Reactive Grasping for Human-Robot Interaction (Abstract)

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I. Introduction

In this paper, we consider a simple task where the robot has to take an object that a human is handing over. This is a challenging task as the robot can not know *a priori* how the human will present the object. In a first time, the robot must be able to select a proper way to take the object, located in the human hand. Once the robot is moving its arm towards the object and in the case the human moves or changes the way he/she presents the object, the robot must be able to quickly decide to keep the same grasp or to select another one. Once the robot has decided how it will take the object, it has to plan a safe motion and executes this motion in a manner that is comfortable to the human.

We will focus on several parts that we have developed so far and present some preliminary results.

The paper is presented as follows. Section II presents our method to precompute a dense list of grasps that can then be used online to quickly select a grasp adapted to the way the human holds the object to give. Section III concerns the planning issues involved with the approach motion of the robot's arm. The robot must first plans a collision-free path to reach the object. The computed path does not explicitely consider time and must be transformed into a trajectory, by the mean of a soft-motion planner that provides a smooth and natural motion. The robot may also have to change the target grasp in the case the human moves too much or changes the way he/she presents the object. Once the robot has achieved its approach motion, it has to decide to grip the object to effectively take it from the human. Such a decision should rely on a fine knowledge of the forces occuring during the object exchange. To measure and analyse such forces, we conceived and built a smart device presented in section IV. Section V proposes some preliminary results for the different techniques mentioned above. Section VI exposes some of the challenging issues that remain to completely achive the task considered in the paper.

II. Grasp Planning

Grasp planning of a complex object has been so far too computationally expensive to consider it can be performed in real-time. Therefore, in a real application, it is preferable to use precomputations as much as possible. In the proposed framework, a grasp list is computed off-line for the considered object so as to capture the best possible the variety of the possible grasps (Fig. 1). This list will then be used to select, during interactive grasping, the grasps that are currently reachable and from them the best one according to a scoring function. As it is computed once, the grasp list has to be dense. We choose to sample the possible relative hand/object poses by the mean of a grid for both position and orientation. Although it is an off-line process, the computation of the grasp list must be as fast as possible. Therefore we make use of data structures that efficiently approximate both object surface and finger workspace in order to fastly determine which part of the object is reachable from the fingers for a given relative hand/object pose.

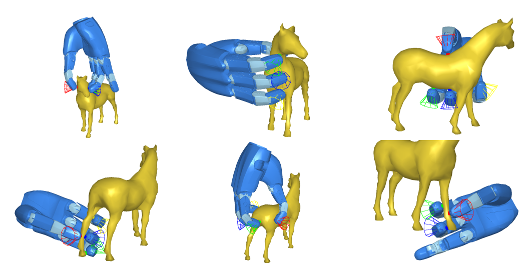

Fig. 1. Some of the various grasps that were computed for an object with a complex shape. (Friction cones are also represented).

III. Approach motion of the robot's arm

A first step is to compute a collision-free path for the arm. This can be simply done with the use of a classic RRT exploration. However, the result path has to be converted into a time trajectory so that it can be used as an input of the arm joint controller. This is the role of our soft-motion trajectory planner. The input path is composed of segments. Along each segment, the motion of the tool frame is a linear cartesian path. The soft-motion planner converts these segments into series of cubic segments for translations and rotations that saturate jerk, acceleration and velocity. For these bounds, that are user-defined, the computed trajectory is time-optimal. The result is a trajectory that looks natural and reduces the risk to surprise the human (Fig. 2).

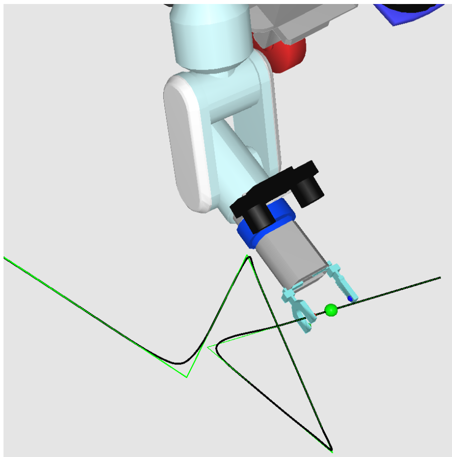

Fig. 2. An example of transformation of a path (green line segments) into a smooth trajectory (black curve), for the tool center point (green sphere).

IV. Force feedback of the object exchange

The interpretation of the force measured during the object exchange phase is of great importance for the robot decision module. Indeed, the robot must decide when it can take the object from the human *i.e.* grip firmly the object and start the motion to bring back its arm. To analyse such interaction forces, we have designed and built a smart device called Bidule (Fig. 3), that is capable of recording interaction forces. Bidule embeds a micro-computer with wifi link, a 6D force sensor and an accelerometer to compensate inertial forces. The shape and size was chosen to be adapted to the human hand.

Fig. 3. The object Bidule can measure the interaction forces that occur during the object exchange.

V. Preliminary Results

Some results have been obtained for the previously described functionalities. The grasp planner has been tested in our simulator, to plan the grasp of an object moved in real-time by the user's mouse. The soft-motion planner is implemented in our robot Jido. It can be used, for instance, to carefully carry a filled glass without pouring liquid. The Bidule device was used to collect force data of human-human exchange. The analysis of the data allows us to build a model of the interaction forces. Considering the case of a robot-human object exchange (*i.e.* the human takes the object from the robot), we built a controller, based upon the model, that can robustly decide when the robot can release the object for the human to take it (Fig. 4).

Fig. 4. This picture shows a human just touching the object; the detector does not misinterpretes this as a grasp and the grip does not open.

VI. Future Work

Several problems remain to be solved to have a complete framework to reactively and safely take the object given by the human. Visual perception is clearly a major difficulty, as it must be real-time, deal with the likely partial occlusion of the object by the human hand and track objects and human movements. As it is not a focus of the DEXMART project or of our research group, we plan to rely on existing techniques or to bypass the difficulty with the use of specific hardware like motion capture system. More interesting topics, from our point of view, concern the decision procedures of the robot. Particularly, knowing when the robot grasps the object is not an easy task and should rely on several sensor modalities like vision and tactile or finger joint torque sennsors. At last, the quality of the realized grasp must be evaluated. Unfortunately the Schunk hand we use is not equiped with tactile sensors to determine the contact points.

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