Intuitive Hand-Guidance of a Mobile Manipulator

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ABSTRACT

Mobile manipulators are robot systems which enable the capabilities of logistics and manipulation tasks. Thus, they potentially close unconsidered gaps regarding flexibility in modern production lines. We address the problem of developing an easy-to-use interface for intuitive robot programming. This interface implements a whole-body compliance control to allow for hand-guidance.

1. INTRODUCTION

Producing small lot-sizes or highly customized products require enhanced flexibility within the manufacturing processes. This raises the need for flexible and easily adaptable robotic systems. While conventional automated production lines are usually prepared and programmed by external experts, modern applications require frequent adaption or reprogramming. To enable this directly for workers, without explicit programming skills but high domain knowledge, an intuitive interface is needed. One well-known technique is kinesthetic programming by demonstration, where a compliant robot can be hand-guided into desired configurations. While the compliance control for serial manipulators has been well investigated, the whole-body compliance for a mobile manipulator, consisting of a serial manipulator on top of a mobile base, has gained little attention yet. Leboutet et al. [1] presented a strategy with hierarchical force propagation for a mobile manipulator with omni-directional base. Navarro et al. [2] proposed a system where the motion distribution between the serial manipulator and the mobile base is done with optimization.

2. METHOD

In our previous work [4] we presented a control strategy for whole-body compliance of a mobile manipulator with differential drive. A force/torque sensor is mounted close to the end-effector (EE) to measure the external wrench applied by the user. The robot shows kinematic redundancies regarding the 3D task space since the 6 degrees of freedom of the arm are supplemented with those of the mobile base. Our control structure focuses on resolving these redundancies by implementing three different modes: A *pull-mode*, where the mobile base can be pulled like a steered trailer, which means that the base is rotating and translating towards the EE and haptic feedback is given to the user by means of a virtual spring. In the *ur-mode* only the serial arm moves, and the *push-mode* allows for pushing the mobile base while receiving haptic feedback of a virtual spring. The decision, which mode is used depends on the actual position of the EE. Two circles in the xy-plane define two borders of cylindrical shapes in the 3D space. If the EE leaves the outer circle *pull-mode* is active, in between the two circles the *ur-mode* is active and inside the inner circle *push-mode* becomes active.

The proposed control structure was successfully validated throughout laboratory experiments, but approaching arm configurations close to singularities proved to be problematic. Since the suggested controller uses end-effector velocities as control inputs, close to a singular configuration, a rather slow end-effector motion may lead to very high joint velocities causing possibly dangerous situations. In [3] we extended our controller to avoid approaching singular arm configurations by providing haptic feedback to the user. We did a detailed analysis of all possible singularities of the UR10 and implemented virtual springs to avoid them.

For future work it is planned to integrate haptic feedback to avoid self collisions. Furthermore, depending on the choice of the radius of the inner circle, the workspace of the serial arm is restricted, since when the inner circle is entered by the EE, *push-mode* is active and a virtual spring will move the EE back outside of the inner circle. We plan to refine the strategy at this point to minimize the volume of the restricted workspace.

3. REFERENCES

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