the course, students become familiar with the historical development of robotics, the fundamental concepts of robotics and mechanism theory, and the applications of rigid-body kinematics in robotics. The course provides a detailed treatment of the mathematical representation of spatial position and orientation, the application of homogeneous transformations, and an overview of the fundamental principles of geometric, kinematic, and dynamic robot modelling. Students learn to develop geometric models of serial manipulators with open kinematic chains using Denavit–Hartenberg parameterization and become familiar with methods for solving forward and inverse geometric problems, with particular emphasis on the principle of kinematic decoupling. The course also covers the fundamentals of differential kinematics, the formulation and application of the geometric Jacobian matrix, and fundamental methods for the inverse differential kinematics of non-redundant manipulators. The objective is to enable students to perform geometric and kinematic analyses of open kinematic chains and to apply rigid-body kinematics methods proficiently in the modelling and analysis of robotic systems.
The practical part of the course aims to enable students to operate, configure, and program industrial robots safely and professionally. Students become familiar with industrial robot safety requirements, the use of robot controllers and teach pendants, and the fundamental configuration tasks required for robot commissioning, including the calibration of tool and work coordinate systems. They learn to independently develop simple robot programs incorporating motion instructions, program control structures, and digital input/output operations, and to implement basic interaction between the robot and its peripheral devices.
A further objective of the course is to familiarize students with modern online and offline robot programming methods and enable them to apply these methods proficiently, together with engineering tools associated with Industry 4.0 and digital manufacturing. As a result, students will be able to create virtual models of simple robotic cells, develop digital twins, and simulate and validate robotic applications using modern offline programming and simulation environments.</td></tr>
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Schedule	
Education week	**Topics**
1.	**Lecture:** Introduction to the course requirements and assessment criteria. Overview of the historical development of industrial robotics, from early concepts to modern industrial robotic systems. Introduction to the definition and fundamental characteristics of robots according to ISO 8373. Overview of the main application areas of industrial robots and current trends in robotics. **Laboratory:** Introduction to laboratory procedures, safety regulations, and the development environment used throughout the course. Familiarization with the robot programming and simulation environment, including project creation and the fundamental concepts and operations required to build and work with a virtual robotic cell.
2.	**Lecture:** Detailed interpretation of the concept of an industrial robot based on the ISO 8373 standard. Introduction to the structure of a robotic cell, the structural components of manipulators, joint types, and the concept of degrees of freedom, together with the fundamental characteristics of kinematic chains. Comparison of serial and parallel manipulators, determination of mobility using the Grübler formula, and introduction to the concept of kinematic redundancy. **Laboratory:** **Task A – Offline Programming and Simulation:** Assembly and configuration of a virtual robotic cell, introduction to the main components of the workcell, creation of a simple virtual environment, and configuration of the robot tool coordinate system within a simulation environment. **Task B – Robot Operation:** Safe manual operation of an industrial robot, application of basic jogging methods in different coordinate systems, and calibration of the tool center point (TCP) using standard calibration procedures.
3.	**Lecture:** Detailed introduction to the structure of serial industrial robots with open kinematic chains, with particular emphasis on arm and wrist architectures, as well as the different types of end-effectors and tools. Introduction to the configuration space of manipulators and its topological properties, fundamental methods for representing robot configurations, and the concepts of task space and workspace, including the relationship between them. **Laboratory:** **Task A – Offline Programming and Simulation:** Assembly and configuration of a virtual robotic cell, introduction to the main components of the workcell, creation of a simple virtual environment, and configuration of the robot tool coordinate system within a simulation environment. **Task B – Robot Operation:** Safe manual operation of an industrial robot, application of basic jogging methods in different coordinate systems, and calibration of the tool center point (TCP) using standard calibration procedures.

4.	**Lecture:** Overview of the modelling levels of industrial robots, including the roles and application areas of geometric, kinematic, and dynamic models. Formulation of the forward and inverse problems associated with the different modelling levels. Introduction to the structural design, characteristics, and typical applications of the most important robot configurations, including Cartesian, cylindrical, spherical/polar, SCARA, and articulated manipulators. **Laboratory:** **Task A – Offline Programming and Simulation:** Development of simple robot programs in an offline programming environment. Students learn to configure the work coordinate system (User Frame) and practise the creation, editing, and error-free execution of robot programs through simple motion tasks. **Task B – Robot Programming:** Calibration of the work coordinate system on a physical industrial robot and application of the fundamental robot motion types, including joint, linear, and circular interpolation motions. Students independently develop and execute robot programs by teaching target points and implementing simple robot trajectories.
5.	**Lecture:** Introduction to closed-form solutions of forward and inverse kinematics problems for simple manipulators with up to three degrees of freedom. Students study the kinematic relationships of fundamental robot configurations and apply analytical methods to determine the position of the end-effector, as well as the joint variables corresponding to a desired end-effector position. The aim of this topic is to develop a deeper understanding of geometric reasoning and the fundamental relationships governing robot kinematics. **Laboratory:** **Task A – Offline Programming and Simulation:** Development of simple robot programs in an offline programming environment. Students learn to configure the work coordinate system (User Frame) and practise the creation, editing, and error-free execution of robot programs through simple motion tasks. **Task B – Robot Programming:** Calibration of the work coordinate system on a physical industrial robot and application of the fundamental robot motion types, including joint, linear, and circular interpolation motions. Students independently develop and execute robot programs by teaching target points and implementing simple robot trajectories.
6.	**Lecture:** Mathematical representation of the spatial position and orientation of rigid bodies. Introduction to rotation matrices and their fundamental properties, together with an interpretation of the special orthogonal group SO(3) from the perspective of robotics applications. The aim of this topic is to establish the mathematical foundations of spatial coordinate transformations. **Laboratory:** **Task A – Offline Programming and Simulation:** Implementation of pick-and-place robotic applications in an offline programming environment. Students develop more complex robot programs by applying previously introduced motion instructions, coordinate systems, and simulation tools. **Task B – Robot Programming:** Implementation of pick-and-place tasks on a physical industrial robot. Students are introduced to the fundamentals of interaction between the robot and its peripheral devices, including gripper control, digital I/O operations, and the role of timing and synchronization in robot program execution.

7.	**Lecture:** Methods for representing spatial orientation, parameterization of rotation matrices, and their geometric interpretation. Introduction to similarity transformations and the mathematical description of successive rotations, together with the application of Euler angles and roll–pitch–yaw (RPY) angle parameterizations for representing and determining spatial orientation. **Laboratory:** **Task A – Offline Programming and Simulation:** Implementation of pick-and-place robotic applications in an offline programming environment. Students develop more complex robot programs by applying previously introduced motion instructions, coordinate systems, and simulation tools. **Task B – Robot Programming:** Implementation of pick-and-place tasks on a physical industrial robot. Students are introduced to the fundamentals of interaction between the robot and its peripheral devices, including gripper control, digital I/O operations, and the role of timing and synchronization in robot program execution.
8.	**Lecture:** Mathematical description of the spatial motion of rigid bodies, including the introduction and interpretation of the special Euclidean group SE(3). Application of homogeneous coordinates and homogeneous transformations for the unified representation of position and orientation, together with an introduction to the significance of coordinate transformations in robotics. **Laboratory:** **Task A – Offline Programming and Simulation:** Development of more advanced robot programs in an offline programming environment. Students apply program control structures and variables and implement simple palletizing tasks, with an emphasis on structured program design and code reusability. **Task B – Robot Programming:** Extension of robot programs through the integration of peripheral devices and digital inputs and outputs. Students are introduced to the fundamentals of I/O configuration and communication between the robot and external devices, as well as simple sensor-based operation, the development of safe control logic, and the application of advanced robot controller functions.
9.	**Lecture:** Introduction to the theoretical foundations and application rules of the Denavit–Hartenberg convention for the geometric modelling of serial manipulators. Determination of Denavit–Hartenberg parameters and formulation of the corresponding homogeneous transformation matrices using an industrial robot as an example, followed by the computer implementation of the model in an engineering computing environment. **Laboratory:** **Task A – Offline Programming and Simulation:** Development of more advanced robot programs in an offline programming environment. Students apply program control structures and variables and implement simple palletizing tasks, with an emphasis on structured program design and code reusability. **Task B – Robot Programming:** Extension of robot programs through the integration of peripheral devices and digital inputs and outputs. Students are introduced to the fundamentals of I/O configuration and communication between the robot and external devices, as well as simple sensor-based operation, the development of safe control logic, and the application of advanced robot controller functions.

10.	**Lecture:** Analytical solution of the inverse kinematics problem for specific articulated industrial robots using the method of kinematic decoupling. The conditions, procedure, and limitations of the method are discussed through practical examples, demonstrating the engineering application of inverse kinematics calculations. **Laboratory:** **Task A – Offline Programming and Simulation:** Implementation of advanced robotic cell simulation tasks with extended modelling capabilities of the virtual environment. Students become familiar with functions supporting robotic cell validation and develop and verify their robot programs using simple sensor models and collision detection. **Task B – Robot Programming:** Implementation and validation of offline-developed robot programs on a physical industrial robot. Students become familiar with the relationship between offline and online programming environments, the processes of program transfer and commissioning, and compare the behaviour of the simulated and physical systems through the implementation of a simple robotic application.
11.	**Lecture:** Differential kinematic description of the rotational motion of rigid bodies. Introduction to the mathematical representation of angular velocity, the properties of skew-symmetric matrices, and the time derivative of the rotation matrix and its relationship to the angular velocity vector. The aim of this topic is to establish the theoretical foundations for the differential kinematic modelling of robotic manipulators. **Laboratory:** **Task A – Offline Programming and Simulation:** Implementation of advanced robotic cell simulation tasks with extended modelling capabilities of the virtual environment. Students become familiar with functions supporting robotic cell validation and develop and verify their robot programs using simple sensor models and collision detection. **Task B – Robot Programming:** Implementation and validation of offline-developed robot programs on a physical industrial robot. Students become familiar with the relationship between offline and online programming environments, the processes of program transfer and commissioning, and compare the behaviour of the simulated and physical systems through the implementation of a simple robotic application.
12.	**Lecture:** Fundamentals of manipulator velocity kinematics, including the determination of angular and linear velocities and their relationship to the time derivatives of the joint variables. Introduction to the linear relationship between joint velocities and end-effector velocities, together with the fundamental principles of numerical solutions to differential kinematics problems and the motivation for iterative solution methods. Introduction to kinematic singularities. **Laboratory:** Make-up session for completing previous laboratory exercises and unfinished assignments, with an opportunity for consultation.
13.	**Lecture:** Introduction to the formulation and computation of the geometric Jacobian matrix for serial manipulators. Interpretation of the physical meaning of the Jacobian and its role in differential kinematics, together with a comparison of the analytical and geometric Jacobians, their relationship, and their respective areas of application. **Laboratory:** Laboratory midterm. Students independently implement a robotic application in an offline programming environment, demonstrating proficiency in robot programming, robotic cell configuration, and the use of simulation tools.
14.	**Lecture:** Midterm. **Lab:** Midterm retake.

Mid-semester requirements					
Test		Assignment to be submitted		Lab measurements	
Amount	Schedule	Amount	Deadline	Amount	Schedule
1+1pcs.	13. és 14. week	-	-	5pcs.	According the schedule

According to the Study and Examination regulations of Óbuda University attendance of group seminars and lab exercises are mandatory

Other requirements for participation in sessions not covered by the regulations and restrictions on substitutions:

Attendance at lectures is mandatory. Absences must not exceed the maximum limit specified in the Academic and Examination Regulations (TVSZ), corresponding to 30% of the total scheduled lecture hours.

Participation in laboratory sessions is permitted only for students who have familiarized themselves with and understood the applicable laboratory safety regulations in advance and who undertake to comply with them fully. Any violation of safety regulations during laboratory work, or any conduct that endangers the health and safety of participants or the safe operation of laboratory equipment, will result in immediate exclusion from the laboratory session.

Laboratory sessions are organized on a rotational basis. Throughout the semester, students complete the tasks involving a physical industrial robot (**Task Set B**) in predetermined, fixed groups, while the tasks performed in the simulation environment (**Task Set A**) are completed individually. In accordance with the weekly course schedule, the groups alternate between the two laboratory work environments.

An absence from a laboratory session is considered excused only upon submission of an official medical certificate. **A maximum of one missed laboratory session may be made up during the semester.** The make-up session is scheduled for Week 12. More than one laboratory absence cannot be made up and will result in failure to meet the laboratory requirements of the course.

Students with signature denied entry are eligible for a signature retake exam that can be taken in the first two weeks of the exam period.

Test		Assignment to be submitted		Lab Measurement	
maximum points available	minimum score required to pass /test	maximum points available	minimum score required to pass / assignment	maximum points available	minimum score required to pass /lab
100 points	25 points	-	-	50 points	25 points

Total number of points achievable in semester:	100 points

Grading thresholds	**Pass** from 50 %	**Average** from 60 %	**Good** from 70 %	**Excellent** from 85 %

Other evaluation criteria: During the semester, students are required to complete the following assessments: • **1 theoretical midterm test,** • **1 laboratory midterm test,** • **5 group-based laboratory assignments.** Performance in the laboratory assignments is assessed continuously by the laboratory instructor during the sessions using a standardized assessment sheet. A maximum of **50 points** may be earned from the laboratory assignments. To obtain the **course signature** (*aláírás*), students must: • obtain at least **50% of the total points available for the laboratory assignments** (minimum **25 points**); and • achieve at least **50% of the total points available for the laboratory midterm test** (minimum **25 points**). Students who fail to obtain the minimum of 25 points from the laboratory assignments are not eligible to receive the course signature. Laboratory assignments cannot be repeated or improved during the examination period. Students who fail the laboratory midterm test (i.e., achieve a result below 50%) are entitled to **one retake opportunity** during the first two weeks of the examination period, in the form of a course-signature make-up examination. The theoretical midterm test is not a prerequisite for obtaining the course signature; therefore, no retake or grade-improvement opportunity is provided for this assessment. Students who achieve at least **50% separately in each of the three assessment components**—the theoretical midterm test, the laboratory midterm test, and the laboratory assignments—may be eligible for an **offered grade** (*megajánlott jegy*). An offered grade may only be awarded if the grade calculated from the combined results of the three assessment components is at least **Good (4)**.	
Student may br dropped from class if:	• exceed the maximum number of absences permitted under the Academic and Examination Regulations (TVSZ); • fail to complete the laboratory midterm test and do not attend the designated make-up assessment, unless their absence is supported by appropriate official documentation; • violate occupational health and safety regulations during laboratory sessions, engage in inappropriate or disruptive conduct, or behave in a manner that endangers their own health and safety, that of other students, or the safe operation of laboratory equipment; • are absent without valid justification from a group-based laboratory assignment and fail to make up the missed session in accordance with the course requirements; • engage in academic misconduct during a midterm test or any other assessment, including cheating or the use of unauthorized materials or aids; • fail to follow the instructions of the laboratory supervisor or course instructor during laboratory sessions; or • fail to obtain at least **50% of the total points available for the laboratory assignments**.

Required references:	Lynch, K. M., & Park, F. C. (2017). *Modern robotics : mechanics, planning, and control*. University Press. Siciliano, B., & Al, E. (2010). *Robotics : modelling, planning and control*. Springer. Spong, M. W. (2012). *Robot Modeling And Control.* John Wiley & Sons.	
Recommended references:		
Quality assurance methods of the subject:		

Things, that are not included, can be found within the regulations of Óbuda University.