Proposal of a Grasp Verification Method Utilizing Background Subtraction and Depth Information

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Abstract

Commonly grasp verification approach involves using the opening width of the robot's gripper. However, methods based on the opening width of the gripper may not apply to slender objects. In this study, we propose a grasp verification method using background subtraction. Our proposed method uses depth information to mask the background, isolating only the images of the gripper and the grasped object. Subsequently, a difference image is created by comparing the current image with the pre-grasp state, and the grasp state is detected based on the magnitude of the observed changes. The method minimizes environmental influences by masking the background, enabling highly accurate grasp verification even for complex objects. Through experiments, we validate the effectiveness of the proposed method.

Keywords: grasp verification, background subtraction, mask

1. Introduction

In recent years, the demand for robots has been increasing in various fields, including both industrial and service sectors [1], [2], [3], [4]. Grasping objects is one of the fundamental functionality required for these robots across different applications [5], [6]. Since there is a possibility of failure in object grasping by robots, grasp verification is necessary to reduce the risk of such failure. Conventional methods for grasp verification often employ the opening width of the robot's gripper. However, these approaches are limited in their ability to accurately determine successful grasps for objects with thin. In this study, we propose a background subtraction based grasp verification for thin objects. Our method uses depth to mask areas other than a robot arm and grasped object. This approach makes it possible to reduce the influence of environmental changes. Afterward, the difference between the images before and after the grasp is calculated. The grasp of success or failure is then detected based on the observed changes. In this study, we validate the proposed method through experiments and demonstrate its effectiveness.

2. Related works

2.1. *Kulkarni et al.'s Method*

Kulkarni et al.'s method [7] integrates inexpensive proximity sensors into the robot's fingers. This method enables the development of a system capable of detecting the grasping state and slippage of an object. In this method, the sensor's reference value is updated online by recording the sensor value in a non-grasping state as the baseline. The grasping state of an object is then evaluated based on this reference value. The method determines a successful grasp when the finger's deformation exceeds a certain threshold. In addition, a moving average filter is applied for noise elimination. This approach enables reliable signal processing with minimal computational load. As a result, a 100% success rate in grasp verification was achieved for 16 out of 19 objects. However, applying Kulkarni et al's method requires attaching proximity sensors to the hands of the robots, resulting in high implementation costs. Furthermore, it is also necessary to consider the impact on other grasping processes. Therefore, exploring methods to improve grasping accuracy without using proximity sensors is required. In this study, we propose a method to improve grasp verification accuracy without using proximity sensors.

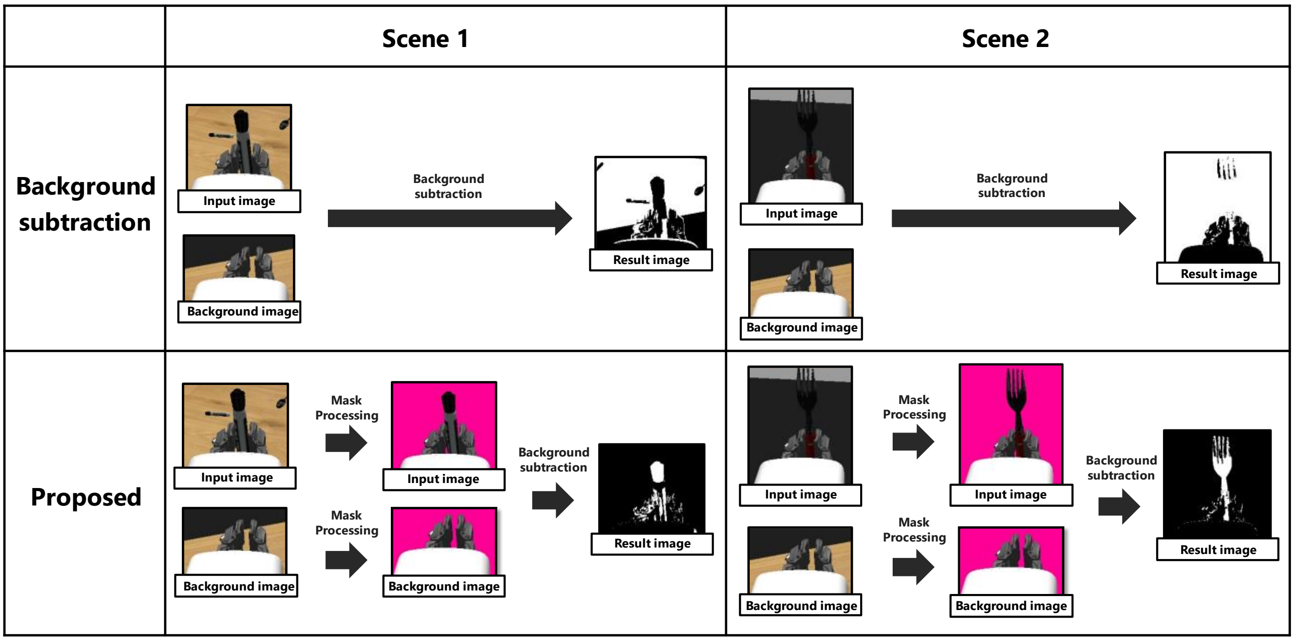

Fig. 1 Grasp verification process flow and output results of the background subtraction method and the proposed method in different scenes

2.2. CAD2GraspMonitor

CAD2GraspMonitor [8] has been proposed as a method to improve the accuracy of grasping in industrial robot picking operations. In this study, object recognition using YOLO [9] (YOLOv7) is combined with background subtraction methods. This method enables multiple quality inspection functionalities, including presence-absence confirmation of objects, type verification, pose estimation, and surplus detection. The pose estimation determines the object's position and orientation with millimeter-level accuracy, enabling the detection and correction of any misalignment in the grasp. The background subtraction method used in this study adopts a constant background and is applied to detect surplus objects. While CAD2GraspMonitor achieves high accuracy under specific conditions, it cannot handle diverse backgrounds. In this study, we propose a method that maintains grasp verification accuracy even in the presence of varied backgrounds.

3. Proposed Method

In this study, we propose a grasp verification method that utilizes background subtraction and depth information. Fig. 1 shows the processing flow of the proposed method and the back subtraction method(without masking). First, an image of the robot hand is captured using the robot's head camera before the grasping action and used as the background image. Next, a new image is captured after the robot performs the grasping action. The proposed method then applies mask processing using depth information to both the input and background images. Through mask processing, regions other than the robot arm and the grasped object are masked. This ensures reliable decision-making even in the appearance of varied backgrounds. Finally, background subtraction is applied between the background and input images to calculate the difference. As shown in fig. 1, the variation of the background causes unreliable judgement. If the difference exceeds a predetermined threshold, it is determined that the robot arm has successfully grasped the object. On the other

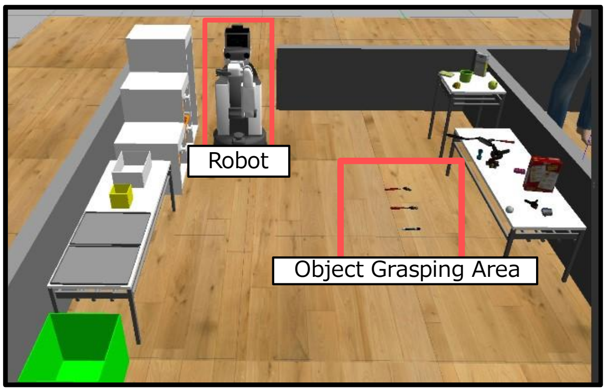

Fig. 2 Simulator environment for grasp verification experiments

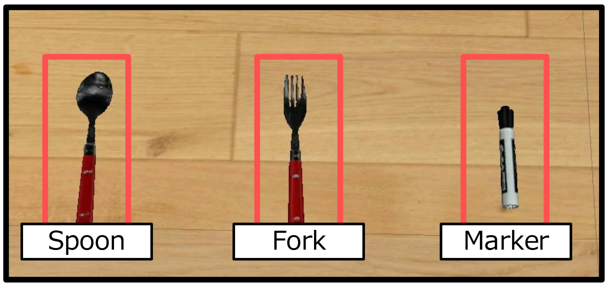

Fig. 3 Thin objects for grasping validation

Table 1 Results of grasp verification using background subtraction and depth information

	Spoon	Fork	Marker	Grasping failures detected
Background subtraction (without masking)	15/20(75%)	16/20(80%)	15/20(75%)	4/20(20%)
Proposed Method (with masking)	**19/20(95%)**	**19/20(95%)**	**18/20(90%)**	**20/20(100%)**

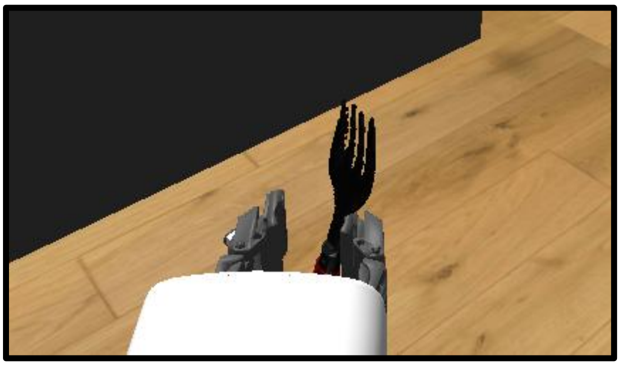

Fig. 4 Example of unexpected differences occurring in unintended areas due to an impossible grasp to achieve in the real world

hand, if the difference is below the threshold, it is judged that the grasping attempt has failed.

4. Experiments

4.1. *Setup for experiments*

Fig. 2 shows the simulator environment used for the grasp verification experiment. Fig. 3 shows a spoon, a fork, and a marker selected YCB object [10] for the experiment. In this study, 20 grasp validation were conducted for each object using the proposed method and the background subtraction method(without masking). In this experiment, a successful grasp is defined as a grasp if more than 20% of the pixels in the resulting image are output as differences. Also, we checked to see if we could detect grasping failures.

4.2. *Experimental Result*

Table 1 shows the experimental results comparing the proposed method and the background subtraction for grasp verification. The background subtraction method (without masking) shows 75% accuracy for spoons, 80% for forks, 75% for markers, and only 20% for detecting grasping failure. The proposed method shows 95% accuracy in grasp verification for the spoon and fork, 90% for the marker, and 100% for detecting grasp failure. These results represent the effectiveness of the proposed method.

5. Discussion

The proposed method was confirmed to enable accurate grasp verification for thin objects. Experimental results showed higher grasp verification accuracy than the existing method, the background subtraction (without masking). When using only the background subtraction (without masking), the accuracy was decreased due to large differences caused by background changes. Therefore, it caused the object to be mistakenly recognized as grasped, even when it was not grasped. The proposed method combines background subtraction with mask processing to reduce such misjudgments and enable more accurate grasp verification. On the other hand, the following two points can be attributed to the failure of some grasp verifications in the proposed method. The first is that there were cases in which the majority of the object was in the camera view field when the object was grasped and the difference was not sufficiently detected. Second, the unexpected part of the difference was caused by the grasping that is impossible in reality, as shown in Fig. 4. The first problem indicates the limits of the proposed method and suggests that further improvements are needed. On the other hand, the second problem is likely to be a simulator-specific factor. Therefore, this issue may be resolved through implementation in a real environment. In the future, this system should be applied to actual equipment to verify in detail the actual operating accuracy and operational constraints.

6. Conclusion

In this study, we proposed a grasping verification method using background subtraction and depth information for thin objects. Experimental results show high grasp verification accuracy for thin objects. The proposed method was also confirmed to be superior to the existing study. It exceeds Kulkarni et al.'s method in its ability to handle diverse backgrounds. However, it was confirmed that some issues occurred during grasp verification. One of the issues was caused by unrealistic grasping actions specific to simulators. To address this issue, we will implement the proposed method into a home service robot [11] in a real-world environment to further validate its efficiency.

Acknowledgments

This research is based on results from a JPNP16007 project commissioned by the New Energy and Industrial Technology Development Organization (NEDO). This research received support from JSPS KAKENHI Grant Number 23H03468 and 23K18495, as well as from JST ALCA-Next Grant Number JPMJAN23F3.

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