Development of an autonomous driving personal robot
"Development of arm's mechanism and control program"

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1. Introduction

Japan is facing a declining birthrate and a growing proportion of elderly people in its population. In such a society, the lack of a sufficient workforce is almost guaranteed. Specifically, the lack of caregivers to support the lives of senior citizens and handicapped persons will become a problem in the future. Therefore, efforts are underway to develop personal robots to provide independent life support for patients or perform light work in the home or office and thus to reduce caregivers' work.
This research was aimed at the development of a personal robot that acts with users in a human living environment to assist the work of humans. Specifically, I designed an arm mechanism that could perform light work such as taking a glass or newspaper or turning on a wall switch, and I created a control program for it.

2. Basic policy of the personal robot

Up to now, robots have primarily been developed to work in a factory or at the scene of a disaster. These robots can operate in a severe environment and can continuously perform simple work at high power and high speeds and with a high degree of accuracy. However, a skilled operator with special knowledge is necessary for their use. They are not easy for the average person to use.
Conversely, a personal robot is designed to live together with humans in a human living environment, and communications skills with humans are demanded. Moreover, because the situation in the surroundings of the robot is always changing, programming that is autonomous and flexible is demanded.
However, at present it is difficult to meet all of the various work instructions that may arise in various environments. Thus, in this research the range in which the robot acts was limited to the home, the office, and the hospital, and the type of work was limited to light work.

3.1 Hardware composition of the robot

Parts of the personal robot under development are the head that carries a CCD camera, the running drive part, the frame chassis, the arm part, and the hand. The camera on the head recognizes the external world. Because it can move in both horizontal and vertical directions, a wide-ranging search is possible both up and down and right and left. A personal computer, battery, ACDC inverter, and various drivers have been placed in the frame chassis.
The driving part is composed of the DC servo motor in the front of the robot, and the caster in the back of the robot. With the pulse, the DC servo motor can control the position of the robot. As for the arm part, five stepping motors are used and make possible an operation that brings the point part of the arm as close to the target object as possible. Hands have three fingers, and three servo motors are in the center finger and four servo motors are in the outside finger. The two outside fingers can move the position of the root and have achieved a flexible correspondence matched to the shape of an object.

3.2 Software composition of the robot

The processing system of the robot is divided chiefly into four parts. It is composed of a space recognition part that consists of the CCD camera, an operation decision part that consists of a limited space map and a movement pattern database, a driving control part that consists of a driver and amplifier, and a driving part that consists of various actuators for arm, hand, and movement mechanisms. With the space recognition part, the robot that receives instruction from a human sets information obtained from the CCD camera against a shape pattern DB. Moreover, the coordinates for the situation and the work object where the robot is being placed are now understood based on information in a limited space map. This information is given to the operation decision part, and the operation that should be executed is determined. For the movement, the best route to a destination is found from the limited space map. The operation that is decided upon is sent to the driving control part, and each actuator is driven. Realtime processing is done by repeating these operations, and the instructions are executed.

4.1 Development of the arm part

I assumed that this mechanism would mainly aim the hand to grip an object. And on this basis I designed this. Figure 1 shows a schematic view of an arm.

A multi-jointed arm that was able to do complex work was adopted as the mechanism in the development of the arm part. The parameters for three postures and three positions are necessary to describe the position of an object in three-dimensional space. I designed the arm with five degrees of freedom in this research. The robot is moved up to a distance from which an object can be easily gripped and then grips the object. Such an operation involves only a small degree of freedom.

Moreover, motors and gears are constructed in the arm. This method makes for a simpler mechanism than one with wires, and it can increase the accuracy of positional control. The arm does become heavy because of the weight of the motor, and therefore the weight that it can handle decreases. However, it is not a problem in this research to limit the content of work to light work.

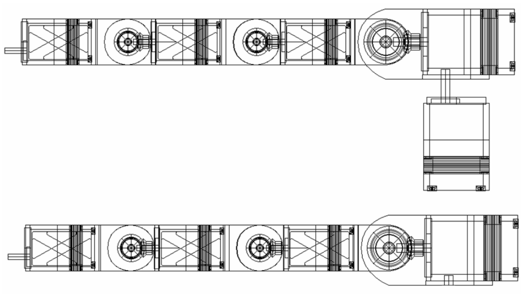


Fig.1 Schematic view of the arm

4.2 Development of the hand part

In this research, the work is limited to light work such as gripping an object or pushing a button. The work object could be something like a glass. The size of each hand part was designed based on the size of the human hand. The weight of the work object is assumed to be about 1kg. The outside two fingers can move the root position through a feature of this hand. Form 1 is the basic arrangement. When a spheroidal object is gripped, Form 2 is used because it is the steadiest one that can add power from three points. When the work object is gripped from the right and left, Form 3 is used. Figure 2 shows the schematic view of the arm. And in Figure 3 the hand was seen from the tip of a finger.

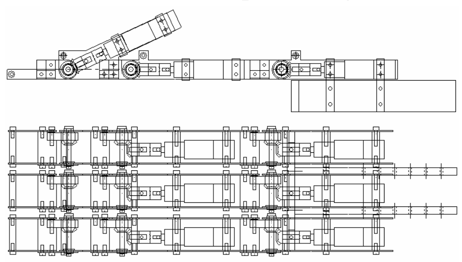


Fig.2 Schematic view of hand

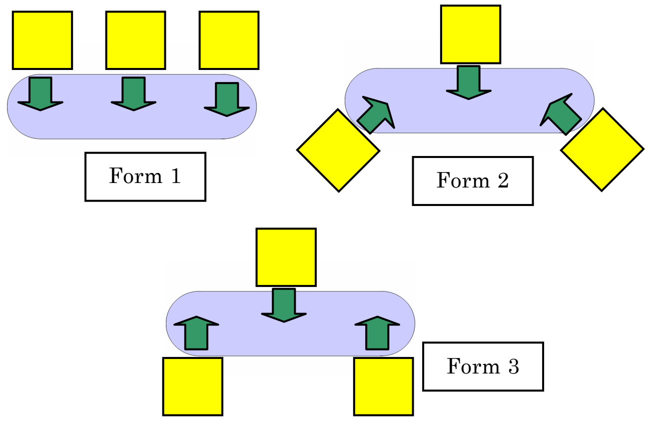


Fig.3 The hand that was seen from the tip of a finger.

5.1 About the control of the arm and hand

Operations that stop the hand in a target location and direction for a particular purpose are called positional control and posture control. By these operations a work object can be grasped and placed. It is necessary to calculate how many degrees each motor must be rotated to control a position. This calculation is called a reverse kinematics calculation.

Before this calculation, it is necessary to calculate the value of the hand's position and posture from the angle of each motor. This calculation is called a direct kinematics calculation. I created the control program based on this principle.

5.2 Coordinates calculation by a transformation matrix

First, I defined a relative position of a link and coordinate system like in Figure 4.

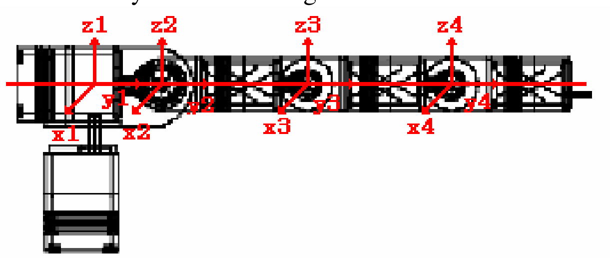


Fig.4 The relative position of the link and the definition of the coordinate system

These relative positions are shown by multiplying the following by the transformation matrix of 4×4.

$$T = \begin{bmatrix} A & a \\ 000 & 1 \end{bmatrix}$$

A is a procession which shows the rotation of the three-dimension procession coordinate system, and A is a three-dimension vector in which the movement is shown. If the positional vector shown in certain three-dimension coordinate systems is r, by the transformation matrix T the new positional vector r' is

$$\left[\frac{r'}{1}\right] = T\left[\frac{r}{1}\right]$$

The driving corner of joint i is θ*i*. The transformation matrix Ti when the distance between joint j and joint j+1 is assumed to be Lj. When O1 is the reference point and O1 is joint i is θi. The transformation matrix Ti when the distance between joint j and joint j+1 is assumed to be Lj. When O1 is reference point and O1 is $^{T}(0001)$, positional vector Oi of joint i is

$$O_i = T_1 \cdot T_2 \cdot T_3 \cdot \cdot \cdot T_{i-1} \cdot O_1$$

As a result, the simultaneous equations to calculate coordinates of each joint can be derived. If the driving corner is determined, the coordinates of each joint can be calculated.

5.3 Calculation of the joint corner using reverse kinematics

The driving corner to drive the hand to the coordinates of the target can be derived when you solve the above-mentioned simultaneous equations about the driving corner θ. At this time, the driving corner can be calculated by imposing the conditions that the angle and the height of the hand be kept constant. The control program was made based on these assumptions.

5.4 Control program of the arm

The control program was made based on the above-mentioned theory. Figure 5 shows the execution screen of the control program.

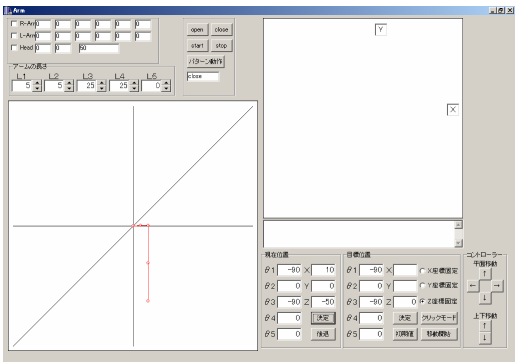


Fig.5 The execution screen of the control program

The left figure displays the present appearance of the arm and the parameter of the angle of each arm joint. The target and the minion's coordinates are displayed on the right side. First, the coordinates of minion's target are input. Next, the joint corner of the arm that fills the coordinates of the target by using the reverse kinematics calculation is calculated. The condition of the drive that locks the direction of the wrist at this time can be added. Figure 6 and Figure 7 show the appearance of the driving experiment that uses an existing arm.

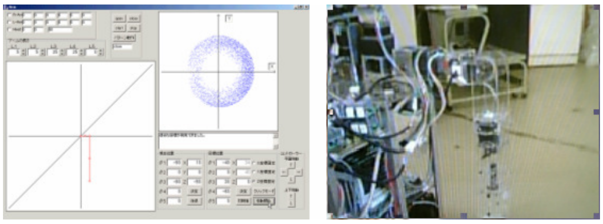
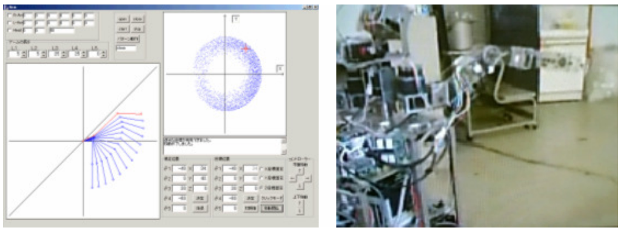


Fig6 Program before it drives and



the appearance of the arm

Fig.7 Program after it drives and the appearance of the arm

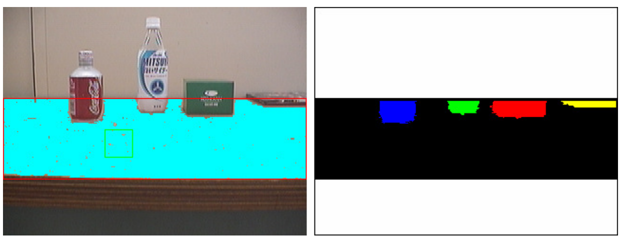
There is a difference in time from the start to the stop of each motor. However, the minion was almost able to be driven to coordinates of the target. As a result, there is no problem regarding its practical use.

6. Recognition of the work object

A plane that is of a similar color is extracted from one image obtained from the CCD camera, and the desk and the floor are recognized. A plane part on the desk and the floor is extracted using the HSV conversion. Next, the part not extracted is considered to be a part of the object, and it is extracted. Figure 8 shows the appearance of the object extraction.

Fig.8 The appearance of the object extraction

The relative coordinates of the work object and the rough size of the object can be calculated by the main body of the robot. These data is sent to the control program of the arm and using it, the robot can grip the work object. Figure 9 shows the size and the relative



coordinates of the work object on the output screen.

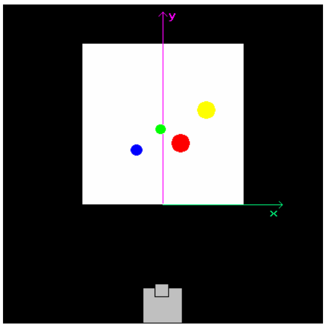


Fig.9 The screen for the output
of the parameters of the work object

7. Conclusions

In this research, the robot arm that met the demand required by a personal robot was designed. It is possible to create the various conditions that will drive the hand to a target position by the driving control program, and it is thought that the work object can be gripped by the hand.

References

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