High Speed Grasping Using Visual and Force Feedback

Akio Namiki, Yoshihiro Nakabo, Idaku Ishii, and Masatoshi Ishikawa

Depart ent of Mathe atical Engineering and Infor ation Physics
University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

E- ail : `namik@k .t.u-tokyo.ac.jp`
URL : `http://www.k .t.u-tokyo.ac.jp/~sfoc/`

bstract

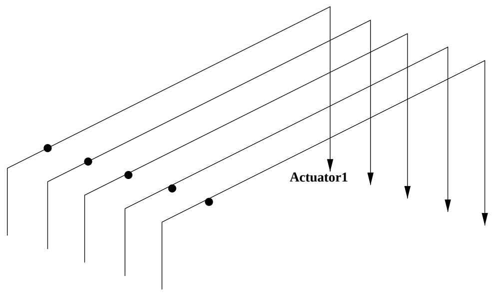
In most conventional manipulation systems, changes in the environment cannot be observed in real time because the vision sensor is too slow. As a result the system is powerless under dynamic changes or sudden accidents. To solve this problem we have developed a grasping system using high-speed visual and force feedback. This is a multi-fingered hand-arm with a hierarchical parallel processing system and a high-speed vision system called SPE-256. The most important feature of the system is the ability to process sensory feedback at high speed, that is, in about 1ms. By using an algorithm with parallel sensory feedback in this system, grasping with high responsiveness and adaptiveness to dynamic changes in the environment is realized.

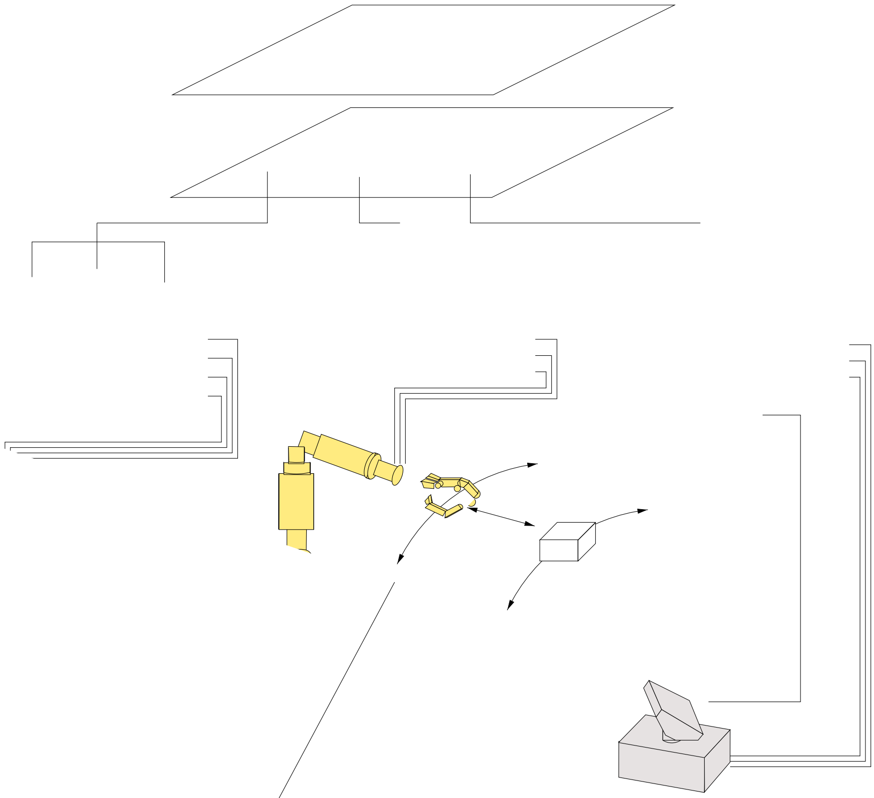
Key Words: *grasping, high-speed visual and force feedback, sensor fusion, hierarchical parallel architecture, multi-fingered hand-arm, active vision*

1 Introduction

A grasping otion is one of the ost i portant processes for control of ulti-fingered hands. To co - plete the grasping process ultiple types of sensor infor ation are needed infor ation at a rate higher than the rate of control. Because the syste can recogni e an external environ- ent in real ti e, responsiveness to dyna ic changes in the grasping environ ent is reali ed.

We adopt an architecture in which both flexibility and responsiveness are reali ed. This is a hierarchical parallel architecture in which each ele ent consists of high-speed sensory feedback within 1 s as shown in Figure 1. Because each feedback process is co pleted within 1 s, adjust ent to various conditions is reali ed at high speed.





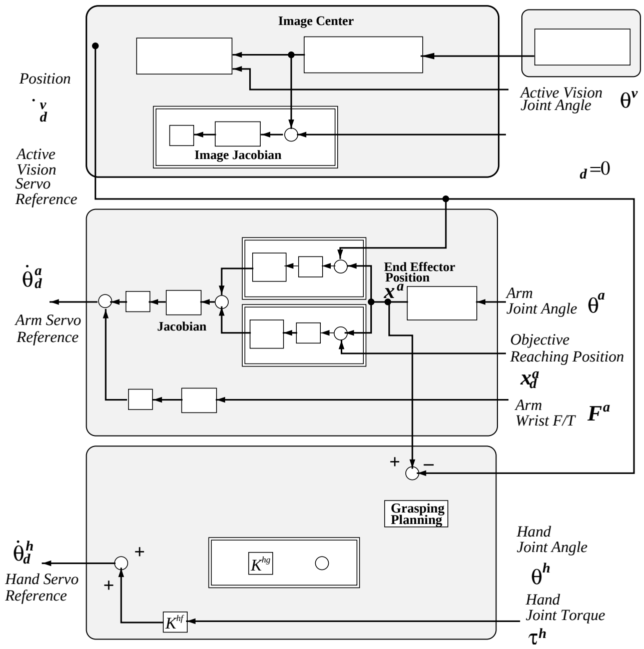


Image Center
Position
Active Vision Servo Reference
Image Jacobian
Active Vision Joint Angle
θ^v
$_d$=0
$\dot{\theta}^a_d$
Arm Servo Reference
Jacobian
End Effector Position
x^a
Arm Joint Angle
θ^a
Objective Reaching Position
x^a_d
Arm Wrist F/T
F^a
+
−
Grasping Planning
$\dot{\theta}^h_d$
Hand Servo Reference
K^{hg}
K^{hf}
Hand Joint Angle
θ^h
Hand Joint Torque
τ^h

where $\dot{\boldsymbol{\theta}}_d^a$ $\boldsymbol{R}^6$ is the control input to the ar servo, $\boldsymbol{\theta}^a$ $\boldsymbol{R}^6$ is the joint angle vector of the ar , and J^a $\boldsymbol{R}^{6\times 6}$ is the jacobian atrix of the ar . The vector $\boldsymbol{x}^o$ $\boldsymbol{R}^6$ is the position and the orientation of the object observed by vision, $\boldsymbol{x}^a$ $\boldsymbol{R}^6$ is the position and the orientation of the hand obtained by haptic sensors, and $\boldsymbol{x}_d^a$ $\boldsymbol{R}^6$ is the objective trajectory for reaching. The atrix K^{ap}, K^{a1}, K^{a2}, K^{av}, and K^{af} $\boldsymbol{R}^{6\times 6}$ are diagonal gain atrices. The atrix I $\boldsymbol{R}^{6\times 6}$ is the unit atrix and $S \equiv \mathrm{diag}\{s_i\}(i = x, y, z, \mathrm{role}, \mathrm{pitch}, \mathrm{yow})$ is a task partition atrix defined as,

$$s_i \equiv \begin{cases} 1 & \text{if } i = y, z, \mathrm{role} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

In Eqn.(2) tracking otion and reaching otion respectively correspond to the first ter and the second ter . Because reaching otion is orthogonal to the tracking otion, there is no interaction. Then the fourth ter is force feedback of the wrist force/torque sensor for co pliance control.

4.3 Processing for Hand

In this syste the objective of grasping control is to fix the object with the hand for anipulation. Using the co pliance control ethod the hand is controlled as follows:

$$\dot{\boldsymbol{\theta}}_d^h = K^{hg}(\boldsymbol{\theta}_d^h - \boldsymbol{\theta}^h) - K^{hv}\dot{\boldsymbol{\theta}}^h + K^{hf}\boldsymbol{F}^h \tag{4}$$

where $\dot{\boldsymbol{\theta}}_d^h$ $\boldsymbol{R}^{14}$ is the control input to the hand servo, and $\boldsymbol{\theta}^h$ $\boldsymbol{R}^{14}$ is the joint angle vector of the hand. Matrices K^{hg}, K^{hv}, and K^{hf} $\boldsymbol{R}^{14\times 14}$ are diagonal gain atrices, and $\boldsymbol{F}^h$ $\boldsymbol{R}^{14}$ is the joint torque vector. The vector $\boldsymbol{\theta}_d^h$ $\boldsymbol{R}^{14}$ is the objective trajectory for grasping and is planned according to reaching otion $\boldsymbol{x}_d^a$.

Further ore, according to the object shape, preshaping otion is executed to set the appropriate hand shape for grasping. In the present configuration the grasping shape is changed by distinguishing a circle and a rectangle in the 2D i age-plane, as shown in Figure 5(b).

5 Experimental Results

We have perfor ed experi ents of grasping an object on the 1 s Sensory-Motor Fusion Syste .

The experi ental result is shown in Figure 6 as a continuous sequence of pictures. All sensory feedback is executed in parallel according to the object otion at high speed: tracking otion of the active vision, tracking and reaching otion of the ar , and grasping otion of the hand. In Figure 7 a close-up view of the sa e otion is shown. In this figure tracking is executed fro 0.0 s to 0.5 s and both reaching and grasping otion start at 0.5 s and all otion is co pleted at 0.8 s. Then in Figure 8 a close-up view of the grasping otion of a spherical object is shown. It is shown that the shape of the hand is changed to a suitable shape for grasping of a sphere.

In Figure 9 the trajectory of the hand is shown when grasping and releasing are alternately executed. I[illegible]

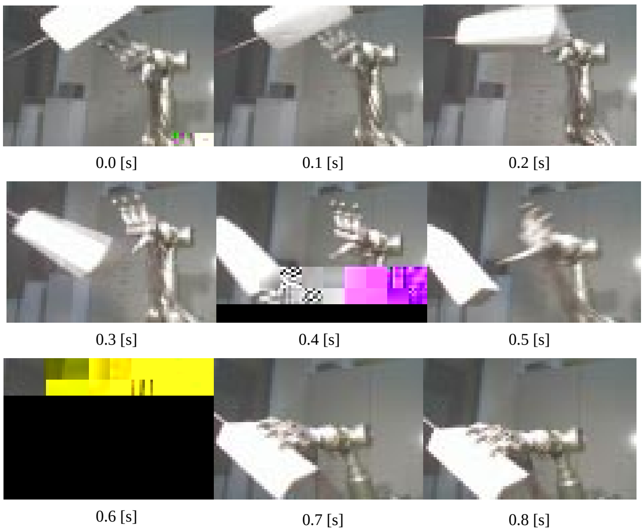


Figure 7. Experimental Result: Grasping of a Hexahedron

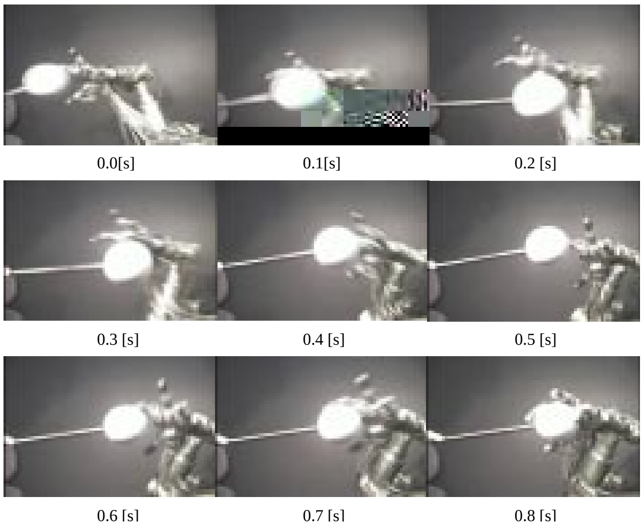
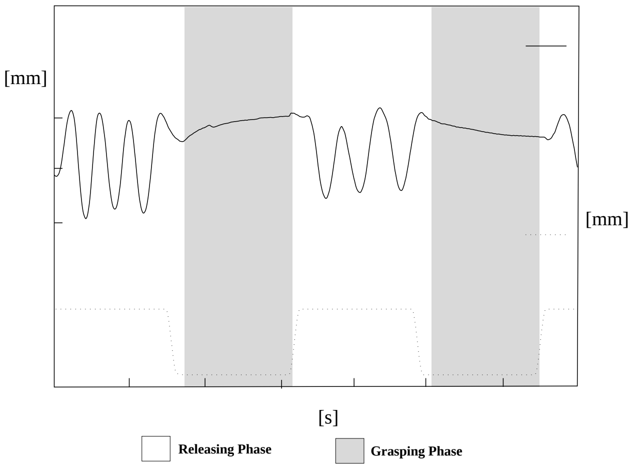


Figure 8. Experimental Result: Grasping of a Sphere



1. 1 s Sensory-Motor Fusion Syste has been developed to process and fuse sensory infor ation at high speed. This consists of a hierarchical parallel processing subsyste with DSPs, a high-speed active vision subsyste and a anipulator with a dextrous ulti-fingered hand. As a result all sensory feedback can be reali ed in about 1 s.
2. An algorith for high-speed grasping is proposed. In this algorith a grasping task is deco posed into so e subtasks and each subtask is executed by high-speed sensory feedback in parallel.

As a result, grasping responsive to dyna ic changes of object otion is reali ed.

Now we are developing various types of application on our syste to reali e responsive and flexible anipulation in the real world environ ent.

References

[1] P.K. Allen, B. Yoshimi, and A. Timucenko. Real-time visual servoing. *Proc. IEEE Int. Conf. Robotics and u-tomation*, pages 2376–238 , 1991.

[2] W. Hong and J.E. Slotine. Experiments in hand-eye coordination using active vision. *Proc. 4th Int. Symp. on Experimental Robotics (ISER'95)*, 1995.

[3] M. Ishikawa, A. Morita, and N. Takayanagi. High speed vision system using massively parallel processing. *Proc. IEEE Int. Conf. on Intelligent Robotics and Systems*, pages 373–377, 1992.

[ ] T. Komuro, I. Ishii, and M. Ishikawa. Vision chip architecture using general-purpose processing elements for 1ms vision system. *Proc. 4th IEEE Int. Wor - shop on Computer rchitecture for Machine Perception (C MP'97)*, pages 276–279, 1997.