Finding agile movements of robots with underactuation and unilateral constraints: The Butterfly robot case studies

Anton Shiriaev[1] Leonid Freidovich[2] Maksim Surov[3] Stepan Pchelkin[3]

[1] Department of Engineering Cybernetics
Norwegian University of Science and Technology
NO-7491 Trondheim, Norway
anton.shiriaev@ntnu.no

[2] Department of Applied Physics and Electronics
Umea University, Umea, Sweden

[3] Educational Robotics LLC, St. Petersburg, Russia

Summary

Challenges in dynamic walking are often associated with under-actuated dynamics and physical constraints that any feasible movement of the robot should satisfy. Newton laws, contact conditions, and limits in actuation are important to take into account already at the stage of designing a robot; and they cannot be substituted or simplified.

The nonlinearity of dynamics and instantaneous constraints, which must be obeyed continuously at every moment, represent obstacles for organization of an efficient model-based search for feasible (agile) behaviors of a robot for extended time intervals even when the robot's dynamics and the instantaneous constraints are known perfectly. The challenges become even higher if one attempts to take into account unavoidable uncertainties in the values of physical parameters and in the description of interaction models and of the associated constraints. This and other general observations make humans' abilities in performing agile movements amazing and of interest to imitate by robots. With severe constraints on actuation, computing power, sensing, communication, possibilities for redesign and adjustments (shoes, gloves etc.), essentially varying dynamic properties over short (hours, days) and long (months, years) periods, humans easily learn to perform many difficult motions. This fact shows feasibility of solutions for many robotic systems and emphasizes importance of discovering relevant structural features in organization of motion planning learned from humans' performances.

The talk is aimed at a discussion of principles for organization of a search for agile movements for mechanical systems with dynamic constraints. The focus will be on the example of planning movements for the Butterfly robot, which is the benchmark robotic system that has been conceptually designed and approached by many researchers, working with non-prehensile manipulations, within the last two decades. The system is inspired by motions of circus jugglers. It is a one-link curvy robotic hand that is expected to perform a dynamic manipulation of an object, which can freely roll on its surface. Rolling of an object, as rolling a foot during walking, represents a unilateral constraint, while sliding and non-sliding as well as under-actuation, for both cases: of manipulation and walking, are dynamical constraints inherently present in the systems' description. Scalable arguments and steps in planning feasible behaviors of the benchmark system and controlling them are presented. They are complemented and illustrated by simulations and experiments, performed on the robotic set-ups in our lab.