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Validating an object placement planner for robotic pick-and-place tasks

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ABSTRACT

This paper proposes an object placement planner for a grasped object during pick-and-place tasks. The proposed planner automatically determines the pose of an object that is stably placed near a user-assigned point on the environment surface. In our proposed method, first the polygon models of both the object and the environment are clustered, with each cluster being approximated by a planar region. The position/orientation of an object placed on the environment surface can be determined by selecting a pair of clusters: one from the object and the other from the environment. We furthermore conduct several tests to determine the position/orientation of the object, namely the Convexity Test, the Contact Test and the Stability Test. We demonstrate that, by using the polygon model of the environment that is obtained by means of conversion of the point cloud, we can determine the position/orientation of an object and can thereby realize a pick-and-place task.

1. Introduction

Picking and placing is one of the most common tasks that a robot is required to achieve. However, it is often difficult for a robot to automatically plan its pick-and-place motion. One reason for this difficulty is the geometrical complexity of both the environment and the grasped object. Fig. 1 shows an example of a robot's working environment for achieving a pick-and-place task. When a robot performs a pick-and-place task in an environment in which many everyday objects are randomly placed, the robot may place the object in a narrow area surrounded by other objects, or on top of other objects. In addition, the robot may sometimes hang an object on a bar. However, there is no clear solution for determining the position/orientation of an object that is stably placed on the environment surface during a pick-and-place task.

To deal with this issue, this paper proposes a general framework for determining the position/orientation of an object that is stably placed near a user-assigned point on the environment surface, under the assumption that a planar part of the object surface makes contact with a planar part of the environment surface. Our proposed planner assumes polygon models for both the object and the environment. Our proposed planner consists of offline and online phases. In the offline phase, we apply clustering of the polygon models of both the object and the environment, with each cluster being approximated by a planar region. In the online phase, the position/orientation of an object is planned by selecting a pair of clusters: one from the object and the other from the environment. For a pair of clusters to be in contact with each other, we consider checking convexity of the shapes, since the concave part of an object surface cannot be in contact with the concave part of the environment surface. Following this, we obtain candidates for the posture of an object placed on the environment surface by determining whether or not an object can make contact with the environment. Finally, we establish whether or not an object can maintain its contact with the environment by checking the gravitational equilibrium.

The remainder of the paper is organized as follows. After the related works are discussed in Section 2, Section 3 shows definitions and assumptions used in this research. Section 4 details the offline surface clustering method. Section 5 describes the searching method for the object pose. In Section 6 we demonstrate the efficiency of our method by means of several numerical examples and experimental results.

2. Related works

This paper proposes an object placement planner for use in robotic pick-and-place planning. Lozano-Perez et al. [1] first proposed the grasp and motion planning problem, and in the decade

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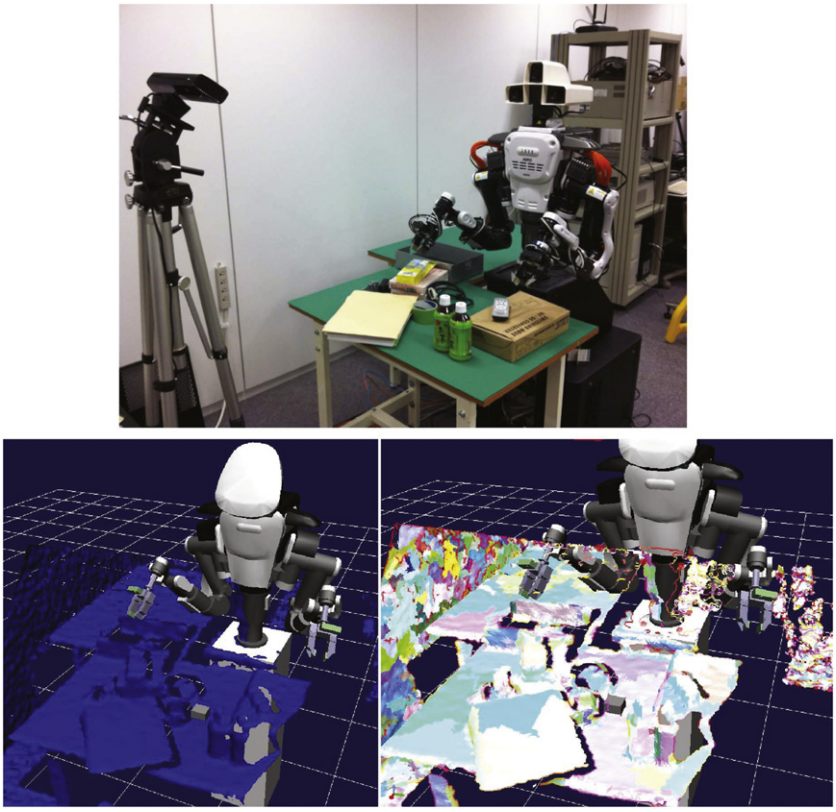

Fig. 1. Working environment for performing the pick-and-place task.

following this, this problem has been extensively researched [2–8]. However, there has not been a great deal of research in object placement planning. Katz et al. [9] pointed out the key technologies for robots working in an unstructured environment, and mentioned the object placement planner. Berenson et al. [4] planned the grasping posture for a multi-fingered hand by taking the placing pose of an object into consideration. In this case, the placing pose of an object is determined in advance of planning the pick-and-place motion. Schuster et al. [10] and Jiang et al. [11] used the point cloud during pick-and-place tasks in order to identify a planar area of the environment. In comparison to these methods, our object placement planner is more general, and also takes shape convexity and gravitational equilibrium into account. The software package OpenRAVE [12] is equipped with a function for determining the position/orientation of an object placed on the environment surface based on physical simulation. On the other hand, this paper proposes a static geometrical approach on the object placement planner. Our planner generates multiple candidates of the object postures placed on the environment based on the geometrical analysis between an object and environment. Then, we check whether or not the static equilibrium under gravity can be maintained. Since our planner does not rely on physical simulators, we can explicitly specify the target area on both the object and the environment that make contact with each other. We already proposed the object placement planner in our previous research [13]. In the previous paper, we provided only two example of the motion of the robot to verify the effectiveness of the object placement planner. However, in our new study, we have newly provided various numerical examples and experimental results. We have furthermore expanded on and improved the description of the theoretical aspects of the proposed algorithm.

Several studies have focused on identifying a planar area from point cloud data, such as [14–16]. Furthermore, the clustering method of polygon models has been extensively researched in the field of computer graphics; for example, in [17,18]. Our research proposes an object placement planner for realizing robotic pick-and-place tasks based on the clustering method of polygon models.

3. Definitions

This section introduces some definitions used in this paper. As we will state in the following assumption section, the proposed object placement planner assumes that a planar area of the object surface makes contact with a planar area of the environment surface. We first motivate the definition of planar areas on the object and the environment surfaces. Then, we will introduce some assumptions used in this paper. Furthermore, we show the solvability of our object placement planner.

3.1. Planar area

We assume that the object and the environment surfaces are modeled by polygons. To realize our object placement planner, we consider defining planar areas on arbitrarily shaped polygon models. Fig. 2 illustrates two methods for defining planar areas on a polygon model, where the original polygon model, its convex hull, and its clustered model are shown at the top, on the left, and on the right, respectively. In the figure on the left, planar areas are defined as a set of faces of the convex polyhedron. In contrast, in the figure on the right, planar areas are defined as a set of clusters, whereby each cluster can be approximated by a planar area (abbreviated as planar cluster). If we define planar areas by using the convex hull, it is impossible for the surface of the object that is hidden by the surface of the convex hull to make contact with the environment. For example, it is impossible to hang the handle of a cup on a bar. However, if we define planar areas by using a set of clusters, it is difficult for multiple points on the surface of the object to simultaneously contact the environment. It is therefore clear that these