Two Mode Impedance Control of Velma Service Robot Redundant Arm

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Abstract. The previous research on reactive torque control of redundant arms led to conclusion, that initial arm kinematic configuration is vital for task executed with the use of Cartesian impedance control. To provide that, in the article the control system is proposed with the two following modes of impedance control of redundant manipulators: Joint space and Cartesian space. For this purpose the system was treated as embodied agent with two behaviors of its Virtual Effector (hardware abstraction layer). Each behavior has been decomposed to several components described by automatons and communicate asynchronously with upper layers of the control system. The whole system has been finally verified on real manipulator.

Keywords: service robot, impedance control, controller design.

1 Introduction

Humans organized their environment adequate to their physical attributes, such as their height and their arms reach. A service robot, which is meant to mimic and relieve man in his daily activities, should have the working space similar to man's. Robot and man manipulation abilities should be also complementary, hence kinematic chain of service robot needs to reflect the capabilities of human movement [1]. As a consequence, redundant robots became more and more popular in service robotics research.

Currently, most of the constructions of service robot redundant arms use torque control. It is possible to achieve desired joint torque in control systems with internal motor current control, if the nonbackdrivable gears are provided and drive friction model used in control is accurate. The PR2 is a service robot with motor current control and with lack of additional joint torque sensors [2]. Its arms have a passive spring counterbalance system so the arms float even when the power is off. As the examples of different approach, there are a few service robots based on LWR arms with direct torque control in theirs joints. The TUM Rosie is a mobile robot designed to perform everyday manipulation tasks in a kitchen environment [3]. The Justin robot [4] is more elaborate construction with active torso which not only enhances the workspace, but also allows to avoid singular manipulator configurations and execute collision-free manipulation in a complex

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environment. Finally Velma robot [5], studied in this article, is equipped with two LWR arms with BarrettHand grippers and active torso with indirect torque control.

The previous research on reactive torque control of redundant arms led to conclusion, that initial arm kinematic configuration is vital for task executed with usage of Cartesian impedance control [6]. In the current article the authors propose an incorporation of two modes of manipulator control (Joint space and Cartesian space) in redundant, impedance controlled arms. The general approach was previously studied for 6-DOF indirectly position–force controlled robots [7]. Joint space trajectory interpolation of redundant robots is crucial for path planning to avoid contact with obstacles, while the end–effector motion is unalterable. It is also an exceptionally useful skill when reaching for objects located deep on the shelves of cabinets, in a refrigerator, etc.

The control system presented in the article (section 2) has been specified as an embodied agent [5]. Here, we assume the asynchronous communication between the Control Subsystems, where the particular tasks are specified, and Virtual Effector stated as universal hardware abstraction layer. The idea comes from specificity of service robot applications, where image recognition and analysis takes variable time and causes synchronous communication inconvenient and inappropriate. The whole approach has been implemented in ROS/OROCOS based system and then verified (section 3). The paper is summarized in section 4.

2 Control System

In general, the robot control system is treated as embodied agent with Control Subsystem, Virtual Receptors and Effectors and Real Receptors and Effectors. The specific variant of the embodied agent, with Control Subsystem c, Virtual Effector e_m and Real Effector E_m, is used in the following description because there is no need to consider receptors. The task algorithm is realized in the Control Subsystem. In the presented work, we focus on the Virtual Effector, which is universal for all tasks.

Three behaviors are specified for the Virtual Effector. The behaviors produce 7×1 desired torque vector $\boldsymbol{\tau}_d$ sent to the manipulator joints. The first behavior ${}^{e}\mathcal{B}_0$, the idle one, generates the constant desired torque vector with zero values set for each of the manipulator joints. The second behavior ${}^{e}\mathcal{B}_{\mathrm{j}}$ realizes trajectory interpolation and impedance control in Joint space (sec. 2.1). The third behavior ${}^{e}\mathcal{B}_{\mathrm{e}}$ realizes trajectory interpolation and impedance control in Cartesian space (sec. 2.2). All behaviors are executed synchronously with the same time period Δi, where i is a discrete time instant placed in right superscript of related symbol, e.g. $\boldsymbol{q}_m^i$ is a vector of measured positions of the joints for time instant i. The i_0 is the first time instant of the particular behavior execution. The Virtual Effector behaviors are switched by the dedicated command sent from the Control Subsystem, that ends one behavior and starts the next one from time instant i_0. The right subscript in square brackets determines the particular coordinate of the vector.