Assembly Planning of Ring-shaped Elastic Objects

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Abstract

This paper discusses a motion planning method for assembling a ring-shaped elastic part to a cylindrical part by using a dual-arm manipulator. When assembling a ring-shaped elastic part, it is important to keep the amount of elastic deformation as small as possible during the assembly task. To achieve this purpose, we show that it is effective to utilize the Covariant Hamiltonian Optimization and Motion Planing (CHOMP) method. We introduce an energy based objective functional that is obtained by adding a term related to the potential energy of the elastic object. This objective functional yields a trajectory where the deformation of the elastic object is minimized. To confirm the validity of the proposed planner, experimental results on the Baxter robot are presented using two different ring-shaped objects.

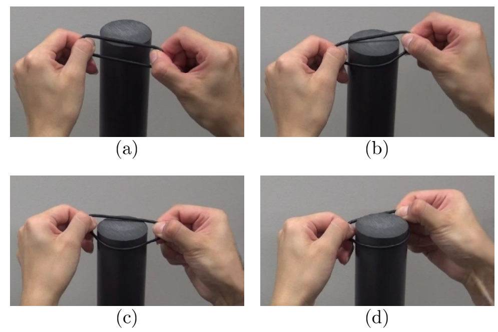

Figure 1: Assembly process of a ring-shaped elastic object performed by a human in four steps, (a) step 1, (b) step 2, (c) step 3 and (d) step 4.

Introduction

The assembly planning of ring-shaped elastic objects, is a task that remains done by humans and is frequently used by the manufacturing industry. This type of assembly is commonly carried out in the fabricating process of machines in order to seal oil or water pipes. When a human does the assembly process described above, usually he/she will first insert just a part of the ring-shaped object at one side of the cylinder, then he/she will pull the object, resulting in the object's deformation, and finally he/she will finish inserting the rest of the object by moving his/her hands towards the opposite side (of the starting position) of the cylinder, as shown in Fig. 1. The goal of this work is to develop a planner able to automatically plan the motion for a dual-arm manipulator that assembles an elastic object into a cylinder, under the assumption that the object's material, size and shape are known. The objects used at this kind of assembly process, usually have a relatively low elasticity which implies that a large deformation requires a considerable amount of force applied by the manipulator. Consequently, it is desirable to keep the object's deformation as small as possible. For this problem, this paper proposes a method that can easily and effectively reduce the amount of elastic deformation during the assembly process. In our previous work, we proposed a motion planner based on the Covariant Hamiltonian Optimization and Motion Planing (CHOMP, Zucker et al.), where an object's elastic energy related term (included into the optimization problem of the CHOMP method) was used for planning the assembly step motion of an elastic ring-shaped object by using a two-arm robot (Ramirez-Alpizar, Harada, and Yoshida 2014). Extending our previous work, we show the experimental results carried out on the Rethink Robotics' Baxter Research Robot using a common rubber band and an o-ring (packing).

Assembly Planning

Let us consider the motion planning for the assembly of a ring-shaped object into a cylinder, as shown in Fig. 1. We assume that the diameter of the ring-shaped object without deformation is smaller than that of the cylinder, which implies that the object must to be stretched in order to be inserted into the cylinder. Furthermore, we make the following assumptions:

1: The manipulator grasps firmly the elastic object.
2: The grasping point of the elastic object with respect to the manipulator's wrist coordinate system is known and it is constant.
3: The size, shape and Young's Modulus of the object are known.
4: The cylinder used for the assembly task is static, rigid and its position and dimensions are known.

In this work, we use a dual-arm manipulator to achieve the assembly task. In a similar fashion to the assembly motion done by a human shown in Fig. 1, the robot first inserts a part of the ring-shaped object at one side of the cylinder,

Figure 2: O-ring shaped objects used in experiments: a rubber band (a) and an o-ring (b).

then the robot pulls the object, resulting in the object's deformation, finally the robot finishes inserting the rest of the object by moving the hands towards the opposite side of the starting position. We divide the assembly process in several steps where only one of the arms moves at each step, alternating between left and right arms. We generate a set of key poses for the robot to determine intermediate goals, that is, a position goal at each step. These key poses are generated based on the position of both grippers at each assembly step, which gives robustness to our planner in the sense that even if the gripper does not arrive to the exact desired position, the positioning error will not accumulate. The trajectory between the key poses of each step is compute with the modified CHOMP algorithm proposed in our previous work (Ramirez-Alpizar, Harada, and Yoshida 2014).

Experimental Results

In this section the experimental results of the proposed assembly planner using a Baxter robot are presented. For validating the proposed assembly planner we used two type of ring-shaped elastic objects, the first one is a common rubber band (natural rubber) shown in Fig. 2(a), and the second is an o-ring (nitrile rubber or NBR) shown in Fig. 2(b) commonly known as a packing, which has fewer elasticity than the rubber band. The undeformed inner diameter of the rubber band is 47.0 mm while for the o-ring is 49.4 mm, the thickness of the rubber band is 1.0 mm and that of the o-ring is 3.0 mm, the diameter of the cylinder is 50.0 mm. The parameters given to both the sequence planner and the CHOMP algorithm are those of the o-ring, that has a Young's modulus of ≈ 4.125 MPa (based on the o-ring's manufacturer data sheet). The joints' trajectories requested to the robot are exactly the same for both objects. Figs. 3 and 4 show the snapshots of the experiments with the rubber band and the o-ring, respectively. It can be verify that the robot successfully assemblies both of the ring-shaped objects into the cylinder.

Conclusion

This paper discussed the assembly planning of ring-shaped elastic objects. We presented an assembly planner for a dual-arm robot that computes key poses of the robot to successfully accomplish the assembly task of a ring-shaped object into a cylinder. We showed experimental results using two different elastic ring-shaped objects to confirm the validity of the proposed assembly planner.

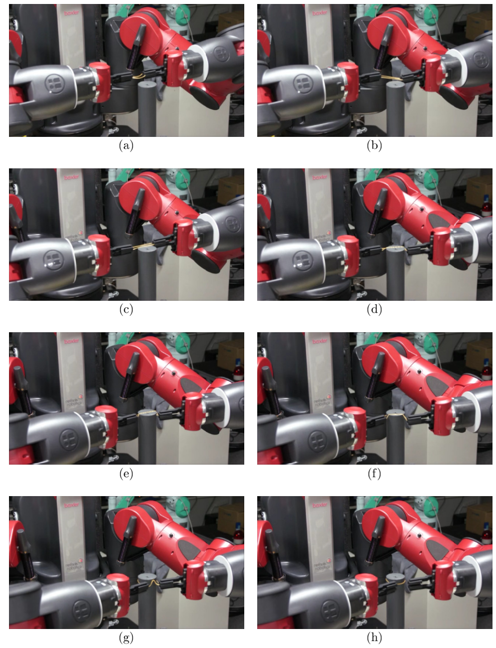

Figure 3: Snapshots of the experiment using a rubber band in sequential order from (a) initial state to (h) releasing the object

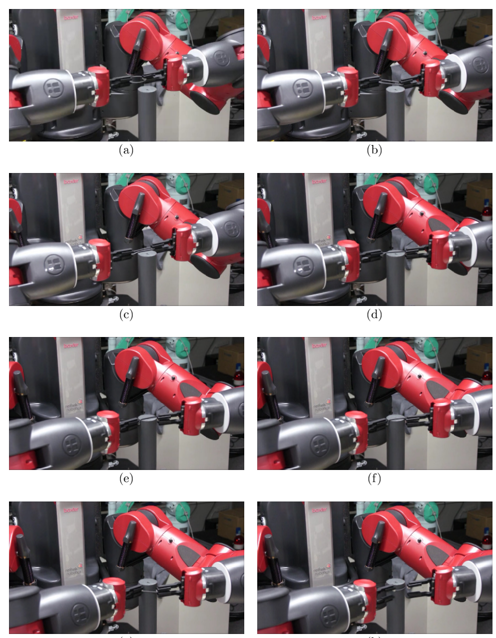

Figure 4: Snapshots of the experiment using an o-ring in sequential order from (a) initial state to (h) releasing the object

References

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