GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Basics of Industrial Robotics, PG_00067495		
Field of study	Automatic Control, Cybernetics and Robotics		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2026/2027
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	Polish
Semester of study	4	ECTS credits	2.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Signals and Systems -> Faculty of Electronics Telecommunications and Informatics -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Piotr Fiertek	
	Teachers		

Lesson types and methods of instruction	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	0.0	0.0	0.0	0.0	30
	E-learning hours included: 0.0						

Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	30	4.0	16.0	50

Subject objectives	The aim of the subject is to introduce students to the issue of stationary industrial robots. The subject discusses the construction of robots: drive elements, types of gears: screw, planetary, cycloidal, wave. The types of drives are discussed: hydraulic, pneumatic and electric. Students learn about the construction and application of various types of tools placed on robots: grippers (mechanical, vacuum, magnetic), executive elements in the form of e.g. welding heads. The subject presents sensory systems used in robots: internal sensors as well as external sensors. Much attention is paid to vision systems and applications of systems in robotics. Among other things, 3D cameras and their application are discussed. The subject discusses aspects related to safety systems in industrial automation, taking into account the specific conditions related to industrial robots. The mathematical part discusses the mathematical description of robot kinematics, in particular related to the Denavit-Hartenberg notation. The formulation and solution of the simple and inverse kinematics problem are discussed.

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K6_W01] knows and understands, to an advanced extent, mathematics necessary to formulate and solve simple issues related to the field of study	The student lists and characterizes the causes and stages of robot development. Defines and classifies industrial robots. Characterizes the construction of industrial manipulators. Describes basic kinematic diagrams. Characterizes the drive units of industrial robots, grippers and technological heads. Characterizes methods of securing robotic systems. Characterizes methods of powering robots. Lists and characterizes the tasks of stationary robot control systems.	[SW1] Assessment of factual knowledge
	[K6_W03] knows and understands, to an advanced extent, the construction and operating principles of components and systems related to the field of study, including theories, methods and complex relationships between them and selected specific issues - appropriate for the curriculum	The student defines the task of direct and inverse kinematics of stationary robots. Defines the Denavit-Hartenberg description for a manipulator to solve the task of direct kinematics.	[SW1] Assessment of factual knowledge

Subject contents	
	Lecture (mathematical part): 1. Basic concepts and definitions: robot, manipulator, pedipulator, cybernetic machine. Laws of robotics. Types of robots and their applications. Robot generations. Block diagram of a robot. Basic classification of industrial robots. Most important parameters of robots. Types of kinematic chains. Determining the number of degrees of freedom of a kinematic chain. Kinematic pairs: prismatic, revolute and others. Graphic symbols of kinematic pairs. Number of degrees of freedom and class of a kinematic pair. Basic kinematic structures of robots: Cartesian, cylindrical, spherical, PUMA, SCARA. 2. Analytical geometry in three-dimensional space (3D) - reminder. Coordinate systems: Cartesian, cylindrical, spherical. Right-hand oriented and left-hand oriented systems. Principle of right-hand rotation - rule of the right thumb. Coordinate conversion in different systems. Elements of vector calculus: vector product, scalar product and mixed product of vectors. 3. Description of elementary rotations: rotation matrices about the X, Y, Z axes. Interpretation of rotations about axes X, Y, Z: roll, pitch and yaw of the effector. Principles of rotation of Cartesian systems: rotations about fixed axes (extrinsic) and rotations about current axes (intrinsic). Obtaining the required orientation of the Cartesian system: composition of rotations using the Eulers method and the Cardan-Tait-Bryan method. Possible sequences of Eulers rotations and Cardan-Tait-Bryan rotations (Eulers angles and Cardan-Tait-Bryan angles). A fundamental theorem on the relationship between rotations about fixed axes (extrinsic) and current axes (intrinsic). 4. Rotation about an arbitrary axis: determination of the axis-angle rotation matrix. Analytical properties of the rotation matrix and interpretation of column vectors in the rotation matrix. Rodrigues rotation formula. Determination of rotation parameters based on the numerically given rotation matrix. Implementation of the assumed axis-angle rotation using the method of composition of three Eulers rotations. Implementation of the assumed axis-angle rotation using the method of composition of three Cardan-Tait-Bryan rotations. The gimbal lock effect - interpretation using the Cardans mechanism of three gimbals. 5. The concept of quaternion. Basic principles of quaternion algebra. Quaternion in the algebraic and trigonometric form. General form and properties of the rotation quaternion. Calculating rotations using the quaternion method. Composition of rotations using the quaternion method. Determination of rotation parameters based on the coefficients of the rotation quaternion. Determination of the coefficients of the rotation quaternion based on the axis-angle rotation matrix. Determination of the axis-angle rotation matrix based on the coefficients of the rotation quaternion. Implementation of the rotation represented by a quaternion using the method of composition of three Eulers rotations. Implementation of the rotation represented by a quaternion using the method of composition of three Cardan-Tait-Bryan rotations. Numerical interpolation of rotation using the quaternion method. 6. The concept and properties of homogeneous coordinates. The general rotation-translation matrix and its properties. A simplified rule for multiplying the rotation-translation matrices. Rules for composition the rotations and translations - with respect to fixed axes (extrinsic) and current axes (intrinsic). Kinematic analysis of manipulators: direct and inverse kinematics. The Denavit-Hartenberg method, joint variables. Solving sample tasks of direct and inverse kinematics: flat manipulator with two revolute joints, Cartesian robot, cylindrical robot, spherical robot, PUMA robot. Inverse kinematics of the spherical wrist. 7. Fundamentals of manipulator dynamics: description of the effectors trajectory in the three-dimensional space (3D). Equation of curve in space - vector function. Elements of differential geometry: differentiation of vector functions, Frenet frame. Natural coordinates: the tangent vector, the binormal vector and the normal vector. Determining the velocity and acceleration vectors. Analysis of the acceleration acting on the effector: representation of the acceleration vector in natural coordinates. Effector rotation analysis - determination of the rotation speed. **Lecture (descriptive part):** 1. Robot construction: robots with serial and parallel kinematic chains, Delta robots and Stewart platforms. Flat parallel manipulators. Monolithic and modular robots. 2. Mechanical design: drive transmission systems in regional and local movements on the example of the IRB-6 robot (classic solution). Gear, belt, screw, ball screw, planetary, wave transmissions. 3. Robot drives: rough discussion of hydraulic and pneumatic drives, conversion of linear motion into rotary motion, discussion of the electro-hydraulic stepping actuator. Discussion of the FESTO BionicCobot robot. Electric drives: brush motors (separately excited, cup, disc), BLDC motors, stepping motors, linear drives. 4. Robot tools: types of grippers (mechanical, vacuum, magnetic), drive systems, grippers with flexible gripping tips, special grippers (Finray, Jamming gripper). Welding heads. Effector couplings on the example of Schunk couplings 5. Sensor systems: potentiometric measurement of displacement and rotation. Measuring resolver, optical and magnetic encoders, touch sensor systems (including artificial skin), ultrasonic sensors, triangulation distance sensors 6. Vision systems: description of vision system components, application of vision systems in robotics, methods of mounting cameras, pinhole camera model, 2.5 D camera, 3D cameras, discussion of an example vision system controlling a robotic heat exchanger welding station. 7. Safety: characterization of devices included in the safety systems of industrial robotic stations (fences, emergency stops, three-state safety buttons, light curtains, safety mats, safety locks, safety relays, safety

	edges, safety scanners. Discussion of safety systems related to industrial robotics: defining safety zones, collision detection, preventing collisions, making robot axes more flexible, using anti-collision joints.		
Prerequisites and co-requisites			
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Written exam	60.0%	100.0%
Recommended reading	Basic literature	1. Craig J.: Wprowadzenie do robotyki. Mechanika i sterowanie. Wydawnictwo Naukowo-Techniczne. Warszawa. 1993. 2. Honczarenko J.: Roboty przemysłowe. Budowa i zastosowanie Wydawnictwo Naukowo-Techniczne. Warszaawa: 2004.	
	Supplementary literature	2. Spong. M. W., Vidyasagar M.: Dynamika i sterowanie robotów. Wydawnictwo Naukowo-Techniczne. Warszawa. 1997.	
	eResources addresses		

Example issues/ example questions/ tasks being completed	**Mathematical part:** 1. Implement the axis [0.6 ; 0.8 ; 0] angle 3.14 /rad/ rotation as the Eulers rotation by sequence Z-X-Z. 2. Find the axis and angle of rotation represented by the rotation quaternion with coefficients a=b=c=d=0.5. 3. Prove that composition of a rotation and translation about the same axis is independent of the operation order. 4. Determine the tangential and normal acceleration of the effector moving along a helical line. 5. Use the Denavita-Hartenberga method to describe SCARA kinematics. Solve the inverse kinematics problem. **Descriptive part:** 1. List and characterize generations of robots (3 - generations). 2. List the advantages and disadvantages of manipulators with a parallel kinematic structure. 3. Describe the construction of the Stewart Platform. What range of motion can the mobile platform achieve? Provide examples of Stewart platform applications. 4. What is a wave gear? What elements does it consist of? Describe the principle of the wave gear? 5. List and characterize older designs of electric motors used in robotics (motors without electronic commutation). 6. Describe the principle of operation of the three-phase reluctance stepper motor (you may need the appropriate drawings). 7. Characterize the construction and principle of operation of linear electric motors (briefly). 8. Provide and characterize five typical ways to transfer the gripper power transmission. 9. What is the structure and operation of the magnetic gripper? What are the types of magnetic grippers (with a short description). 10. What is selsyn? Describe briefly its structure and principle of operation on the example of a resolver. 11. What sensors can be used to detect the presence of a manipulation object before it is captured (except for optical and vision sensors)? The mentioned sensors are briefly characterized. 12. What is the difference between elastomeric "artificial skin" and "artificial skin" consisting of flexible microspheres? 13. What is a smart camera? What elements does it contain and what can it be used for? 14. Present the construction and principle of the 3D camera. 15. List and briefly describe (up to three sentences) how to detect human presence in a robotic position. 16. What is the three-state button? Describe the situations in which it is used.

	17. What is the use of door lock restricting access to the inside of a production cell? 18. What is the safety contact strips? How it works and in what situations is it used? 19. List the different operating modes of the light curtain. 20. How does the safety laser scanner work and when is it used? 21. How is detected the collision between an industrial robot manipulator and the environment? 22. What is the mechanism for more flexible the robot manipulator and what it is used? 23. What is the collision detection devices and the mechanism of its action?
Work placement	Not applicable