Dynamics and control of bounce juggling

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Beyond the artistic enchantment, bounce juggling leaves few scientists indifferent and offers its own puzzle to many disciplines. As a control problem, it raises basic questions pertaining to the feedback stabilization of rhythmic tasks. The talk will survey the multidisciplinary history of the problem, then focus on our ongoing work on two-dimensional bounce juggling in the actuated wedge billiard shown in the figure.

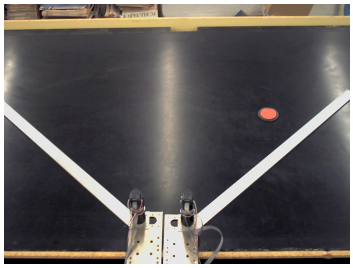

Figure 1: Experimental setup of a wedge billiard in a gravitational field, currently used both for robotic experiments and for experiments with human subjects. The robot uses no camera; it only detects impacts on the (actuated) edges.

The mathematical model of this toy experiment exhibits amazingly rich dynamical properties, tightly linked to properties of Hamiltonian systems in the vicinity of integrable configurations (KAM theory) and to the dynamics of coupled impact oscillators. In the spirit of energy-based stabilization methods, exploiting the open-loop dynamics in the design of feedback laws results in robust and well-performing schemes.

The results demonstrate the important role of phase variables in the control of rhythmic tasks. Particular emphasis will be put on how much and what type of feedback is needed to reach stabilization in large domains of attraction. The metronome will be shown to be a key ingredient.

The talk will also describe ongoing experiments with our wedge billiard to assess key parameters of robotic and human performance in the control of rhythmic tasks. The work is in collaboration with Manuel Gerard, Renaud Ronsse, and Philippe Lefèvre.

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