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Multi-priority Impedance Control with Torque Estimation

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Abstract
In this paper a prioritized impedance control method for a kinematically redundant robot is proposed. The approach specifically enables us to control a task space impedance accompanied with a given joint space impedance in the null-space of the main task. Thus the proposed algorithm not only can handle the interaction of the robot's body with its environment by an impedance behavior, but also tries to minimize the main task error caused by this interaction. This is performed by means of an estimation algorithm for the external torques exerted on the body of robot. This method neither uses torque sensor information nor joint acceleration feedback. The performance of the proposed control is verified through numerical simulations.

Keywords: Multi-priority control, Redundant robots, Null-space impedance control.

Introduction

One of the current trends in robotics is to develop new robots and control algorithm, capable of doing daily life applications with high degree of compliance and safety. This compliance is useful for the applications in human environment such as service and medical robotics where safety of interaction is crucial and the occurrence of unmodeled and unexpected impacts is probable. To cope with this problem two strategy may be thought; one is to cover the manipulator with a sensitive skin (tactile sensors) [1] capable of detecting external interaction. The other is to increase the robot's compliance. Compliance can be introduced passively by using elastic decoupling between the actuator and the driven link [2] or by actively relying on fast force and torque feedback loops [3]. Impedance control topic provides a very suitable framework for controlling robots in contact with an unknown environment. The problem of position based impedance control has been extensively studied in literature. Also for torque controlled robot like DLR lightweight arm impedance control has been used effectively [4]. In most of the proposed approaches the compliant behavior usually is given to the operational task to control the interaction of the end-effector.

For kinematically redundant robots, redundancy can be used to implement additional sub-tasks beside the main task. A complete theoretical and empirical evaluation of different operational space control for redundant manipulators has been investigated in [5]. One approach to deal with this redundant degrees is multi-priority control that is a well-established framework and can be performed both in kinematic [6,7] and dynamic level [8,9]. The so-called *null-space impedance control* as a result of multi-priority control in acceleration level was introduced in [9] by authors of this paper. The approach was motivated by the need to have control over the interaction of the robot's body with the environment in spite of the end-effector interaction control. The compliant behavior obtained by the null-space impedance is useful in the case where the robot works in a cluttered environment or human environment and interaction between environment or an obstacle and any part of the robot's body may occur. In our previous paper [9] it was shown that in the case where the robot is equipped with torque sensors both the main task impedance and the null-space impedance is perfectly realized. However when the torque information is not available, any interaction with environment on the body of robot affects the main task (end-effector mission), while the null-space impedance yet can be realized under some circumstances.

The Cartesian impedance control for torque controlled lightweight robots was investigated by Albu-Schaffer and Hizenger [4]. Later in [10] impedance control, accompany with the null-space stiffness implementation for DLR 7DOF flexible joint arms based on singular perturbation approach was addressed.

The multi-priority Cartesian impedance control has been investigated by Platt and Abdallah [8]. Their approach realizes several impedances in Cartesian space based on a specified order of priority.

The multi-priority control also has been applied on humanoid robots. Sentis and Khatib [12,13] established a control hierarchy among the behavioral primitives in a humanoid robot. The formulation is in torque level and multiple Cartesian acceleration, force or impedance objectives can operate with a specified order of priority. A close relationship between this approach with acceleration level resolution has been investigated in [9] by the authors.

In the field of adaptive force control, Danesh et al [14] investigated the problem of force sensor-less disturbance rejection in robot manipulators. They used an adaptive force estimator to compensate external force disturbance that is applied on the end-effector. Later the method was extended in [15] to the case where parametric uncertainty also exist despite unknown