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Motion Control of 2 DOF Orthogonal robots with Adaptive Control

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Abstract: This study considers motion control of 2 DOF orthogonal robot that is crossed two industrial linear robots with adaptive control under the various load condition. We constructed experimental facility with putting 0.5m length linear robot on a 1m length linear robot and confirmed performance under various conditions with applying adaptive control of fast sampling and control interval. The results show a prescribed control performance can be satisfied. Therefore, adaptive control can be expected as a useful control method for industrial, high-speed positioning robot.

Keywors: linear robot, motion control, adaptive control

I. INTRODUCTION

The adaptive control that can reflect the change of characteristics of the control targets was thought as an effective control method for modern control system. However it requires many and complex calculation in the control for real time estimating of the target model and adjusting control signal, then control interval becomes rather large. It is a weak point of adaptive control. So, main current of the control theory moves to the robust control. On the contrary, the conventional PID control is used in industrial fields because of the easiness and high speed. However, needs to high productivity or accuracy in production system require high level of automatic control system which can comply with a change of characteristics of target or environmental condition in those days instead of conventional PID control.

In the fields of industrial robot, it becomes more evident, so we treated the motion control that can satisfy the predetermined condition under the change of load for linear transfer robot with applying adaptive control of high performance of computer. which the weak point is thought to be improved with the

Saying concretely, we constructed experimental system with crossly putting 0.5m length linear robot on a 1m length linear robot, and moved both robots at the same time with predetermined pattern under the change of carrying weight with adaptive control. Through those experimental researches, we confirmed the effectiveness of adaptive control.

II. EXPERIMENTAL SYSTEM

Figure 1 shows the configuration of experimental system. Each linear robot is composed of servomotor with resolver, ball screw, carrying table, motor driver and controller. The carrying load is set on the carrying table of upper robot. In this system, we used a personal computer as the controller and control program is designed with using Simulink toolbox of MATLAB by Mathworks. Here, the torque control signal is calculated with adaptive control algorithm based on the position signal with resolver and output to motor through driver.

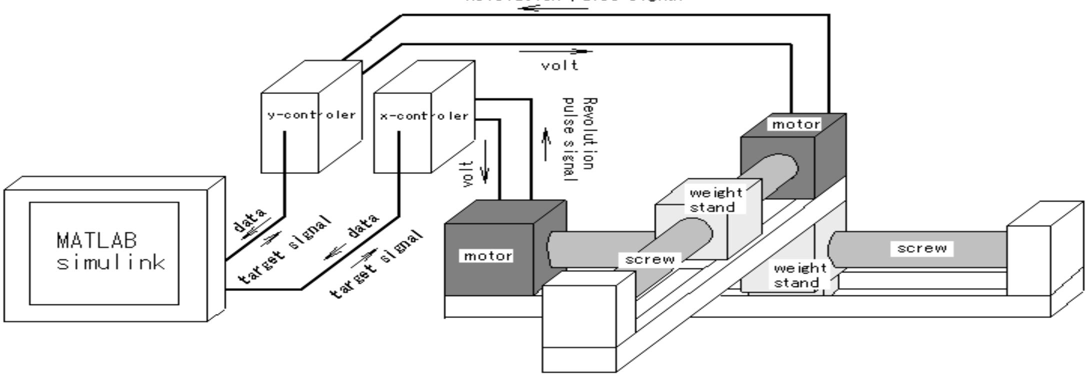


Fig.1 Experimental system

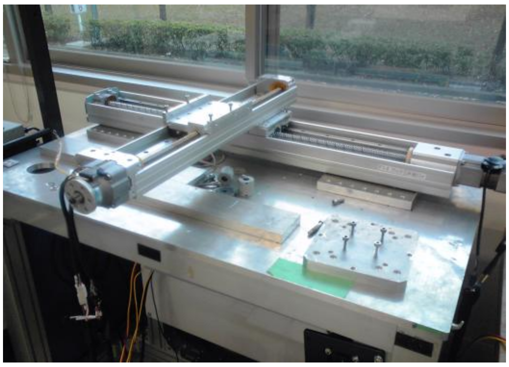


Fig.2 Photo of Experimental system

The specifications of main components are shown in Table 1.

Table 1 Specifications of main components

Lower Linear Robot

Stroke	:1000mm
Max. Carrying Load	: 30kg
Carrier	: Ball Screw(Lead: 20mm/rev.)
Power Source	: AC SERVO MOTOR (Output; 200W, Max. Rpm; 3000, Max. Torque;0.64Nm)
Reduction Gear Ratio	: 1/3
Position Sensor	: Resolver (Resolution; 16384 pulse/rotation)

Upper Linear Robot

Stroke	: 500mm
Max. Carrying Load	: 10kg
Carrier	:Ball Screw(Lead: 20mm/rev.)
Power Source	:AC SERVO MOTOR (Output; 200W, Max. Rpm; 3000, Max. Torque;0.64Nm)
Reduction Gear Ratio	: 1/3
Position Sensor	: Resolver (Resolution; 16384plase/rotation)

III. CONTROL DESIGN

The control problem of precise positioning robot is to make the angle of the motor accurately follow to the target signal. It is well known in PID control, that the control system contains a PI speed control loop, and a P position control loop. In this study, we use adaptive control instead of PI control for the speed control loop, as shown in Fig. 2, the purpose of which is to absorb the response speed change caused the load change .

The RLS method (recessive minimum mean square method) is used as the model identification, and the model order is assumed 2 in consideration of the complexity and rapidity of response of the system. Some referred expression is as follows.

Model :

$$\begin{aligned} y(k) &= a_1 y(k-1) + a_2 y(k-2) + b_1 u(k-1) + b_2 u(k-2) \\ &= \theta^T(k)\varphi(k) \end{aligned} \tag{1}$$

Where, y( ) and u( ) indicate plant output and control input, respectively, and

$$\theta = [a_1 \quad a_2 \quad b_1 \quad b_2]^T$$

$$\varphi = [y(k-1) \quad y(k-2) \quad u(k-1) \quad u(k-2)]^T$$

The parameter vector $\theta(k)$ is calculated repeatedly as follows.

$$\theta(k) = \theta(k-1) + \frac{P(k-1)\varphi(k)}{1+\varphi^T(k)P(k-1)\varphi(k)}\varepsilon(k) \tag{3}$$

$$P(k) = P(k-1) - \frac{P(k-1)\varphi(k)\varphi^T(k)P(k-1)}{1+\varphi^T(k)P(k-1)\varphi(k)} \tag{4}$$

$$\varepsilon(k) = y(k) - \varphi^T(k)\theta(k) \tag{5}$$

,with the following initial conditions.

$$\begin{aligned} \theta &= [1 \quad 1 \quad 1 \quad 1]^T \\ P &= I \end{aligned} \tag{6}$$

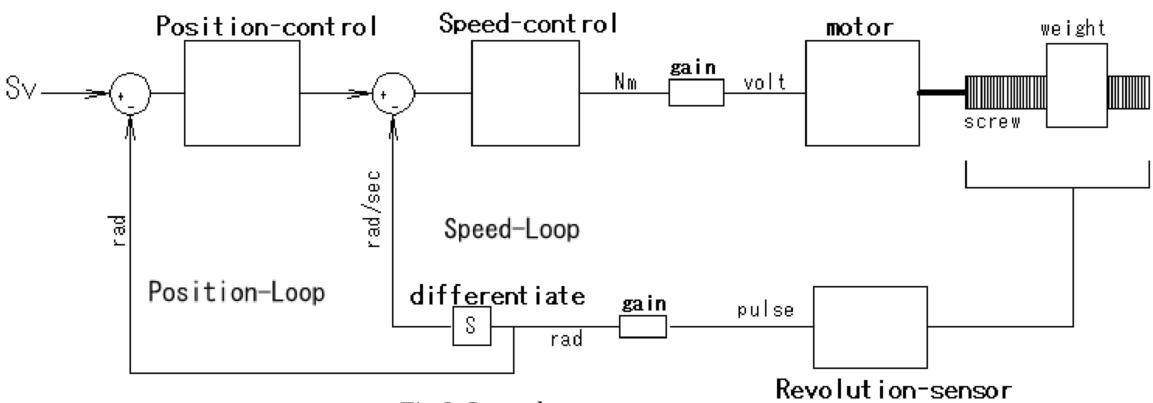


Fig.3 Control system

Lastly, the expression of the control input is as follows.

$$u(k) = \frac{u_m(k) - b_2 u(k-1) - a_1 y(k) - a_2 y(k-1)}{b_1} \qquad (7)$$

IV. RESULTS AND EVALUATION

Here we show the results of experiments and make evaluation for them.

In the following figures, we only referred to the results of motion on lower robot when both robots were moved in the experiment. The sampling rate of those experiments was 0.001 second.

Figure 4 and Figure 5 show the results of the motion following to sine wave under the load of 0kg and 5kg. Here, continuous line is set value, and dash line and dot line are responses for 0kg and 5kg lords, respectively.

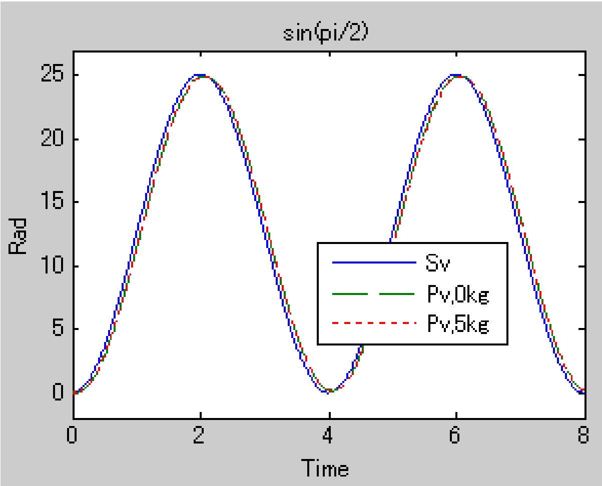
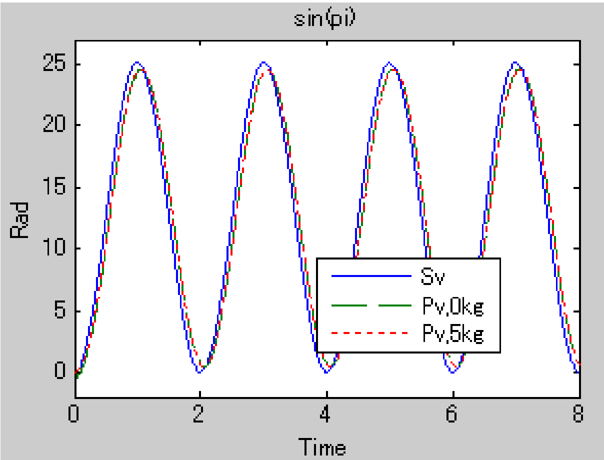
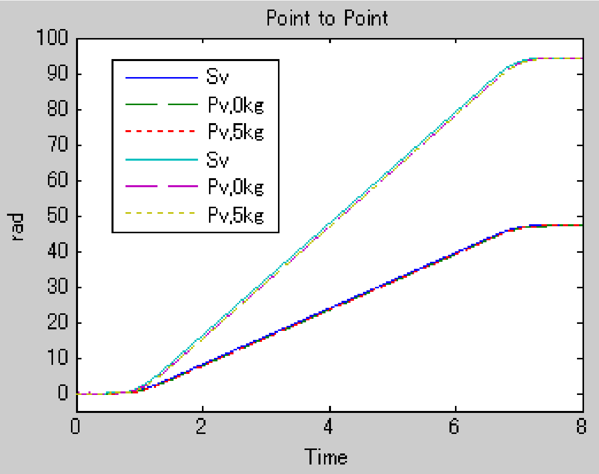


Fig.4 Response to 4πsin(π/2・t)



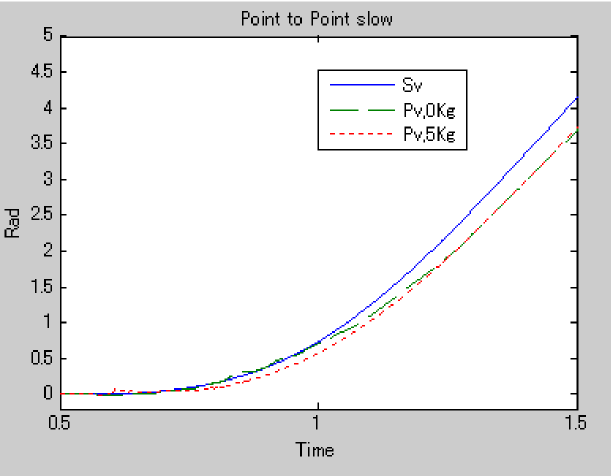
・Fig.5 Response to 4πsin(π・t)

Figure 6 shows the results of the motion following to linear patterns of different speed, one is 94rad/8sec (300mm/8sec) and the other is 47rad/8sec (150mm/8sec).

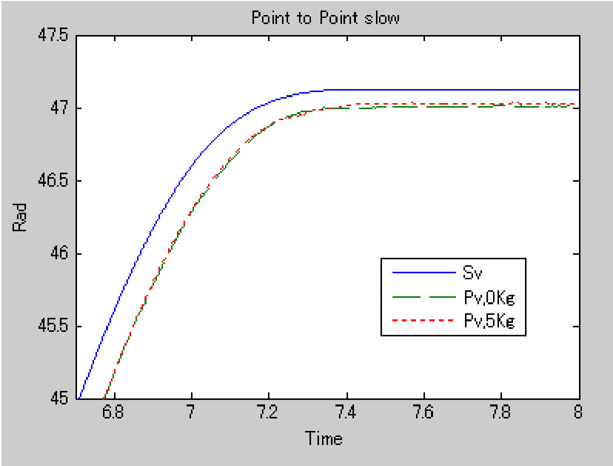


・Fig.6 Comparison of linear motion
(Moved distance: 150mm and 300mm)

Figure 7 and Figure 8 show the starting and stopping process to the order of moving 150mm/ 8sec for evaluation. We tried this test for the case of 300mm (94 radian of total rotation). The result is omitted here because they are nearly equal to the results of 150mm (47 radian).



・Fig.7 Detail at starting of 150 mm movement



・Fig.8 Detail at stopping of 150 mm movement

In those results, the dash line and dot line in each figure show almost same responses. This means that the difference of load does not influence to the results. Especially, the difference of stopping position between the carrying weight of 0kg and 5kg is very small (from Fig.8, it is 0.03mm). We think this is the allowable margin of error because it is the level of machinery error. All these merits obviously come from adaptive control.

Figure 7 shows a small shaking of response at just after starting. This is allowable, because it is an initial and usual process of adaptive control, and shows that control system has started learning for targets, and disappears immediately.

On the other hand, it is seen that the delay of response becomes remarkable depending on a frequency of input signal. In this case, the delay is connecting to control error directly. Also, the positioning error at stopping point (see, Fig.8) is about 0.3mm, this is larger than the demanded accuracy (0.04mm).

We think these problems are depending on the structure of control system, because the position control loop use the conventional P control. How to control both speed and position of high speeded robot with adaptive control is our next subject.

V. CONCLUSION

This study shows that the performance of transfer system with linear robot can be improved with adaptive control. We can ensure the desired performance to the linear robot under specified range of load condition. The weak point of adaptive control that is not so fast is improved to the level of robot motion control with computer performance. Of course, the study was accomplished in a laboratory and having big difference to actual industrial use. Decreasing the level of error, optimization of initial parameter for adaptive control, or simplifying the algorithm and speed up of calculation for small computer are the subjects for actual use.

Now we are continuing study for the level-up of accuracy with improving position and speed control, especially optimizing the initial value of θ, and the speed-up of calculation with combining speed and position control and/or decreasing the degree of referring model.

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