

Experimental Evaluation of Synergy-Based In-Hand Manipulation

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Abstract

In this paper the goal of extending the results obtained in [1] including tasks concerned with internal manipulation has been addressed. The main idea is to enrich the experiments by requiring the subjects to reproduce not only the most natural grasping configuration belonging to the considered grasping taxonomy, but also the boundary configurations for those grasps that admit internal manipulation. The final goal is to represent grasp and manipulation tasks as trajectories connecting suitable configuration sets in the synergy subspace.

Index Terms

Postural Synergies, Robotic Grasping, Internal Manipulation, Robotic Hands

I. INTRODUCTION

The problem of robotic grasping and manipulation involves many complex issues and the theoretical approach based on the research of optimal solutions results too complex to be implemented in practice with the actual technologies (sensors and computational capability) and poorly reliable due to the simplified modeling of the real system behavior [2]. On the other hand, neuroscience studies point out the natural ability of humans to unconsciously find sub-optimal solutions to those problems. Moreover, the observation of human behavior shows the presence of coordinated motions among the degrees of freedom of the fingers in common to many different grasping postures. These intuitions lead us to consider the possibility to mathematically extract the predominant postural synergies from human behavior and map them to different robotic hand kinematics. In order to prove this concept, in [1] a method based on the acquisition of contact points related to a set of 36 human grasping tasks (defined in [3]) performed by different test subjects has been described. Since data were collected from subjects with hands that have different kinematics, it was necessary to adopt a normalization procedure to a common kinematic structure which in our case is the UB-Hand IV (University of Bologna Hand version IV) kinematics. Then through kinematic inversion the scaled data were transformed from the Cartesian space to the robotic hand's joint space. Finally the elaborated data have been investigated using Principal Components Analysis (PCA) showing that our assumption on the existence of motion patterns are confirmed by the presence of dominant eigenvalues. We have found that the subspace generated by the eigenvectors associated with the first three highest eigenvalues, is enough to let the robotic hand reproduce the set of considered grasping configurations with a sufficient accuracy in relation to the grasping task. This result allows to implement a grasp planner based on defining a trajectory within the obtained subspace. The trajectory is basically the interpolation between points of the synergy subspace that represent particular configuration of the hand. In practice the trajectory starts from the rest position, pass through the complete extension configuration of the hand (that is the origin of the synergy subspace) and reach the desired grasping configuration. The release trajectory is planned contrariwise.

In this work the starting point is the observation that there are grasping postures that admit internal manipulation, an example is depicted in figure 1. For this reason we want to enlarge the database of postures acquired adding these hand configurations. Therefore the experiments required to the test subjects is extended to not only reproduce the most natural grasping posture for each element of the taxonomy, but also the maximum and minimum bounds for those that admit internal manipulation without losing the contact between fingertips and the object.

The PCA is recomputed on the extended database and then the eigenvalues are examined. It is of interest to evaluate how many eigenvectors are needed to reproduce with a sufficient precision the new set of postures. The task planner must be modified including the capability to generate trajectories within the synergy subspace that connects points representing the rest position, a defined grasping posture and the points relative to the manipulation of the same grasping type. The



Fig. 1. The reference (central) and the boundary (left and right) configurations for the cylindrical precision grasp.

benchmark of the algorithm will be tested on the UB Hand IV and the performance evaluation will be done by examining the success rate over of the considered task set.

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