Achievement of Carrying Objects by Small-Sized Humanoid Robot

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Abstract. It is expected that the sphere of activity of robots will spread widely in the near future not only in fields of industry but to various aspects of our everyday life. On the basis of this expectation, in this research we aimed at the creation of a robot that supports our daily life and tried to develop a small-sized humanoid robot that can find an object, pick it up, and carry it. We developed an algorithm for a robot to recognize an object using color information. Also, based on the algorithm the robot calculates the direction and the distance to the object, moves to the precise position and picks up the object and carries it. Finally, we carried out an experiment to evaluate the performance and were able to obtain a high success rate.

Keywords: humanoid robot, object recognition, physical support.

1 Introduction

Various types of robots are used mainly in industrial areas in modern society. It is expected that new types of robots such as humanoid robots and pet robots will emerge and be introduced in our society in the near future. Corresponding to this expectation, research and development of humanoid and pet robots is flourishing [1][2]. So far the major application area for most of these robots is entertainment, such as playing soccer games [3], dancing [4][5], and so on. At the same time, however, it is expected that in the future these robots will support the physical aspects of our life like other industrial robots. Therefore, it is necessary to carry out a study on allowing these robots to help us in our daily life. In this study, we aim at achieving a function of carrying an object for a small-sized humanoid robot. For this purpose it is necessary for the humanoid robot to have capabilities of recognizing an object, moving toward it, picking it up, and carrying it. Based on this consideration, we developed an algorithm for a humanoid robot to fulfill the above functions. In the following, details of the algorithm are described. Also, we carried out experiments to evaluate the algorithm we developed, and the details of the evaluation experiments will be described.

2 Related Studies and the Aim of the Research

Various types of pet robots and humanoid robots have been studied and developed. One of the most famous pet robots is a dog-like robot called AIBO [1]. Also, there are several humanoid robots being studied and developed. One of the representative humanoid robots is ASIMO [2]. The main role of AIBO is entertaining people by achieving various types of dog-like behaviors. On the other hand, it is expected that ASIMO would help us in many ways in our daily life, though so far, the main role of ASIMO is to perform various types of human-like actions such as walking and going up/down stairs at events and thus entertaining us. On the other hand, there are several studies underway that aim at supporting our life physically using humanoid robots. One of the studies, using a humanoid robot called HRP2, has examined how to achieve life support functions such as dish washing or room cleaning [6]. In other research, an assistant robot in a nursing home has been studied [7]. This robot has the capability of finding a person, giving a reminder to a person, accompanying a person to a desired place, giving a person required information, and so on.

In the case of a small-sized humanoid robot, as it becomes much harder for these robots to support us physically in our daily life, most of the research has focused on robots entertaining us by achieving various types of performance such as dancing [4], soccer games [3] and so on. And there have been few studies on physical assistance by these robots.

Taking these situations into consideration, we started research on letting a small-sized humanoid robot physically support our daily life. As a first step toward such a goal, we tried to develop a function in which a small-sized humanoid robot would pick up and carry a light object. For this purpose, it is necessary for the robot to achieve the following functions:

(1) To find an object to carry,
(2) To approach the object and stop at the object so that it can pick it up,
(3) To grasp the object,
(4) To carry the object.

In the following, we will describe a system that fulfils these functions.

3 System Construction

3.1 Platform robot

As a platform robot for this task, we have adopted a commercially available small-sized humanoid robot called "Tai-chi" shown in Fig. 1. Table 1 shows the specifications of the robot. Tai-chi has a total of twelve servo motors for its legs with each leg having six motors, and a total of 8 motors for its arms with each arm having four. Furthermore, Tai-chi has one motor for its head. Therefore, Tai-chi has a total of 21 motors. Tai-chi can do basic movements such as going forward, going backward, turning to the right, and turning to the left. In addition, users can develop various kinds of movements freely by using a special software called "Motion Editor," dedicated to motion creation.

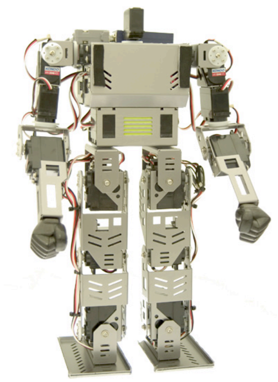

Fig. 1. Humanoid robot used for the research

Table 1. Specifications of humanoid robot

Size/Weight	34 cm / 1.7 kg
Degree of flexibility	22 (12 legs, 8 arms, 1 waist, 1 head)
CPU	SH2/7047F
Motor	KO PDS-2144, FUTABA S3003, FUTABA S3102, FUTABA S3103
Battery	DC6V

3.2 Achievement of the search function

As is described in Chapter 2, the system should have the following functions:

(1) To find an object to carry,
(2) To approach the object and stop at the object so that it can pick it up,
(3) To grasp the object,
(4) To carry the object.

As an object to detect and carry, we adopted a small-sized ball with a color of blue, red, or yellow. To give the system the capability of searching/finding objects using image processing, we installed a small CCD camera in the head of Tai-chi. The ball to be detected is decided beforehand as one of the three kinds of balls with red, blue or yellow colors. Then Tai-chi detects the ball utilizing image processing and moves to the location of the ball.

3.2.1 Overview of the process

First we explain the whole process briefly. Figure 2 illustrates the flow chart of the whole process. At first an image captured by the camera attached to the head of the robot is sent to the PC using a wireless connection. Then the image is transformed into a binary image using the threshold that is established beforehand using the HSV color system. Next, noise is removed from the image using a median filter, and then using labeling processing groups corresponding to a specific color are detected. Next, a group with the largest area is decided as the area corresponding to the ball. Finally, based on the position of the center of the ball image in the image frame, the distance and the direction of the object from the robot is judged. And combining the motion of going forward and turning left/right, the robot approaches the object. In the following, details of the processing will be described.

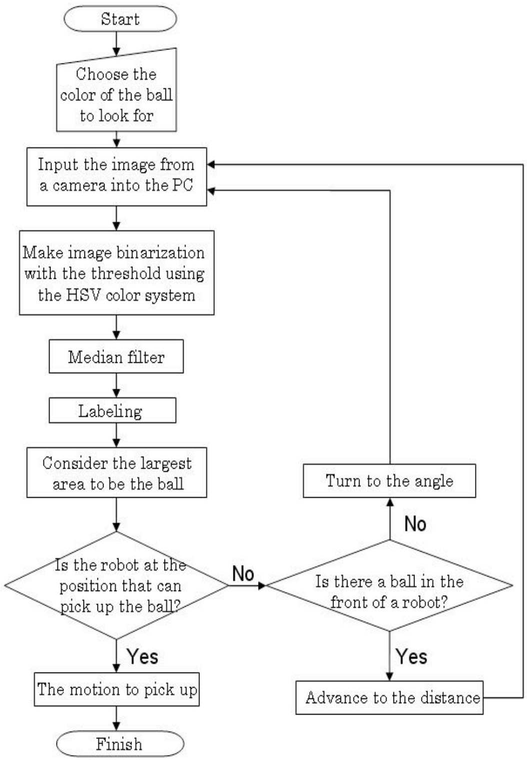

Fig. 2 Flowchart of the search function

3.2.2 A function to detect a ball

The first processing in the whole process is performed by detecting the color information assigned beforehand (either red, blue, or yellow) from the original image to find the ball. The original image that has been sent from the camera is based on RGB color information. The detection precision becomes unstable by a change of the illumination where the threshold for detection is based on this RGB information. This is because the RGB information is a color system expressed by a combination of the brightness of each of three primary colors. So the RGB information is not suitable for color detection for a color expressed as the combination of three basic colors. Therefore, we adopted the HSV color system consisting of the combination of H (Hue), S (Saturation), and V (Value) proposed by A. Smith [8]. Changing the lighting condition in many ways, we decided the threshold for the color detection. Using these thresholds, the original image is transformed into a black & white image and the area corresponding to the appointed color is detected from the original image. As noise is still contained in this image, a 3x3 median filter is processed on this image. Then using labeling processing, several areas, one of which is considered to be the ball, are detected and the labeled area with the largest space is detected from the original image as the area corresponding to the ball.

3.2.3 A function to move to the position of the ball

Then the robot has to recognize the distance and the angle to the ball to move to the position of the ball. Because we use only one camera in this study, we cannot use a method to measure the distance to an object with a stereo camera. Therefore, we fixed an installation position and the installation angle of the camera in this study and developed an algorithm to calculate the distance and direction to an object based on the position of the center of the ball image in the original image.

We set the camera angle so that when the robot was at the position where it could pick up a ball, the image of the ball is at the bottom line of the image. In this case the camera was able to obtain the image about 120 cm away from the position of the robot. In addition, the view of the camera right and left is about 45 degrees. Then measuring a relationship between a ball position in a real space and a a ball position in the image captured by the camera, we developed a map on the image that indicate the robot what to do. Figure 3 illustrates the map. Under the condition mentioned above, we explain the algorithm by which the robot moves in front of a ball. At first the robot performs image processing at its initial position, and the robot performs the turn using the map when the ball is not precisely in front of the robot. It performs the image processing again after it finishes a turn. If a ball is in front of the robot, it advances for the distance to the ball. Although the robot should go straight on precisely with the calculated distance, actually there is a case slipping off to the right or left. Therefore, the robot performs the image processing again after having advanced and it performs an additional turn or progress if necessary. Thus by repeating these movements, the robot moves to the position where it can pick up the ball. Then the robot performs the movement to pick up the ball after having moved.

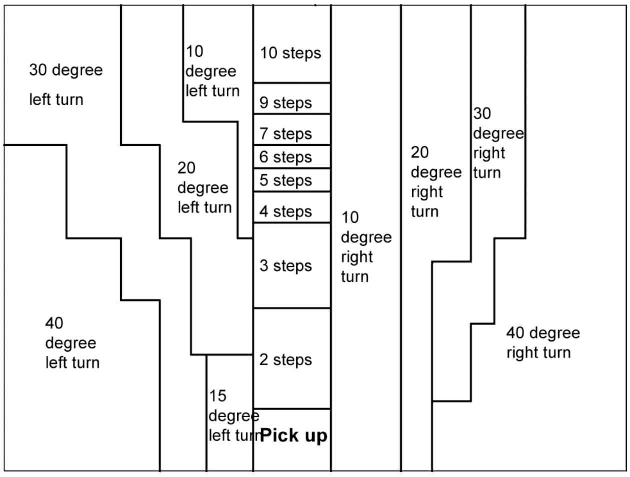

Fig. 3. What to do map on a captured image

3.3 Achievement of the grasping movement

In this study, we used "motion editor," which is the software dedicated to the humanoid robot "Tai-chi" to make special movements of the robot. The most general and stable movement when we grasp an object and lift it is squatting down, leaning our upper body a bit forward, then grasping the object by stretching our hand forward, then standing up holding the object. We carried out a preparatory experiment to check whether the robot could really pick up a ball with the movement that we developed using the motion editor. Then it was found that the robot was able to pick up the ball when the position of the ball was just in front of the robot or a little to the side of the right position. However, the robot was not able to pick up the ball when the position of the ball was slightly far from the right position. This is because the form of the hand of Tai-chi is a fist and was not able to grasp a ball well. Therefore, we designed another hand form so that it could hold an object stably. Thus the success rate for the robot in picking up and lifting the ball was greatly improved.

3.4 Development of the walking motion holding a ball

The robot Tai-chi is a compact small-sized robot and has only two modes for achieving motions. One is basic motions such as walking forward, walking backward, turning left, and turning right. These basic motions are achieved based on real-time calculation of motions based on inverse kinematics [5]. On the other hand, other motions dedicated to some special behaviors such as kicking, bowing, and other emotional behaviors are achieved by reading out the data corresponding to the behavior. These data are, as described before, designed and developed using a special software called motion editor. In this study we have to develop a motion by which a robot walks holding a object. Therefore, when a robot walks, the lower part of the body is controlled by a program as before, and it is necessary for the upper part of the body to continue the posture of the last key frame of the motion mentioned in 3.4. To achieve this system, we separated the program of the walking motion into two programs, one of which controls the motion of the upper body and the other the lower body. And we developed a program in which the control of the upper body and the lower body are carried out separately. This new program has an advantage that by combining different motions, new kinds of motions can be developed easily. Logically if there are n motions for upper and lower bodies, n^2 motions can be created using this method. Although we have to be careful not to let the robot fall down, this method has a great advantage when we want to develop complicated motions such as dancing motions. Thus by this method we could achieve the movement of a robot walking with a ball.

4 Evaluation Experiment and Results

4.1 Experiment results and consideration

With this system, we tested how correctly the robot could pick up the ball of the color that we appointed beforehand. For the position of the ball, we selected five places, each of which was less that one meter from the robot and within 30 degrees left/right from the front of the robot. For each of these positions we carried out a test for each ball twice. In this study, the robot does not decide all of its behavior patterns at the initial position. Instead, at the place to where the robot moves, it carries out the decision process using image processing and chooses the next action, and by repeating this process it approaches the object. Therefore, the success rates would change depending on the color of the ball and also depending on the location of the ball. Also the time required for approaching the ball and picking up the ball would change depending on these conditions. Therefore, we tried to evaluate these factors.

First, Fig. 4 illustrates the graph of the success rate for each color of the ball. According to Fig. 4, the success rate of the blue ball was the worst, and the success rate of the yellow ball was the best. The one failure trial for the red ball was because the robot lost the location of the ball and could not reach the ball position. On the other hand, in the case of the blue ball, even though it could approach the ball, when it tried to pick up the ball, it made a mistake. The reason for this fault is considered to be as follows. In this case, when the robot came near the ball, because of the reflection of light, only the lower part of the blue ball was extracted using the color information and recognized as a ball. Thus this incorrect image processing led to the incorrect judgment of the ball position and then to the failure to pick up the ball.

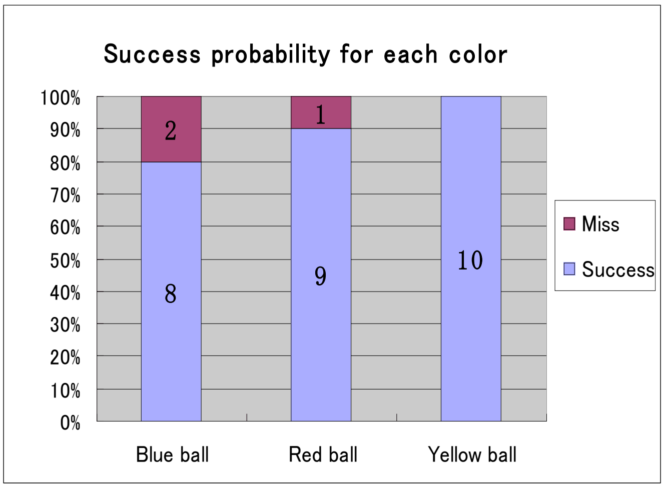

Fig. 4 Success probability for each color

Next, Fig. 5 shows the graph of the success probability for each place where the ball is placed.

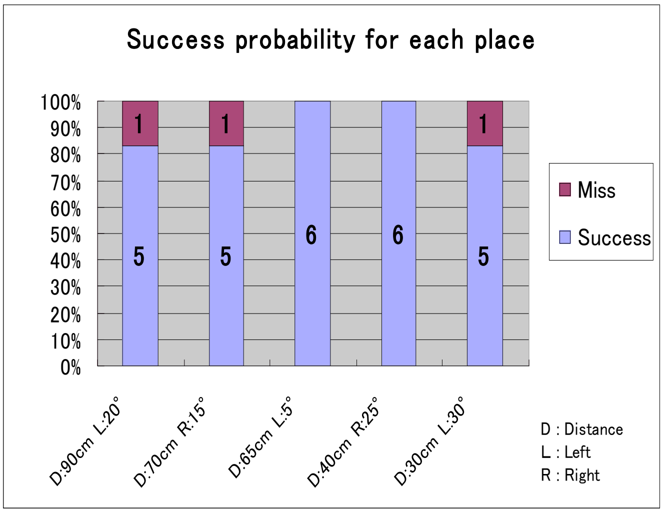

Fig. 5. Success probability for each place

According to Figure 5, there were three failures; in the case of distance 30 cm / left 30 degrees, in the case of distance 70 cm / right 15 degrees, and in the case of distance 90 cm / left 20 degrees. These results do not show big deflection, and it is thought that the success rate would not be affected much by the place condition.

Finally Fig. 6 shows the graph of the average time required until picking up a ball.

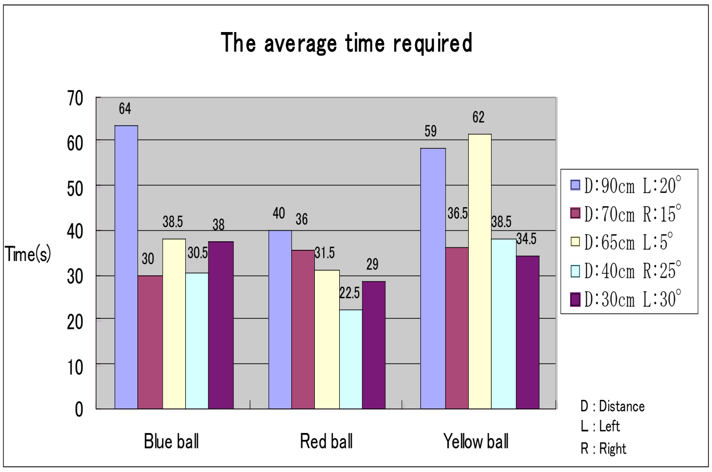

Fig. 6. Average time required

The values associated in the graph show the mean time required for the robot to approach the ball from the initial position and pick up the ball. The three failed trials described above are not counted in this case. As a matter of course, it took long time to arrive at the most distant place (distance 90 cm / left 20 degrees) from the initial position. However, there were not big differences of time between the other four places. The major reason for this would be the following. There is not an appropriate command for the robot to change direction. Instead, the robot tries to change direction by doing stamping. Thus it is difficult for it to adjust to the precise angle by only one trial. This means that the robot could adjust to the precise angle by repeating the direction change movement by stamping several times.

Next let's look at the difference in the required time depending on the color of the ball. It took the longest time for the robot to pick up the yellow ball, and the shortest time to pick up the red ball. The reason for this is that there is a difference in recognition precision depending on the color of the ball. For example, in the case of a yellow ball, there were cases in which it took much time to perform the fine angle adjustment because the extraction of the ball region became unstable because of the light reflection, and only part of the ball was extracted as a ball region. On the other hand, the robot was able to recognize the red ball well regardless of the distance to the ball in contrast with a yellow ball.

We understood that there was a big difference in recognition precision depending on the color of the ball. Especially when the lighting condition changed, the recognition of a ball became difficult.

4.2 Future study

Even though a fairly simple search algorithm using image recognition based on color information was adopted, a fairly high ball detection rate was obtained. At the same time we found that the recognition precision of the ball changes depending on the lighting condition and the viewpoint. Therefore, it is necessary to improve the image recognition system by introducing object recognition using its own form. Another problem is the fine tuning of the robot movement both for the distance and the angle. The robot has simple commands for the locomotion motions. For going forward and backward, the prepared commands are only to go forward/backward with the appointed steps. Also for angle change, the prepared commands are turn left/right by performing stamping with the appointed repetition. Thus for the locomotion of a precise distance and angle change with a precise angle, it is necessary for the robot to carry out these commands repeatedly, thus requiring a rather long time for the robot to achieve the required action. Coping with this problem is an important research topic. Another issue for shortening time is image processing while walking. As the locomotion of the humanoid robot is achieved by walking using two legs, the image captured by the camera while walking is not stable. Because of this, we adopted an algorithm in which the calculation of the distance/angle based on image processing is carried out when it stops. This repetition of moving then stopping and direction/angle calculation is another reason for the long time required. Therefore, it is necessary to try to develop an algorithm for carrying out image processing while walking by canceling out image shake.

5 Conclusion

In the future it is expected that humanoid robots will be introduced widely into our society. In that case, it is expected that humanoid robots would support our life physically in addition to entertaining us. As a first step toward this goal, in this study we aimed to create a small-sized robot that would support us physically by carrying such objects as coffee cups or newspapers. Based on this basic concept, we tried to achieve functions by which a small-sized humanoid robot discovers an object, approaches it, picks it up, and carries it. Then we carried out experiments to evaluate the capability of the functions achieved by the small-sized robot. The experimental results showed the robot could pick up a ball with considerable precision and was able to achieve the aim of finding an object and carrying it.

On the other hand, we discovered some points that needed improvement while we pushed forward with the study. Primarily, the robot is considerably uneven in recognition precision in indoor environments. In addition, it is necessary to improve the robot on the hardware side. High functionality of the robot is necessary, so we want to examine these points and will continue to study them in future research.

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