The Eighteenth International Symposium on Artificial Life and Robotics 2013 (AROB 18th '13),
Daejeon Convention Center, Daejeon, Korea, January 30-February 1, 2013

A precision position arrangement of the SCARA robot by H∞robust control

Yasuyuki Hirofuji, Zhang Feifei, Masanori Ito

Tokyo University of Marine Science and Technology, Japan
(Tel:+81-3-5245-7422, Fax: +81-3-5245-7422)

Abstract: The SCARA (Selective Compliance Assembly Robot Arm) robot is playing an active role in many manufacturing stages of electrical machinery, electronic components etc. In those days, improvement of productivity is becoming important subject. And it will be realized with improvement in a capacity utilization rate, and industrial accident prevention, development of the technology for speed up of motion, accuracy of operation, or abnormality detection. Especially speed, accuracy and safety are most important items for it. We applied modern control theory, such as H_∞ robust control and confirmed the performance with experiments.

Keywords: H∞Robust Control SCARA Robot

1 INTRODUCTION

Currently, the control method of industrial robots, such as a SCARA robot is PID control, which is classified as a classical control. As PID control is relatively simple and easy to use, it is widely used in various situations and not limited. On the other hand, modern control theory is not so used in the field with the reason of difficulty to use because of its stringency and complexity. However, various control theory have been studied and many advanced control theory have been established until now.

As the factors that cause to parameter change of SCARA robots, some mass change at the time of holding the work, posture change, interference from other joints, and aging of the device are pick-upped. Modern control is different from classical control, such as PID control, and able to handle multiple-input multiple-output systems. With applying the H_∞ robust control, robust stabilization for parameter variations, disturbance from peripheral inhibitory effect can be expected. Then it is possible to improve the performance such as high-precision positioning with smooth operation of the arm, stabilization of the system, and reduction of maintenance.

2 CONTROLLED OBJECT

In this study, we used a SCARA robot (very small) YX-XG series by Yamaha Motor CO. Ltd.

Table 1. Spec. of controlled object

Shaft X length	45(mm)
Shaft Y length	75(mm)
Motor capacity	30(W)
Maximum rotation	8000(rpm)
Reduction ratio	1/50

The mass of each joint, the moment of inertia, friction coefficient are identified with experiment.

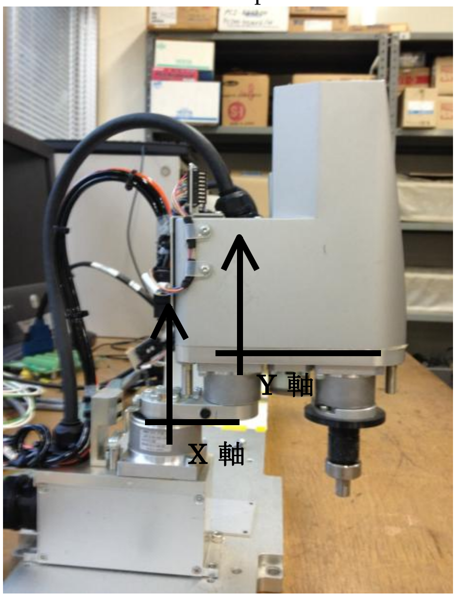

Fig. 1 SCARA Robot

3 H∞ROBUST CONTROL

Control design to stabilize the closed-loop system including the control target is to minimize the H_∞ norm of the closed-loop transfer function between the input and output.

The actual system is complex, and it can't be represented with a single transfer function. So, we adopted the method to estimate the uncertainly from the difference between actual and model system.

Model for this design is that of the nominal plant. Real systems are included in the plant.

Therefore, on the design of the controller, instead of thinking the actual system, we considered the collection of this plant model, to guarantee the stability and control, also ensures the stability and control to the real system.

4 SCARA ROBOT MODELING

At first, from the experiment, we calculated mass, moment of inertia of each axis and the friction coefficient including a motor and load.

Equation of motion and the transfer function of the motor is as follows,

$$J\ddot{\theta} + D\dot{\theta} = J\dot{w} + Dw = kV \quad (1)$$

$$G(s) = w(s)/V(s) = k/(Js + D) \quad (2)$$

θ : Angle of rotation of the arm

J : Moment of inertia of the base of the arm

D : Coefficient of friction of the arm

V : Input voltage

k : Motor parameters

Time constant : $T = J/D$ (3)

Gain : $g = k/D$ (4)

$$D = V \times 50 \times 50 \times k / A \quad (5)$$

Fig.2 and 3 are the output data of the angular velocity of each arm when input to the X-axis is 0.25 (V), and input to the Y-axis is 0.5 (V),

From measured data graph, we can read Time constant: T, the Gain: g, and calculate the unknown J and D.

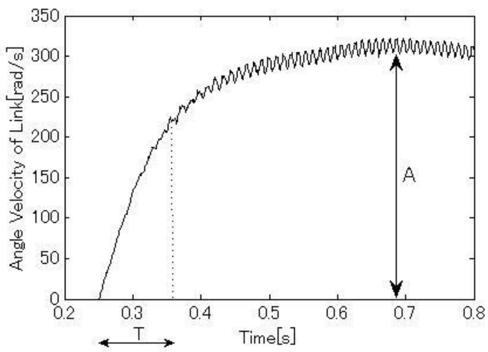

Fig. 2 Experiment x

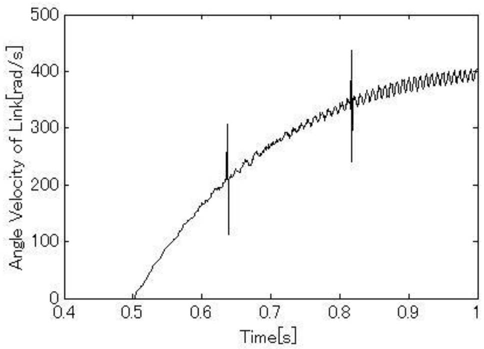

Fig. 3 Experiment y

Next, from the moment of inertia calculation, mass can be estimated as follows,

$$Jy = Dy \times Ty \quad (6)$$

$$Jy = Iy + My\left(\frac{h}{2}\right)^2 \quad (7)$$

Unknown parameters can be obtained with those processes.

$$Mx = 1.5(kg) \; My = 2.4(kg)$$
$$Jx = 0.04(kgm^2) \; Jy = 0.02(kgm^2)$$
$$Dx = 0.486 \; Dy = 0.226$$

From those data, we can fix model of target.

The transfer function from the input voltage to the rotation angle of each of the X-axis, Y-axis of controlled object is as follows.

$$P_x = \frac{89.39s + 5959}{s^3 + 187.1s^2 + 4755s} \quad (8)$$

$$P_y = \frac{159.8s + 6561}{s^3 + 175.6s^2 + 4253s} \quad (9)$$

5 DESIGN OF H∞ROBUST CONTROLLER

Using MATLAB, we designed a H∞ robust controller.
The design procedure is as follows,

1) Selection of nominal model
2) Formulation as a mixed sensitivity problem
3) Configuration of the general plant
4) H∞ robust controller design

First, for the step 1) each transfer function of X axes and, Y axes uses.

Next, in order to design a H∞ control system, the problem of determining the controller K is considered to minimize following evaluation function.
.

$$\left\| \begin{matrix} W_1 PK(1+PK)^{-1} \\ W_2(1+PK)^{-1} \end{matrix} \right\|_\infty \rightarrow \text{Minimization}$$

Fig. 4 Evaluation function

As shown in the Fig.5, it corresponds to the transfer function from W1 to z, and from W2 to z.

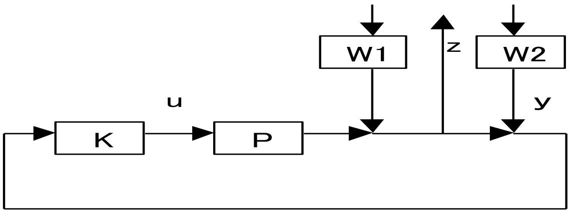

Fig. 5 Mixed sensitivity problem

Then, as shown in the following figure, we configure the general plant.

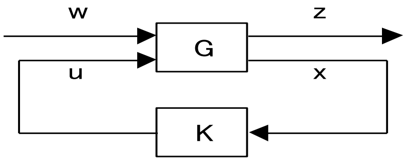

Fig. 6 General plant

· How can we choose the weighting function?

It was depicted as follows. The frequency response variation were estimated on bode diagram, and so as to cover this, it was determined with the low-order transfer function on the graph. At this time, we determine the weighting function as shown in the broken line with approximation. Then, at the same time we draw the Bode plots of the variation and weight, and make sure that the top of the Bode plot of weight variation. In addition, as the control is not performed in a high frequency band, we set the frequency as high as possible and increase the gain of the variation. Then vibration input is reduced.

In Fig.7, P is solid line, W1 is broken line, and W2 is alternate long and short dash line.

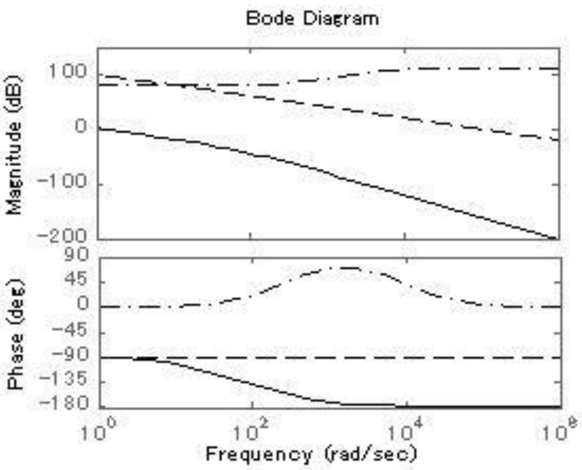

Fig. 7 Bode diagram

$$K = \left[\begin{array}{c|c} A_k & B_k \\ \hline C_k & D_k \end{array}\right]$$

$$A_k = \begin{bmatrix} 0.001603 & -0.3104 & -0.5645 & 1.529e+004 \\ 0.004666 & -1.545 & -57.34 & 3.452e+004 \\ -0.4592 & 166.4 & 141.8 & -3.899e+006 \\ -2.64e-005 & 0.0003646 & 0.02252 & -279.8 \end{bmatrix}$$

$$B_k = \begin{bmatrix} -9.008e-005 \\ -0.0002033 \\ 0.02296 \\ -5.725e-005 \end{bmatrix}$$

$$C_k = \begin{bmatrix} -7.997 & 1577 & 6319 & -7.508e+007 \end{bmatrix}$$

$$D_k = \begin{bmatrix} 0.4422 \end{bmatrix}$$

6 RESULTS OF EXPEREMENT

We performed comparative experiments of H∞ controller and PID controller. Confirming the robustness, we experimented to change positioning speed. Fig. 8 to 11 are the results of PID control. Fig 12 to 15 are the results of H∞ control. On each control, we experimented with different positioning speed at 1.4 seconds to three times, four times, five times. The horizontal axis is Time (s). The vertical axis is angle of each link (rad.). Solid line is the target angle. The dotted line is the measured angle

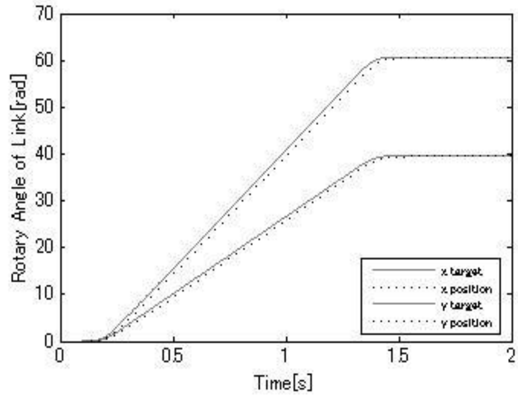

Fig. 8 Experiment result of PID control (1.4sec)

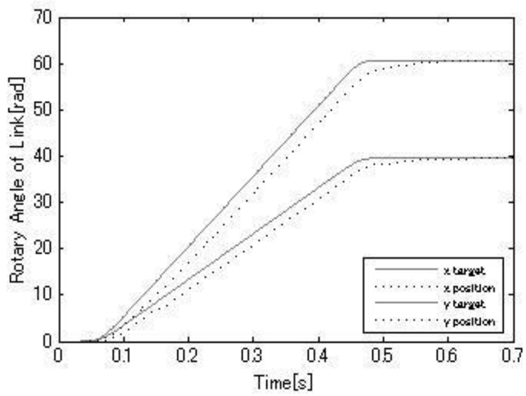

Fig. 9 Experiment result of PID control (0.47sec)

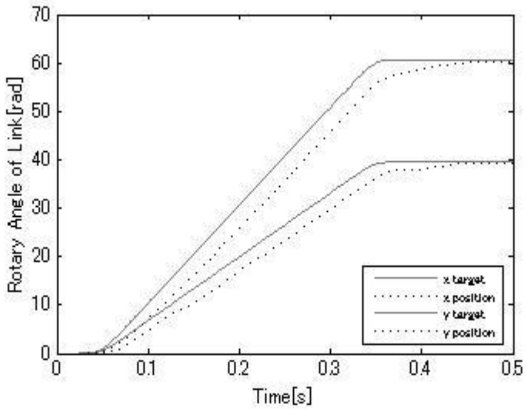

Fig. 10 Experiment result of PID control (0.35sec)

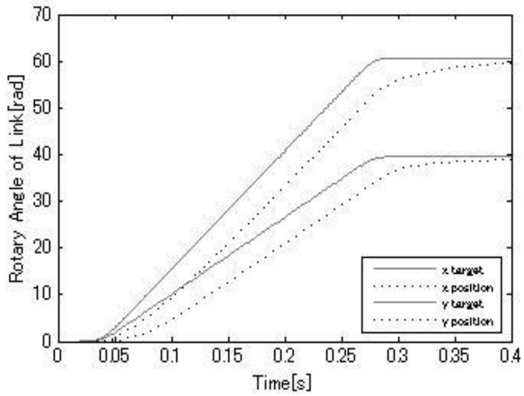

Fig. 11 Experiment result of PID control (0.28sec)

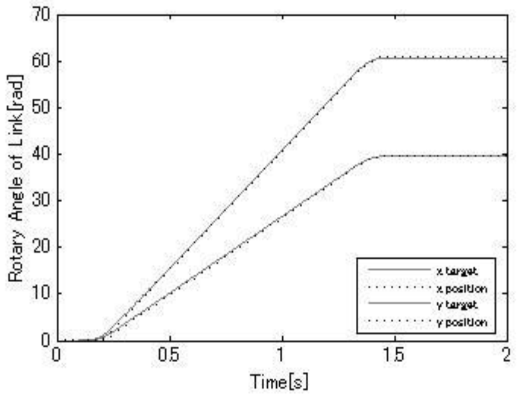

Fig. 12 Experiment result of H ∞ control (1.4sec)

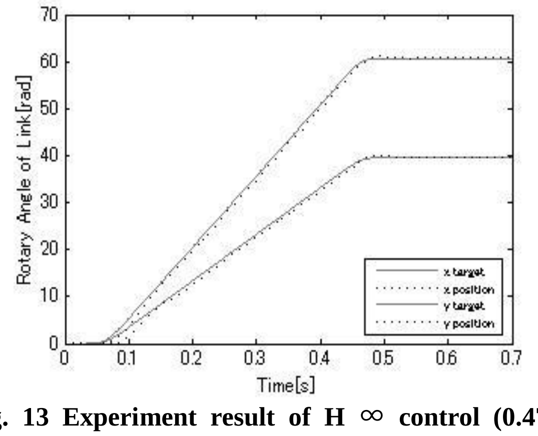

Fig. 13 Experiment result of H ∞ control (0.47sec)

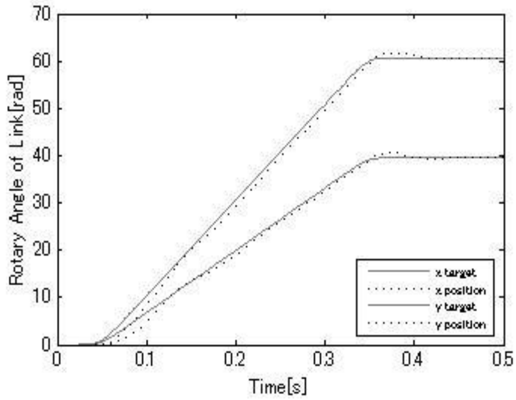

Fig. 14 Experiment result of H_∞ control (0.35sec)

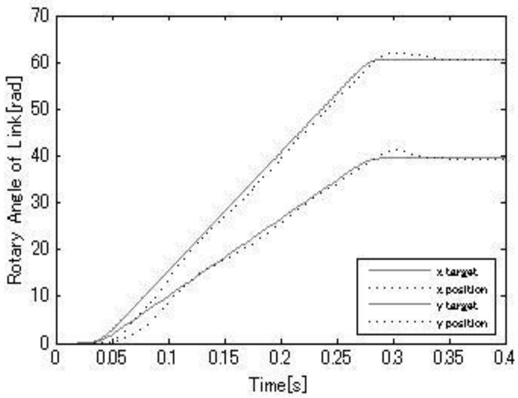

Fig. 15 Experiment result of H ∞ control (0.28sec)

7 CONCLUSION

In this study, we applied H_∞ robust control to SCARA robot, in order to confirm the possibility of control performance improvement. We performed comparative experiments of H_∞ controller and PID controller with actual device, and the following conclusions were obtained.

1) To get faster operation speed of SCARA robot, robust H_∞ control obtained good results in target joint angle tracking capability and we confirmed the robust stability. In addition, for the parameter variations due to load fluctuation or change in the attitude of the arm, the stability could be confirmed as well.

2) Based on the results of this study, we want to expand the control to multi-input multi-output system from the single-input single-output system.

REFERENCES

[1] Y. Liu (2002), Linear robust control
[2] Hideki Kimura (2000), H∞control