Robotics

F Curriculum

Final Exam Topics

Topic 1 – Theoretical Foundations of Mechanisms

Describe the basic concepts of the structure and motion of mechanisms, the characteristics of kinematic pairs and kinematic chains, and their classification. Explain the concept of degrees of freedom, how to determine the degrees of freedom of mechanisms, and the characteristics of redundant mechanisms.

Topic 2 – Mechanism Theory, Characterization of Industrial Robots

Describe the characteristics of arm mechanism of industrial robots and the classification of their kinematic structures. Explain the design of arm and wrist configurations of robots, the concept of the configuration classes, and the method for determining the joint equation.

Topic 3 – Mathematical Representation of Robot Motion Space

Describe the concepts, characteristics, and relationships among the workspace, configuration space, and task space of robots. Discuss the topological characteristics of configuration spaces, the possibilities for mathematical representation of topology, as well as the characteristics of explicit and implicit representations and their relationship to singularities.

Topic 4 – Mathematical Modeling of Industrial Robots

Describe the different levels of mathematical modeling of industrial robots, as well as the concepts and characteristics of geometric, kinematic, and dynamic models. Explain the physical relationships described by each model, and discuss their roles and potential applications in the motion planning and control of industrial robots.

Topic 5 – Geometric Modeling of Cylindrical and Articulated Robots

Describe the configuration class, kinematic structures, and geometric characteristics of cylindrical and articulated robots. Compare the characteristics of the two configuration classes, and describe the closed-form solutions to the direct and inverse geometric problems of these configuration classes, using geometric and trigonometric relationships.

Topic 6 – Geometric Modeling of Spherical and SCARA Robots

Describe the configuration class, kinematic structures, and geometric characteristics of spherical and SCARA robots. Compare the characteristics of the two configuration classes, and describe the closed-form solutions to the direct and inverse geometric problems of these configuration classes, using geometric and trigonometric relationships..

Topic 7 – Mathematical Description of Spatial Position and Orientation of Rigid Bodies

Describe the methods used to mathematically describe the position and orientation of rigid bodies in 3D space! Explain the geometric interpretation of position vectors and rotation matrices, the concept and properties of the Special Orthogonal Group (SO(n)), and the concept of elementary rotations!

Topic 8 – Spatial Rotations and Representation of Orientation

Describe the mathematical description of spatial rotations and the composition rules for rotation matrices. Explain the concepts of Euler- and Roll–Pitch–Yaw (RPY) angles, their geometric interpretation, and their application in describing spatial orientations. Explain the significance of order of rotations and the characteristics of angular parameterizations! Explain the phenomenon of gimbal lock

Topic 9 – Homogeneous Coordinates and Spatial Transformations

Describe the combined mathematical description of the position and orientation of rigid bodies in 3D space! Explain the concept and geometric interpretation of homogeneous coordinates, as well as the structure and properties of homogeneous transformation matrices! Describe the definition of the composition and inverse of spatial transformations, as well as their application in transformations between coordinate systems!

Topic 10 – Solving a Direct Geometry Problem Using the Denavit–Hartenberg Method

Formulate the forward kinematics problem for robotic manipulators. Explain the fundamental principles of the Denavit–Hartenberg (DH) method, including the existence and uniqueness of the solution. Describe the procedure for applying the method, the conventions for assigning coordinate frames, and the geometric interpretation and role of the DH parameters in determining the position and orientation of the robot's end-effector.

Topic 11 – Solving the inverse geometric problem using kinematic decoupling

Describe the general formulation of the inverse geometric problem for industrial robots and the conditions for applying the kinematic decoupling method! Explain the basic principle and steps of the method, as well as the procedure for solving the inverse position and inverse orientation problems separately!

Topic 12 – Kinematic Description of Spatial Rotational Motion

Describe the kinematic description of the rotational motion of rigid bodies about a fixed axis and explain the concept of angular velocity. Explain the time derivative of rotation matrices, the concept and mathematical properties of antisymmetric matrices, and their relationship to the angular velocity vector! Describe the principle for determining angular velocity in the case of general spatial rotational motion!

Topic 13 – Kinematics of Open, Non-Redundant Kinematic Chains

Describe the formulation and solution of the direct and inverse kinematic problems for open, non-redundant kinematic chains. Explain the concept of the Jacobi matrix, its geometric interpretation, and its role in describing the relationship between joint velocities and the velocity of the end-effector! Derive the mathematical conditions for the occurrence of kinematic singularities and interpret their physical consequences!

Topic 14 – Determining the Jacobi Matrix

Describe the method for determining the geometric Jacobi matrix of robots. Explain the role of the Denavit–Hartenberg parameterization in calculating the Jacobi matrix, as well as the structure and geometric interpretation of the Jacobi matrices associated with linear velocity and angular velocity! Describe the contribution of rotational and translational joints to the determination of the Jacobi matrix!

Topic 15 – Fundamentals of Path and Trajectory Planning for Robots

Describe the role of path and trajectory planning in a robot control system! Explain the concepts of path and trajectory, as well as the basic principles, characteristics, and areas of application of point-to-point (PTP) and continuous path (CP) motion planning methods!

Topic 16 – Trajectory Planning for PTP Motions

Describe the basic principles of PTP trajectory planning in the joint coordinates! Present the trajectory planning methods based on polynomial and trapezoidal velocity profiles, explain the role of boundary conditions, and compare the characteristics, advantages, and limitations of these methods!

Topic 17 – Planning Trajectories Passing Through Multiple Points

Describe the basic principles of trajectory planning for robot motions passing through multiple consecutive positions in joint coordinate space! Present the generalization of methods based on polynomial and trapezoidal velocity profiles to motions passing through multiple points, as well as the possibilities for ensuring continuity conditions between trajectory segments!

Topic 18 – Trajectory Planning for Continuous Path Tracking

Describe the basic principles of planning continuous path tracking in Cartesian coordinates. Present the mathematical description of linear and circular path primitives, the geometric parameterization of the path, and the method for time parameterization of motion along the path.

Topic 19 – Constraints and General Coordinates of Mechanical Systems

Explain the concepts of general coordinates and constraints used in the description of mechanical systems. Describe the mathematical formulation, characteristics, and role of holonomic and non-holonomic constraints in determining the degrees of freedom and motion relationships of mechanical systems.

Topic 20 – Newtonian and Lagrangian Mechanics

Describe the basic principles and characteristics of the Newtonian and Lagrangian approaches to mechanics. Compare the two approaches, and present the derivation and physical interpretation of the Euler–Lagrange equations for mechanical systems with one degree of freedom.

Topic 21 – The Principle of Virtual Work and d'Alembert's Principle

Explain the concepts of virtual displacements and virtual work, as well as the mechanical interpretation of the principle of virtual work! Describe the basic idea behind d'Alembert's principle, the concept of general forces, and their definition! Explain how to formulate the Euler–Lagrange equations of motion for closed mechanical systems and systems that are subjected to external forces and driven by actuators!

Topic 22 – Dynamic Model of Open Kinematic Chains

Describe the general mathematical form of the dynamic model of open kinematic chains! Explain the physical significance and mathematical properties of the inertial, Coriolis, centrifugal, and gravitational terms! Explain the role of the dynamic model in describing and controlling the motion of industrial robots!

Topic 23 – Dynamic Modeling of Cylindrical Robots

Describe the process of dynamic modeling for robots with a cylindrical configuration. Explain how to derive the equations of motion using the Euler–Lagrange method, and interpret the inertial, Coriolis, centrifugal, and gravitational terms that appear in the dynamic model.

Topic 24 – Dynamic Modeling of Permanent Magnet DC Motors

Describe the operating principle and dynamic model of permanent magnet DC motors (PMDC)! Present the mathematical description of the electrical and mechanical models, the conditions for developing a reduced-order model, and the structure of the motor's control system block diagram!

Topic 25 – Independent Joint Control of Industrial Robots

Describe the basic principles and structure of independent joint control of industrial robots. Explain the effect of dynamic couplings between joints on the control, and describe methods that can be used to address the effect of coupled dynamics.

Topic 26 – PD Control of Permanent Magnet DC Motors

Describe the implementation of position control for permanent magnet DC motors using a PD controller. Present the mathematical model of the closed-loop control system, examine the stability conditions, and analyze the behavior of the steady-state control error.

Topic 27 – PID Control of Permanent Magnet DC Motors

Describe the implementation of position control for permanent magnet DC motors using a PID controller. Present the mathematical model of the closed-loop control system, examine the stability conditions, and analyze the role of the integral term in eliminating the steady-state control error.

Topic 28 – Practical Implementation of Joint Control

Describe the measurement and signal processing methods required for the practical implementation of joint control in robots! Explain the operating principle of incremental encoders, the quadrature decoding method, and the estimation of joint velocity using discrete differentiation! Analyze the effects of measurement resolution and quantization error on the quality of control!

Topic 29 – Feedforward Compensation in Robot Joint Control

Describe the role of feedforward compensation in the control of robots! Explain the basic principle for determining the feedforward control signal and its combined use with feedback control! Analyze the method's effect on tracking accuracy, as well as its advantages, limitations, and model dependency!

Topic 30 – Model-Based Control of Robots Using the Computed Torque Method

Describe the basic principle and mathematical formulation of the Computed Torque Control method! Explain how the nonlinear dynamics of robots are compensated for, as well as the role of feedback control in achieving the desired motion! Analyze the conditions for applying this method, its limitations, and the effect of model inaccuracies on the accuracy and stability of the control!