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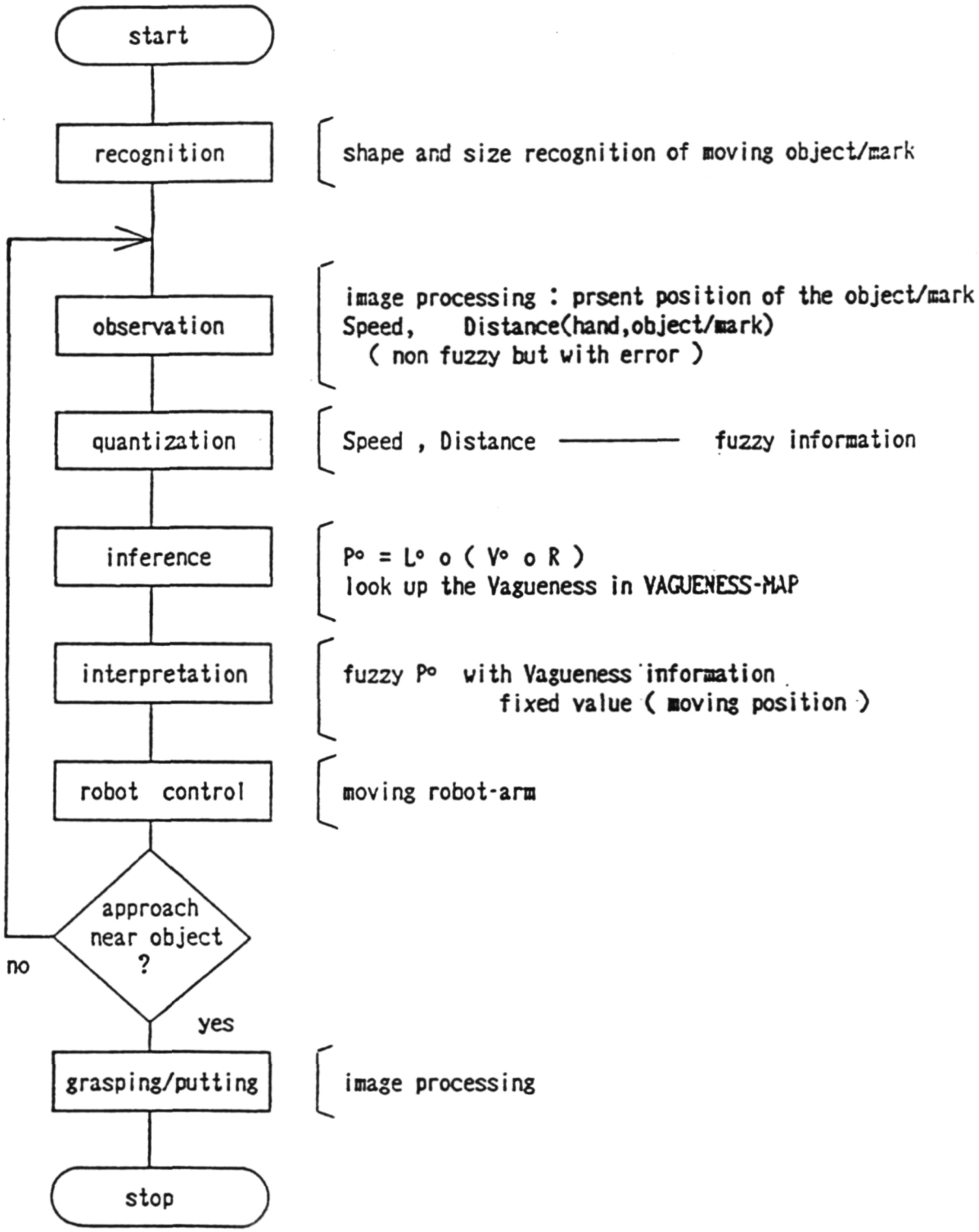
Dr. Hirota received his B.S. in electronics in 1974, his M.S. in electrical engineering in 1976, and his Ph.D. degree in electrical engineering in 1979 - all from the Tokyo Institute of Technology. From April 1979 to March 1982, Dr. Hirota was an assistant professor in the Department of Computer Sciences, Sagami Institute of Technology in Fujisawa, Kanagawa, Japan. He was an assistant professor from April 1982 to March 1983, and has been an associate professor since April 1983 in the Department of Instrument and Control Engineering, College of Engineering, Hosei University, Koganei, Tokyo, Japan. Dr. Hirota has been a part-time lecturer at the Sagami Institute of Technology since April 1982, Tokai University since April 1984, and the Technical College of FACOM since September 1986. Research interests include image pattern recognition, intelligent robotics, fuzzy control, artificial intelligence, and industrial applications of these subjects.

AN APPLICATION OF FUZZY LOGIC TO ROBOTIC VISION AND CONTROL

Abstract

A robot arm system able to manipulate a moving object on a belt conveyor at various speeds is built, consisting of two parts. The first part is related to recognizing patterns in real time. In this part, a method of constructing a fuzzy discriminant tree is proposed, where three newly defined measures called effectiveness, importance, and applicability are introduced. The robot arm system is able to recognize the shape and the size of moving patterns on a belt conveyor based on the fuzzy discriminant tree. The second part is to replace (grasp and put) a moving object based on fuzzy inference (or approximate reasoning) rules with the aid of an image processing technique. The whole system is controlled by one 16-bit personal computer and works in real time. The advantages of the proposed method are the reduction of processing time and the availability of low-level devices which have not been realized by other methods.



A flow chart of robot-arm system

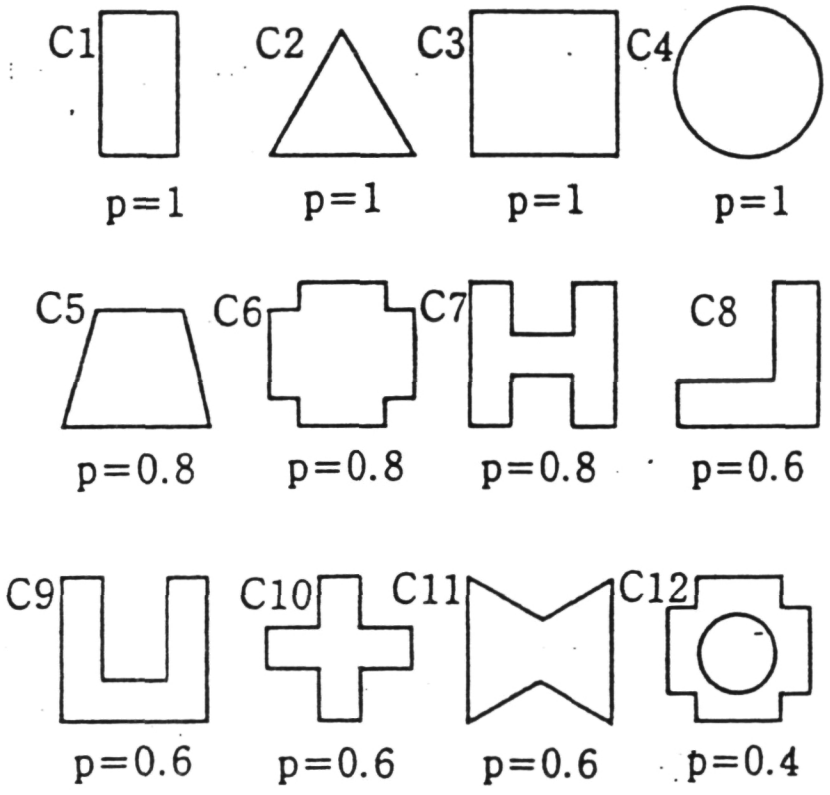


Fig. 6. Twelve patterns used in the shape recognition experiment.

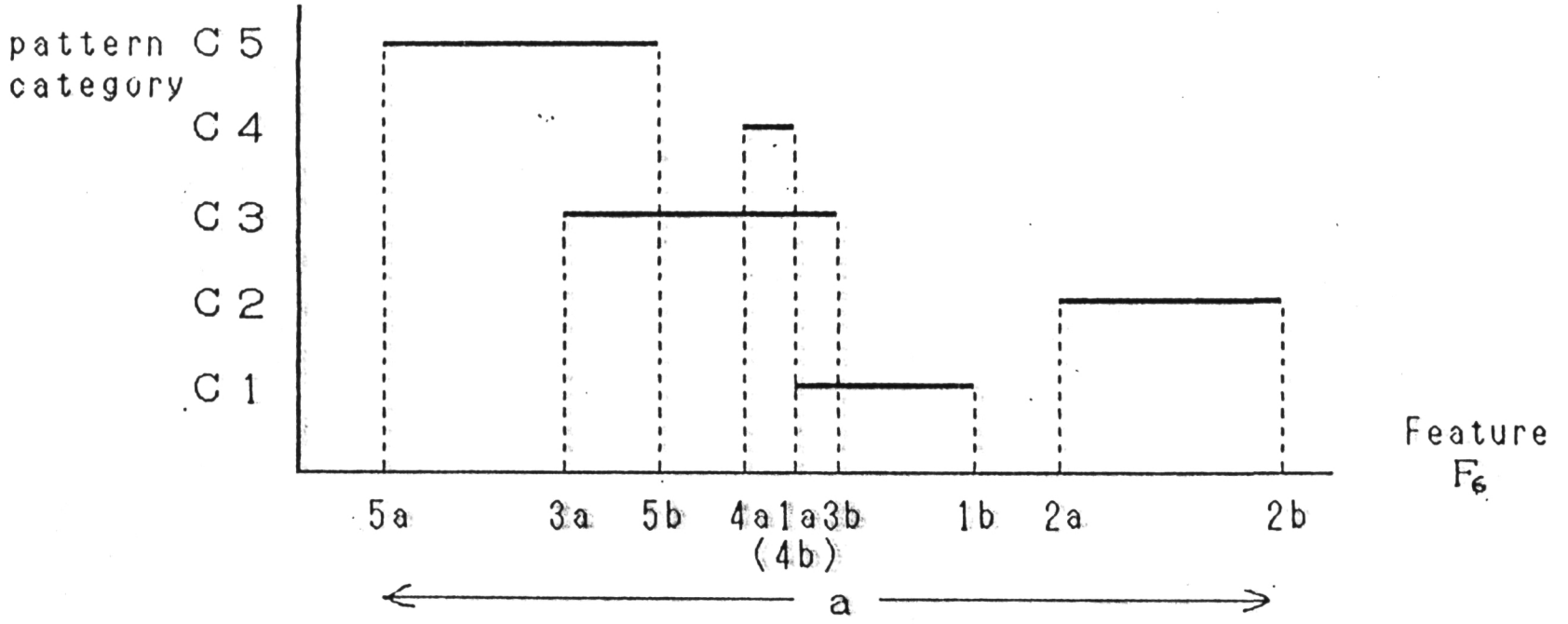
given features and their computing time in recognition process

	F_1 aspect ratio	F_2 variance of marginal distribution on x-axis	F_3 variance of marginal distribution on y-axis
computing time [sec]	0.25	0.808	0.807

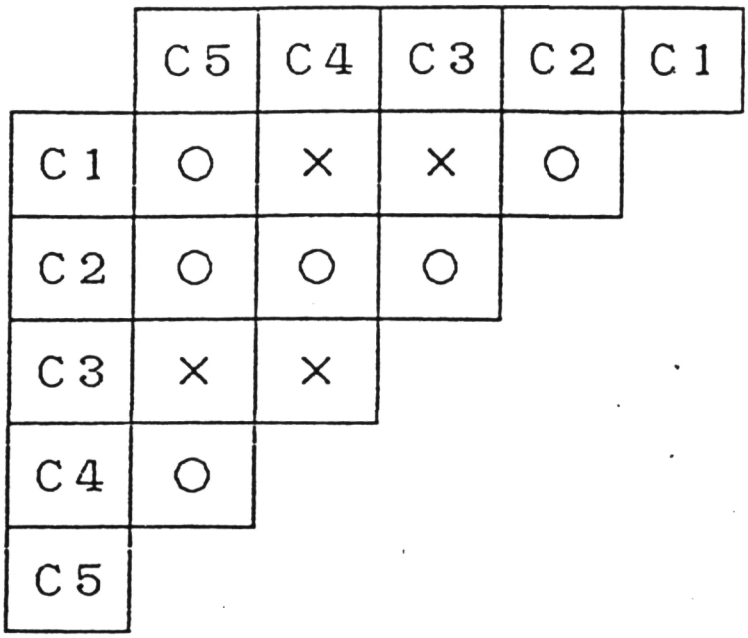
F_4 x-mean : max length	F_5 y-mean : max length	F_6 area density
0.778	0.60	0.59

F_7 circum-area ratio	F_8 CG offset in x-axis direction	F_9 CG offset in y-axis direction
1.04	0.59	0.59

Computer PC-9800 (5MHz clock)
Language Assembler



Distribution map of Feature F_6



Discriminant table of Feature F_6

	C5	C4	C3	C2	C1
C1	0.15	×	×	0.1	
C2	0.45	0.3	0.25		
C3	×	×			
C4	0.1				
C5					

$E_6 = 1.35$

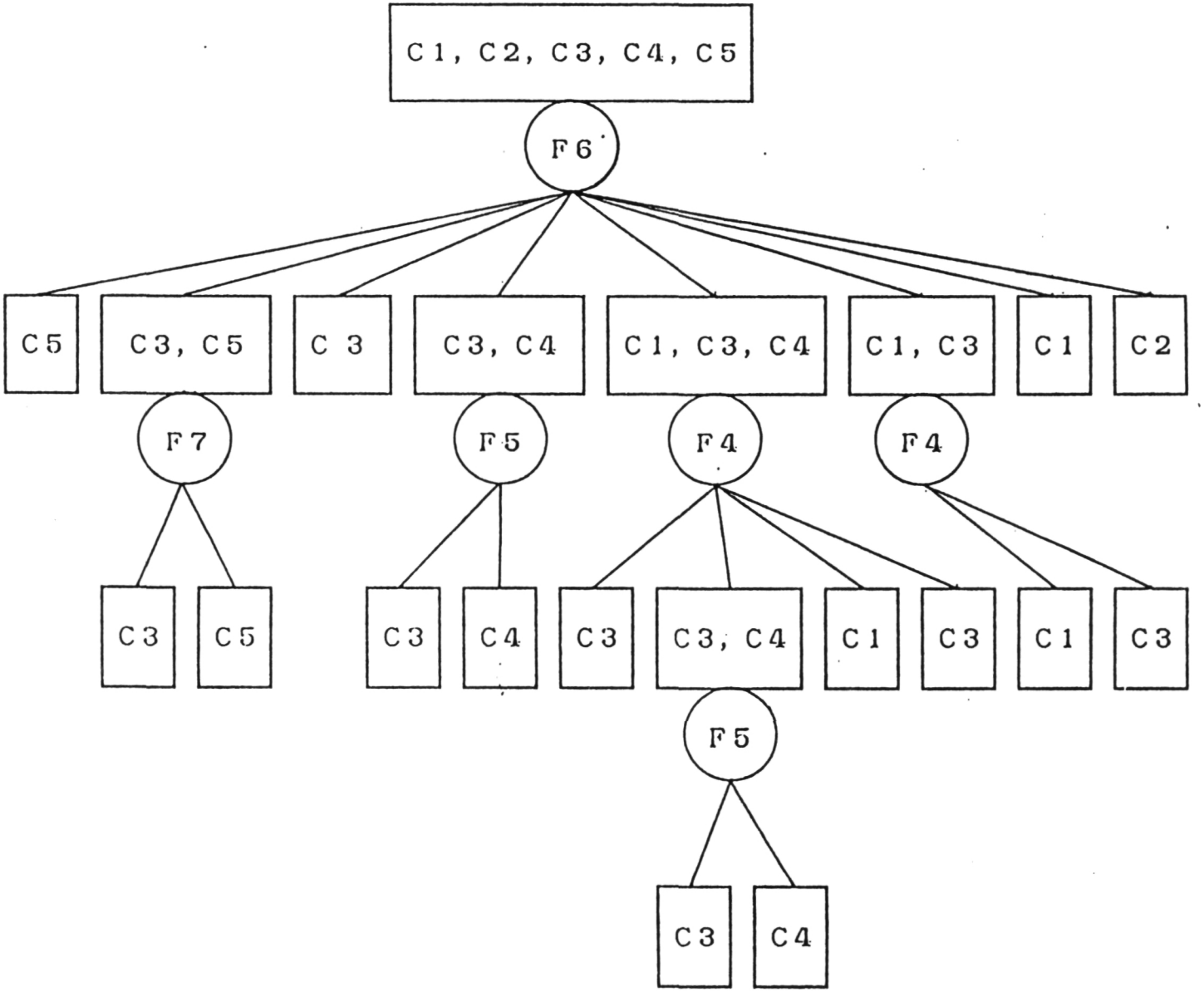
Effectiveness of Feature F_6

p_i		1 C5	2 C4	3 C3	4 C2	5 C1
5	C1	0.9	×	×	0.9	
4	C2	2.25	1.8	1.75		
3	C3	×	×			
2	C4	0.3				
1	C5					

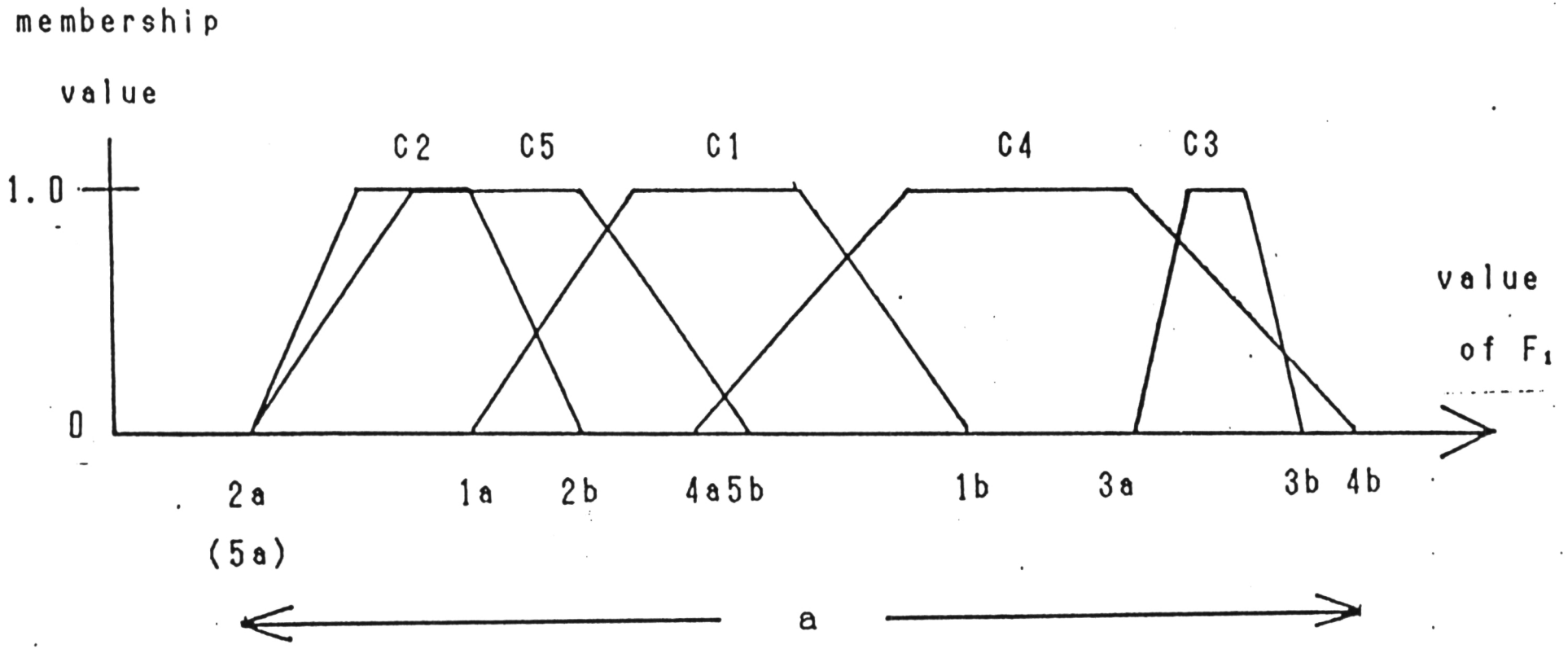
$\Sigma = 7.9$ $t_6 = 2$

$I_6 = 3.95$

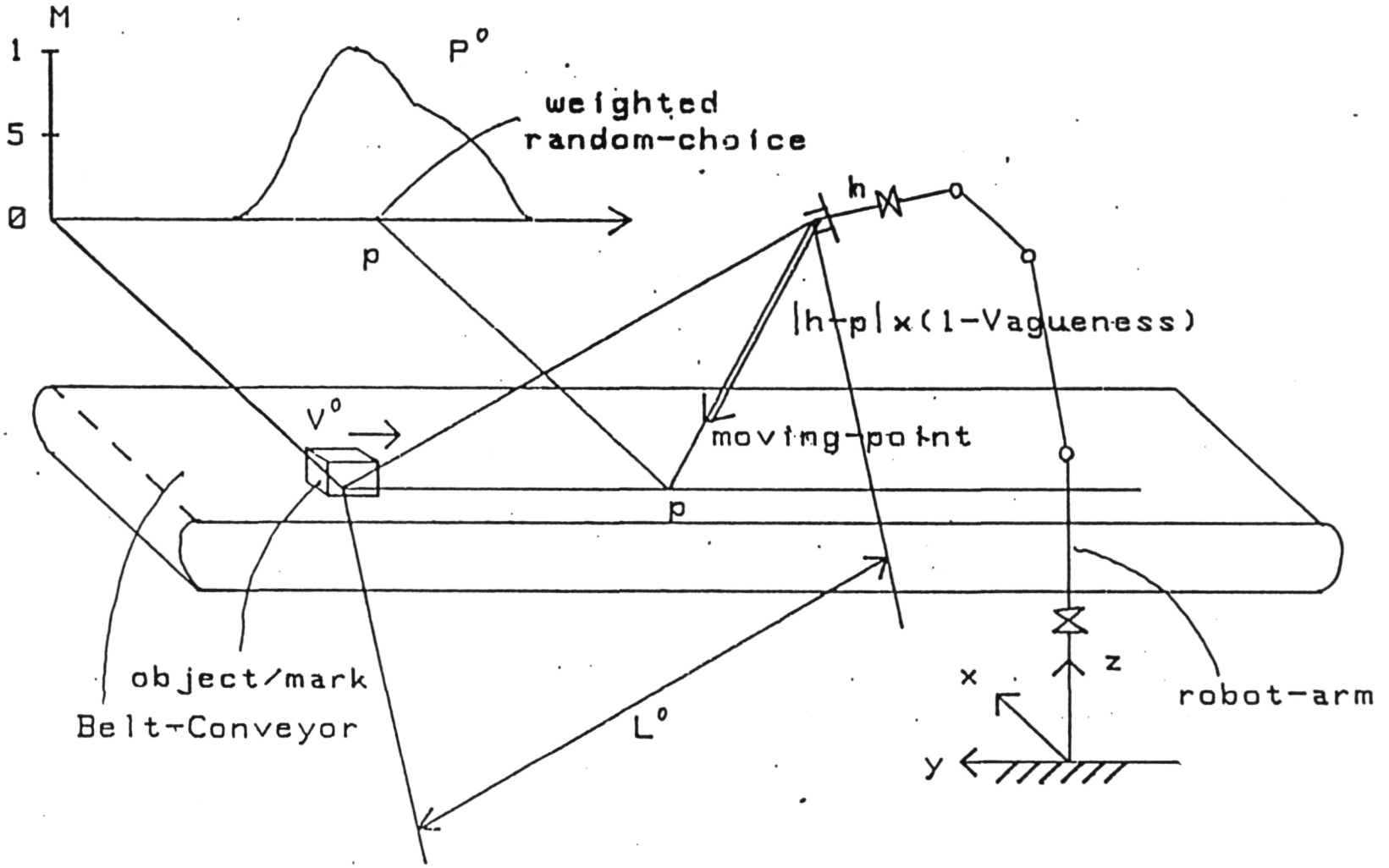
Importance of Feature F_6



An example of discriminant tree



distribution map of F_1


M
1
5
0
P°
weighted
random-choice
p
h
|h-p| x (1-Vagueness)
V°
moving-point
p
object/mark
Belt-Conveyor
L°
x
z
y
robot-arm

(e.g. If speed is "high" and distance is "far"
then move hand "far away")

```
IF V IS V1 AND L IS L1 THEN P IS P1  ELSE
IF V IS V1 AND L IS L2 THEN P IS P1  ELSE
 :          :          :          :
IF V IS V4 AND L IS L5 THEN P IS P7  ELSE
IF V IS V4 AND L IS L6 THEN P IS P8
```

Vi: Speed Lj: Distance Pk: (estimated) Distance
i=1~4 j=1~6 k=1~8

Rule map

near <----------> far

		L1	L2	L3	L4	L5	L6
low ↑	V1	P1	P1	P1	P1	P1	P1
:	V2	P1	P2	P2	P3	P4	P5
:	V3	P1	P2	P4	P5	P6	P7
↓ high	V4	P1	P3	P5	P6	P7	P8

a little a way <----------> far a way

P1 P2 P3 P4 P5 P6 P7 P8

Vagueness map

	L1	L2	L3	L4	L5	L6
V1	0	0	0	0	0	0
V2	0	0	0	.2	.3	.4
V3	0	.2	.2	.3	.4	.5
V4	0	.3	.3	.4	.5	.5

Fuzzy labels of V , L , P

(a) Fuzzy labels of Speed (V)

low <----------> high

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V1	1	1	1	1	.5	.1	0	0	0	0	0	0	0	0	0
V2	0	.2	.4	.8	.1	.8	.4	.2	0	0	0	0	0	0	0
V3	0	0	0	0	0	.2	.4	.8	1	.8	.4	.2	0	0	0
V4	0	0	0	0	0	0	0	0	0	.2	.4	.8	1	1	1

(b) Fuzzy labels of Distance between object and robot-hand (L)

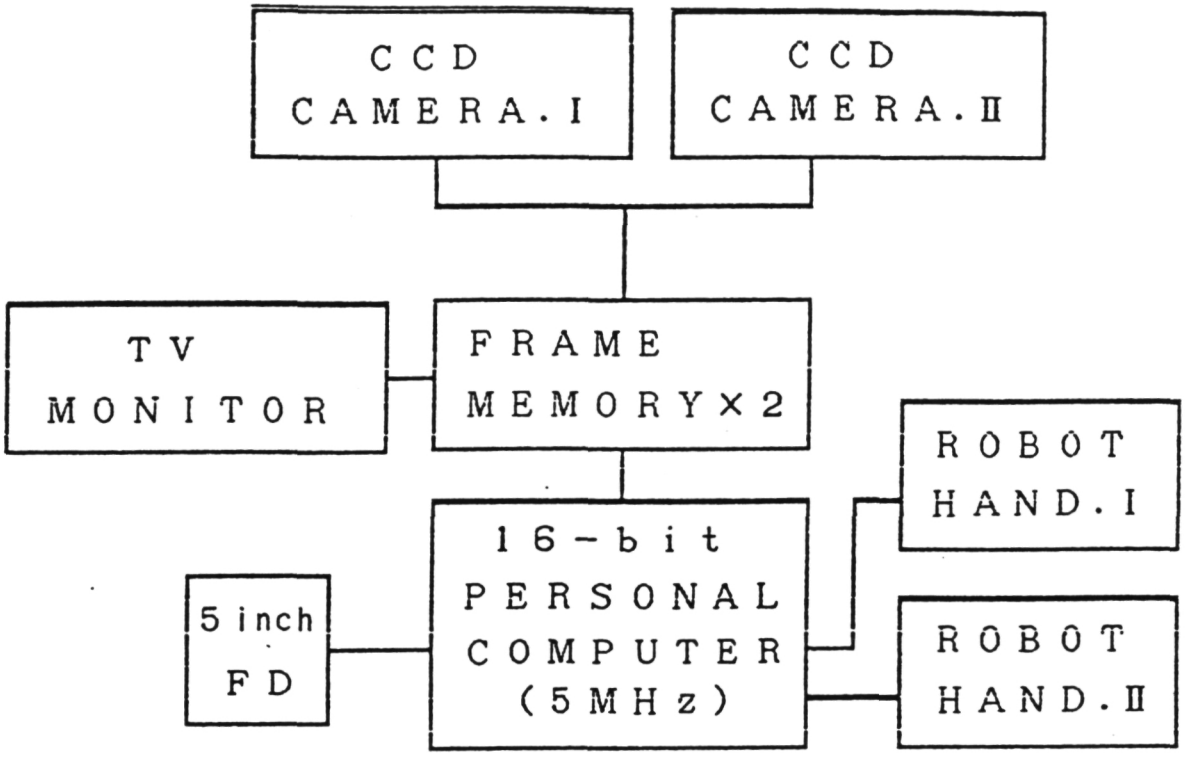
near <----------> far

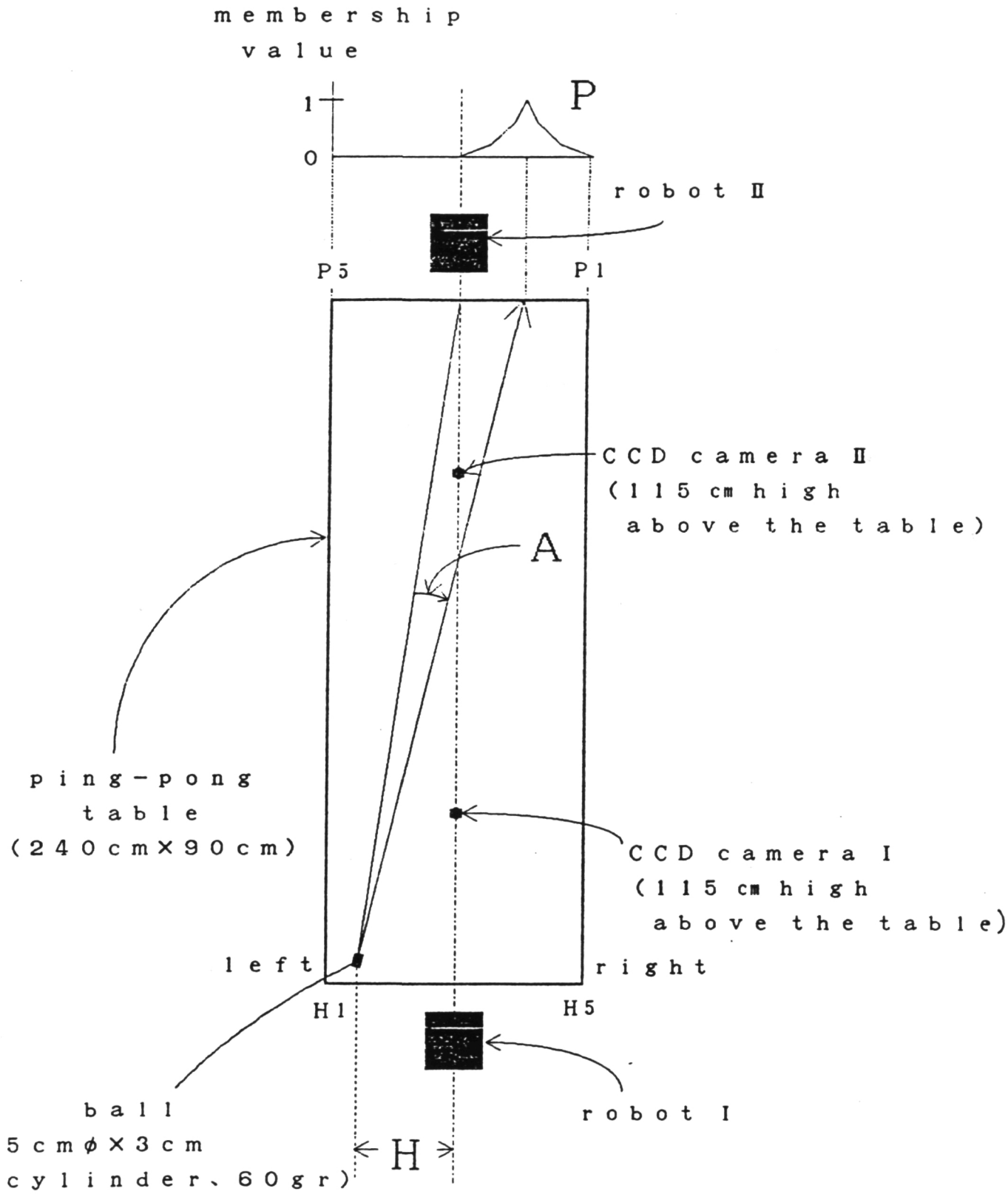
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
L1	1	.8	.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L2	.1	.6	1	.6	.1	0	0	0	0	0	0	0	0	0	0	0	0
L3	0	0	.1	.6	1	.6	.1	0	0	0	0	0	0	0	0	0	0
L4	0	0	0	0	.1	.6	1	1	1	.6	.1	0	0	0	0	0	0
L5	0	0	0	0	0	0	0	0	.1	.6	1	1	1	.6	.1	0	0
L6	0	0	0	0	0	0	0	0	0	0	0	0	.1	.6	1	1	1

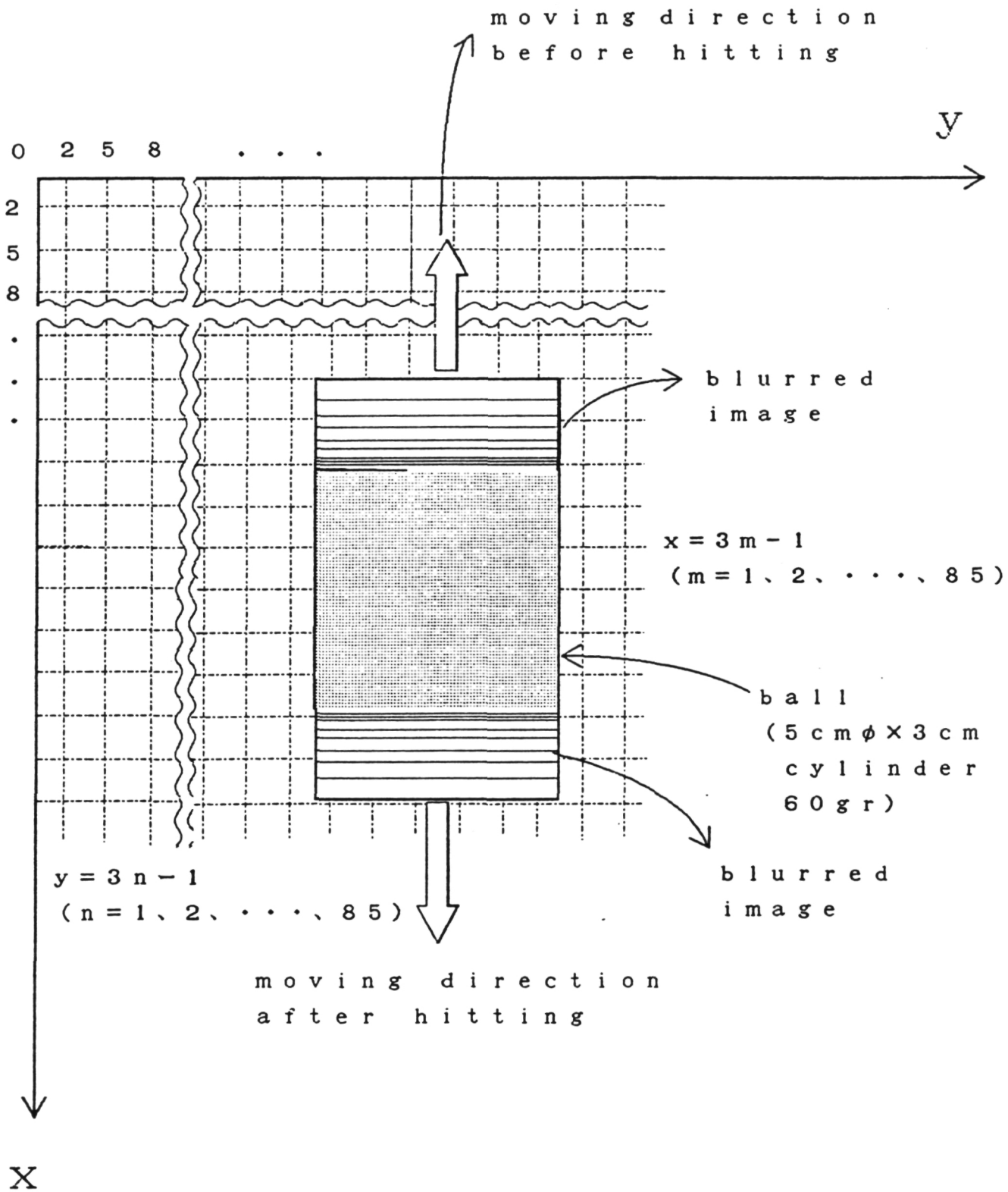
(c) Fuzzy labels of (estimated)moving-Distance (P)

a little away <----------> far a way

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	.1	.6	1	.6	.1	0	0	0	0	0	0	0	0	0	0	0	0
P3	0	.2	1	.2	0	0	0	0	0	0	0	0	0	0	0	0	0
P4	0	0	.1	.6	1	.6	.1	0	0	0	0	0	0	0	0	0	0
P5	0	0	0	0	.1	.6	1	.1	.6	.1	0	0	0	0	0	0	0
P6	0	0	0	0	0	0	.1	.6	1	.6	.1	0	0	0	0	0	0
P7	0	0	0	0	0	0	0	0	.1	.6	1	1	.6	.1	0	0	0
P8	0	0	0	0	0	0	0	0	0	0	0	.1	.6	1	1	1	1


CCD
CAMERA.I
CCD
CAMERA.II
TV
MONITOR
FRAME
MEMORY×2
ROBOT
HAND.I
16-bit
PERSONAL
COMPUTER
(5MHz)
5 inch
FD
ROBOT
HAND.II


membership value
1
0
P
robot II
P5
P1
CCD camera II
(115 cm high above the table)
A
ping-pong table
(240cm×90cm)
CCD camera I
(115 cm high above the table)
left
right
H1
H5
ball
(5cmφ×3cm cylinder、60gr)
H
robot I


moving direction
before hitting
y
0 2 5 8 . . .
2
5
8
.
.
.
blurred
image
x = 3 m − 1
(m = 1、2、・・・、85)
ball
(5 cmφ×3 cm
cylinder
60 gr)
blurred
image
y = 3 n − 1
(n = 1、2、・・・、85)
moving direction
after hitting
X

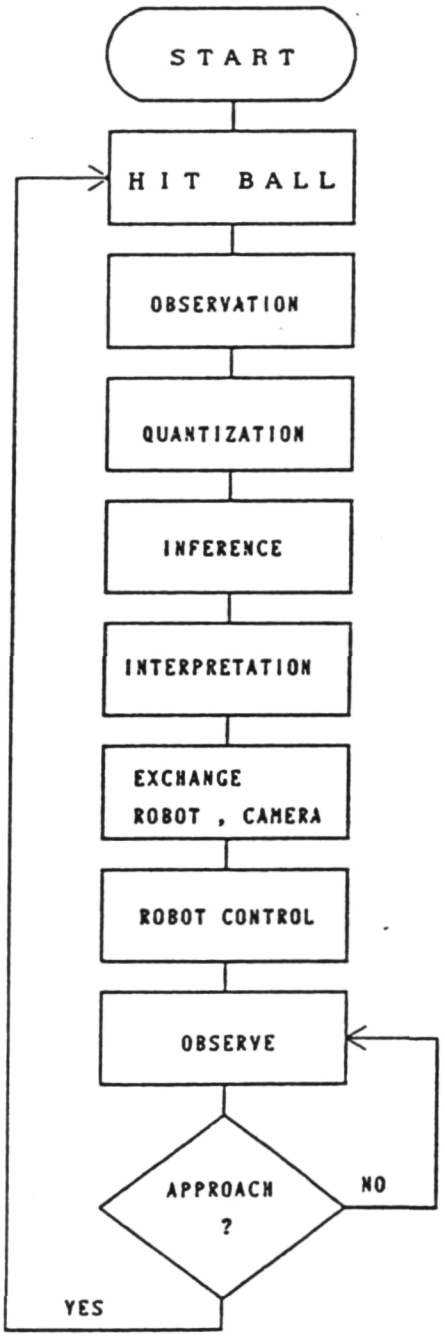

START
HIT BALL
OBSERVATION
QUANTIZATION
INFERENCE
INTERPRETATION
EXCHANGE
ROBOT , CAMERA
ROBOT CONTROL
OBSERVE
APPROACH
?
NO
YES

Table 1 Fuzzy labels of H, A, P

(a) Fuzzy labels of H

	left ---------- right																		
	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9
P1	1	1	.9	.6	.2	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0	0	0	0	0	0	0	0	0
P3	0	0	0	0	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0	0	0	0	0
P4	0	0	0	0	0	0	0	0	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0
P5	0	0	0	0	0	0	0	0	0	0	0	0	0	.1	.2	.6	.9	1	1

(b) Fuzzy labels of A

	negative ---------- positive																			
	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10
A1	1	1	.9	.6	.2	.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	0	.1	.2	.4	.8	1	1	.8	.4	.2	.1	0	0	0	0	0	0	0	0	0	0
A3	0	0	0	0	0	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0	0	0	0	0	0
A4	0	0	0	0	0	0	0	0	0	0	.1	.2	.4	.8	1	1	.8	.6	.2	.1	0
A5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.1	.2	.6	.9	1	1

(c) Fuzzy labels of P

	left ---------- right																		
	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9
P1	1	1	.9	.6	.2	.1	0	0	0	0	0	0	0	0	0	0	0	0	0
P2	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0	0	0	0	0	0	0	0	0
P3	0	0	0	0	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0	0	0	0	0
P4	0	0	0	0	0	0	0	0	0	.1	.2	.6	.9	1	.9	.6	.2	.1	0
P5	0	0	0	0	0	0	0	0	0	0	0	0	0	.1	.2	.6	.9	1	1

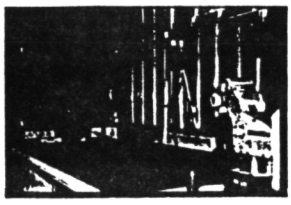
	order of fuzzy inference	1st	2nd	3rd	4th	5th	6th	7th
	corresponding photos in Photo 1 (a)	(2) (3)	(5) (6)	(8) (9)	(10) (11)	(12) (13)	(14) (15)	(16)
Antecedent	(H°) observed hitting posi (mm)	0	11	−296	−350	−4	314	387
	(A°) obsered hitting angl (°)	0	5.8	7.1	0	−6.2	−7.2	−0.5
Conclusion	(P°) inferred moving posi (mm)	0	−285	−367	0	300	376	−30

(1)

(2)

(3)

(4)



(5)

(6)

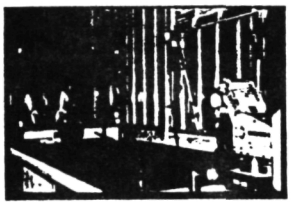
(7)

(8)

(9)

(10)

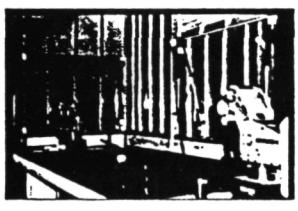
(11)



(12)

(13)

(14)



(15)

(16)

(1)

(2)

(3)

(4)

(5)

(6)

(7)

(8)

(9)

(10)

Photo 1