Open-Loop Stable Control of Periodic Multibody Systems

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Abstract: Multibody systems can be either closed-loop or open-loop controlled. While closed-loop control clearly is the most flexible solution applicable to most systems and motions, some significant drawbacks exist: It requires sophisticated and expensive sensory systems and feedback-controllers. The computation of appropriate reactions is time critical and often a limitation for making the motion of a multibody system faster. An open-loop control strategy, on the other hand, does not use active reaction to respond to perturbations but entirely relies on the mechanical system's natural kinematics and dynamics to stabilize the trajectory. Histories of input torques and forces to the system are a priori determined, prescribed for the motion and not changed by any feedback interference. The outstanding advantages of this control concept are low cost and the absence of any control delay. We have shown in previous publications that open-loop control can be an interesting alternative for regular periodic motions of some systems. And even for irregular motions where closed-loop control is a necessity, robust open-loop stable trajectories can provide a basis on top of which closed-loop control is applied. The determination of adequate systems configurations, model parameters and control inputs, that lead to open-loop stable motions, is a very difficult task. For this purpose, we have developed an efficient numerical method for the optimization of the open-loop stability of periodic systems. Stability is defined in terms of the spectral radius of the monodromy matrix which is non-differentiable and may be non-Lipschitz at points of multiple maximum eigenvalue and involves the computation of sensitivities hence representing a difficult non-standard optimization criterion. We have used a two-level optimization approach splitting the problems of finding a periodic motion and of stabilizing of the system. In our research on open-loop stable systems we have especially focused on open-loop controlled walking robots with one and two legs. Walking robots represent a very complex class of periodic multibody systems with discontinuities and multiple motion phases requiring sophisticated mathematical modeling techniques and numerical methods. In this paper, we present previously unpublished results for a new open-loop stable running robot.

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