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Development of an autonomous-drive personal robot "An environment recognition and the position detecting system that used image processing and an LRS"

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Abstract: We are developing an autonomous personal robot that will be able to perform practical tasks in a human environment based on information derived from camera images and a laser range sensor(LRS). It is very important that the robot be able to move autonomously in a human environment, and to select a specific target object from among many objects, and these functions will be possible in our system. The robot's environmental recognition system is composed of an autonomous driving system and an object recognition system. First, the autonomous driving system calculates the driving route from the visual information provided by a CCD camera. The robot is driven by this system. The object recognition system proceeds by identifying the specified object using image processing and an LRS, and the robot can grasp the object. An environment recognition system is essential to both of these functions. Here we explain the algorithm by which the robot recognizes the surrounding environment. In addition, we describe the application of this system to our robot, evaluate its performance and discuss our experimental results.

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

1. Introduction

In the near future, autonomous driving robots are expected to provide various services in human living environments. To perform these services, the robots will need to grasp the feature of the human environment. Therefore, systems to provide environmental recognition based on image information are being widely studied. However, it is very difficult to recognize all driving environments from image information only; so far, no prospects for such a system have emerged. Therefore, we report on the development of an autonomous personal robot able to perform practical tasks in a human environment based on information derived from camera images and a laser range sensor (LRS), which is used to acquire two-dimensional distance information.

The system for this robot is composed of an autonomous run system for movement and an object recognition system for the recognition and grasping of an object. First, the autonomous run system decides upon a robot driving command based on information in the limited space map. Information such as the placement of walls and barricades is established on to the map, and the data obtained from a CCD camera are compared with the map data. The route is decided, and the robot drives. The object recognition system is composed an object-recognition processing part and a location-information acquisition processing part, both of which use the monocular CCD camera and the LRS. An object is recognized and identified using range information obtained from the LRS in addition to the processed image data provided by the camera. The robot then performs a grasping operation for the object.

2. System view

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. To acquire image information, both a single CCD camera with approximately 2,000,000 pixels and an LRS 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.

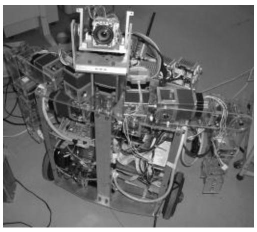


Fig. 1 Our developed robot

3. Specification of the LRS

LRS is a noncontact laser measurement system; our LRS is made by Hokuyo Automatic CO., Ltd. The maximum detection distance of this LRS is 4m. The horizontal plane space is scanned over a 270° angle at intervals of about 0.36° (360°/1024) to detect both the distance and the direction of the target body. This LRS requires a time of only 100 msec for a single scan, and thus a very short distance acquisition time is needed to gain details about the target object recognized with the monocular camera. Fig. 2 shows the externals of the LRS.

Fig. 2 Scanning laser range sensor

4. Autonomous driving system

4.1 System outline

We developed an autonomous driving system for robots that can move in response to image information captured by a monocular CCD camera. It has two subsystems: a route searching system, which decides the course of the robot, and a course correction system, which traces a safe course during the actual run.

4.2 Method for autonomous driving

In this section, we explain the method for autonomous driving. The flow chart for performing autonomous driving is shown in Fig. 3.

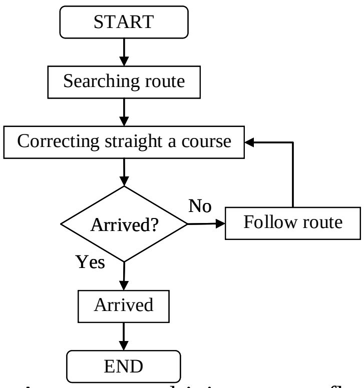
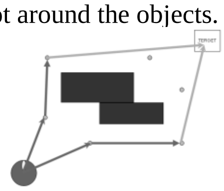


Fig. 3 Autonomous driving system flow chart

I. Route searching system

In this system, the robot searches for routes based on a limited space map. This map includes information such as the start position of the robot, the goal, walls, and danger zones. When there is a wall and an obstacle on the course to a goal, the robot travels along the middle point between them. The robot always takes the shortest route and removes other routes. Fig. 4 shows two routes that were removed because there are objects in the robot's way, and Fig. 5 shows two routes that are correct because they lead the robot around the objects.



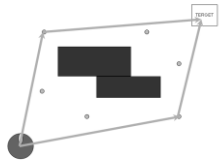


Fig. 4 Removed routes Fig. 5 Correct route

II. Course correction system

Using this system the robot corrects its path by measuring and equalizing the distance on the right and left to prevent it from crashing into a wall.

(i) Data storage

The data consist of the pattern of the slopes of the line on the image, and once calculated, the data are stored in a database. The data are calculated based on the width of the course and the CCD camera angle. The width of the course, direction of the robot, slope of the line and the distance from the center of the course are stored in the database.

(ii) Image processing

The robot acquires the image, and it is processed by edge-based binarization and noise removal. After that, straight lines are extracted, and the image is processed by the Hough transform into straight lines. This process is shown in Fig. 6.

(iii) Self-position correction

The robot estimates its position and direction and corrects the latter by a straight line matched with the data from the database.

Original image Noise remove Hough transform

Fig. 6 Image processing

4.3 Experiment to evaluate the system evaluation

I. Experiment setup

To evaluate this system, we conducted an experiment at Research building 3F of Kyushu Institute of Technology. The total distance that the robot ran was about 35m, and we verified that its systems worked successfully.

The images used in the experiment were acquired from a camera mounted on the robot. This camera was at a height of 875mm from the floor and its depression angle was 20 degrees.

II. Results of the experiment

The robot could reach the goal thanks to the successful operation of the systems. The course correction system was at work during the run. A picture of the course that the robot followed is shown in Fig. 7. As shown, the course correction system worked, so that robot was able to move around obstacles.

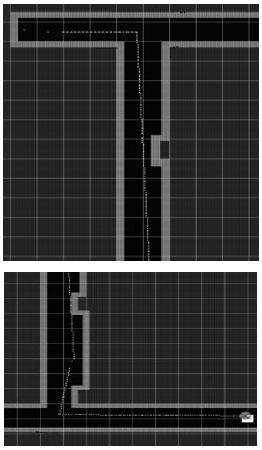


Fig. 7 Results of experiment

5. Object recognition system

5.1 System outline

We developed an object recognition system for robots that can acquire the target object position with image information captured by a monocular CCD camera and range information obtained by an LRS. This system can acquire the object position on the assumption that the object is placed on a desk. The system acquires the location information of the object by using the LRS with the recognized object. Afterwards, the arm is driven based on the location information, and the object can be grasped and held.

5.2 Method for object recognition

In this section, we explain the method for object recognition. The flow chart for the object recognition process is shown in Fig. 8.

I. Object recognition processing

Through object recognition processing, the system 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 in the database by narrowing the search range to match the camera image step by step. Using this method, objects in the domain can be found. Fig. 9 shows an example of the results of object recognition processing.

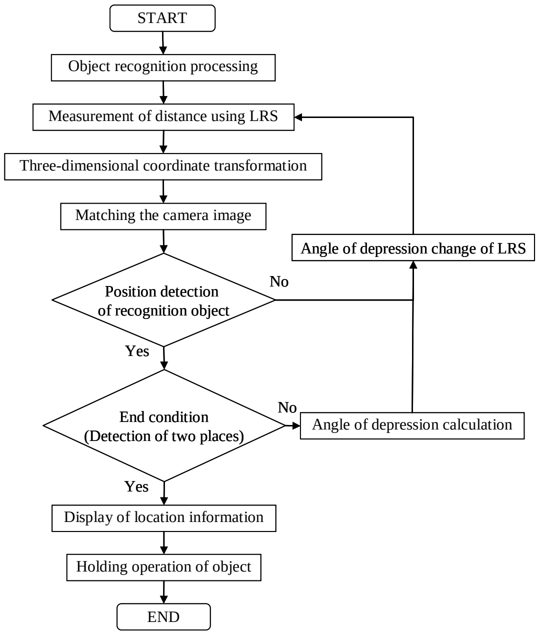


Fig. 8 Object recognition system flow chart

Fig. 9 Object recognition processing

II. Measurement of distance using an LRS

The LRS acquires range information on the object recognized during object recognition processing. The LRS is fixed to the robot head, and moves with the camera. Fig. 10 shows the situation in which the range information is acquired.

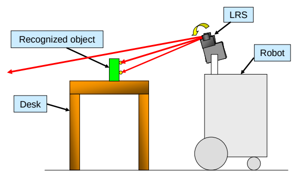


Fig. 10 Position information acquisition

III. Three-dimensional coordinate transformation

The range data of the LRS is range information from the irradiation point to the measurement point of the LRS. Therefore, this range data is converted into three-dimensional coordinates. This conversion is derived in the provided data based 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.

V. Position detection of the recognized object

The system judges whether the LRS data accurately describes the location information of the object. This involved determining which position of the camera image provides the best measurement point for LRS to detect the object. If the object area recognized in the object recognition processing corresponds to the image coordinates of the LRS measurement point, the measurement can be considered successful. This system acquires three-dimensional coordinates in the vicinity of the center of the object as the location information, provided that the LRS measurement point is at the 60% height level, from the bottom of the object. In addition, to prevent false detection and to provide good, accurate detection, data acquisition is done at a second level on the object (below the 60% mark).

VI. Angle of depression calculation method

The system acquires location information on the object at two places (an upper part and a lower part). After the first set of location information is acquired in the upper part, the angle of depression of the LRS is calculated according to this information. If the distance between 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 about two places in the recognition object can be acquired, final location information on the object is displayed. Because it is preferable that the acquired positional data reflect the exact position of the object, the area in the center of the two examined places is acquired as the final object location information.

VIII. Recognition of circumference environment

To perform grasping of the recognized object, it is necessary to know the object's circumference. The system acquires the object at center of the camera image, to determine the object's circumference.

VIIII. Grasping operation of object

The target object is located within a certain distance (2 feet) of the robot. Target coordinates are first set in front of the object, based on the acquired object position, and the arm is driven to the coordinates. An image is acquired after the arm arrives, and the remaining drive distance of the arm is calculated from the position of the object and the distance of the hand to the object. The arm is driven again based on the calculated driving amount, and the grasping operation of the object is performed.

5.3 Experiment to evaluate the system

I. Experiment setup

We performed an experiment to evaluate the performance of this system in the grasping operation of an object, in which it searched by object recognition processing. The angle of depression of the camera was set at 10°. Fig. 11 shows the experimental environment when the object was a PET bottle. Its location was on a single-color desk in the laboratory.

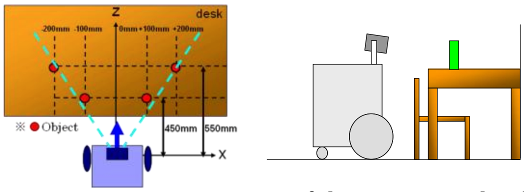


Fig. 11 Experiment environment of the target PET bottle

II. Results of the experiment

As the result of acquiring position information for the PET bottle placed in a variety of places, the maximum error of each set of coordinates was less than 5 mm, and the error in the distance to an object was less than 3%. If the robot is assumed to grasp an object based on this result, we think that it could successfully perform the grasping task.

However, if some parts of the object are hidden, the object recognition may not be able to be carried out correctly. Therefore, it is necessary to improve this system so that it can recognize an object's position based only on some parts of the object.

6. Conclusions

We propose a system that recognizes the driving environment of a robot using image processing and an LRS. This environmental recognition system is composed of an autonomous driving system and an object recognition system. The driving environment of the robot can be processed using these systems, and the behavior pattern of the robot can be expanded within that environment. At present, it is possible for the robot to move in a preselected area, and to locate and grasp a target object. Expansion of the action area and the addition of the transportation operation of the robot with the object are within our sights and will be developed in the future.