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A REINFORCEMENT LEARNING APPROACH TO DYNAMIC OBJECT MANIPULATION IN NOISY ENVIRONMENT

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Abstract. *Dynamic object manipulation by 3-DoF robot manipulators has been studied. There are three major stages in this task; first, the object is thrown, then it has a free flight, and finally it is caught by a second manipulator. We present a new method to meet the environmental uncertainties existing in the problem that can affect the trajectory of the object and the subsequent impact force generated between the manipulator and the object at the catching instant. To reduce the impact force at this very instant, a reinforcement learning method is applied to the second manipulator to find the best time and velocity for receiving the flying object.*

To verify the proposed methodology, a set of simulations is carried out within SIMULINK-MATLAB linked to ADAMS for mechanical modeling of the system. An acceptable robustness is obtained for the second manipulator in catching the thrown object despite the noisiness of initial velocities of the object at throwing time.

Keywords: Dynamic object manipulation, Non-prehensile object manipulation, Reinforcement learning

1. **Introduction.** Object manipulation has become an important problem in industrial applications of robot manipulators. In general, there are two main approaches here: prehensile and non-prehensile manipulation. Non-prehensile or graspless manipulation implies manipulation without grasping, while prehensile manipulation involves the situations in which the object is grasped. Both types have their special applications, advantages, and disadvantages. For instance, applying smaller forces, using simpler mechanisms, and working along with the environmental and object dynamics are some merits of graspless manipulation [1].

Non-prehensile manipulation methods can be divided into two different categories: quasi-static and dynamic manipulation methods [2]. The former considers slow enough motions so that the inertial forces can be neglected and the object always keeps contact with the robot; the later deals with problems that involve high levels of inertial forces. Consequently, in dynamic manipulation approach, the robot has to exploit the equations of motion of the object and should work with the environment dynamics, not act against it. Also, it is not required for the object to be in contact with the robot during the whole period of manipulation [2,3].

Juggling could be a good example of non-prehensile dynamic object manipulation (NPDOM) in which a sophisticated juggler should move his hands in such a way that the object tracks the desired trajectory. In fact, the challenge is to control a high degrees-of-freedom object by a dexterous manipulator with fewer arms either by a parallel [4] or serial manipulator. Lynch and his colleagues studied this subject in several papers [5-10]. For example, in [6], he showed that almost any planar object can be locally controllable for