STUDY OF INTELLIGENT CONTROL OF AN ARM ROBOT EQUIPPED WITH A C-MOS CAMERA USING A NEW TYPE OF IMAGE PROCESSING

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ABSTRACT

This paper proposes an approach that allows an arm robot equipped with a C-MOS camera to utilize new image recognition in order to intelligently and autonomously grasp objects, and introduces a method that uses the conventional way of teaching position to the arm robot, after which the intelligent robot employs a program that allows the arm robot itself to autonomously determine the action required to move the arm into that position. In experiments, an intelligent robot was successfully engineered to use image recognition to identify colored blocks and autonomously move toward a target and grasp it using a new centroid search approach.

Keywords: image processing, arm robot, intelligent control

INTRODUCTION

Recently, arm robots have been widely used in industries for purposes including parts assembly and conveyance. Their present primary use, however, involves a simple system where the arm is taught a position, then moves into that position in accordance with programming. In this study, the arm robot was equipped with intelligence and a C-MOS camera placed on the arm to enable the robot to judge the position of an object from a captured image, thus allowing autonomous movement of the arm to the optimum position for grasping the object.

ARM ROBOT INTELLIGENCE SYSTEM

Summary of the intelligence system

The arm robot's intelligent, autonomous grasping system was made possible by using a new type of image processing that utilizes a C-MOS camera. In this control approach, the arm robot determines the position of a target object and automatically moves to grasp it. Fig. 1 shows a block diagram of the total system, which calculates block color from an image captured with the C-MOS camera, then sends the image and data to a PC using an external Bluetooth wireless module. Pixel information is acquired from image data obtained through the PC's wireless module, then digitalized. Next, colors are distinguished to determine red, yellow, and blue. The target object's position is judged using image segmentation. Then, a correction program determines if the object is in the center of the image (centroid), and the arm robot moves.

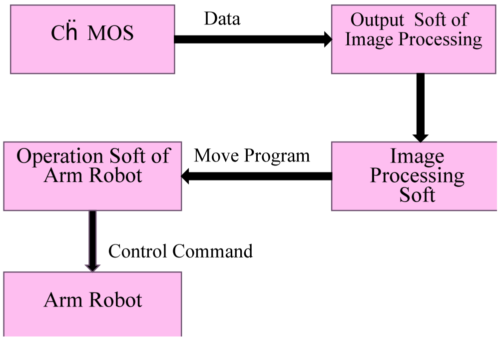


Fig. 1 Block Diagram of the Total System

The mounted C-MOS camera is angled at 25° relative to the hand axle so the apex of the hand can be imaged. Fig. 2 shows the tip of the arm.

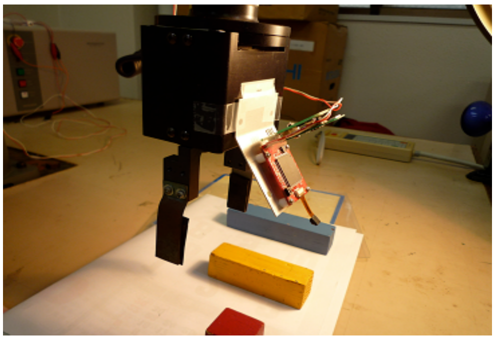


Fig. 2 Tip of the Arm Robot

The image is segmented into 15 areas, as in Fig. 3, then read 1 pixel at a time to digitalize the pixel information. Colors are discerned from the values, then found in the image (excluding white) and counted. Then, the 15 areas are compared to discover the area that has the most of a particular color to find the object's position. In addition, the design allows, to a certain extent, the determination of object shape and angle by locating left, right, up, and down endpoints.

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14

Fig. 3 Diagram of Segmentation

Intelligence Design

Approach to image processing

Fig. 4 shows a flowchart of the proposed approach to image processing. The mounted C-MOS camera is angled at 25° relative to the hand axle so the tip of the hand can be imaged. The image supplied of the tip of the arm shown in Fig. 2 is segmented into 15 areas as illustrated in Fig. 3, then read 1 pixel at a time, and the data digitalized.

Fig. 5 shows the acquisition of the pixel information and digitalization. The pixel information is obtained by RGB coordinate values specified by the Get Pixel (X, Y) function. Next, to digitalize the pixel information, the colorized data is converted into to 32-bit Argb by using the Color to Argb method.

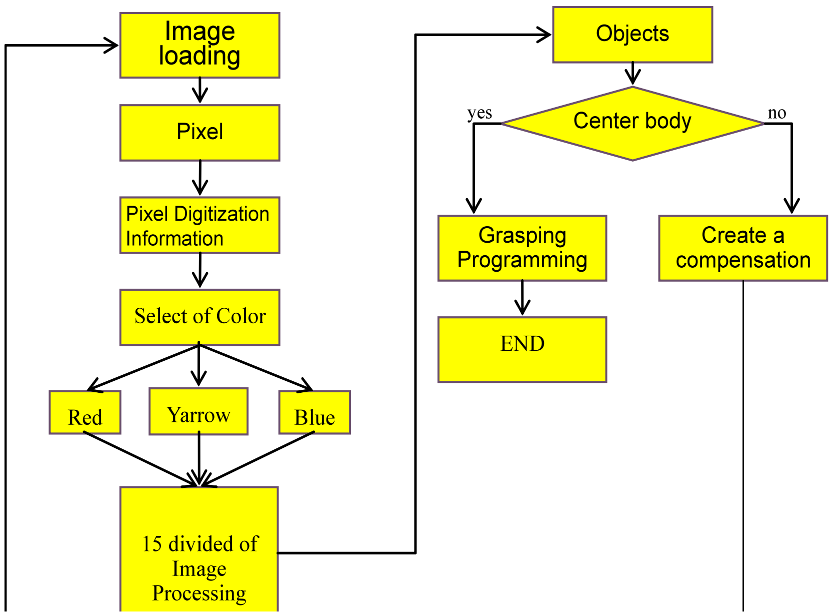
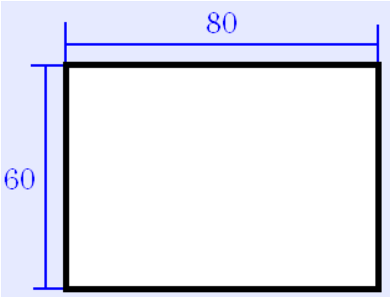


Fig. 4 Flowchart of Image Processing



Color	RGB(R,G,B)	numerical inversion	Identifica range
Red	255,0,0	65536	10^5～7*10
Blue	0,0,255	16776961	1000 100000
Yellow	255,255,0	256	101~1000
White	255,255,255	0	0~10

Fig. 5 Pixel Information & Digitalization

Color distinction

Color is discerned from the numerical values that were digitalized from the pixel information, then colors within the image (excluding white) are searched for and counted. Object position can be identified by finding the area in the 15 sectors with the greatest amount of a certain color.

Color output utilizes the YUV422 format to simplify color calculations. YUV output data compared to RGB primary colors are as follows.

$$\begin{aligned} &Y=0.299R+0.587R+0.114B \\ &Cb=B-Y=-0.299R-0.587G+0.886B \\ &Cr=R-Y=0.701R-0.587G-0.114B \end{aligned} \qquad (1)$$

RGB coefficients in the Y signal of these equations were created by taking the relative luminosity curve into account. When R=G=B, or, when achromatic color exists, then Y=R=G=B. Color information Cb and Cr are the values of the luminance signal Y subtracted from B and R. This is called the color-difference signal. The color space that uses Y, Cb, and Cr as independent variables expressing color is called the YCC color space. Also, converting this YUV into 3 RGB primary colors yields the following.

$$\begin{aligned} &R=R+Cr \\ &B=B+Cb \\ &G=Y-(0.299Cr+0.114Cb)/0.587 \end{aligned} \qquad (2)$$

Degree of luminance is an 8-bit value. The whiter the color, the higher the value, and conversely, the darker the color, the lower the value. Cb and Cr color differences are considered to include a negative value based on 128. When Cb=128, the color difference for blue is 0.

The number 422 expresses the color information values. Data is extracted from the C-MOS camera to produce color information 1 pixel at a time. The human eye is less sensitive to changes in color information than brightness, so humans do not see much change even when color information is somewhat reduced. This characteristic was utilized to reduce data volume. Of 4 pixels, Y has 4, Cb has 2, and Cr has 2, so it is referred to as YUV422. Fig. 6 shows an example of color discernment of a target object.

Color	Identification range
Red	$10^5 \sim 7*10^5$
Blue	10001d 100000
Yellow	101~10000
White	0~100

Case

Color	Example pixels
Red	273
Blue	0
Yellow	24
White	4503

Fig. 6 Color Discernment of a Target Object

Method of Robot Control

The captured images are segmented into 15 parts and processed. It is believed that even more precise information on position can be gained through further fragmentation. Efficiency and accuracy will be examined when using, for example, 30 segmentations. Moreover, since a shape recognition algorithm only vaguely recognizes the size and angle of a target object and is unable to handle complex shapes because 2D-image processing might falsely register an object's shadow as a change in shape, as a countermeasure, it is thought that shape recognition capability can be improved by processing shadows and increasing the accuracy of extracting minutia.

Three processing algorithms were used for reading images, image processing, and robot handling. The software for those had to be linked to improve operability. Fig. 7 indicates what occurs when determining the object's position through image segmentation.

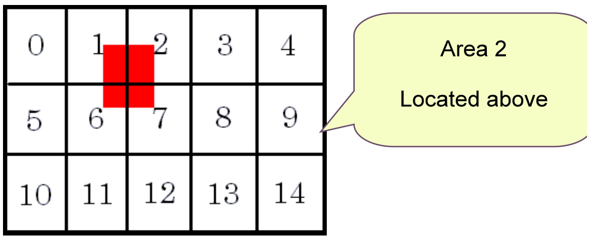


Fig. 7 Determining Object Position with Image Segmentation

The flowchart in Fig. 8 shows the algorithm developed for the process up to the point the robot arm grasps the object.

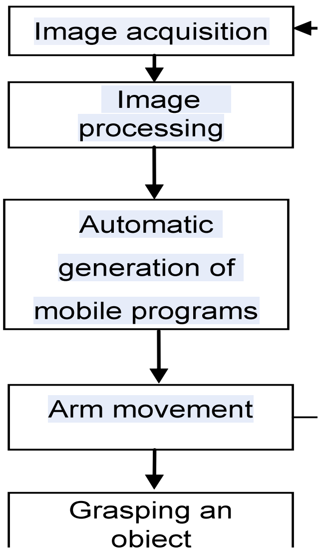


Fig. 8 Basic Flowchart for Robot Control

EXPERIMENT

The arm robot shown in Fig. 9 was used, and both an image processing technique and an intelligent control approach were applied for general operation. The only human command given was "TAKE." Once the system starts, there is no need for humans to supply information. The arm robot moves while collecting necessary information on its own. Execution time took 0.5 seconds to identify object type, and 10 seconds until the object was grasped. Thus, control was achieved very close to real-time.

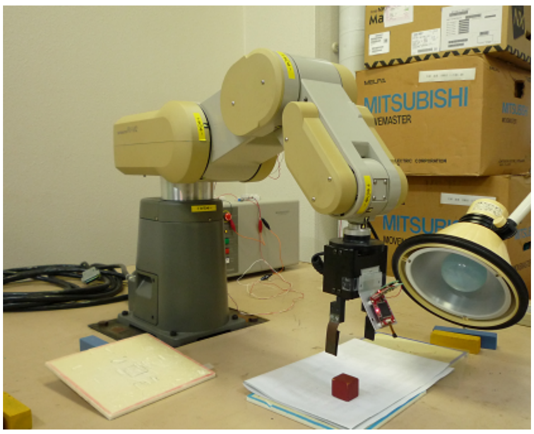


Fig. 9 Arm Robot

Fig. 10 shows the development environment for the image processing software.

Development Environment

OS	Windows XP servicepack3
Software Development	Microsoft visual Basic 2008 Express Edition
Language	Visual Basic

Fig. 10 Image Processing Software

The program's auto-generation function is built from the movemaster command, a correction program, and a grasping program. The first is a language used for robot motion, and the second is a program that moves the arm from its current position to the center of the image. Correction values change depending on position. The grasping program allows the arm to lower, and the hand to close and grasp the target object. Fig. 11 illustrates the program's auto-generation.

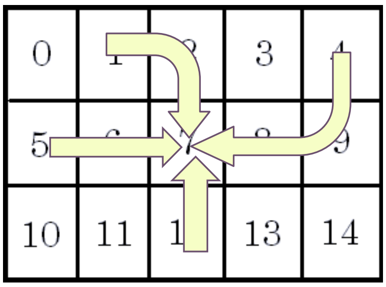


Fig. 11 Program Auto-generation

RESULTS & DISCUSSION

The robot arm movement is repeated until the object comes just below the arm. The average number of movements executed until the object was grasped was 2.6. The created program could recognize 4 colors—red, blue, yellow, and white. Table 1 shows the color identification values.

The scope of the discernable colors enabled the division of the acquired color information into red, blue, and yellow. There were an especially large number of blue values, and because they were similar to black, in many instances black was mistaken for blue, making the scope setting difficult.

Table 1. Color Identification Values

Color	RGB(R,G,B)	numerical inversion	Identification range
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Blue	0,0,255	16776961	10001 ～ 100000
Yellow	255,255,0	256	101~10000
White	255,255,255	0	0~100

CONCLUSION

This study presents an intelligent arm robot equipped with a C-MOS camera capable of autonomous grasping by using a new type of image processing. The arm is an intelligent robot that moves by making autonomous judgments. In experiments, it was able to recognize an image of a colored block and autonomously moved toward that target and grasp it using a new centroid search technique. The results of this study can be applied to numerous industrial production sites.

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