Control of Underactuated Mechanical Systems for Stabilization and Limit Cycle Generation

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Title

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Abstract:

Underactuated mechanical systems are those systems with less control inputs than generalized coordinates (degrees of freedom) i.e they have generalized coordinates that are not actuated, and this is a source of dynamic constraints which are generally non integrable and therefore second order non-holonomic. Many examples of such systems exist, mainly in robotics, they include, among others, the underactuated robot manipulators, the gymnast robots and particularly the acrobot, the pendubot, the Planar Vertical Takeoff and Landing (PVTOL) aircrafts, some undersea vehicles and other mobile robots. Another basic feature of this class of systems is the nonlinear dynamics that they have; moreover their actuated coordinates are nonlinearly coupled with the unactuated coordinates.

This talk deals with control of underactuated mechanical systems, where two main problems have been treated; the first one concerns stabilization around unstable equilibrium point, whereas the second one deals with stable limit cycle generation.

To resolve the first control problem, the nonlinear dynamics of the system is linearized around the unstable equilibrium point and discretized; then a Generalized Predictive Control (GPC) is applied to stabilize the system. To resolve the second control problem, two solutions are proposed, the first one is based on partial feedback linearization and dynamic control for optimal reference trajectories tracking. The second solution is based on a control structure containing two model-free controllers. The first controller is designed for tracking of parameterized reference trajectories on a subset of the coordinates; while the second controller is designed using one parameter of reference trajectories as input to stabilize the internal dynamics of the system.

The proposed control methods are illustrated through numerical simulations as well as real-time experiments on different examples of underactuated mechanical systems and mainly the inertia wheel inverted pendulum.