Seeing through Obstacles by Using Movable RGB-D Sensors

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For remote operation of robots in dangerous situations such as disaster sites, visual information affect the operational efficiency to a great extent. This paper presents a system which generates images as if users saw through obstacles by integrating images from two RGB-D sensors attached to a robot. The system is designed for use in more general situation than previous works.

1 Introduction

Nowadays, there is increasing demand for remote control robots to conduct dangerous tasks in disaster sites [1]. In remote operation, providing appropriate images for operators plays an important role in improving operational efficiency [2]. If a target work objects are occluded by obstacles, operators have difficulty confirming the shape or the position of the objects, which leads to a drop of operational efficiency.

We propose a system in which users can see occluded objects through obstacles by processing images from cameras (In the field of computer vision, a technique of this kind is called Diminished Reality (DR)).

2 Related Research

In this paper, we define "background" as an area which can not be seen in images because of obstacles. Since DR is a technique to remove obstacles and see the background, acquiring information of background is an important component.

Acquiring information of background is realized mainly by using multiple cameras and acquiring images from different viewpoints [4–7]. In addition, systems which allow to move cameras [3, 5, 6] produce less dead angle than those with fixed cameras. However, very few studies deal with three-dimensional information of the background [7]. Most studies mentioned above approximate the background as a two-dimensional plane because they assume that the background is faraway enough from cameras. This assumption is not acceptable for our goal, because robots work near the background (the target objects), hence three-dimensional information of background is desired.

3 Proposed Method

In this research, we suppose a robot with an arm and propose a system in which RGB-D sensors (not only RGB information as ordinary cameras can get, but also information of distance between the sensor and each point in the image can be acquired) are attached in front of the robot and on the arm, as illustrated in Fig. 1. Fig. 2 shows the flow of the process. First, images from the sensors attached in front (we call it "front sensor") and on the arm (we call it "arm sensor") are converted to three-dimensional point cloud data. Second, point clouds are coordinate-transformed to the coordinate system of "imaginary sensor", which is set in arbitrary position in space. Then, point clouds are projected on a two-dimensional output image. Finally, images generated from the front sensor and the arm sensor are integrated by alpha blending to present see-through-obstacles images.

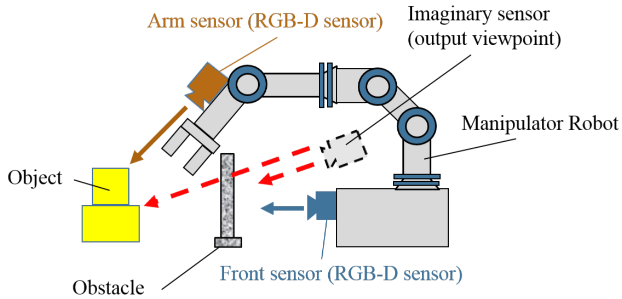

Fig. 1: The schema of the system. The RGB-D sensor on the arm moves along with the arm. The imaginary sensor, which is set in arbitrary position in space, represents the position of the viewpoint of output images.

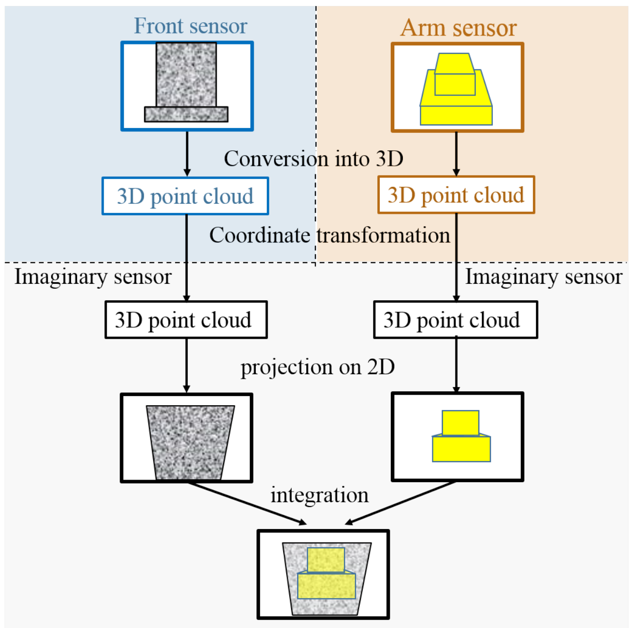

Fig. 2: The flow chart of the proposed method. Conversion from two-dimensional images into three-dimensional point cloud data, coordinate transformation, projection on the output image, and integration of two images are performed sequentially.

4 Experimental Results

Experiments are conducted to verify the effectiveness of the proposed method. Images acquired by the experiments are shown in Fig. 3, Fig. 4 and Fig. 5. The two images in Fig. 3 are input images from the front sensor and the arm sensor at a certain moment. There are an obstacle in front

Fig. 3: Input images from the front sensor (left) and the arm sensor (right) at a certain moment. In the image from the front sensor, the background behind the obstacle can not be seen.

Fig. 4: The output image at this moment. The background can be seen through the obstacle.

of the front sensor and the background can not be seen in the image from the front sensor. Fig. 4 shows the output image from the imaginary sensor at this moment, in which the background can be seen through the obstacle. Fig. 5 shows an output image after moving the position of the imaginary sensor. The position of the imaginary sensor can be moved arbitrarily even while operating the manipulator to see the environment from various viewpoints. The experimental results suggest that our system helps users to acquire information of objects behind obstacles by moving the arm sensor and/or the imaginary sensor while operating the manipulator.

5 Conclusions

We proposed a system in which operators of remote control robots can see the background through obstacles by applying DR. Our system is suitable for more general situation than previous works, because the proposed method uses RGB-D sensors, which enable to acquire three-dimensional information of the background, and the arm sensors and/or the imaginary sensor can be moved according to the environment.

For future works, efforts have to be made to expand the method for any numbers of sensors and to reduce errors in image integration.

Fig. 5: An output image after moving the position of the imaginary sensor.

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