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Development of an autonomous-drive personal robot: An object recognition system using a database

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Abstract: We are developing an autonomous personal robot with the ability to perform practical tasks in a human environment based on information derived from image sensors and a knowledge database. In its adjustment to a human environment, it is very important for the robot to identify specific objects. We have thus developed an object recognition system that allows the autonomous robot to identify objects within its environment. The system requires only image data captured by an ocellus CCD camera. This object recognition system is composed of a shape recognition system and a color recognition system. In the shape recognition system, an object is identified based on its distinctive shape. The color recognition system identifies the object based on its color information. Here we explain the algorithm used for the object search and the method for processing images. In addition we describe the result of an experiment done to evaluate the system as it performed an object search.

Keywords: Robotics, Image processing, Ocellus camera, Object recognition

I.Introduction

In the near future, autonomous self-driving robots are expected to provide various services within humans' living environments. Such robotic technology is already seeing practical use in industry. So far, however, industrial robots simply perform motions in imitation of humans. Therefore, we are developing an autonomous personal robot with the ability to perform practical tasks in a human environment based on information derived from image sensors and a knowledge database.

The robot's object recognition system is composed of a shape recognition system and a color recognition system that uses only a CCD camera. The system processes the image information displayed by the camera. In the shape recognition system, an object is identified based on its outline. In the processing flow, the outline of the object is extracted from the edge image, and label processing is performed based on HSV information. An object is searched for by comparing the extracted outline from the image with a template in the database. The color recognition system identifies the object based on its color information. In the processing flow, a histogram is made based on the object's HSV information, and then another histogram is made based on the data of object that was registered previously in the database. The system identifies an object by comparing these two histograms. The object recognition system searches for the object using both of these recognition systems.

II.The robot's overall design

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

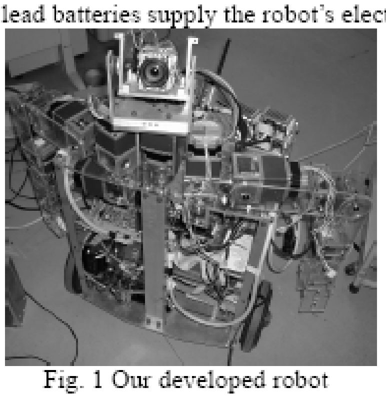

Fig. 1 Our developed robot

III. Object recognition system.

3.1 Outline of the system

We developed an object recognition system that allows our robot to search for an object with image information captured by an ocellus CCD camera. This system searches for an object on the assumption that the object is lying on a desk. The system searches for an object with the shape and color of the object that most closely matches an object previously registered in the database. The system notes the shape and color of the object and step by step narrows the search for an object with the same features.

3.2 The shape recognition system

In the shape recognition system, an object is identified based on its shape. Objects picked up by hand in daily use are not especially complex in shape, so this system especially notices the outline of the object. The processing flow is as follows.

I. Image Acquisition

The image obtained by the CCD camera is read into a PC in the robot. This image is a 24-bit full-color image of the RGB data form.

II.HSV conversion

The system converts 24-bit RGB image data into HSV data.

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III. Extraction processing of the desk surface

First of all, the robot extracts the data of the desk surface, on which it assumes that there is an object. In the processing flow, the system gets image data of the desk surface by sampling. The robot calculates the standard deviation of each HSV parameter from the acquired sample data. If the pixel of the image has a value within the threshold of the standard deviation, it extracts the data and assumes it is from the surface of the desk.

VI. Object extraction processing

Initially, the system performs labeling about pixel group except the part recognized by desk surface extraction. A chain code is used to make one set of data for each group of image pixels extracted from the image. The group of image pixels that leads to the detection of an object is distinguished by this process. The system cannot accurately judge shape based on the group of image pixels contacting with the edge of the image then. Therefore, the group of image pixels contacting with the edge of an image excludes from a group of image pixels that recognize an object. Figure 2 shows an object image recognized by this object extraction processing.

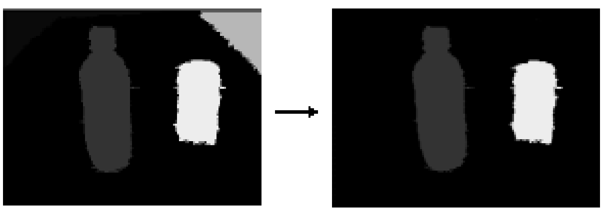

Fig. 2 Object extraction processing

V. Outline extraction processing

The outline extraction processing extracts the object's outline about a mass of the pixel that recognized the object by object extraction processing. Then the system performs edge enhancement processing, and it performs binarization. Also, it adds expansion processing to the outline of the object. The system compares the edge image with the outline image to which was added expansion processing. In this way, it extracts only the outline of the object based on its edge image. Figure 3 shows the outline image of an object recognized by this outline extraction processing.

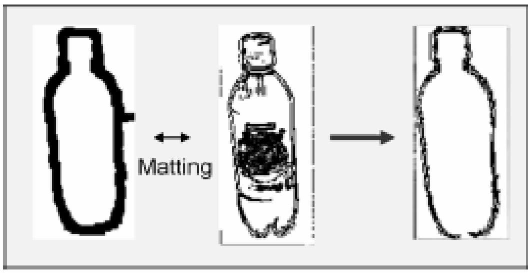

Fig. 3 Outline of object extraction

VI. Template matching processing

This processing compares the outline image of the object that was extracted by outline extraction processing with the shape data of the object that was registered in the database. The system calculates a matching rate and decides whether the rate exceeds a given threshold. When the same shape is not found, the system performs contractive processing of the outline template and then performs matching processing again. Also, the system performs rotary processing for an object caught on the right and left of the camera image. The system can correct the inclination of an object by this rotary processing. The system searches for an object by repeating the matching processing, the rotary processing, and the contractive processing.

3.3 The color recognition system

The color recognition system is the system searching for an object based on color data of the object. The system acquires the color data of the object that was searched for by the shape recognition system. It compares the color data already registered in the database with the color data of the object. If the features of the two sets of color data are in accord, the system judges the result to be a match. The processing flow is as follows.

I. Color data acquisition

The system acquires the color data of the object that was searched for by the shape recognition system. The color data use information of Hue of the HSV information about the object.

II. Making of the histogram

The image is regarded as an assemblage of pixel values. The color data of the object's hue is expressed in degrees ranging from 0 to 360. This processing divides the hue data into 72 groups and counts the frequency of each pixel value. Figure 4 shows a sample hue histogram.

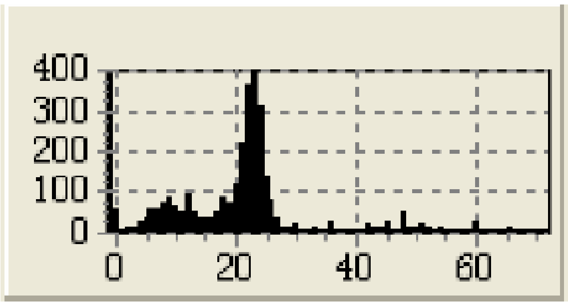

Fig. 4. Histogram

III. Comparison of the histograms

The system calculates regularization histogram. Then the system compares the regularization histogram data of object which was searched for by a shape recognition system with regularization histogram data of search object. This processing compares regularization histogram and compares the average of pixel value and compares the pixel value that frequency is the highest.

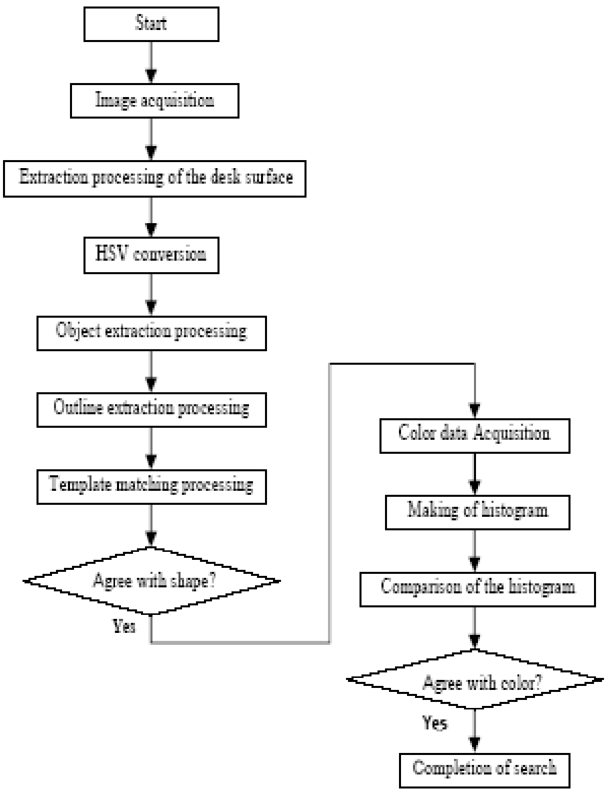

Fig. 5 System flow

VI. Experiments

We performed three experiments to evaluate the performance of the shape recognition system and the color recognition system.

A: Experiments addressing the shape of an object.

We performed an experiment that searched for the sh ape of a PET bottle, a can, and a paper-pack juice box.

B: Experiments addressing the color of an object.

We performed an experiment that searched for an object that matched an object of the same shape by the use of color data of the object.

C: Experiments about the influence of the light..

We performed an experiment that checked system movements in response to the light.

In the case of A, the system searched for objects shaped like a PET bottle, a can, and a paper-pack juice box, but the system mistook the can and the paper-pack juice box, and it mistook the different can of capacity too. The shape recognition system could not identify these objects because objects like a paper-pack juice box have a different outline shape depending on the angle at which they are encountered. In the case of B, the system was able to search for the object based on the color data registered by the database, because the histogram was not influenced by angle. In the case of C, the system was able to confirm that a fluorescent lamp does not influence the results very much. Figure 6 shows an example of the result of the shape recognition system, and Figure 7 shows an example of the result of the color recognition system. Figure 8 shows the result of experiments testing the influence of the light.

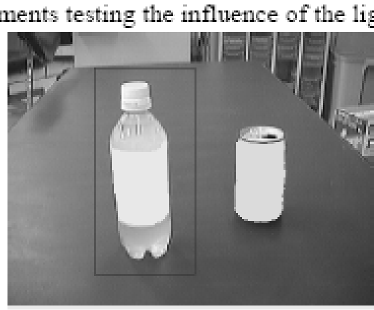

Fig. 6 Shape recognition system

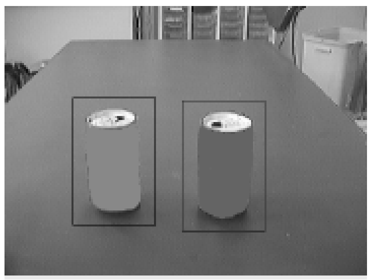

Fig. 7 Color recognition system

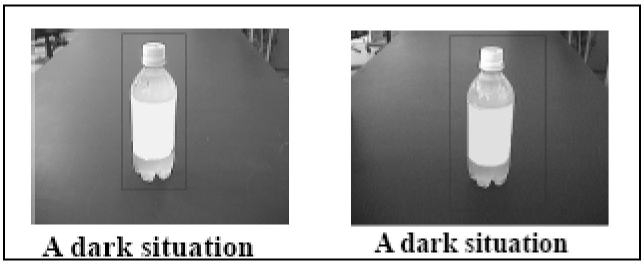

Fig. 8 Experiments about the influence of the light.

V. Conclusions

We have proposed a system that searches for objects using only an ocellus camera. Many objects handled during daily life are not complex in shape, and our experimental results show that searches for objects of simple shape could have a high probability of success. However, the system could not search for a cube-shaped object, so we will need to increase the number of search templates. Also, the system needs a way to display an object in three dimensions, which will require another processing method.

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