Development of an autonomous-drive personal robot "An object recognition system using image processing and an LRS"

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Abstract: We are developing an autonomous personal robot able to perform practical tasks in a human environment based on information derived from camera images and an LRS (a laser range sensor). In the robot's adjustment to a human environment, it is very important that it be able to identify objects. If an object cannot be identified, the robot cannot hold or transport the object. For this reason, we have developed an object recognition system that allows a robot to identify an object and acquire exact location information about the object. This object recognition system is composed of both an object recognition processing part and a location information acquisition processing part. At first, the object recognition processing part searches for the object based on the shape and color of the object, image information that the user specifies. Next, the location information about the searched object is acquired by the location information acquisition processing part, which comes from LRS. Here we explain the algorithm used to acquire the location information of an object. In addition, as an evaluation of our system, we describe the results of an experiment in which location information for an object is acquired.

Keywords: Personal robot, monocular camera, Image processing, LRS, Object recognition

1. Introduction

In the near future, autonomous self-driving robots are expected to provide various services in human living environments. For this to occur, the robots will need to gain a grasp of the drive environment. Therefore, systems to provide environmental recognition based on image information are being widely studied. However, it is very difficult to determine the exact position of an object from image information only. For that reason, we are developing an autonomous personal robot able to perform practical tasks in a human environment based on information derived from camera images and an LRS (a laser range sensor), which is used to acquire two-dimensional distance information.

This object recognition system is composed an object recognition processing part and a location information acquisition processing part, both of which are based on a sensor using a monocular camera and an LRS. An object is identified by using range information obtained from LRS in addition to the processing of the image information provided by the camera. At first, the object recognition processing part searches for the object that a user specified in terms of its shape and color, characteristics based on image information from the monocular camera. Next, location information concerning the searched object is acquired by the location information acquisition processing part, which uses LRS. The range information which LRS obtains is converted from its irradiation point and measurement distance into three dimensional coordinates. However, the LRS measurement regarding the object position cannot be understood only from the data. Therefore, the measurement part of LRS is matched to the camera image, and whether it is correct data about the object's position is then judged. In addition, this system acquires the location information from two places within the object area, thus preventing false detection. The robot can do a holding operation for the object according to this object location information.

2. System for robot

Our robot has a drive mechanism consisting of two front and two back wheels. The front wheels are attached to a motor that operates the wheels on either side independently, while the back wheels function as castor wheels. This method has the advantage of allowing a small turning radius. In addition, to acquire image information, a single CCD camera with approximately 300,000 pixels and an LRS, to acquire range information, are installed on the head of the robot and can be rotated to all sides by two motors. DC servo motors are used for the robot's drive mechanism, and position and speed control are achieved by the control system of the drive mechanism. The robot also has two arms and hands equipped with sensors, which enable it to respond to the various demands of humans. Finally, an installed wireless LAN can provide remote control for humans. All devices are controlled by a PC, and lead batteries supply the robot's electric power.

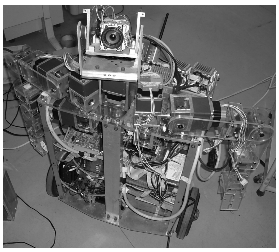

Fig. 1 Our developed robot

3. Object-recognition system

3.1 Outline of the system

We developed an object-recognition system for robots that can acquire the object position with image information captured by a monocular CCD camera and range information obtained by LRS. This system can acquire the object position on the assumption, for example, that the object is put on a desk. The system then acquires the location information of the object by using LRS with the recognized object.

3.2 Method for object-recognition

In this section, we explain the method for object-recognition. The flow for the object-recognition is shown in Fig. 2.

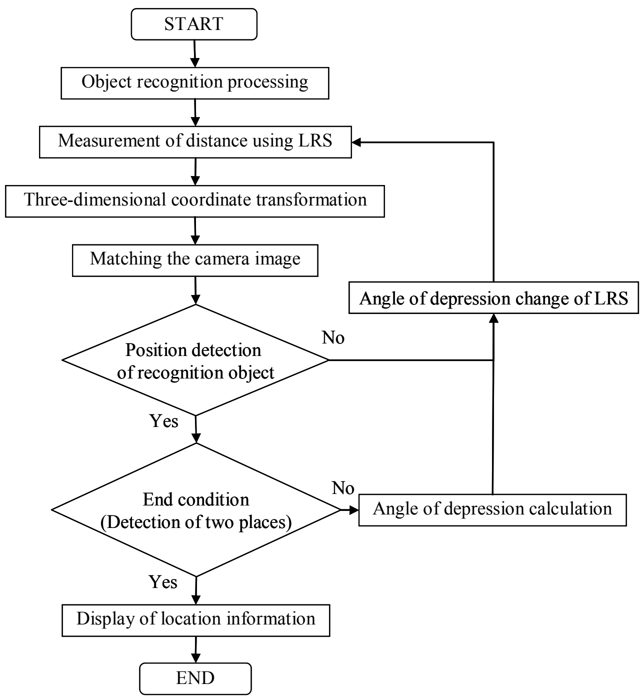

Fig. 2 System flow

Ⅰ. Object recognition processing part

This processing part can search for objects with image information captured by a monocular CCD camera. The system then searches for the object with the shape and color of the object registered by the database. This processing part notes the shape and color of the object and then step by step narrows down the objects. Fig. 3 shows an example of the results of the object-recognition processing.

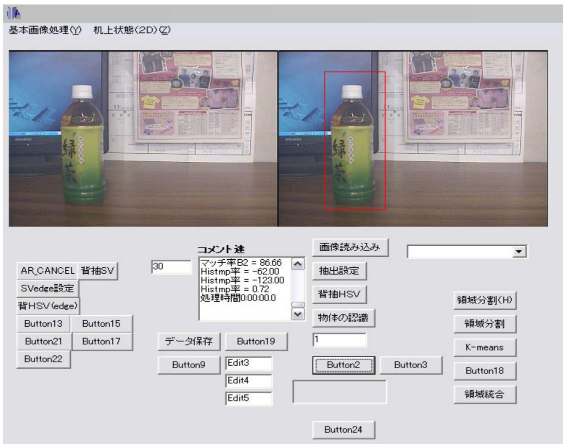

Fig. 3 Object-recognition processing

Ⅱ. Measurement of distance using an LRS

LRS is a noncontact laser measurement system and is made by HOKUYO AUTOMATIC CO., Ltd., for use in this study. The maximum detection distance of this LRS is 4m. Moreover, a horizontal plane space is scanned by 270° at intervals of about 0.36° (360°/1024), and the distance and the direction of the detection body are detected. However, this LRS requires the time of 100msec for a single scanning. Therefore, a reduction in the distance acquisition time was enabled by using LRS only for the material part recognized with the monocular camera in this study. Fig. 4 shows the externals of the LRS.

Fig. 4 Scanning laser range sensor

LRS acquires range information on the object recognized in the object recognition processing. LRS is fixed to the robot head, and moves with the camera.

Fig. 5 shows the situation in which the range information is acquired.

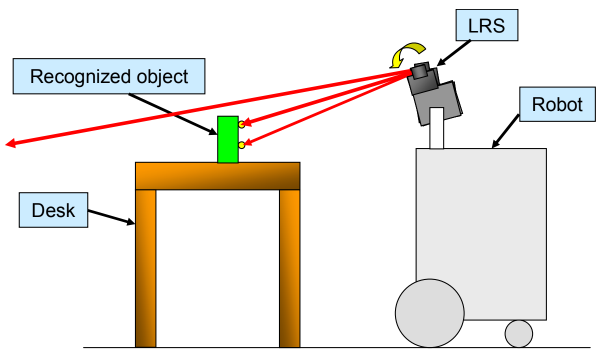

Fig. 5 Position information acquisition situation

Ⅲ. Three-dimensional coordinate transformation

The range data of LRS is range information from the irradiation point to the measurement point of LRS. Therefore, this range data is converted into a three-dimensional coordinate. This conversion is derived in the provided data on the distance data and the horizontal and perpendicular angles.

Ⅳ. Matching the camera image

The system successfully matched the LRS data to the camera image by integrating the camera image with the LRS data. First, a perspective projection face with the same aspect ratio as a camera image was set. The system converted the data into three-dimensional coordinates, as explained above. Then the system matched the perspective projection face with a camera image. Therefore, the LRS data was matched with the camera image. Fig. 6 shows an example of matching the LRS data to the camera image.

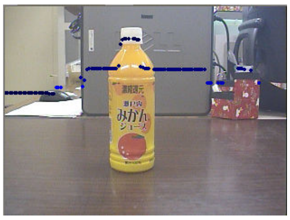

Fig. 6 Matching the camera image

Ⅴ. Position detection of recognition object

Whether the LRS data describes the location information of the object is judged. This involves determining which position of the camera image, provides the measurement point for LRS to detect the object. It can be determined that the object can be measured if the object area recognized in the object recognition processing corresponds to the image coordinates of the LRS measurement point. This system acquires a three-dimensional coordinate in the vicinity of the center of the object as location information when the LRS measurement point is in the part that is in the below 60% of the object. However, when the LRS measurement point is not in this area, LRS must be inclined. The location information acquisition judgment is repeated with the distance information acquisition using LRS through a three-dimensional coordinate transformation and matching to the camera image. In addition, to prevent false detection and to provide good, accurate detection, data acquisition is done in two places in the area (the upper part and the lower part). Fig. 7 shows an example in which location information acquisition is done for the first time and where the measurement point of LRS changes the angle of depression of LRS because it cannot acquire the location information at the time of points A and B. In this case, however, the location information could be acquired at point C. Fig. 9 shows an example of an inclining LRS after Fig. 8 where the location information was acquired a second time at point D.

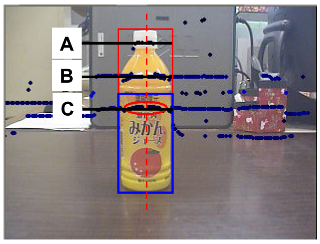

Fig. 7 First location information acquisition

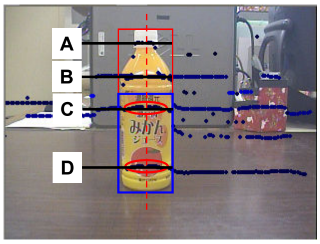

Fig. 8 Second location information acquisition

The location information in two places in the area (the upper part and the lower part) could be acquired in this processing. Fig. 9 shows an example where the LRS data of the image is acquired at two places.

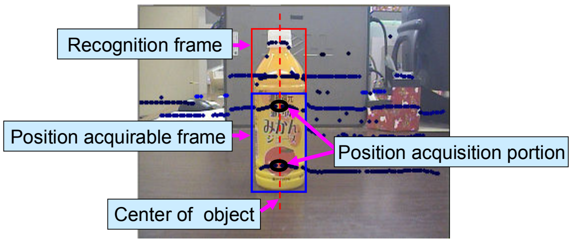

Fig. 9 Object location information acquisition

Ⅵ. Angle of depression calculation method

The part where the system seeks to acquire location information of the object is at two places in the area (the upper part and the lower part). After the first location information is acquired in the upper part of the area, the angle of depression of LRS is calculated according to this information. If the distance of the object and the robot can be found, the angle of depression can be calculated from the image information by a geometrical calculation.

Ⅶ. Display of location information

When the location information of the recognition object in two places can be acquired through acquisition of the range data using LRS, the three-dimensional coordinate transformation, and the determination of matching between the camera image and the location information, final location information on the object is displayed in two places. Because it is preferable that the acquired positional data reflect the exact position of the object, a part in the center of the object in two places is acquired as object location information. The calculation of final location information for the object involves computing the average of the location information in two places for x and z coordinates. Y coordinates use the first value acquired in the upper part of the object by LRS because the purpose of this system is to hold the object. A part near the center of the object was displayed as the y coordinate value.

4. Experiment

4.1 Method of experiment

We performed the following experiment to evaluate the performance of this system in acquiring the location information of an object for which it searches by object recognition processing. Two kinds of objects were put on a desk, and the actual measurement value was compared with the acquisition value for various positions. As a result, an error caused by the acquisition of the location information was measured. The angle of depression of the camera was set at 10°. Figs. 10 and 11 show the experimental environment when the object were a PET bottle and a can, respectively. The experimental location was a placement on the desk in the laboratory that has a single color. It was measured 12 times in each measurement place.

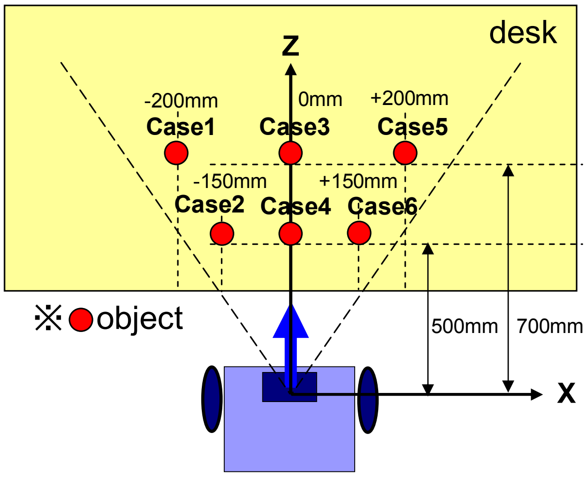

Fig. 10 Experiment environment of PET bottle

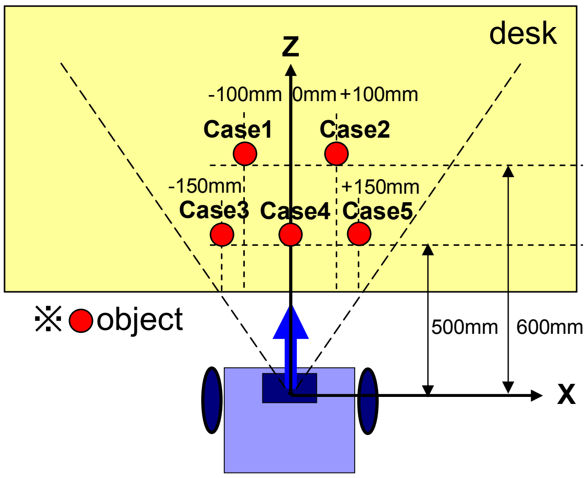

Fig. 11 Experiment environment of can

4.2 Result of experiment

Table 1 shows an average error and the maximum error by the actual measurement value and the acquisition value at each object position when the object is a PET bottle. Table 2 shows the same when the object is a can.

Table 1 Location information of PET bottle

	Actual measurement [mm]			Average error (Maximum error) [mm]		
	X	Y	Z	X	Y	Z
Case1	−200	793	700	1.583 (2.0)	0.583 (1.0)	0.583 (2.0)
Case2	−150	800	500	0.667 (2.0)	1.167 (2.0)	1.167 (2.0)
Case3	0	793	700	0.917 (2.0)	0.167 (1.0)	1.500 (3.0)
Case4	0	800	500	0.500 (3.0)	0.250 (1.0)	1.000 (3.0)
Case5	200	793	700	1.250 (2.0)	0.417 (1.0)	1.250 (2.0)
Case6	150	800	500	0.417 (1.0)	0.750 (2.0)	0.917 (3.0)

Table 2 Location information of can

	Actual measurement [mm]			Average error (Maximum error) [mm]		
	X	Y	Z	X	Y	Z
Case1	−100	742	600	1.250 (2.0)	0.417 (1.0)	0.750 (2.0)
Case2	100	742	600	0.917 (1.0)	0.750 (1.0)	1.250 (3.0)
Case3	−150	753	500	1.500 (3.0)	1.167 (2.0)	1.333 (3.0)
Case4	0	753	500	0.167 (1.0)	0.417 (1.0)	0.833 (2.0)
Case5	150	753	500	0.750 (2.0)	0.417 (1.0)	1.083 (2.0)

For both objects, we could confirm that there was no problem in the accuracy of the acquired location information, even when the object was at each position. Moreover, the result of measurements for the two kinds of objects showed the maximum error of each coordinate was within 3mm, and the error of the distance to the object was less than 1% . It is thought that this result is sufficient considering that the holding operation of the object was done based on acquired information.

5. Conclusions

We proposed a system for acquiring exact location information of an object by using image processing and LRS. This object recognition system acquires the location information of a recognition object by integrating range data obtained by LRS and image processing results recognized by the shape and color of the object. In an assessment experiment with the system, the object location information with very good accuracy could be acquired even when the can or a small object was recognized by the object recognition processing.

Our next subject of study will be the development of a program to acquire object location in formations other than those of a recognition object. The reason is that the final purpose of our robot development involves developing the best way for it to hold an object.