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Priority Oriented Adaptive Control of Kinematically Redundant Manipulators

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Abstract—**In this paper an adaptive multi-priority nonlinear control algorithm for a redundant manipulator system is developed based on the Lyapunov like approach. The method considers the parametric uncertainties in the system and defines a proper filtered error signal to achieve asymptotic stability and convergence in tracking error, both for the main task and sub-tasks according to the allocated priority. The performance of the proposed method is studied by some numerical simulations.**

I. Introduction

KINEMATICALLY redundant robots have more degrees of freedom than those necessary to achieve a desired task. The redundant degrees of freedom can be conveniently used to perform some additional tasks besides the main task. These additional tasks can be a defined performance objective or any secondary task as somehow similar to the main task. For example a given Cartesian position for a point on the body of robot different from its end-effector can be considered as the additional task.

There are plenty of papers that deal with how to use redundancy effectively to optimize some performance objective besides the main task control. This optimization is usually performed in the null-space of the main task to ensure its perfect tracking. In order to solve the conflict between tasks in a case where several objective functions are going to be satisfied simultaneously, the so-called task priority strategy developed in [1,2] is adopted. The formulation has later been extended to a general framework for managing multiple tasks by Siciliano and Slotine [3]. Their formulation uses first-order differential kinematic equation and solves redundancy in the Least-Squares (LS) sense, based on the assigned priority by resorting to pseudo-inverse solution. Because of using the pseudo-inverse of the *projected Jacobians* –the Jacobians of the lower-priority tasks that are projected into the null-space of the higher-priority tasks– the formulation may suffer from high velocity norms during transition into and out of algorithmic singularities.

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Usually a singularity-robust pseudo-inverse that allows limiting joint velocities at the expense of small tracking error in lower priority tasks is the first remedy to cope with this problem. Efficient damping techniques have been suggested by Nakamura and Hanafusa [4] and Wampler [5] and also by Nenchev and Sotirov [6] for the case of multiple priorities.

Chiaverini [7] proposed the singularity-robust task-priority resolution without using the projected Jacobian. This formulation always involves tracking errors in the additional tasks but singularities do not occur as long as the Jacobian of each additional task is full rank. The stability of this formulation has been shown in [8].

In contrast to velocity-based control approach, The acceleration-based control approach computes the desired joint accelerations for a given tasks [9,10,11,12]. Synthesis of joint accelerations in a redundant robot usually requires a more involved analysis. However, for second-order systems such as robotic systems this formulation is the most natural one that offers improved tracking ability due to the explicit incorporation of the acceleration information.

Adaptive nonlinear tracking control of kinematically redundant manipulators has been presented in [13] by Zergeroglu et al and later in [14] by Tatlicioglu et al. They used a Lyapunov approach to design a controller that achieves asymptotic tracking in the task space with systematic integration of the sub-task control into the stability analysis.

In this paper a nonlinear controller for the case of multiple tasks control based on the allocated priority is designed. Usually in a multi-priority control algorithm the joint space trajectories are obtained based on the inverse kinematics formulation, considering the priority orders. This joint space trajectory is then tracked by an inner control loop. A resolved acceleration or an inverse dynamics controller is typically adopted to track these joint space trajectories [15]. The resolution which is performed at velocity or acceleration level is usually based on the kinematics of the manipulator and thus is model dependent. It is clear that in the case of parametric uncertainty, the joint space trajectories obtained are no longer accurate. In addition to this deficiency, the inverse dynamics control method which is usually used for the joint space trajectory tracking is also model dependent. This, itself, doubles the system errors.