Master's Department of Engineering Sciences
MSc in Automation Engineering and Robotics

Name of the unit: Robotic Manipulators Modeling

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Course code:
Student workload: 22 h of lectures, 8 h of tutorials
Credits: 3 ECTS
Specialization tracks: ☒ ROBOT ☐ SI ☐ MeDH
Semester offered: ☐ S1 ☐ S2 ☒ S3 ☐ S4
Language of instruction: ☐ French ☐ English
Targeted audience: ☐ Engineering Sciences students ☐ Other (specify): ENSAM
Localization : ☒ PMC Campus ☐ Other (specify):

Course Overview
This course unit trains students in the dynamic modeling of serial and parallel robotic manipulators and, more generally, of multibody systems connected by bilateral joints and involving unilateral frictional contacts with the environment, such as walking robots and multi-fingered grippers.
Keywords: Kinematics of serial and parallel robotic manipulators, forward and inverse models, geometric wrenches, singularities, redundancy and optimization. Principle of virtual work, generalized coordinates, generalized forces, holonomic and nonholonomic constraints, Lagrange equations, Lagrange multipliers, Cartesian versus joint parameterization, quaternions, solution of differential-algebraic equations, parameter changes, partitioning and parameter reduction, unilateral contact, friction models and nonsmooth dynamics

Prerequisites
Students should have previously acquired the following prerequisites to follow this course:

- Parameterize a serial robot using the DH convention and master rotation matrices and homogeneous transformations
- Calculate the kinetic and potential energy of a rigid body and write the mass matrix of a rigid-body system
- Write the Jacobian of a rigid body and calculate a generalized force

Intended Learning Outcomes
By the end of this course, students will be able to:

1. Analyze the mobility and static indeterminacy of a mechanism or parallel robot
2. Identify the singularities of parallel robots and write their geometric or kinematic models
3. Identify the different terms in the equations of motion
4. Reduce a model parameterization
5. Solve a differential-algebraic system
6. Model joints involving unilateral frictional contact
7. Write the dynamic model of a tree-structured, parallel or hybrid system
8. Compare the advantages and disadvantages of different parameterizations according to the intended use of the model
9. Model a system with unilateral contacts

Indicative Teaching Sequence and Methods

Week	C/TD/TP*	Content	Preparation	Learn. outc.
S1	Lecture	Kinematics of serial robots, geometric wrenches, Jacobian, singularities		AAV1
S2	Lecture	Kinematics of serial robots, redundancy and optimization		AAV1
S3	TD	Kinematics of serial robots		AAV1
S4	Lecture	Kinematics of parallel robots, mechanism theory		AAV2
S5	Lecture	Kinematics of parallel robots, models, singularities		AAV2
S6	TD	Kinematics of parallel robots		AAV2
S7	Lecture	Lagrangian dynamics: principle of virtual work, generalized coordinates and forces, holonomic and nonholonomic constraints		AAV7
S8	Lecture	Lagrangian dynamics: Lagrange equations with and without multipliers		AAV7
S9	TD	Lagrange equation: serial robot		AAV7
S10	TD	Lagrange equation with multipliers: parallel robot		AAV3
S11	Lecture	Multibody systems: Cartesian versus joint parameterization		AAV8
S12	Lecture	Multibody systems: Cartesian parameterization and quaternions		AAV8
S13	Lecture	Solution of differential-algebraic equations		AAV5
S14	Lecture	Unilateral contact and friction		AAV9
S15	TD	Lagrange equation: nonholonomic mobile robot or humanoid robot		AAV9

* C/TD/TP respectively corresponds to lectures, tutorials and lab sessions.

Indicative Assessment of Intended Learning Outcomes (1st session)

Week	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
S8	Individual	In-person	Written exam		50 %
S16	Individual	In-person	Written exam		50 %

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Session	Individ./group	In-person/remote	Type of exam	Evaluated outcomes	Scale %
2	Individual	In-person	Written exam	All	100 %

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