Energy-Based Approaches for Modelling and Control of Modern Robotic Systems

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Course abstract

Energy and energy exchange govern interactions in the physical world. By explicitly considering the energy and power in a robotic system, many control and design problems become easier or more insightful than in a purely signal-based view. Starting from theoretical foundations, course shows the application of these energy considerations to robotics; starting from the fundamental aspects and continuing to the practical application to robotic systems. Using the theory of Port-Hamiltonian Systems as a fundamental basis, we show examples concerning energy measurement, passivity and safety. Control by interconnection covers the shaping and directing of energy inside the controller algorithms, to achieve desired behavior in a power-consistent manner. This idea of control over the energy flows is extended to the physical domain. In their mathematical description and analysis, the boundary between controller and robot disappears and everything is an interconnected system, driven by energy exchange between its parts.

Lectures schedule

Day 1 – Theoretical Foundations of port-Hamiltonian Framework

Topic 1 – Mathematical background: extracts from differential algebra, Lie groups, and bond graphs

Topic 2 – Overview of port-Hamiltonian systems framework

Day 2 – Port-Hamiltonian Framework for Robotic Systems Modelling

Topic 1 – Kinematics of rigid mechanisms in the framework of port-Hamiltonian systems

Topic 2 – Dynamics of rigid mechanisms in the framework of port-Hamiltonian systems

Day 3 - Energy in Controlled Physical Systems

Topic 1 – Passivity and energy budgets in robotic systems

Topic 2 – Energy and distributed architectures

Day 4 – Energy-Based Control in Robotic Systems

Topic 1 – Control by Interconnection: impedance control, energy routing and shaping

Topic 2 – Control by physical interconnection: physical compliance and variable stiffness actuators

Day 5 (Friday, optional) – Examples of Energy-Based Control

Topic 1 – Applications and examples of the port-Hamiltonian approach.