Force Control of a Manipulator with Hyper Degrees of Freedom: Impedance Control for the Whole Arm

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Abstract

An HDOF manipulator has many more kinematic degrees of freedom than a conventional manipulator. This manipulator has a potential capability of the whole arm grasping, i.e., to grasp an object by its whole arm. This type of manipulator enables us to handle objects of various size and shapes. The whole arm grasping means that a manipulator exerts forces on a grasped object to use a whole arm. Therefore, we purpose force control to use a whole arm of a manipulator with HDOF.

The whole arm grasping can be achieved by the following two types of control. One is force control where we impose forces on an object with a whole arm of a HDOF manipulator. The other is shape control where we fit an HDOF manipulator to a surface of an object. In this thesis, we consider impedance force control and shape control. Impedance force control is one of typical force controls and its control can be use same control law when we exert forces on an object or do not. In impedance control, we give a mechanical impedance, i.e., inertia, damping and stiffness with respect to the position error between a manipulator and a grasped object.

We achieve the whole arm grasping to apply an mechanical impedance imposed over a whole arm to shape control. An ordinary impedance control achieve a force control only at the tip. We impose mechanical impedances not only at the tip but also at all links for the whole arm grasping. Kinematic

constraints of a manipulator disable us to impose mechanical impedances at an arbitrary position. We give a spatial curve for target joint positions and we consider a curve parameter estimator similar as a shape control to estimate joint positions. Using this curve parameter estimator, we can impose mechanical impedance at each joint position. Moreover we can obtain the easy to deal control law and we can decrease a amount of calculation.

A recursive expression is very important for a calculation of control law for an HDOF manipulator which has many degrees of freedom. We derive a recursive expression of a whole arm impedance force control law. To decrease amount of a calculation for a recursive expression, we transform shape Jacobian into a lower triangular. Inverse shape Jacobian can calculate more simply from the lower traiangular shape Jacobian. Shape Jacobian is characteristic Jacobian of an HDOF manipulator and it has curve parameters in it.

The derived control law has a following two similar properties as an ordinary impedance control law. We compare the derived control law with an ordinary impedance control law and shape control law. One is a property where we can achieve force control using no force feedback loop to choose suitable impedances. The other is a property where if there are no given force, then this control law is exactly equal to a shape control law. The drived control law is extention of an ordinary impedance control law, i.e., the control law involve mechanical impedaces of a whole arm ,it has same form of an ordinary impedance control law and it has two same property of an ordinary impedance control lwa.

We apply a whole arm impedace control law to an HDOF manipulator simulation model which has 4 joints and 8 degrees-of-freedom. In the simulation, we simulate following two control. One is whole arm impedance control and the other is shape control. In both control, we give a impact force at a link of an HDOF manipulator at a steady state. In the simulation results, we can see the manipulator react softly depending on a given impedance for a whole arm, which shows we can adopt impedance force control for the whole arm. In whole arm impedance control, an HDOF manipultor can be moving different types with respect to given a inertia property in mechanical impedaces different from shape control.

We also consider generalized impedances for a whole arm, i.e., to consist of not only translational motion error but also rotational motion error over a whole arm. The end of this thesis, we point out some problems of generalized impedances. One of the problems is difficulty of seting up each frame of all joint on the spatial curve. Another is difficulty of choosing shape errors of rotational motion over a whole arm. The former difficulty is caused by corresponding frames at each joint position on a manipulator to frames at each target postion on a spatial curve. The latter difficulty is caused by the former difficulty and many degrees of freedom of an HDOF manipulator. To realize both of them, we may consider to change the corresponding a spatial curve with a manipulator to the corresponding spactial plane with a manipulator.