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Study of action control for five-fingered hand

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Abstract: In those days, the requirements for robot are becoming higher and higher depending on the advance of technology. The application of underwater robots is also changing to underwater work from exploring now and conventional robot of 3-fingered hand cannot use for construction or maintenance work. We thought 5-fingered hand is necessary for the work and started the study on developing control method for work operation with 5-fingered hand that is attached on a 7-DOF manipulator (PA-10 7C). At first, we put a focus on a hand tool operation from gripping hand tool to finishing work and completed it on experiments.

Keywords: Robot hand, five finger, hand tool.

I. INTRODUCTION

In those days, higher accuracy of work or more complex work is desired for robot. Such kind of work is accomplished with robot hand and specialized mechanism can afford to satisfy the requirement. The authors thought to put the target on doing same level of work as human with robot. So, it should equip 5-fingered hand as human like. As 5-fingered hand, Gifu hand is well known, But it has not established yet how to apply for high level work. In this study, we made same size as human hand consisted of 20 joints and applied it for typical work using hand tool.

II. MOTION OF FIVE-FINGERED HAND

The motion of human hand for work is classif yed to several basic actions and combined basic act ions. Basic action are gripping, picking, holding, rot ating, pushing and so on. In this paragraph, we wo uld like to discuss about finger motion of basic act ion.

(1) Gripping

Representing hand tools such as hammer, saw or pliers are handled with bending all finger joints to inside and hold tool's body with all fingers.

Of course, when using hammer, the hand gripping hammer is moved with wrist and arm and gripping force is also controlled.

(2)Picking

When we handle a small object, we usually use thumb and fore finger, and changing posture of both finger with the size, shape or material of object. In some case, we use middle finger with adding two fingers.

(3)Holding

When we handle an object between two fingers, we call this action as holding. We can handle tobacco or small ball in such a manner. In this case, the joints of finger should be straight.

(4)Rotation

After supporting basket ball with thumb, fore finger and middle finger, we can rotate it with moving only the base joint of thumb and middle finger to become the finger end along arc trajectory. In this case, another fingers are bended until the finger end touching to palm face.

(5)Pushing

When we push some object, we attach the palm face to the object and all fingers take the posture without disturbing the action. For example, when pushing a flat surface, all fingers are expanded in straight posture and their face are also touched to the object.

III. FIVE FINGERED HAND FOR ROBOT

1. Structure and Specification

Thinking about above mentioned hand actions, we designed 5-fingered robot hand as shown in Fig. 1. It has roughly same size and shape to human hand. It has a flat palm and each finger is attached to the palm with rotating joint. Each finger has 4 joints. The end joint and middle joint have a motion bending to palm, but base joint has a motion bending to palm and rotating in a

palm surface. Each motion except end joint is driven with micro-DC motor and end joint is linked to middle joint. We show the moving range, speed and torque of each joint in Fig. 2 as the specification of the hand.

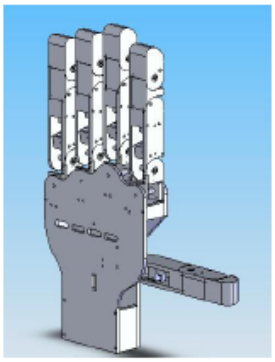


Fig. 1 Five Fingered Robot Hand

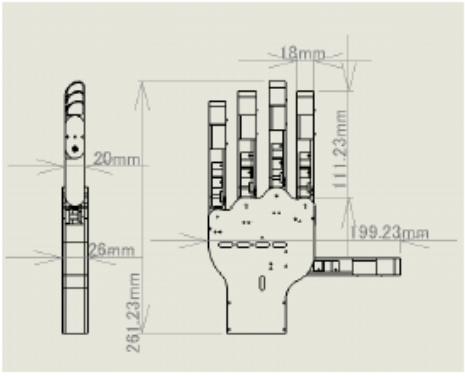
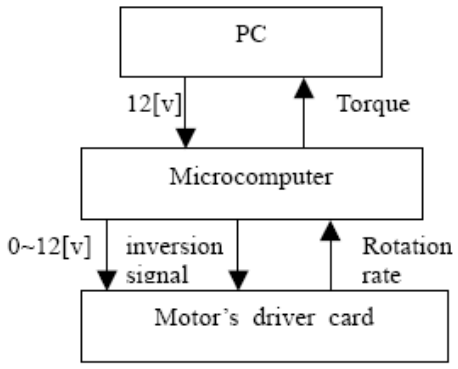


Fig. 2 Specification of Five Fingered Robot Hand

2. Driving System

Each micro-dc motor has a driver card and we should supply +12 volt for normal revolution, -12 volt for reverse revolution and 0 volt for stopping to driver card. When we control hand motion, we must select useful finger and joints depending on a hand action and send power to the driver card.



Finger motion should be decide with computer, so we made signal distributor that is connected to each driver board and combined to computer with serial line. The distributor is consisted of PIC and I/O parts, and send power to active joints. The construction of power distribution system is shown in Fig. 3.

IV. ACTION CONTROL FOR FIVE FINGERED HAND

1. Decision of work sequence

Before starting control, we must design total sequence of toe work. Here we treat a hand work with gripping hand tool as a most typical case.

・Binding work with bolt and nut using box wrench

When we connect something with bolt and nut, we usually use box wrench. In this work, the sequence becomes as follows.

(1)Pulling up a wrench from tool holder
(2)Gripping wrench
(3)Making work
(4)Return the wrench to tool holder

Detail of motion on each stage is as follows.

At first, we must choose a useful wrench from a size of bolt and pull it up with two fingers from tool holder. Then, we must grip it in normal posture with a help of another hand, and move the wrench box to bolt head and attach it over it. Move the wrench repeatedly in a range decided from mechanical limitation until torque limitation coming. After finishing work, we must remove wrench box from bolt head and release the wrench with help of another hand.
Then return it to holder supporting with two finger.

In this work, co-operated work with both hands, visual recognition for tool situation, bolt situation and wrench situation are of course necessary. But we are thinking those subjects are put on next stage and assume that hands co-operation is completely available and all indispensable information is given in this study.

2. Control of Hand Action

Depending on the work sequence, we put forward the stage automatically.

(1) For pulling up the tool from holder, we use thumb and forefinger. It is a picking action. Decide the picking position and posture at first then, We define a reference point and direction of fingers as follows.

(a) Consider a flat surface consisted form both center line of each finger.
(b) Consider a line connecting both center position of each finger head.
(c)The center position in the line is the reference point, and direction of vertical line at the reference point on the surface is reference direction.

Move hand to the tool as meeting those reference point and direction to tool's them.

After confirmation of touching, remove tool from holder.

This control is shown in Fig. 4.

Wrench holder Recognition	→ ←	Visual Recognition
Left Hand st/by & Approaching	→ ←	Hand Shape/ Position/ Posture Control
Wrench Holding & Removing	→ ←	Finger Motion/ Force Control Hand Position/ Posture Control

Fig. 4 Control of Tool Pulling Action

(2) For wrench gripping, working hand should grasp at the most effective position from the most effective direction. In this case, wrench is hanged up with left hand and right hand grasp it for work. The initial posture of right hand is like this; palm surface is vertical.

All fingers except thumb are straight shape and paralyzed each other, and exist in a same surface with palm. The thumb is also straight shape but bended to palm about 90 degrees. . In this case, the reference point is the center position between the head of thumb and forefinger. So, this point is approached to gripping position until the base joint of both finger touch to the wrench. Then bend joint of all finger to inside until enough grasping power gained. This control is shown in Fig. 5.

Left Hand & Wrench Recognition	→ ←	Visual Recognition
Right Hand st/by & Approaching	→ ←	Hand Shape/ Position/ Posture Control
Wrench Gripping	→ ←	Finger Motion/ Force Control Hand Position/ Posture Control

Fig.5 Control of tool grasping action

(3) In this control, we put the center of wrench box as reference position and central line of the box as reference line. Then move wrench as the reference point meet to center of bolt head and reference line meet to central line of bolt.

After attaching box to bolt head, we turn the wrench arm in the range of 45 degree to 60 degree repeatedly.

When the torque limit comes, we stop turning action and release box from bolt head. This control is shown in Fig. 6 with block diagram.

Bolt Head Position/Posture Recognition	Visual Recognition
Attaching of Wrench Box	Right Hand Position/ Posture Control
Binding	Right Hand/ Arm Motion & Force Control

Fig.6 Control of Binding Work

(3)After the work, we must return wrench to the holder. At first, left hand comes to right hand and hangs up the wrench. This action control uses same reference point and direction. Then move hand to holder to meet those reference to holder's them. After setting the wrench to the holder, all action for the work is finished. This control is shown in Fig. 7 with block diagram.

Wrench Head Recognition	→ ←	Visual Recognition
Wrench Holding with Left Hand /	→ ←	Same Action C ontrol with Pulling
Holder Recognition	→ ←	Visual Recognition
Wrench Restoring	→ ←	Finger Motion/ Force Control Hand Position/ Posture Control

Fig.7 Control of tool restoring action

V. EXPERIMENT

1. Experiment with Simulation

Confirming abovementioned automatic work, we made three-dimensional graphical simulator for those hand and arm system. The model of robot arm is PA-10

7C of Mitsubishi Heavy Industry Co. Ltd (Fig. 8). As a software of graphical motion, we used PRO-Engineering. Under this situation, we started simulation from basic action. Some typical results are shown as follows. (Fig. 9, Fig. 10)

And fully automatic working sequence were confirmed with simulation. (Fig. 11)

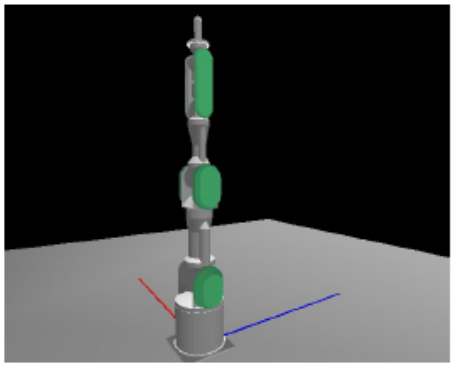


Fig.8. Graphic Simulator

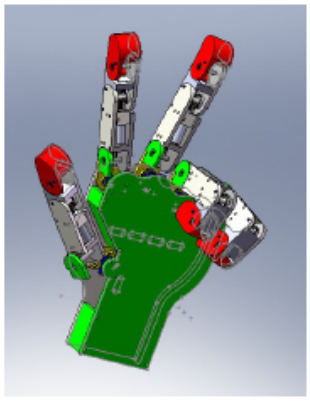


Fig.9. Simulation result

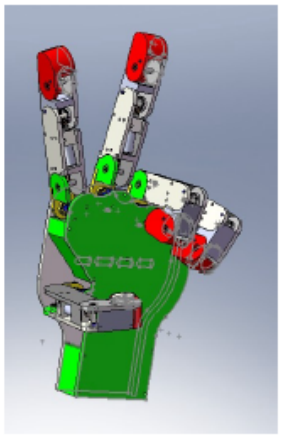


Fig.10. Simulation result

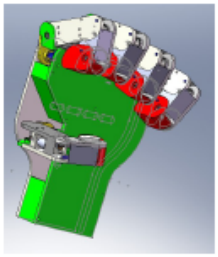


Fig.11. Simulation result

2. Experiment with PA-10 and Five Fingered Hand

We are constructing the same experimental system as the graphical simulator. We are going to try a same action with graphical simulator and show the experimental results on the symposium. We have already studied same action with PA-10 and four chuck type of hand.[1] Considering about the former result, we are expecting to have a better results, because the hand could not grasp wrench in any condition and we must prepare special tool for grasping. On the contrary, five fingered hand dose not need special tool for all kind of action in this work.

VI. CONCLUSION

In this study, the authors developed five fingered hand which has roughly same size and freedom to human hand. To confirm the availability of this hand, we classified human hand action and considered control algorithm for same action. As the first step of this study, we developed three dimensional graphic simulator of this hand and PA-10, and tried the control algorithm for actual work. This study showed better availability than conventional hand. But we must expand the confirmation to another kind of work with considering former studied subjects[2],[3] to establish this type of hand. We would like to improve the hand mechanism for more useful action.

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