Energy–Based Hybrid Control of a Ball–Dribbling Robot

Stefano Massaroli[1], Federico Califano[2], Angela Faragasso[1], Atsushi Yamashita[1] and Hajime Asama[1]

***Abstract*— This paper deals with the problem of controlling a ball–dribbling robotic system. In particular, a novel hybrid controller which combines elements of passivity and iterative learning control theories has been developed. Numerical simulations have been performed to prove the validity of the proposed solution. Results confirmed the effectiveness of the developed methodology.**

I. Introduction

In this paper, a novel energy-based control technique for a ball-dribbling robot (see Fig. 1) is proposed. The developed controller, the *iterative energy shaping*, is derived by merging the theories of *port–Hamiltonian systems* [1] and *hybrid dynamical systems* [2] and attempts at casting passivity-based control in a learning context. By "learning" here it is intended that the control law is adjusted on the bases of previous iterations. While compared to previous work, our method relaxes most of the the assumptions made on the model by including viscous frictions and not requiring the knowledge of any parameter characterizing the ball's dynamics. Numerical simulations, performed to steer the output of such a system along a periodic reference, successfully demonstrate the efficacy of the proposed approach. In particular, the control task regards the periodic bouncing of the ball by means of impacts at a constant and prescribed height.

II. Methodology

We designed a hybrid controller with two modes: *wait* and *hit*. In the wait state, the robot must stay at a constant height above the ball, waiting for it to reach the peak of its bounce. Then, the controller switches to the hit state, forcing the robot toward the ball so that the exchanged impulse during the impact would lead the ball to come back to the desired peak. In both states, we would like to exploit the *energy–balancing passivity–based control* [1]. Indeed, the behavior of the system strongly depends on the choice of the controller's parameters. However, it is not possible to obtain analytically the values of the parameters which stabilize the system on the desired periodic trajectory. Thus, the parameters must automatically learned by the energy based controller in an iterative learning fashion. Let e be the ball's tracking error at the peak of the bounce. The main idea is to iteratively adjust the slope k_p of the robot's energy as function of e. For instance, when $e > 0$, the robot had hit the ball with not enough momentum. Thus, at the next cycle, the energy function should be steeper so that the robot will accelerate faster toward the ball. The same concept can be adopted for $e < 0$, by making the the energy function less steep. A possible choice of k_p is $k_p(e_i) = k_0 + ae_i + b\sum_i e_i$ which provides a proportional and integral action with a constant offset k_0 in response to the error ($a,\ b > 0$). The integral action should ensure zero steady state error.

[1]Massaroli, Faragasso, Yamashita and Asama are with the Department of Precision Engineering, The University of Tokyo, Japan {massaroli,faragasso,yamashita,asama} @robot.t.u-tokyo.ac.jp [2] Federico Califano is with Faculty of Electrical Engineering, Mathematics & Computer Science, University of Twente, The Netherlands f.califano@utwente.nl

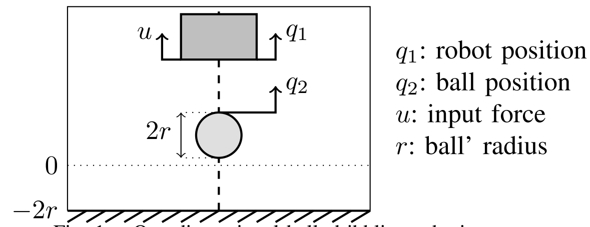

Fig. 1. One-dimensional ball–dribbling robotic system.

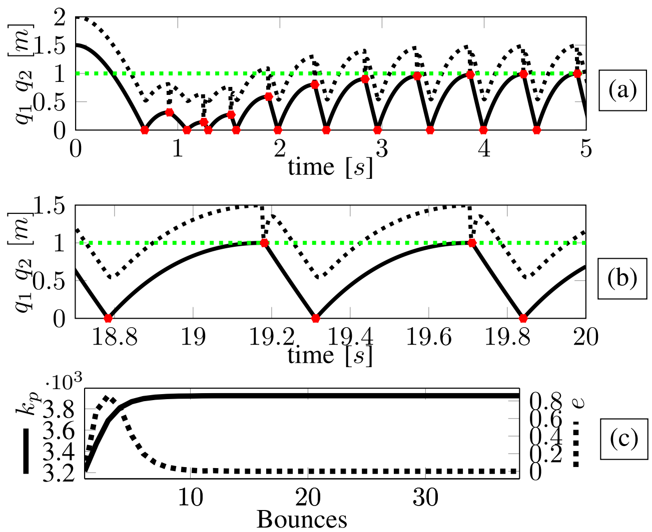

Fig. 2. (a) Convergence of the robot (dotted black) and ball (solid black) positions q_1, q_2 toward the periodic trajectory . (b) Motion of the system in steady–state. (c) Ball's tracking error and parameter k_p, computed at each bounce peak.

III. Simulation Results

Simulations have been performed to prove the effectiveness of the proposed approach. Results shown that the trajectory of the ball becomes periodic (asymptotically), reaching at each bounce the desired peak, confirming the stabilization property of the proposed control scheme (see Fig. 2.a,b). Moreover, the error goes to zero with the number of cycles. On the other hand, the function $k_p(e_i)$ converges exponentially to a constant value (see Fig. 2.c).

IV. Future Work

Future work will include evaluation with real hardware as well as the adaptation the controller to the 6DOF case.

References

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