Object Search and Empty Space Detection System for Home Service Robot

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Abstract

Home service robots have pick-and-place tasks to grasp and carry objects. When performing pick-and-place tasks, robots need to process to search for objects in the case of missing a target object. We propose approaches for the robot to search for a target object from a shelf and a method for selecting empty spaces to move off-target objects. The proposed method is based on two recognition models to select a space and plan motions. The object is to be moved and the space is selected based on the size and position of empty spaces. In the experiments, the robot planned actions to search for a target object from a shelf and to place an object near a group of similar objects. We used these in the RoboCup@Home competition to evaluate the effectiveness of the proposed method.

Keywords: Home service robot, mobile manipulator, Object detection, RoboCup@Home

1. Introduction

Home service robots have begun to attract increasing attention due to the needs of an aging society with a declining birth rate [1],[2],[3]. The essential functions of home service robots are object recognition, picking and placing, recognition of people and environment, and interaction with people. We have conducted various studies using TOYOTA's home service robot HSR [4] and our robot Exi@ [5]. So far, Various studies on the social implementation of service robots for home use have been presented through competitions [6],[7],[8],[9]. These studies have mainly proposed tidying environment recognition, object recognition at edge devices, efficient motion planning, and pick-and-place strategies.

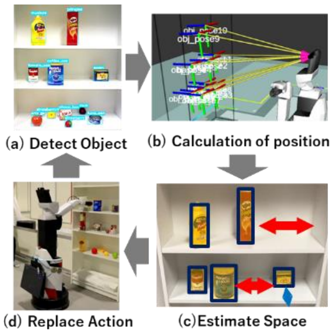

Fig. 1. System Overview

Home service robots use these proposed techniques to perform various tasks, such as shelf placement, room cleaning, and restaurant clerking. Common to all these tasks is searching for the target object.

If the person cannot find the target object, they perform actions such as moving an obstacle object. The person moves an object with predictability, and we wondered if it would be possible for the robot.

This paper proposes a method for the robot to search the shelf. This method defines space at the back end of object recognition systems. And the robot moves obstructive objects into empty spaces.

We implement these methods on TOYOTA's home service robot HSR. As a validation, we used them in RoboCup@Home [10], a competition for home service robots, to verify their effectiveness.

2. Previous research

2.1. *Object recognition & estimate position*

There are various methods for mobile manipulators to detect the location of objects and pick them. In our previous research, we created one that utilizes YolactEdge [11] and point cloud information. This recognition technology can estimate the position and posture of an object [12].

2.2. *Problem*

There are many objects in the home environment, including furniture such as desks and shelves. Because of this, objects overlap, creating blind spots where the desired object cannot be detected, and the desired object may not be located.

3. Proposed Method

3.1. Motion to move obstacle objects

First, we propose a simple method for locating objects on the shelf. In this model, the size of the shelf is assumed to be known. The theme of this model is how to grab an object in the way. Then, it is how to move it to an available location. (Fig. 1.)

(a). Object recognition by YolactEdge
(b). Calculation of position from depth information
(c). Estimating empty and unseen areas based on the size and position of an object
(d). Move larger-sized objects to a space.
(e). Object detection again (to (a))

3.2. Estimate space

The second method is estimating the number of available placement locations using semantic segmentation to detect planes. We use Estimating Available Placement Locations [13] (Fig.2.).

(a). Planar detection by semantic segmentation
(b). Clop and convert planar point cloud information
(c). Morphology transformations
(d). Blurred to remove information on the edges

The robot must decide where to place the object from the candidate regions. The robot scores each point in the candidate region and places the object at the highest rated point. In the experiment, the robot selects the point in the candidate region that is the nearest to it (Fig.3.). In the case of (Fig. 3.), the point closest to the robot was the bottom left of the output image in (Fig. 2.). We defined a distance map such that the bottom left is the highest point, and the score decreases with each Euclidean distance away from the robot.

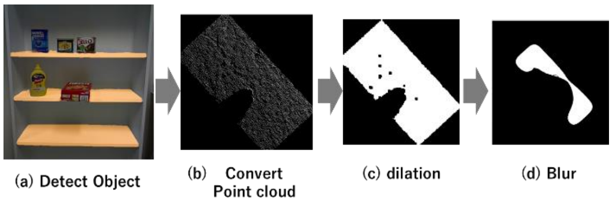

Fig. 2. Estimate empty space

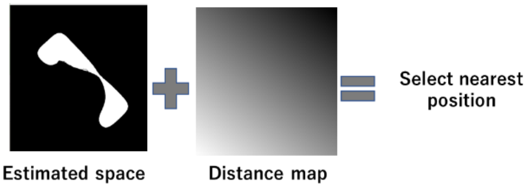

Fig. 3. Select the available position

4. Experimental

4.1. *RoboCup@Home*

The system's validity was verified and experimented with in this section through a RoboCup@Home competition. The conditions and results are summarized.

4.2. *Go and get it task*

We have tested the effectiveness of an object search task by running it on a shelf at the World Robot Challenge 2020 (WRC2020) [14], the RoboCup Asia-Pacific 2021

(RCAP2021) [15], and RoboCup Japan Open 2021(RCJ2021) [16].

The task performed was to search for the target object on a shelf. The object used is the YCB object [17]. It searches for the target object on a shelf with 15~20 objects. An example of object placement is shown in (Fig. 4).

Fig. 4. YCB object placed on the shelf [14]

4.3. *Storing Groceries task*

In RoboCup@Home 2022 [18], the task of placing an object on a shelf was performed. The method of estimating space described in 3.2 has been verified.

An example of object placement is shown in (Fig. 5). From the initial state, four to six objects are placed on the shelf. The robot must place objects on the shelf near objects of the same category. The robot can place up to 5 objects on the shelf.

Fig. 5. Storing Groceries task shelf

5. Experimental result

5.1. *Go and get it task*

We tested the effectiveness of this task six times in WRC2020 and four times in RCAP2021 and RCJ2021 in each competition. The results are summarized in Table 1. As a result, the target object was found 12 out of 14 times with a success rate of more than 85%.

Table 1. Success rate in grasping the target

Competition	Challenge [times]	Success [times]	Success rate [-]
WRC 2020	6	6	1.00
RCAP 2021	4	3	0.75
RCJ 2021	4	3	0.75
total	14	12	0.86

5.2. *Storing Groceries task*

We tested the operation of the estimation of empty space in four trials at RoboCup 2022. Ten empty space estimations were performed in the four trials. The results are summarized in Table 2.

The task has two evaluations: the number of successful attempts to place an empty space and the number of times an object could be placed near the same category. The number of successful attempts to place the object in an empty space was 10 out of 10, but the overall correct classification rate was about 60%.

There are cases of classification errors. This is because the robot tries to place objects in larger spaces. The robot tends to select open spaces between object categories.

Table 2. Storing Groceries grasping task

Trials	Challenge [times]	Success [times]	successful classification [times]	successful classification rate
First	0	-	-	0
Second	0	-	-	0
Third	5	5	2	0.4
Fourth	5	5	4	0.8
total	10	10	6	0.6

Notice : The first and second attempts did not proceed to object grasping due to robot errors.

6. Discussion

In this study, we proposed search method from shelf for home service robots and conducted experiments in RoboCup tasks. The experimental results show that our method is effective in that.

However, when classification is required, as in the storing groceries task, it makes an incorrect select. This is because it selects an area that is easier to place a larger area without even an object of the same category.

To solve this problem, it is necessary to define a new region for each category and select a space from among them.

7. Conclusion

In this study, we proposed and applied a search method that fully utilizes object rearrangement and spatial detection to search for objects on the shelf of a home service robot.

The proposed method is simple and can be implemented at a later stage of existing recognition methods, and its effectiveness was evaluated in competitions such as RoboCup@Home. In the future, we aim to incorporate overlap recognition methods into the recognition itself, such as UOAIS [19], and to define candidate regions for each category for accurate placement selection.

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