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Optimization of Manipulator Base Placements for Multi-Arm Grasping

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***Abstract*— In our previous work we constructed an enormous robot hand composed of multiple KUKA LWR IV+ representing fingers cooperatively manipulating heavy objects. Manipulator bases were placed on a flat table symmetrically without further consideration. As next step we propose to optimize base placements with respect to object manipulability and workspace.**

I. Introduction

Grasping objects with robot hands have been studied extensively during the last 30 years. Recently, we composed a highly redundant multi-robot system by mounting four KUKA LWR IV+ manipulators on a table, which we treat as a single underactuated robot with 28 actuated joints and six virtual joints for the free-floating object. Employing the well-known grasp matrix constraint this robot system represents an enormous hand with four fingers, each of approximately 1.2m length when including the end-effectors. In [1] we demonstrated compensation of object dynamics for precise manipulation tasks with two different solid objects (mass $m_1 = 3.0$kg and $m_2 = 9.2$kg) and in [2] we optimized contact wrenches during grasping. Our torque-control software architecture for impedance-based manipulation via a force-closed grasp is described in [3].

Similar to related works, in our experiments manipulator bases have been chosen without further evaluation (see Fig. 1). However, in comparison to classical robot hands, finger base placements in our multi-fingered setup are not fixed in general and can easily be varied. We are interested in the effects when changing the manipulator base placements: What is the maximum possible workspace volume and how do we maximise object manipulability? Where are internal singularities due to the closed kinematic chain/tree?

We propose as next step to optimize robot base placements in simulation employing state-of-the-art CMA-ES. In an initial study we focus on a bi-manual setup with two KUKA manipulators involved (see Fig. 2) and evaluate only the static case for a given robot setup. We compare two different approaches: First, the 6 DOF robot base is optimized for one robot while the second base is fixed. In this case, it may happen that the kinematic chain cannot be closed for a given robot base. This fact becomes even more problematic when optimizing multiple robot fingers. As second approach we propose to treat the bi-manual setup as a single manipulator and optimize the higher-dimensional 14 DOF joint configuration where local minima are more likely to appear due to the redundancy.

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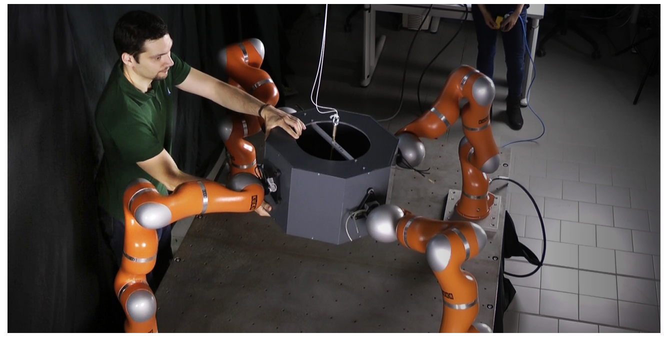

Fig. 1: A enormous robot hand with four fingers manipulates a 9.2kg object. Compensating for object dynamics enables to provide an impedance-based human-robot interaction mode.

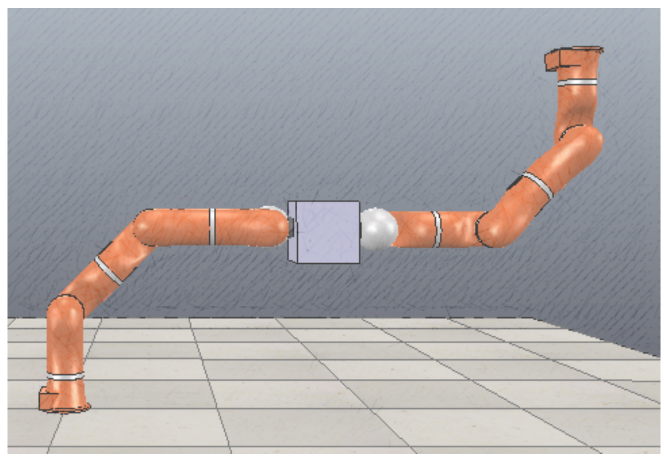

Fig. 2: Different manipulator base placements are evaluated in simulation and optimized employing CMA-ES.

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References

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