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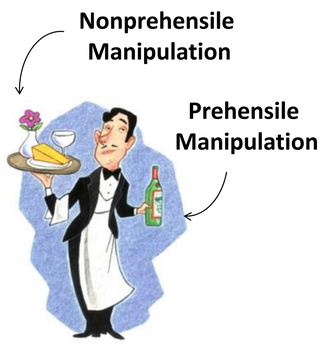
XXIX Cycle - II year presentation

Nonprehensile Manipulation Primitives Control

We perform a huge amount of *nonprehensile manipulation tasks* everyday, both with and without hands, such as pushing objects, folding clothes, bringing wineglass on a tray, cooking in a pan, or walking on legs.



Fields of application:

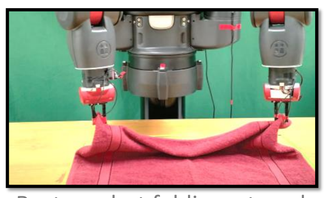
- Industrial applications where it is not directly possible to manipulate the object by grasping;
- Service and human assistance robotics;
- Motion planning for spherical or bipedal robots.

Potential benefits:

- Increase of available robot actions;
- Bigger operative workspace;
- Reduction of task execution time;
- Enhanced dexterity in dynamic tasks.


Stewart platform


Sphero BB-8

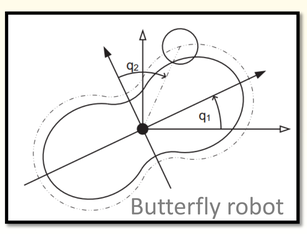

Baxter robot folding a towel

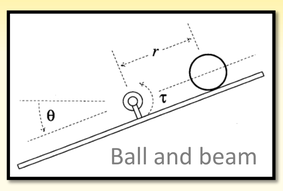
A *nonprehensile* task is complicated, skillful and dexterous. It can be undertaken by splitting the complex task in many simpler subtasks, usually called *primitives*, such as rolling, pushing, throwing, batting, etc.

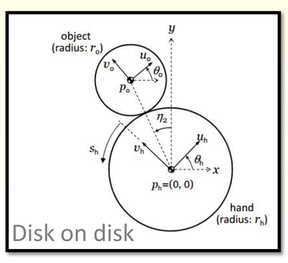
~ Planar Rolling Primitive Control

The *goal of the work* is the application of the Interconnection and Damping Assignment Passivity Based Control (IDA-PBC) to the planar rolling manipulation between two arbitrary shapes.

- One shape is actuated (hand), the other one is free to move (object).
- The *IDA-PBC* renders the closed loop as a desired Port-Hamiltonian system.



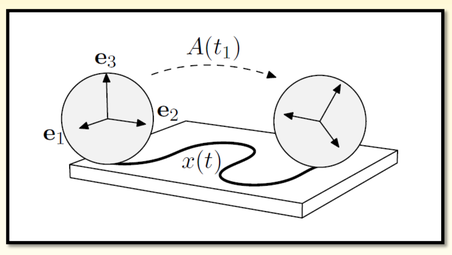




Results:

- Assuming constant mass matrix, an energy shaping control law, which can be particularized for the specific shapes od the object and the hand, is analytically derived and applied to the *disk on disk* case study;
- Removing the assumption of constant mass matrix, a new method is proposed to derive a control law, employing a *target PE-ME*. The procedure is applied to the *ball and beam* case study, which is not a feedback linearizable system.

~ 3D Rolling Primitive Control



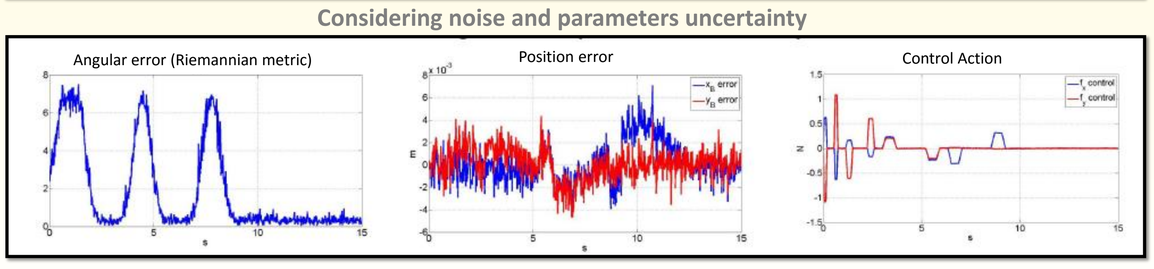
The *goal of the work* is to control the ball position and orientation through the rolling motions obtained moving the plate, and taking into account the nonholonomic constraint.

Results:

- System *analysis* shows that the ball dynamics is controllable, while the plate dynamics can be only bounded;
- The proposed *planning and control algorithm* computes the ball position, velocity and acceleration trajectories to reach a desired position and orientation. The plate is controlled in closed-loop to track a pre-computed path.

Ideal simulation

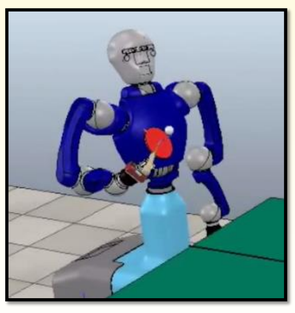
Considering noise and parameters uncertainty

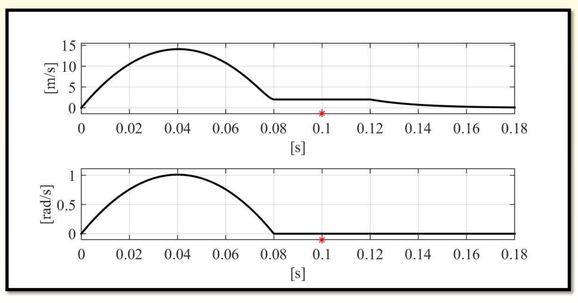


This simulation shows the reorienting of the sphere

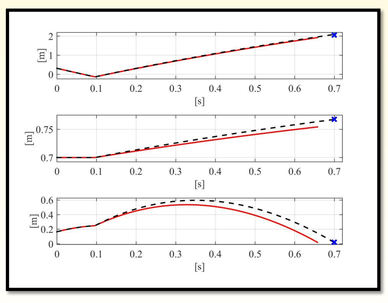
~ Batting Primitive Control

The *goal of the work* is the application of an optimal numerical prediction algorithm, well suited for real-time execution, to a robotic batting task.


V-REP simulation



Paddle linear and angular planned velocity

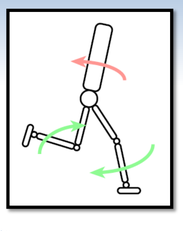


Ball trajectory comparison

Results:

- Considering a *full aerodynamic* ballistic model, the accuracy of control is improved w.r.t. state-of-the-art methods, preserving the real-time constraint;
- Rigorous methods from calculus on manifolds are emplyed to generate an *optimal trajectory on SE(3)* for the paddle to strike the ball at the impact time.

Work performed at PRISMA Lab within ERC Advanced Grant RODYMAN – *RObotic DYnamic MANipulation* – project. www.rodyman.eu



Inria INVENTEURS DU MONDE NUMÉRIQUE Forthcoming *collaboration with the BiPoP team at INRIA – Grenoble* – to learn about nonsmooth systems and to transfer concepts between dynamic manipulation and walking robots.

Future research directions:

- Application of the control method developed for planar rolling to other case studies;
- Experimental validation of the control method for the 3D rolling manipulation primitive.