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TACTILE PATTERN RECOGNITION BY BELGRADE HAND PROSTHESIS

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Abstract

This paper presents results in tactile pattern recognition performed by Belgrade hand prosthesis. The prosthesis is provided with proprioceptive transducers. Due to mechanical adaptation of each finger to the shape of the object it can be used for classification of grasped objects by their geometrical shape.

Criterion, decision function and the recognition algorithm are presented. The measure of goodness of the used decision criterion is given.

Introduction

The Belgrade hand prosthesis is designed for prosthetic application. It can be used, as well, as a terminal device of large manipulator systems [1,2,3]. The first and main reason, which allows the Belgrade hand prosthesis to be used for geometrical pattern recognition, is the basic characteristic of the prosthesis: automatic mechanical adaptation to the shape of the grasped object. The second reason is that the existing mechanical system of the Belgrade hand prosthesis does not need any serious reconstruction in order to perform recognition. The aim of these experiments is to show the advantages of the parallel and simultaneous gathering of information about the pattern. The articulated systems with considerably greater number of articulations would be surely more favourable than the hand prosthesis. The best solution wold be a nonarticulated continually adaptable system with elastic shanks instead of fingers.

Characterization problem

Characteristic parameters are taken out of the mechanical system of the prosthesis. Thus we get the feature vector $X = \{x_1, x_2, x_3\}$, [4,5,6]. The elements of the feature vector contain the information about the geometrical shape of the grasped object. The features represent:

x_1 - measure of the relative position of the thumb and forefinger;

x_2 - measure of the relative position of the ring finger against the middle - finger and the forefinger;

x_3-measure of the relative position of the little finger and the ring-finger.

Three transducers have been built in the mechanical system of the prosthesis in order to get the features. Feature x_1 is realized through the potentiometer R_1, set between the lever (5) /Fig. 1/ and the body of the prosthesis, and features x_2 and x_3 through strain gauges, glued on the plate springs (8) and (11). According to the changes in the mechanism of the prosthesis, voltages x_1, x_2 and x_3 change their values. The features x_1, x_2 and x_3 as functions of the diameter of the grasped object are given in Fig. 2. Only two classes of objects are taken into consideration: the class of cylinders and the class of spheres. The objects must be grasped so that the axis of the cylinder is parallel with the palm of the hand or that the sphere lies in the palm. It can be seen from Fig. 2. that changes of the signal x_1 in the cases a) (cylinder) and b) (sphere) are almost identical.

Essential differences exist between the cases a) and b) of the signals x_2 and x_3.

The signal x_1 has almost no information about the geometrical shape of the grasped object. However, it gives very important data about the dimension of the object. Those data are important for the decision function implementation and for the estimation of the measure of the recognition goodness. Signals x_2 and x_3 with approximately the same weights give abundant information about the geometrical shape of the grasped object.

Decision function

Functions x_1 and (x_2+x_3), both for the sphere and the cylinder, versus diameter of the grasped objects, are given in Fig. 3. It can be noticed that $x_1 = x_1(\phi)$ is such that we can put x_1 instead of ϕ at the axis of abscises. Then, the decision function [4,5,6] is defined by

$$d(X) = a_1x_1 + a_2x_2 + a_3x_3 - T \qquad (1)$$

In equation (1) T is the threshold and a_1, a_2,a_3 are the weights.

The decision criterion is given by

for $x_1 \leq 3$ V

$$\begin{array}{ll} x_2 + x_3 > 0.1\ x_1 + 0.5 & \rightarrow \text{sphere} \\ x_2 + x_3 < 0.1\ x_1 + 0.5 & \rightarrow \text{cylinder} \end{array} \qquad (2)$$

for $x_1 \quad 3$ V

$$\begin{array}{ll} x_2 + x_3 > -\ 0.2\ x_1 + 1.4 & \rightarrow \text{sphere} \\ x_2 + x_3 < -\ 0.2\ x_1 + 1.4 & \rightarrow \text{cylinder} \end{array} \qquad (3)$$

where

$$y_1 = 0.1\ x_1 + 0.5$$

is the straght line (1) /Fig. 3/, and

$$y_2 = -0,2\ x_1 + 1.4$$

is the line (2).

The decision function, from (2) and (3) is given by

$$d(X) = \begin{cases} -0.1\ x_1 + x_2 + x_3 - 0.5 & \text{if} \quad x_1 \leq 3\ \text{V} \\ 0.2\ x_1 + x_2 + x_3 - 1.4 & \text{if} \quad x_1 > 3\ \text{V} \end{cases} \qquad (4)$$

Let F be the characteristic function given by

$$F = a_1x_1 + a_2x_2 + a_3x_3$$

then the recognition criterion is

$$d(X) = F - T = \begin{cases} > 0 & \rightarrow \text{sphere} \\ < 0 & \rightarrow \text{cylinder} \end{cases}$$

where,

for $x_1 \leq 3$ V

$$F = -0.1\ x_1 + x_2 + x_3\ ;\quad T = 0.5\ ,\quad \text{and}$$

for $x_1 > 3$ V

$$F = 0.2\ x_1 + x_2 + x_3\ ;\quad T = 1.4$$

Characteristic functions F_s for spheres and F_c for cylinders are given in Fig. 4. The threshold T is also shown.

The threshold T defined above has caused a classification error [7]. A region of indefinitude is defined in order to avoid the error in classification. The weights a_i, (i=1,2,3), remain the same, but instead of one threshold line (Fig. 4), two of them (Fig. 5).are defined. The threshold lines, as a function of the diameter, are given separately for spheres and for cylinders. The region between those lines is the region of indefinitude. The classifier can not decide, in that case, to which class the pattern belongs.

The threshold lines are given in Table 1.

The program is written in BASIC for the VARIAN 620/i. In Fig. 6. the recognition agorithm for the computer is presented.

The Goodness of the Decision Criterion

In the case, when the classifier can not make a decision, the measure of goodness of the recognition,(probability),is P = = 1/2. Maximum goodness is P = 1 in the point where the classification is best. Between these extremes, P is given by

$$P = \frac{1}{2} + \frac{|F-T| + |(F-T)\max|}{4 \cdot |(F-T)\max|} \tag{5}$$

Experimentally obtained curves P = PS, for spheres, and P = PC for cylinders, are given in Fig. 7.

Conclusion

The importance of a parallel gathering of data grows with the increasing number of parameters in a system. The technique presented in this paper, can be used without difficulty in large systems with great number of input parameters. Classification car be manyfold.

It is possible to realize the decision function without the use of a digital computer. Relatively simple and cheap electronical hardware can be designed for industrial applications.

The threshold lines

ϕ(cm)	cylinder	sphere
0 - 2.75	T = 0.4	T = 0.31 x_1 + 0.34
2.75 - 3	T = 0.21 x_1 - 6.2	T = 0.31 x_1 + 0.34
3 - 3.75	T = 0.21 x_1 + 0.37	T = 0.31 x_1 + 0.34
3.75 - 5	T = 0.21 x_1 + 0.37	T = 0.04 x_1 + 1.37
5 - 7.5	T = 0.092 x_1 + 0.96	T = 0.04 x_1 + 1.37
7.5 <	T = 1.65	T = 1.65

Table 1.

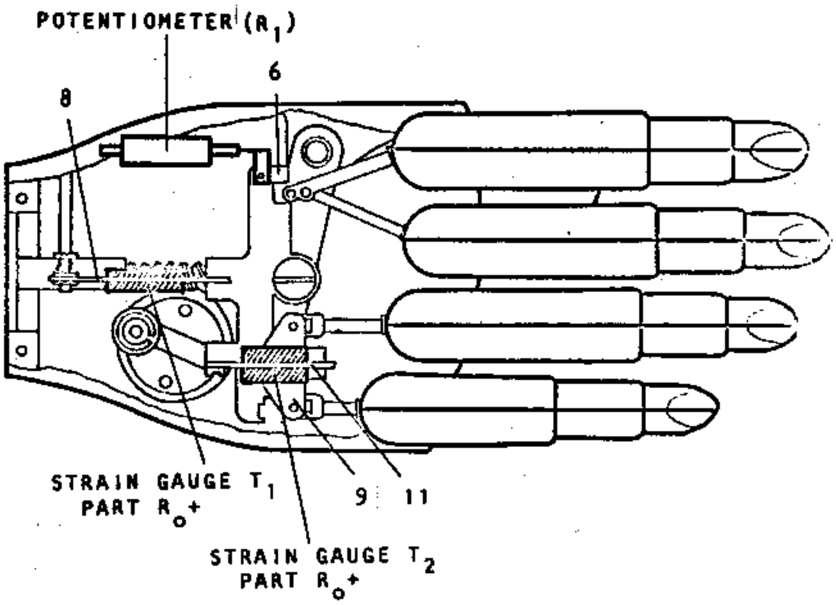


Fig. 1. Proprioceptive transducers

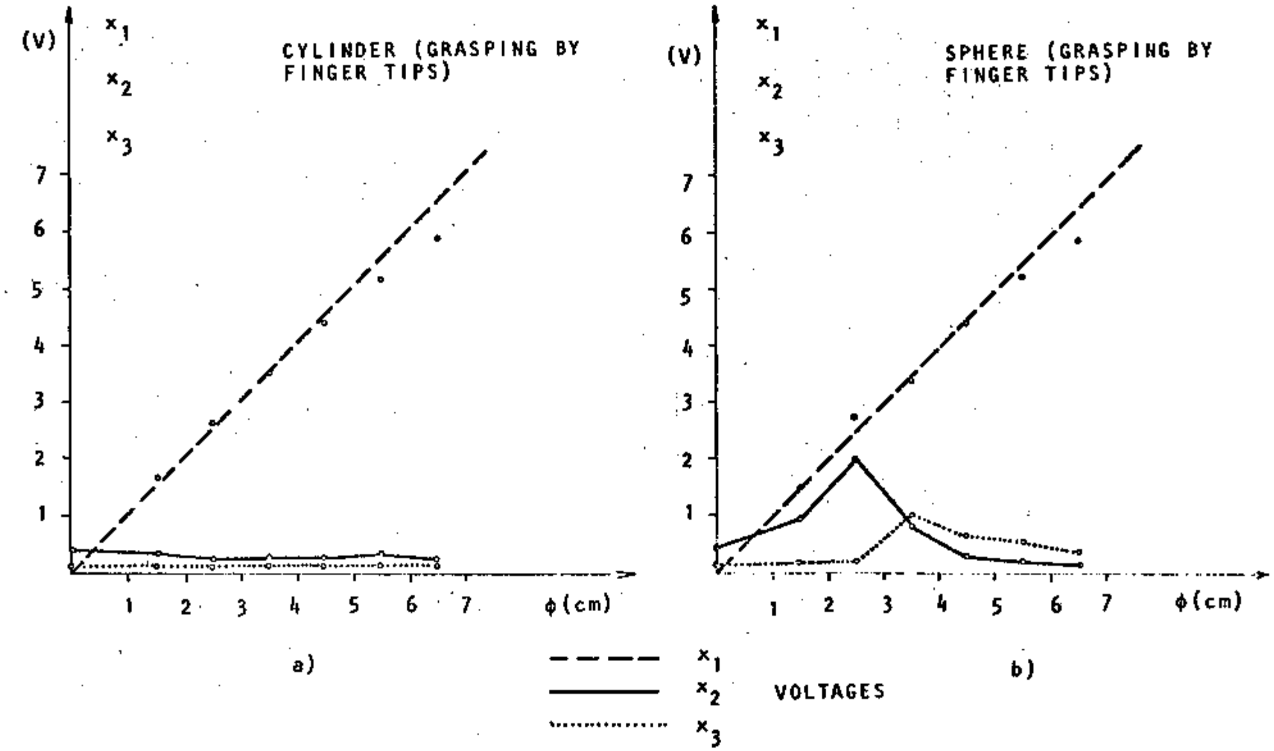


Fig. 2. The features

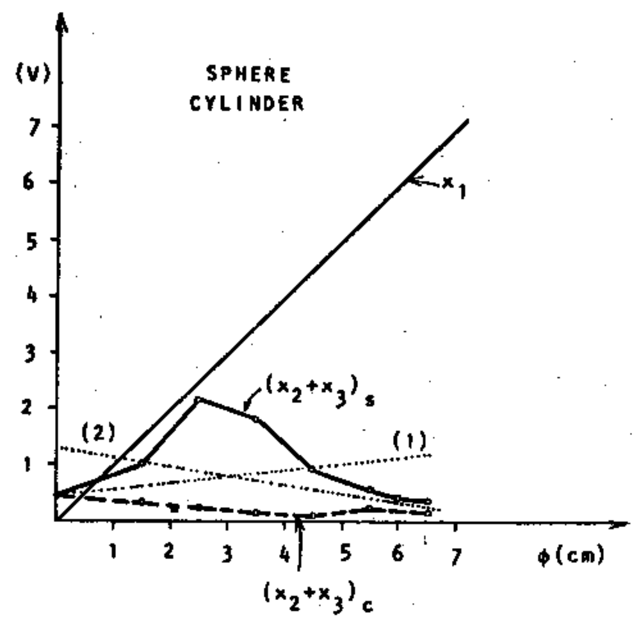


Fig. 3. Determination of the weight coefficients

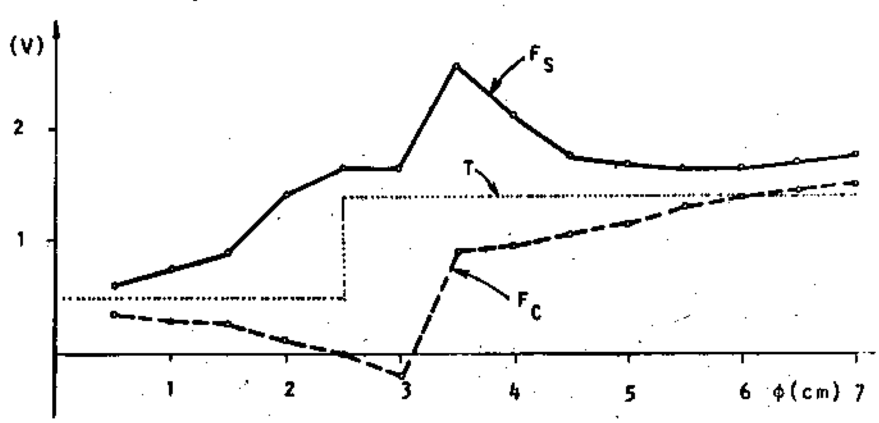


Fig. 4. Characteristic functions

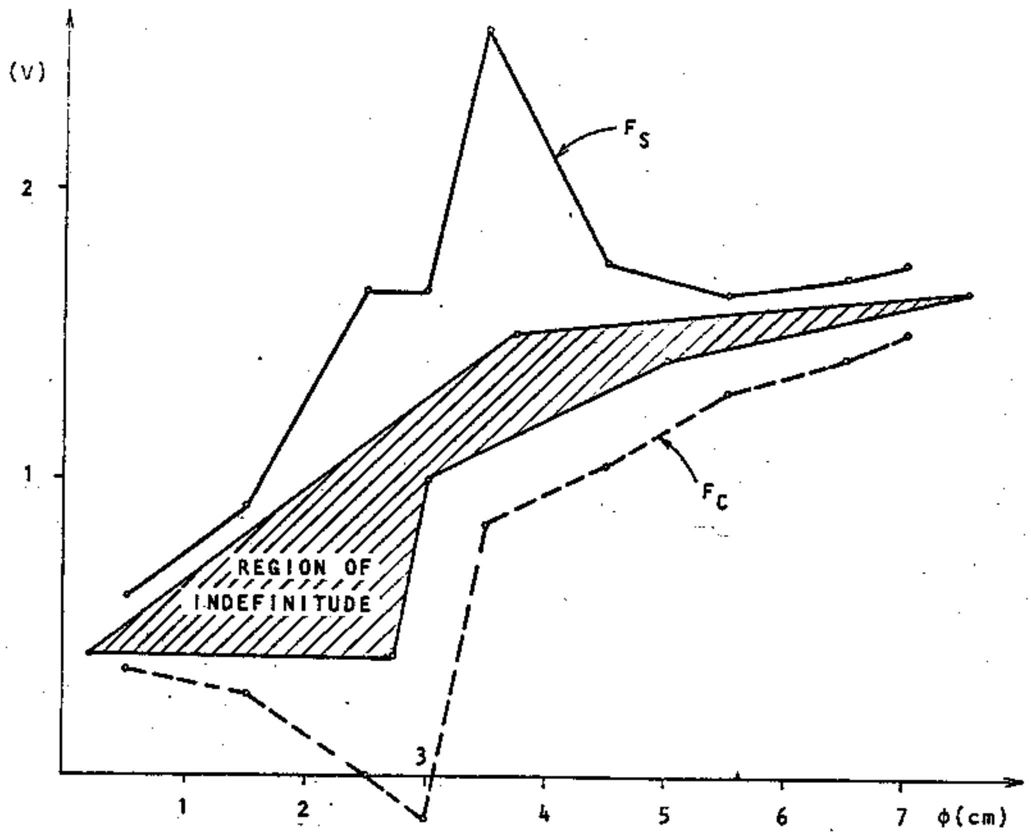
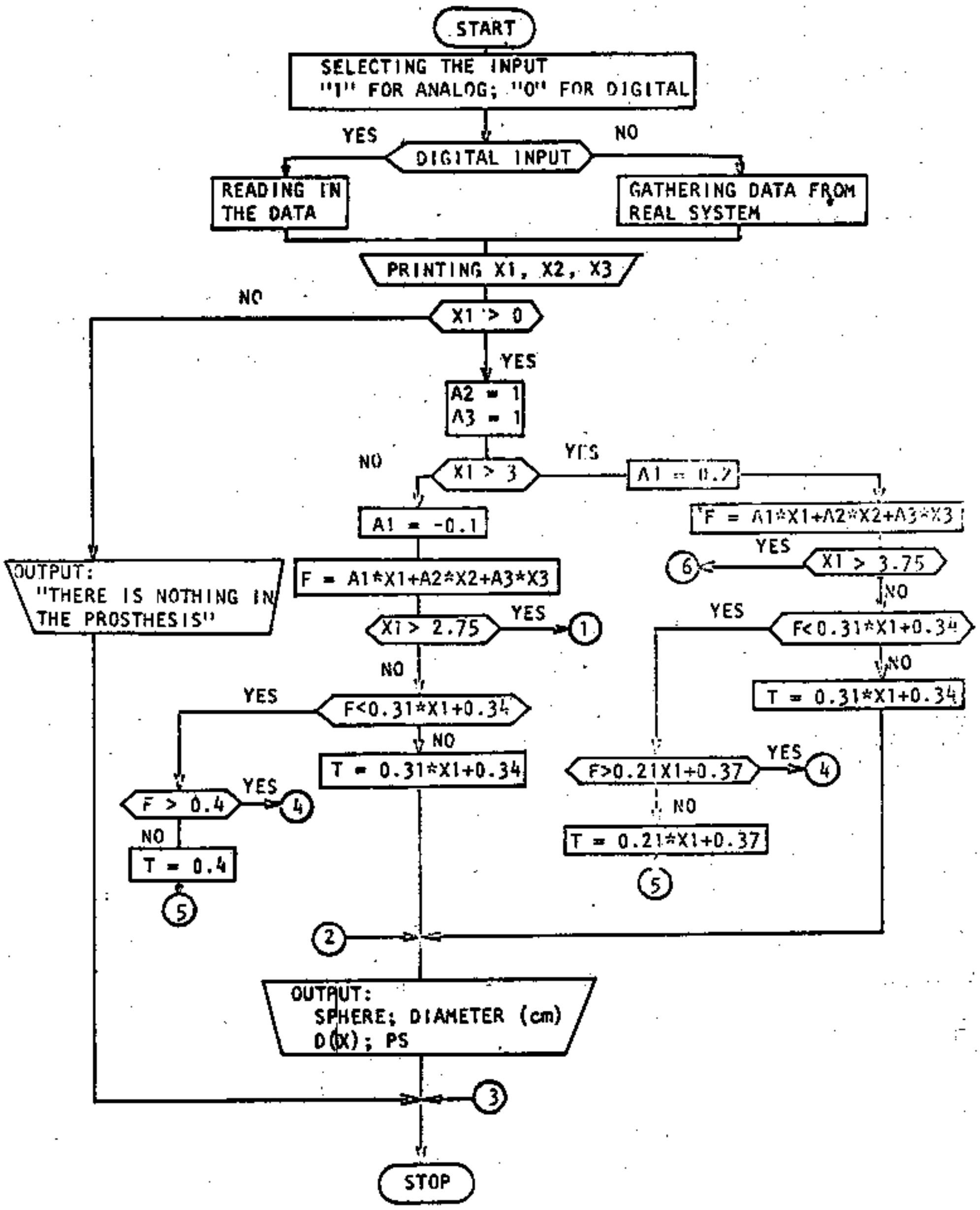


Fig. 5. Characteristic functions and threshold lines


START
SELECTING THE INPUT
"1" FOR ANALOG; "0" FOR DIGITAL
DIGITAL INPUT
YES
NO
READING IN THE DATA
GATHERING DATA FROM REAL SYSTEM
PRINTING X1, X2, X3
X1 > 0
NO
YES
A2 = 1
A3 = 1
X1 > 3
YES
NO
A1 = 0.2
A1 = -0.1
F = A1*X1+A2*X2+A3*X3
F = A1*X1+A2*X2+A3*X3
X1 > 3.75
X1 > 2.75
F<0.31*X1+0.34
T = 0.31*X1+0.34
F>0.21X1+0.37
T = 0.21*X1+0.37
F > 0.4
T = 0.4
OUTPUT:
"THERE IS NOTHING IN THE PROSTHESIS"
OUTPUT:
SPHERE; DIAMETER (cm)
D(X); PS
STOP

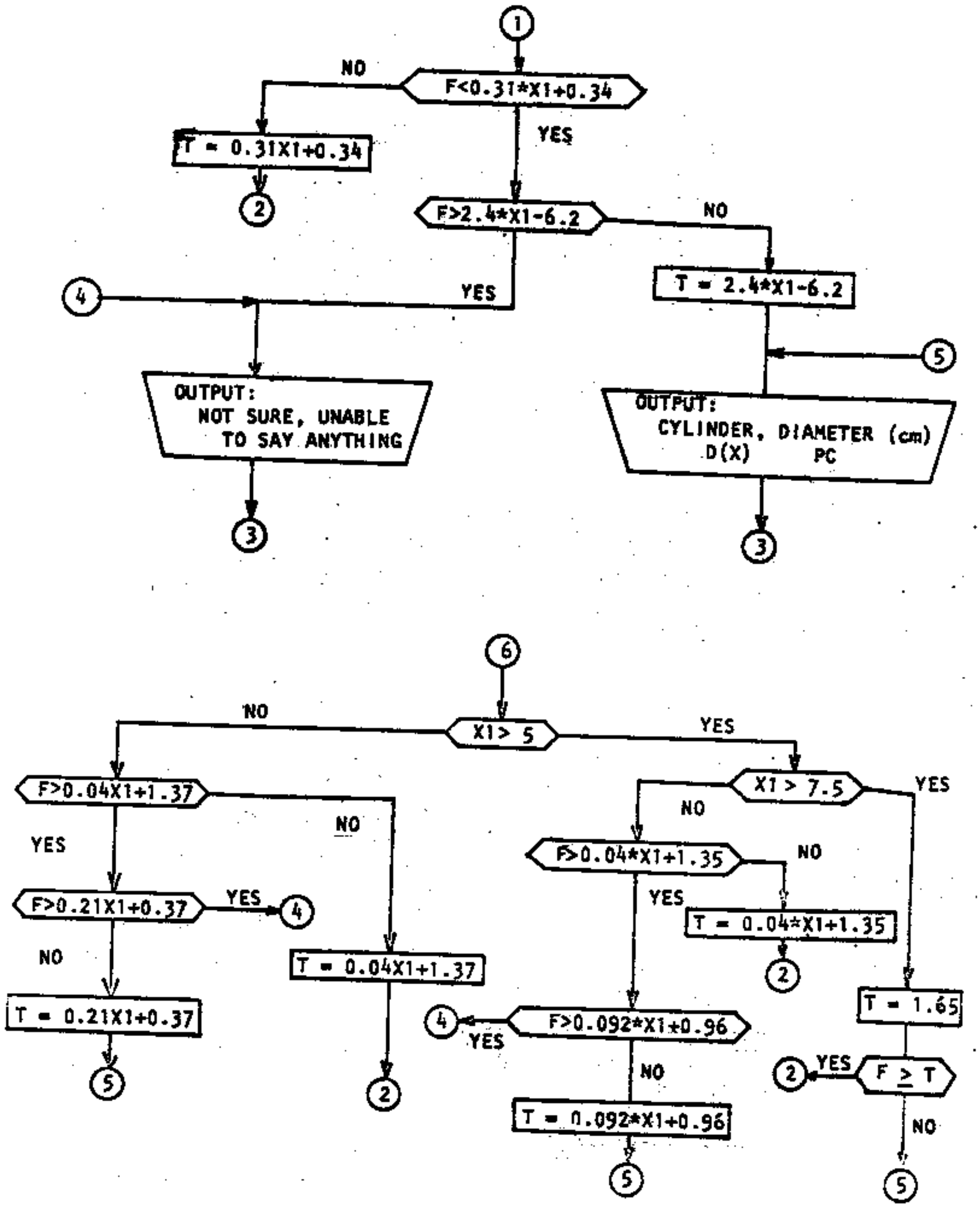


Fig. 6. The recognition algorithm

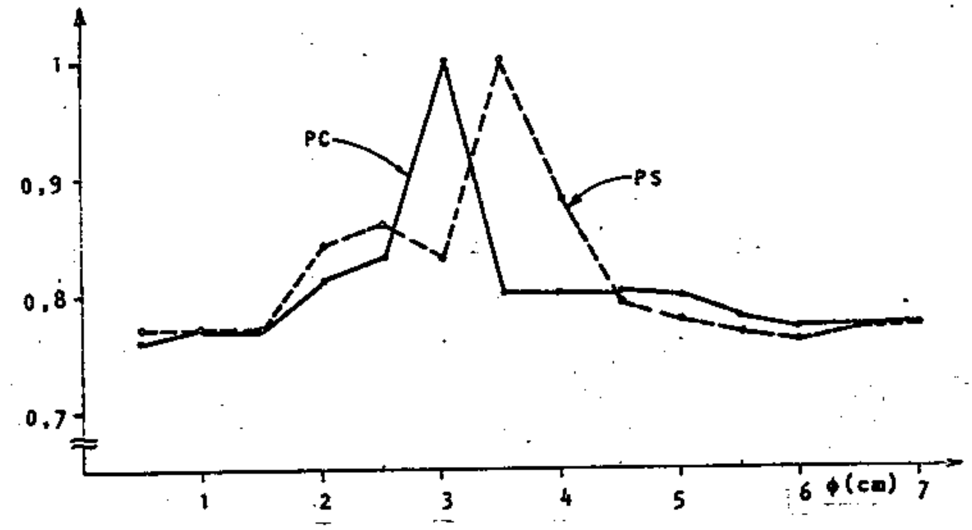


Fig. 7. The measure of goodness of the recognition criterion

SOME OUTPUTS:

```
INPUTS ARE: B(V)= 5                U2(V)= .3                        U3(V)= .2
NOT SURE,UNABLE TO SAY ANYTHING!

INPUTS ARE: B(V)= 2.5              U2(V)= .25                       U3(V)= 0
****************************************************************
*        CYLINDER,   DIAMETER (CM)= 2.5
****************************************************************
         F-T=-.4                        PROBABILITY PC= .832856
INPUTS ARE: B(V)= 0                U2(V)= 0        U3(V)= 0
THAT'S JOKE,THERE IS NOTHING!
INPUTS ARE: B(V)= .5               U2(V)= .55                       U3(V)= .1
****************************************************************
*        SPHERE,     DIAMETER (CM)= .5
****************************************************************
         F-T= .104999                   PROBABILITY PS=  .770192
INPUTS ARE: B(V)= 6.5              U2(V)= .12                       U3(V)= 0
****************************************************************
*        CYLINDER,   DIAMETER (CM)= 6.5
****************************************************************
         F-T=-.138                      PROBABILITY PC= .779285

INPUTS ARE: B(V)= 7                U2(V)= .1                        U3(V)= 0
****************************************************************
*        CYLINDER,   DIAMETER (CM)= 7                              *
****************************************************************
         F-T=-.104                      PROBABILITY PC= .777142
```

References:

[1] TOMOVIĆ, R.: "On Man-Machine Control", Automatica, Vo 5, Pergamon Press, 1969.

[2] RAKIĆ, M.: "Belgrade Hand Prosthesis", Symp. on Basic Problems on Prehention Movement and Control of Artificial Limbs, London, 1968.

[3] STOJILJKOVIĆ, Z.: "Kontrola multifunkcionalne proteže šake", Magistarski rad, Centar za multidisciplinarne studije, Beograd, 1971.

[4] NILSSON, N.: "Learning Machines" Mc Graw Hill New York, 1965.

[5] HO, Y; AGRAWALA, A.K.: "On Pattern Classification Algorithms Introduction and Survey", Proc. of IEEE, Vo 56, No 12, Decembar, 1968.

[6] VAPNIK, V.N.; ČERVONENKIS, A.JA.: "Teorija raspoznavanja obrazov", Nauka, Moskva, 1974.

[7] STOJILJKOVIĆ Z.V.; ŠALETIĆ D.Z.: "Raspoznavanje oblika artikulisanim terminalnim uredjajima, Conferenc. ETAN, Ohrid, 1975.

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