Observer-Based Impedance Control of Robot Manipulators

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***Abstract*—In this paper, an observer-based impedance controller for robot manipulators during a constrained motion is developed. The proposed controller requires the measurements of link position and interaction force. A filtering technique is applied to eliminate the need for link velocity measurements. The proposed control strategy provides semiglobal asymptotic tracking performance for the end-effector position and compliant interaction force between the environment and the robot end-effector. In order to verify the effectiveness of the proposed controller, a numerical simulation for a two-link planar robot is also provided.**

***Index Terms*—Impedance control, output feedback, robot arms, Lyapunov theorem, asymptotic stability.**

I. Introduction

Control of robots in contact with the environment is an important problem in real life and industry applications. The majority of robot applications such as automated deburring, grinding, spot welding, scribing and precision assembly, will naturally require the robot to come into contact with a physical environment. This interaction with the environment will put some sort of constraints on the robot path to be followed, a circumstance noticed as *constrained motions*. It is notorious that constrained motion tasks requiring a strong interaction between the manipulator and its environment necessitate some kind of force control.

Force control methods are classified as passive and active methods. In passive methods, the interaction force is contemplated by equipping the robot end-effector with an auxiliary mechanical device, generally composed of springs and dampers.

In active methods, a proper control strategy and force feedback is required to handle the constrained force. In this method the controller parameters are easily modified with respect to the required task which engenders this method to be more adjustable. Many robot manufacturers are now producing force controlled industrial robots [1-5].

Several force control methods have been reported in literature. The impedance control is one of the most intuitive approaches of interaction control, which provides a unified method for controlling the robot in both free space and constrained motion phases. In fact this method affects the robot to function as a mechanical device made up of a mass, a damper and a spring. It controls the contact force by controlling the position of the manipulator utilizing the desired impedance, defined as the relation between the contact force and the velocity of the end-effector [6]. This method was extremely theorized by N. Hogan [7] and put in experimental application by H. Kazerooni, et al [8]. Several reports on impedance control have been presented following the work of Hogan. A combination of impedance control with the hybrid control has been proposed by Anderson and Spong [9]. Mills and Liu [10] proposed an impedance control method to control the generalized contact force and position.

Gonzalez, et al. presented a hybrid impedance control scheme which utilized a desired force as the commanded variable to replace the desired trajectory and demonstrated the improved performances of an explicit force control structure with a similar degree of robustness [11]. For more recent investigations around impedance controller design, see [12-14]

The aforementioned studies require the complete measurement of system states, including link positions and velocities, and the interaction force. Link velocities, or the end-effector Cartesian velocities, are mostly targeted for elimination due to unavailability or practical issues of velocity measurements. High precision velocity sensors are frequently refrained due to the savings in cost, volume, and weight [15]. Hence the problem of control of robotic systems by the sole measurement of joint positions, of output feedback control fame, has been a topic of great enthusiasm for nearly two past decades. A particular approach in output feedback control problem is the design of an observer which estimates the system states. In fact by the word *observer design*, one means designing a dynamic which mimic the physical behavior of the system and estimates the system states.

The problem of developing non adaptive output feedback controller for robotic systems has been contemplated in [16-29] and the references therein. In [19], based on the complete knowledge of robot dynamic, an observer based controller is designed utilizing a nonlinear observer. In [23], the feasibility of utilizing high gain linear observers in conjugation with several different controllers is verified by experimental results. In [21], a linear velocity observer is designed assuming the complete knowledge of the robot structures and afterward utilizing the passivity approach; an observer based controller is designed. In [24] the system states are estimated by sliding