Compliance Control of Robot Manipulator for Safe Physical Human Robot Interaction

av

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Abstract

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Inspiration from biological systems suggests that robots should demonstrate same level of capabilities that are embedded in biological systems in performing safe and successful interaction with the humans. The major challenge in physical human robot interaction tasks in anthropic environment is the safe sharing of robot work space such that robot will not cause harm or injury to the human under any operating condition.

Embedding human like adaptable compliance characteristics into robot manipulators can provide safe physical human robot interaction in constrained motion tasks. In robotics, this property can be achieved by using active, passive and semi active compliant actuation devices. Traditional methods of active and passive compliance lead to complex control systems and complex mechanical design.

In this thesis we present compliant robot manipulator system with semi active compliant device having magneto rheological fluid based actuation mechanism. Human like adaptable compliance is achieved by controlling the properties of the magneto rheological fluid inside joint actuator. This method offers high operational accuracy, intrinsic safety and high absorption to impacts. Safety is assured by mechanism design rather than by conventional approach based on advance control. Control schemes for implementing adaptable compliance are implemented in parallel with the robot motion control that brings much simple interaction control strategy compared to other methods.

Here we address two main issues: human robot collision safety and robot motion performance.

We present existing human robot collision safety standards and evaluate the proposed actuation mechanism on the basis of static and dynamic collision tests. Static collision safety analysis is based on Yamada's safety criterion and the adaptable compliance control scheme keeps the robot in the safe region of operation. For the dynamic collision safety analysis, Yamada's impact force criterion and head injury criterion are employed. Experimental results validate the effectiveness of our solution. In addition, the results with head injury criterion showed the need to investigate human bio-mechanics in more details in order to acquire adequate knowledge for estimating the injury severity index for robots interacting with humans.

We analyzed the robot motion performance in several physical human robot interaction tasks. Three interaction scenarios are studied to simulate human robot physical contact in direct and inadvertent contact situations. Respective control disciplines for the joint actuators are designed and implemented with much simplified adaptable compliance control scheme.

The series of experimental tests in direct and inadvertent contact situations validate our solution of implementing human like adaptable compliance during robot motion and prove the safe interaction with humans in anthropic domains.

Keywords: physical human robot interaction, collision safety, variable stiffness actuators, compliance control.