Stability Optimization of Juggling

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Abstract: Fast periodic motions of robots can be open-loop stable or self-stabilizing if all the model parameters of the robot, like masses, geometric properties, springs, dampers etc. as well the torques and forces driving the motion are carefully adjusted and selected exploting the inherent dynamic properties of the mechanical system. Biological systems exhibit another possible source of self-stability which is the force-generation in the muscles themselves. These effects can be included in the mathematical model of the system taking into account all dependencies of the muscle force on muscle length, contraction speed and activation level. We present periodic single-arm juggling motions involving three muscles that are self-stabilizing that have been produced by numerical optimization. The stability of a periodic motion can be measured in terms of the spectral radius of the monodromy matrix. We optimize this stability criterion using special purpose optimization methods and leaving all model parameters, control variables, trajectory start values and cycle time free to be determined by the optimization.

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