

A Unified Control Framework for Human-robot Interaction

Shangke Lyu

Abstract:

Co-existence of human and robot in the same workspace requires the robot to perform robot tasks such as trajectory tracking and also interaction tasks such as keeping a safe distance from human. According to various human-robot interaction scenarios, different interaction tasks usually require different task requirements or specifications, leading to different control strategies. Besides, due to different natures of the robot tasks and interaction tasks, different controllers may be required when the task is switched from one to another. So far, there is no theoretical framework which integrates different robot and interaction task requirements into a unified robot control strategy.

In this research, a general human-robot interaction control framework is proposed for the scenario of human and robot coexisting in the same workspace. We propose a general potential energy function which can be used to derive a stable and unified controller for various robot tasks and human-robot interaction tasks. Instead of designing a particular task function formalism for each subtask requirement, various tasks can be specified and achieved by using a single controller at a user level through simply adjusting certain task parameters. Interactive weights are also defined to specify the interaction behaviours of robots according to different human-robot interaction applications. Specific interaction modes such as human-dominant interaction and robot-dominant interaction are given in details to demonstrate the applications of the proposed control method. We show how the control framework can be applied to existing robot control systems with velocity control or torque control mode by developing a joint velocity reference command and an adaptive controller.

Typically, industrial manipulators have closed architecture control systems and do not come with external sensors. During human-robot interaction, robots are operated in an uncertain

environment with presence of humans and are required to adjust the behaviours according to human's intentions. Hence, external sensors such as vision systems must be added and integrated into the robots to improve their capabilities in perception and reaction. Since different configurations and types of sensors result in different sensory transformation or Jacobian matrices and thus lead to different models, it is in general difficult for operators or users in factory to model the sensory systems and deploy the robots according to various human-robot interaction applications. In this thesis, a new learning algorithm is derived and employed in the proposed control framework to estimate the unknown kinematics such that various external sensors can be easily integrated into the proposed framework to perform interaction tasks without modeling the kinematics.

In the proposed framework, the robot's behaviours during the interaction can be varied by manually adjusting the task parameters. As some of the task parameters do not correspond to any physical meaning, it is in general difficult for normal non-expert users to set the task parameters according to a specific interaction task. On the other hand, it is anticipated that task specification through human's demonstration would be one of the effective ways for robots to understand or imitate human's behaviours, especially during human-robot interactions. Therefore, a task requirement learning algorithm is proposed where the motion behaviours demonstrated by human can be acquired or learned by the robot systems in a unified way.

Publications:

- [1] S. Lyu and C. C. Cheah, "Adaptive robot control for human-dominant interactions using a general task function," *IEEE International Conference on Real-time Computing and Robotics*, 39-44, 2016. **(Best paper award)**
- [2] S. Lyu and C. C. Cheah, "Human-Robot Interaction Control based on a General Energy Shaping Method," *Automatica*, (under review).
- [3] Q. M. Ta, S. Lyu and C. C. Cheah, "Human-guided Optical Manipulation of Multiple Microscopic Objects," *IEEE International Conference on Robotics and Automation*, 2018, (accepted).
- [4] S. Lyu, and C. C. Cheah, "Human-robot Interaction Control through Demonstration," *26th Mediterranean Conference on Control and Automation*, 2018, (accepted).
- [5] S. Lyu, and C. C. Cheah, "Vision based Neural Network Control of Robot Manipulators with Unknown Sensory Jacobian Matrix," *IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, 2018, (accepted).
- [6] S. Lyu, and C. C. Cheah, "Intention based Control for Physical Human-robot Interaction," *IEEE International Conference on Real-time Computing and Robotics*, 2018, (accepted).