Detailed Program and Requirements

Óbuda University Bánki Donát Faculty of Mechanical and Safety Engineering	Institute of Mechatronics and Vehicle Engineering

Course title and code: **Industrial Robots Kinematics and Dynamics** **Credits: 7**
Full-time, semester 3 (2024-2025 Academic year, Autumn semester)

Faculties in which the subject is taught: **mechatronics engineer MSc**

Supervised by:	**Dr. Tar József**	Instructors:	Dr. Tar József

Prerequisites conditions:	**Applied Mathematics**

Lessons per week:	Theory: 2	Practice (in Auditorium): 0	Laboratory: 2	Consultation:
Exam type (s,v,f):	exam			

Syllabus

Aim: To provide the Students with the fundamental mathematical and modeling methods by the use of which for a redundant, open kinematic chain of general structure the forward and the differential inverse kinematic task can be formulated in well structured, lucid form. For solving the inverse kinematic task the method of optimization under constraints is applied. Providing the students with the Euler-Lagrange equations of motion for the dynamic model of the arm with negected frictions effects. Presentation of the siplest model-based control solutions for such robots. The aim of the laboratory exercises is proving the Students with the most efficient simulation and documentation methods.

Curriculum: Robot arms of open kinematic chain: kinematic parameters related to the „home position". Workshop („World") coordinates and joint coordinates in trajectory planning: homogeneous coordinates and matrices, the forward kinematic task. Formulation and solutin of the differential inverse kinematic task using optimization under constraints: Newton – Raphson Aalgorithm, Gradient descent Algorithm, Laglrange's Reduced Gradient Algorithm, the Moore-Penrose generalized invrese. Kinematic singularities. Creation of the dynamic model by the use of the hmogeneous matrices; Euler-Lagrange equations of motion, the physical interpretation of the generaéized forces. The Computed Torque Control method. The Robust Variable Structure/Sliding Mode control for the compensation of modeling errors and external disturbances. Simulation of the solution if inverse kinematic and dynamic control tasks by the use of Julia language and documentation of the results using LATEX.

Topics:	**Lec.**	**Lab.**
1. Possible operations with rigid bodies: rotations as linear operations, scalar products, definition of the orthogonal rotation) matrices; Rigid translation.	**2**	**2**
2. Rotation around the origin and subsequent shift: homogenous coordinates and matrices.	**2**	**2**
3. Parameters of the rotation operator: Representation of the rotation and homogeneous matrices as hypersurfaces embedded into a higher dimensional space; The identity element and the tangent space of the hypersurface at the identity element; Constant directional lines over the hypersurface as matrix exponential functions a scalar variable; Determining the possible tangents by the use of the definition equation.	**2**	**2**
4. Transformed tangents; The tangent space at the identity element as a linear space and algebra; Introduction of right handed system of reference in the tangent space; The Rodrigues formula, computing the axle and the angle of rotation from the elements of the orthogonal matrix. Rotated rotational axis.	**2**	**2**
5. Definition of the kinematic parameters of the robot by using the concept of „home position". The forward kinematic task.	**2**	**2**
6. The velocity of the Tool Center point and the rotational velocity of the grasped rigid object. Formulation of the differential inverse kinematic task.	**2**	**2**
7. Optimization under constraints: Newton-Raphson Method, Gradient Descent Method, Lagrange's Reduced Gradient Method; The Moore-Penrsore generalized inverse.	**2**	**2**

8. Basics for using Julia language: definition of integer and floating point variables; arrays and operations with arrays; global and locak variables; Declaration and calling functions; Dealing with the global variables within the dfunctions and cycle running in the stack; Making graphs usiyng PyPlot, Matplotlib. The LATEX document as an ``object oriented program". Document class, embedded objects, labels and references, BIBTEX bibliographic data bases, citation, typical formats for citation bibliography style files. The use of TexStudio as a graphical aid.	**2**	**2**
9. Introduction of the inverse kinematic solver developed for a redundant 8 DoF robot arm;	**2**	**2**
10. The Euler-lagrange equations of motion based on an inertial frame; generalized coordinates and forces, the physical inetrpretation of the generalized force components. Formulating the dynamic model by the use of homogeneous matrices.	**2**	**2**
11. The Computed Torque Control; Kinematic plans to drive the tracking error to zero asymptotically: exponentially damped polynomials, Lyapunov equation, PID and PD control. The effects of modeling errors to the quality of the CTC control.	**2**	**2**
12. The Robuts Variable Structure / Sliding Mode Controller.	**2**	**2**
13. Application of robot model or robot model-like dynamic models for simulation and investigation of control solutions.	**2**	**2**
14. End of semester consultation.	**2**	**2**

Semester requirements

Due to the special nature of the subject area the traditional „test-based" evalaution is not an appropriate method. Understanding the mathematical foundations can be best evaluated in a classic oral examination (colloquicum). The skills for problem solution can be better measured in numerical exercises, in which the control methods are coded in sample problems that can be transformed by the Student using a model library of which the attrbutes of the system to be controlled can be copied and pasted into the sample program. Following that the sample program can be tailored to the specialties of the new model, can set its parameters, and invesrigate the operation of the method via simulations. For obtaining signature and obtaining possibility for participation in the examinations the activity of the student during the courses can be evaluated.

Method of the replacement:

The latest opportunity is the examination for signature at the beginning of the examination period. Generally the Regulations of the University can be kept in mind for denying the signature.

Calculation of the midterm grade:

In the case of examination no midterm evaluation is applied.

For obtainin g signatute the Students have to submit two relatively complex course work solution: one for inverse kinematic task for redundant robots of arbitrary arm structure, and another one about dynamic control of a simple dyanmical system. The last time of submission is the "signaure makepu exam".

Signature is **denied** if the student cannot submit the course work, or the absences exceed the number of classes specified in TVSZ.

Exam method: oral

Literature:

Mandatory:

Free of charge available lecture notes in PDF format, sample programs, sample docuentaions.

Offered:
1. Somló J., Lantos B.,P.T. Cat, Advanced Robot Control. Akadémiai Kiadó, Budapest 1997
3. Programming aids to FANUC robots; Mitsubishi – programming aid.