Advanced Modelling and Control of Robotic Structures

Credits: 4 Semester 3 (UNIGE) Compulsory: Yes

Format	Lectures 24 h	Examples 16h	Private study 80 h

Lecturer: G. Casalino, M. Zoppi, M. Baglietto, A. Turetta

Objectives:

The course formerly generalizes the modelling techniques (Geometric, Kinematic and Dynamic) to robotic structures more complex than simpler cascade ones (e.g. branched, open/close and parallel connections) with extension to cases of presence of flexible links.

Then it will be shown how the developed methods can be used for calibration, simulation, kinematic/dynamic/interaction control, parametric identification and adaptive control of such more general robotic structures.

Contents:

Geometric and kinematic modelling: constraints equations, mobility analysis, singularity analysis. Fundamentals of screw theory and its application to modelling, design and calibration

Dynamic modelling: principle of virtual work, Lagrangian formulations, Newton-Euler formulation.

Simulation: inverse and direct dynamic problems; use of Lagrangian formulation; use of Newton-Euler formulation; evaluation of constraints reaction force-torques.

Kinematic/dynamic/interaction control: the overall two layered functional architecture; the upper-lying kinematic control layer and relevant algorithmic structures; underlying dynamic/interaction control layer and relevant algorithmic structures, conditions for control robustness

Parametric identification: least-squares based recursive techniques, Lyapunov based techniques within fully and partially sensorized conditions; conditions of persistency of excitation identifiability

Adaptive control: certainty-equivalence-principle based techniques and Lyapunov based techniques.

Fundamentals of Modelling and simulation of flexible structures: flexible joints and links shaping; modal analysis and finite elements analysis, generalized Newton-Euler equations. Identification and control aspects for flexible structures.

Practical Work: Exercises will be set, involving modelling, simulation, identification and control of complex structure robots. Advanced technical papers from recent international conferences will be analysed and reviewed.

Abilities: After completing this course, the students will be able to:

Understand the fundamentals of the mathematical models for complex robotic structures and related applications for their design, simulation, parametric identification and control.

Use the best methods to develop the models of a given complex robotic structure

Design the relevant functional and algorithmic control architecture.

Assess and use the relevant most appropriate parametric identification techniques

Organize and implement the relevant simulation scheme within available simulation packages (Matlab-Simulink, Adams, etc.)

Capability ofextending its ability to the modelling and simulation of flexible robotic structures

Assessment: 30% continuous assessments, 70% from end of semester examination.

Recommended texts:

S. Caro, lecture notes on *Geometric and Kinematic Modelling of Serial and Parallel Robots*

W. Khalil, E. Dombre, *Modelling, identification and control of robots*, Hermes Penton, London, 2002.

J. Angeles, *Fundamentals of Robotic Mechanical Systems*, Springer-Verlag, New York, 3rd edition, 2007

Merlet, J. P., 2006, *Parallel Robots (Solid Mechanics and Its Applications)*, Springer, New York, Vol. 128.

S. Briot, lecture notes on *Advanced Dynamic Modelling of Robots*
S. Briot and W. Khalil, *Dynamics of Parallel Robots*, Springer.
K.H. Hunt. *Kinematic Geometry of Mechanisms*. Clarendon Press, Oxford, 1978.
R. Murray, Z. Li, S. Sastry. *Mathematical Introduction to Robotic Manipulation*, CRC press, Boca Raton, 1994.
J.M. Selig. *Geometric Fundamentals of Robotics*. Springer-Verlag, Heidelberg, 2005.
X. Kong, C. Gosselin. *Type Synthesis of Parallel Mechanisms*. Springer-Verlag, Heidelberg, 2007**.**

Further readings:
Modelling and simulation software documentation.Other readings will be provided during the course in the form of teacher notes or Technical papers.