ADVANCED MODERN APPROACHES TO DYNAMICS AND CONTROL FOR ROBOTS

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COURSE OBJECTIVES

The course introduces fundamental concepts for modeling of robots. It is intended for final year undergraduate, graduate, and PhD students. It gives a thorough introduction to the representation of the topology of robots and classifies them accordingly. Thereupon the kinematics modeling is addressed and a computationally efficient formulation is introduced. This is then employed for deriving a task space formulation of the dynamics equations of motion. The latter is directly applicable to model-based control of robots. The modeling of kinematics and dynamics of robots make use of a formulation on the Lie group of Euclidean motions SE(3), and uses concepts from screw theory. This admits using compact matrix notations and coordinate invariant algorithms using screw theory for efficient modeling of complex systems. Each lecture unit is accompanied by an exercise session with numerical examples. Participants are encouraged bring their computer to the course.

LEARNING OUTCOMES

Students will get familiar with the phenomenology of PKM and advanced Lie-group and screw theory methods to generate kinematic and dynamic models. They will able to derive and implement these equations for practically relevant systems. Participants will be able to generalize the examples to more complex systems.

PREREQUISITES

Basic knowledge from linear algebra, vector algebra, and basic calculus is required.

HOURS:

Lectures: 21 Hours
Exercise: 11 Hours

TARGETED AUDIENCE

Final year undergraduate, graduate, and PhD students in Engineering and Applied Mathematics

COURSE CONTENT

1 Rigid Body Kinematics
1.1 Coordinate and frame transformations
1.2 Rigid Body Motions
1.3 Canonical Coordinates for Rigid Body Motions, Exponential Map on SE(3)
1.4 Screws and rigid body twists

2 Motion of a Kinematic Chain
2.1 Product of Exponentials (POE)
2.2 Body-Frame Formulation
2.3 Single-Frame Formulation
2.4 Lower Pairs – Subgroups of SE(3)

3 Instantaneous rigid body motion
3.1 Rigid Body velocity
3.2 Body-fixed representation
3.3 Spatial representation
3.4 Vector fields on SE(3)
3.5 Higher-order vector fields, rigid body acceleration

4 Instantaneous motion of kinematic chains
4.1 Geometric Jacobian
4.2 Infinitesimal transformations, Lie-brackets
4.3 Derivative of system Jacobian
4.4 Recursive algorithm

5 Rigid Body Dynamics
5.1 Lie group formulation of Newton-Euler Equations
5.2 Dynamics of Tree-Topology System
5.3 Recursive dynamics algorithms

6 Representation of robot topology
6.1 Graph representation of kinematic topology
6.2 Specific representation of PKM topology
6.3 Modularity

7 Dynamics of robots
7.1 Tailored modular dynamics formulation
7.2 Robots with simple and complex limbs
7.3 Task space formulation of dynamics
7.4 Joint space formulation

8 Model-based control
8.1 Tracking control
8.2 Feedback linearizing control
8.3 Advanced control strategies

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