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Object Recognition and Planning of Ring-type Caging for Scissors

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This paper studies retrieving geometrical features of objects with hollows and motion planning of caging constraint for such objects. To achieve caging a ring-like object, position of hollow parts is essential information, which can be acquired by vision system. With basic image processing methods, we can detect the features and posture of scissors, which has hollows on its handle. Motion planning for caging a pair of scissors can be successfully achieved within reasonable computing time.

1 Introduction

This paper studies robotic caging for objects with hollows, and proposes a method of estimating objects' posture with vision system and motion planning. Caging is a geometrical constraint for objects, where robots surround the objects to prevent them from escaping from the robotic "cage". Then it is not necessary to take force equilibrium into consideration, and only geometrical features of objects such as shape, position and orientation are required to confine the objects. As for caging for ring-like objects, the loop shape and its position are essential information to achieve caging grasps. Thus these should be acquired by any vision systems.

The authors performed caging a ring-like object to which an AR marker was attached for identification by a two-fingered robot hand [1]. Similarly caging grasps have been studied by various approaches: using point clouds [2]; vision-based planning for polyhedron [3]. This paper focuses on vision-based caging grasps for ring-like objects, whose strategy was proposed in our previous works. Object recognition to retrieve geometrical features of objects and motion planning for caging are main contributions of this paper.

2 Object Recognition

2.1 Position of Handle of Scissors

Estimating position of handle of scissors, which has two loop shapes, is performed using contours detection and ellipse approximation as following procedure:

Step 1. Convert an image to a gray-scale one and apply median filter to it.
Step 2. Detect contours using luminance gradient and run closing processing to connect separated contours.
Step 3. Recognize loop contours from a binary image. Then the loops make nested structure [4].
Step 4. The loops surrounded by the outermost loop are approximated by each ellipse using least square method.
Step 5. Estimate major and minor axis of each ellipse and compare the distance of each axis, l_{ij} and s_{ij}, in all the combinations of ellipses.
Step 6. Assume a handle that is composed by two ellipses whose sum of differences, $|l_{ij}| + |s_{ij}|$ is smallest in all the combinations. This condition can lead two ellipses who are in almost same size.

2.2 Orientation of Scissors

After estimating position of handle of scissors, we also estimate their orientation because it is necessary to grasp a pair of scissors in proper posture to use. In this subsection, we estimate orientation of scissors from relative position between the blades of scissors and the handle examined by calculating outer product of vectors. The procedure of estimating is described below:

Step 1. Define a direction vector, $\boldsymbol{p}$, between each center of two ellipses approximating the hollows of handle.
Step 2. Detect the blades of scissors as several line segments recognized from Hough transform [5] applied to contours in a gray-scale image in Step 2 in Sec. 2.1.
Step 3. Define a direction vector, $\boldsymbol{x}_i$, from the foot of $\boldsymbol{p}$ to a endpoint of a line segment detected above, X_i.
Step 4. Examine the relative position of X_i to the blades. X_i locates either side of blades, right or left, and it can be determined by the sign of $\boldsymbol{p} \times \boldsymbol{x}_i$. This test is done for every endpoint of detected line segments.
Step 5. Estimate orientation of the scissors by majority decision.

2.3 Distance Estimation by Stereo Vision

In this paper, distance estimation are performed using stereo vision. To reduce costs of exploring matching points in two images, we adopt epipolar geometry, which can make two-dimensional exploring area to one dimension. Additionally stereo rectification also contributes to reduce exploring dimension by putting two epipolar lines in parallel. In matching process of corresponding points between stereo images, SURF features are utilized.

2.4 Experimental Results

We experimentally verify our proposed method to recognize position and orientation of scissors by vision. We use two webcams: C525, a product by Logicool, which has 2 million pixels, and OpenCV [4] for image processing running on Linux PC with Intel Core i5-3450S-2.8GHz.

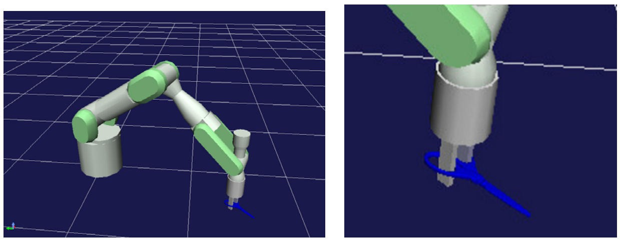
As results, scissors with a simply-decorated handle can be easily detected with high success rate over 90% while the objects are looked down vertically (Fig. 1(a)). In contrast, very decorated handle such as with multiple colors or complicate textures is less recognized with 33% success rate (Fig. 1(b)).

Next we try to estimate the orientation of the scissors which are properly detected with their handle with same conditions. The estimation is performed with high success rate over 90% for all the scissors. Consequently, our proposed method to estimate orientation of scissors can succeed if detection of handle of scissors is properly performed.

Distance estimation with stereo vision is performed for each condition: the distance between the object and the cameras from 200 to 1000 mm. Average error ratio against estimated distance in 10 trials are about 4±2%.

(a) Successful detection of scissors (b) Failure case of detection

Fig. 1 Posture estimation for scissors



(a) Planned posture of the robot (b) Hand posture for caging grasp

Fig. 2 Planned caging grasp

3 Planning Caging Motion

With obtained geometrical information of target object by above proposed method, we perform motion planning for caging grasps using Choreonoid [6] and graspPlugin [7]. Choreonoid is a platform for motion planning using PRM (Probabilistic RoadMap), and graspPlugin is a plugin package for Choreonoid, focusing on grasping and task planning. We modify the grasp planner to generate caging grasps, where force equilibrium is not considered but geometrical conditions are essential.

3.1 Experimental Conditions and Procedure for Caging Scissors

Caging scissors can be achieved by inserting robot fingers to hollows of handle. If the scissors are laid on the desk, the combination of inserted fingers and the desk can constraint the object geometrically as [8]. This caging grasps (constraints) can be performed by a usual robotic gripper with 1 DOF. In our simulations, the scissors are caged by a gripper attached to PA10, a 7 DOF manipulator.

In this paper, the following conditions are presumed: there are no obstacles around target objects; the target object lies on the XY plane; a camera is attached to a palm of the robot hand. With the conditions, the following procedure is performed in motion planning.

Step 1. Obtain position of both hollows of the handle in the camera coordination, p_{1c}, p_{2c}.

Step 2. Calculate each position in the world coordination, p_{1w}, p_{2w} with position and orientation of the palm in the world coordination, $p_{\mathrm{palm}}, \boldsymbol{R}_{\mathrm{palm}}$:

$$p_{iw} = p_{\mathrm{palm}} + \boldsymbol{R}_{\mathrm{palm}} p_{ic} \qquad (i = 1, 2) \tag{1}$$

Step 3. Move the robot hand to right over of midpoint between p_{1w} and p_{2w}, and rotate it to let the gripper vertical.

Step 4. Let the line segment between both gripper fingers in parallel to the line segment between p_{1w} and p_{2w}.

Step 5. Approach the gripper to the object, and close it.

3.2 Simulation Results

We demonstrated motion planning of caging for scissors with two object setting: open and closed scissors. Since our vision system has not yet connected to the planner, we manually give the planner the position and orientation of scissors.

To approach the gripper from right over the scissors, the gripper fingers can be inserted to the hollows of the handle without any occupation, that is, caging motion can be achieved (Fig. 2). The computation time to generate robot posture for caging and to plan a path to the goal configuration is 10 ms and 10 ms respectively.

4 Conclusion

This paper studied caging an object with hollows, and proposed estimation method of object posture with vision system and motion planning using Choreonoid [6] and graspPlugin [7]. As an example of the object, we focus on pairs of scissors, and obtain position of the handle and orientation of scissors. In motion planning, Choreonoid with our modified graspPlugin worked well to generate caging constraint for scissors within reasonable computing time.

In future works, connecting practical vision and robot systems to our object recognition and motion planner should be considered. Moreover other objects with hollows and other shapes, which need other caging strategies, will be included.

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