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Experimental Results in Shape Description

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Abstract: - The shape recognition in robotics is often based on models; a model description results by processing many imprints of the same known shape. The paper presents some experimental results obtained in 2D-shape description by geometrical parameters. A program simulates the shape exploration with a tactile matrix sensor, generates the binary imprint and computes many geometrical parameters that describe this imprint. The program can generate almost all possible imprints of the explored shape that can be a geometrical one, a shape previously learned or a shape created by the user. This program is very useful in shape recognition study.

Key-Words: - shape, description, parameter, binary imprint, position, orientation.

1 Introduction

Many static tactile matrix sensors, based on the piezoresistive, magnetostrictive or electrooptical transduction [1,8,9], generate the binary imprint of the touched shape. Its characteristic features (parameters, descriptors) describe each binary imprint. For a quick recognition, an unknown shape must be touched only once, regardless of its position and orientation in the sensory plane. This constraint imposes the binary imprint description through some parameters invariant or quasi-invariant to rotations and translations of the shape in the sensory plane [1,2,3,4,7]. The computation of these characteristic features is fast (because the number of the sensory cells is usually smaller than 300) and does not imply complicated mathematical apparatus.

The recognition procedure imposes the definition of the models (known shapes, prototypes) that the unknown shapes can be identified with. For different positions and orientations of each shape in the sensory plane, different binary imprints usually result. In order to obtain the characteristic feature vector of each model, a great number of binary imprints of that known shape must be processed for different positions and orientations in the sensory plane. So, a program that

- generates many binary imprints of a shape (for different locations in the sensory plane) and
- computes the characteristic features of each imprint

is very useful in shape recognition study. Some considerations about such program are presented in [5,6]; the program simulates the generation of the binary imprint for a shape touched with a matrix sensor (16×16 square cells). The making of the binary imprint is based on the following principle: a sensory cell is activated if the object imprint covers 50% or more from the elementary sensitive surface. The analyzed shape can be a geometrical one, a shape previously learned or a shape created by the user.

Based on the facilities of this program, the paper presents the possibilities for generating various 2D-shapes, with many different positions and orientations in the sensory plane. For such a shape, almost all-possible binary imprints are generated and processed; the resulted parameters enable a correct model description.

2 Imprint Generation

The program for imprint generation and description [5] has seven options (New, Load, Figure, Picture, Save, Delete, Quit) that are presented below.

2.1 Option Figure

It is the option that ensures the selection of a geometrical figure (2D-shape) and establishing of its characteristics. The selected geometrical figure can be one among the following seven: ellipse, equilateral triangle, rectangle, pentagon, hexagon, heptagon, and octagon. Many characteristics values of the selected figure must be then established; these

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characteristics define the size, position and orientation of the geometrical figure and the size of its internal cavity.

a) The figure size is characterized by two radiuses for an ellipse, the length and width for a rectangle and the side for a triangle, pentagon, hexagon, heptagon and octagon. The relative values of these parameters are established with one or two decimal digits (0.00-9.99 and 10.0-16.0).
b) The figure position in the sensory plane is characterized by the coordinates x_0 and y_0 of the point closest to the origin. The relative values of these coordinates are established with one or two decimal digits (same as the parameters that define the size of the shape).
c) The figure orientation in the sensory plane is characterized by the clock-wise rotation angle, whose value (in degrees) is an integer number. The shape can be rotated around its central point. So, for a fixed position of each figure, the program enables 360 possible different orientations.
d) The size of the internal cavity is characterized by the distance between the exterior outline of the figure and the outline of the hole; this distance represents the *Thickness* in Fig. 1 and its relative value is established with two decimal digits.

Observations

- A geometrical figure can contain only one hole with the same shape and disposed in the center of the selected geometrical figure.
- Only relative values are established for the characteristics that define the size and position of the geometrical figure and the size of the internal cavity. The attached real values can be obtained in millimeters, if the relative values are multiplied with the side of the square sensory cell.

Fig. 1 shows the selection of the parameters that define the size (*Radius x* = *Radius y* =4.00) and position ($x_0 = 1.99$, $y_0 = 1.47$) for an ellipse with one hole. The internal cavity is also an ellipse and its size is specified through the *Thickness* $d_H = 2.00$. For 56 different positions ($1 \le x_0 \le 1.99$, $1 \le y_0 \le 1.99$) and the same orientation ($\alpha = 0$) of the selected geometrical shape, 8 different binary imprints were obtained.

2.2 Option Picture

The size, position and orientation of a memorized shape can be changed using this option. The selected shape (among those initial established) can be

a) counterclock-wise rotated (around the central point of the shape) with a desired *Angle*,
b) translated in the sensory plane (writing the coordinates x_0 and y_0 for a fixed point of the analyzed shape, before its rotation),
c) increased or decreased along the x or y axes (writing adequate numbers for *Zoom x* and *Zoom y*).

Observations

- *Zoom x* (or *Zoom y*) increases or decreases both the shape and its coordinates x_0 and y_0.
- The shape size, position and orientation are established in the same manner with that presented above, for the geometrical figures.
- The binary imprint is generated after the validation of the shape size, position and orientation.

A previously learned shape (selected using the option *Picture*) and its position ($x_0 = 5.75$, $y_0 = 3.87$), rotation angle ($\alpha = 10$) and size (*Zoom x* =0.84, *Zoom y* =0.75) are presented in Fig. 3. The resulted binary imprint can be memorized.

2.3 Options Save, Load, New, Delete, Quit

The option *Save* assures the memorization (in the shape library) of the shape generated with this program; a name of attached file must be established for each memorized shape.

We can select a binary imprint name, among those learned, with or without internal cavities, using the option *Load*. The shape delimited by the exterior outline or each internal cavity can be then described by many geometrical parameters.

The previously analyzed binary imprint is deleted when the option *New* is selected. An arbitrary binary imprint can be then generated by the user, with the mouse: each selected sensory cell changes its state (the attached taxel changes its value: 1 – for activated sensory cell, 0 – for inactivated sensory cell).

A binary imprint, selected from the shape library, can be deleted using the option *Delete*.

The option *Quit* ensures the exit from the program.

The binary imprint generated with this program can be then modified with the mouse: each selected taxel changes its value.

3 Imprint Description

The program also computes and displays some parameters which describe the binary imprint.

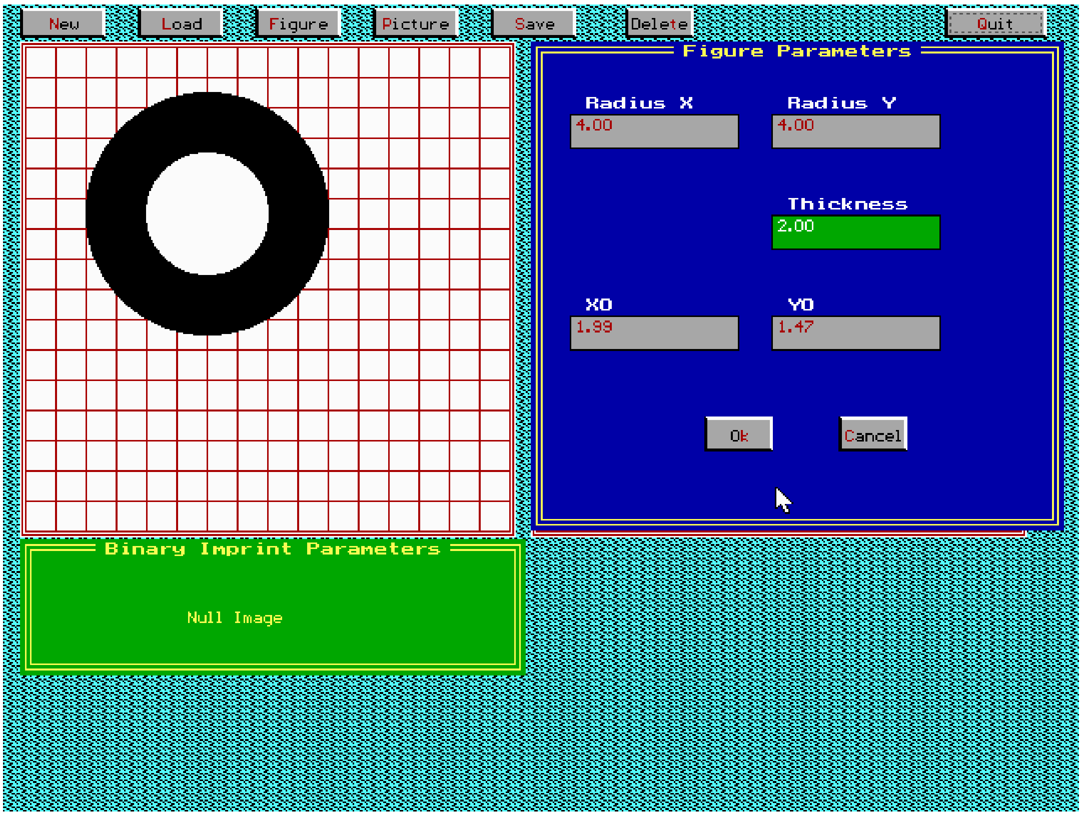

Fig. 1. A selection of the parameters that define the size and position for an ellipse with one hole.

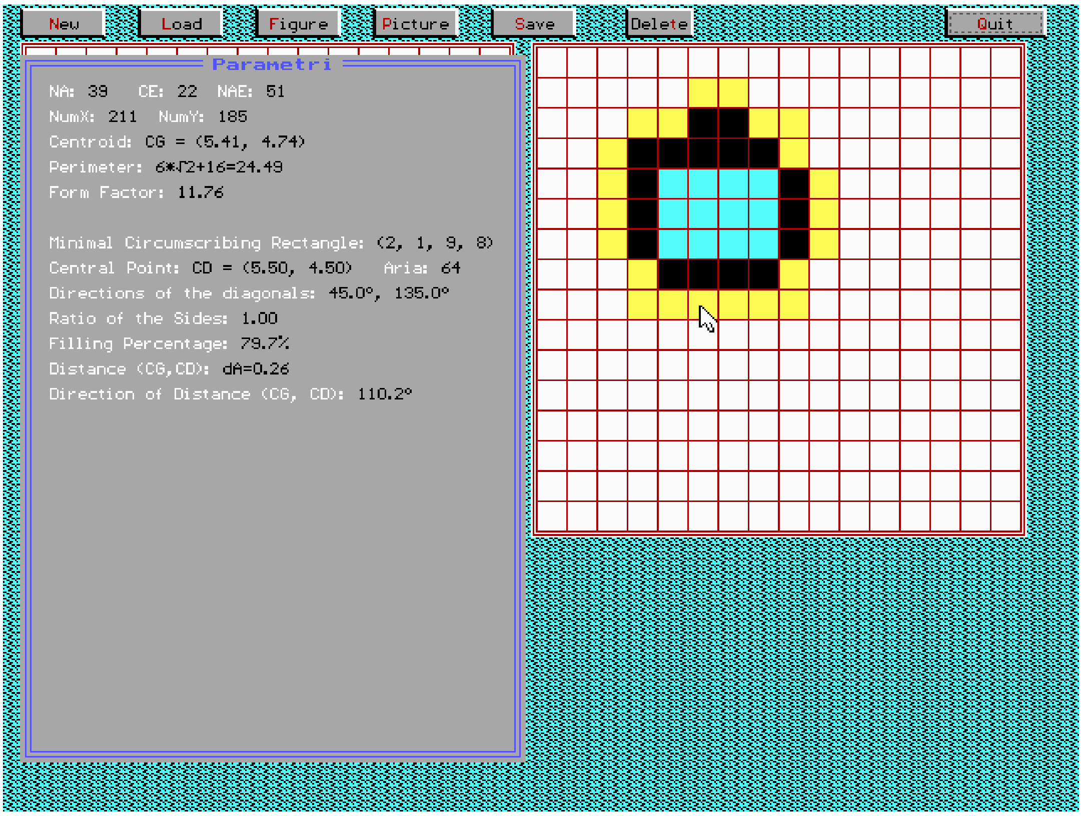

Fig. 2. The binary imprint and its characteristic features of the shape from Fig. 1.

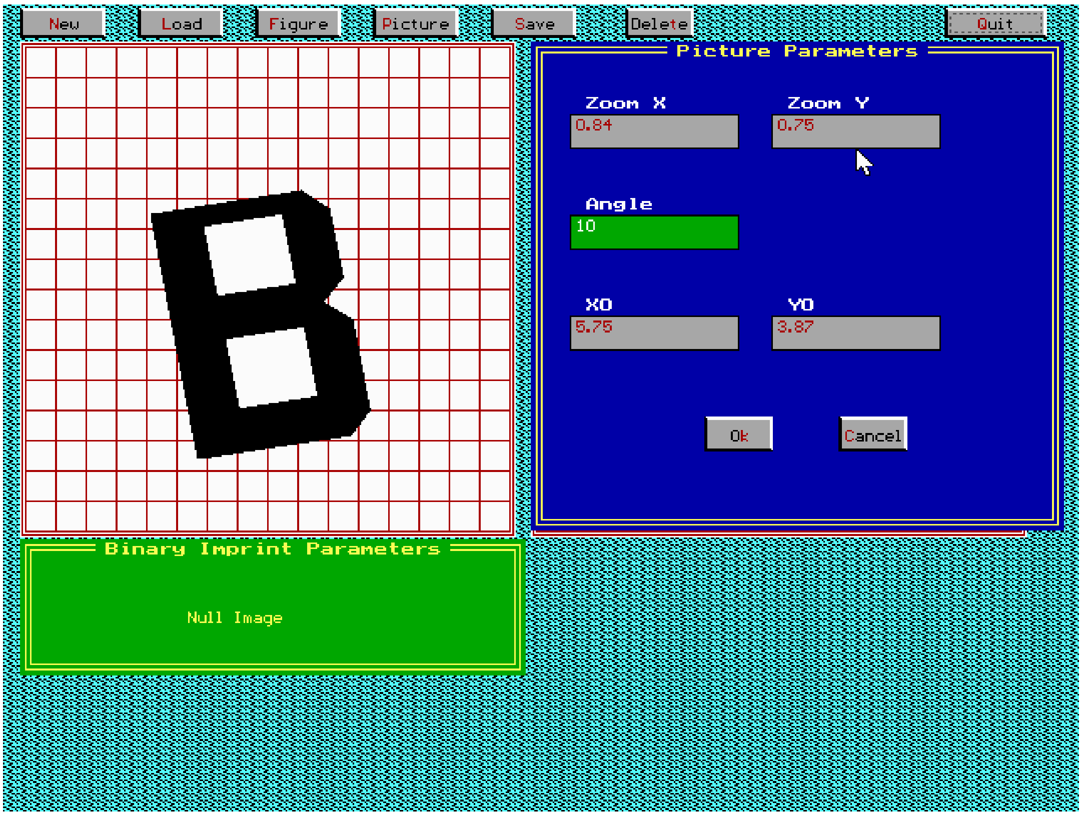

Fig. 3. A previously learned shape and its present position, rotation angle and size.

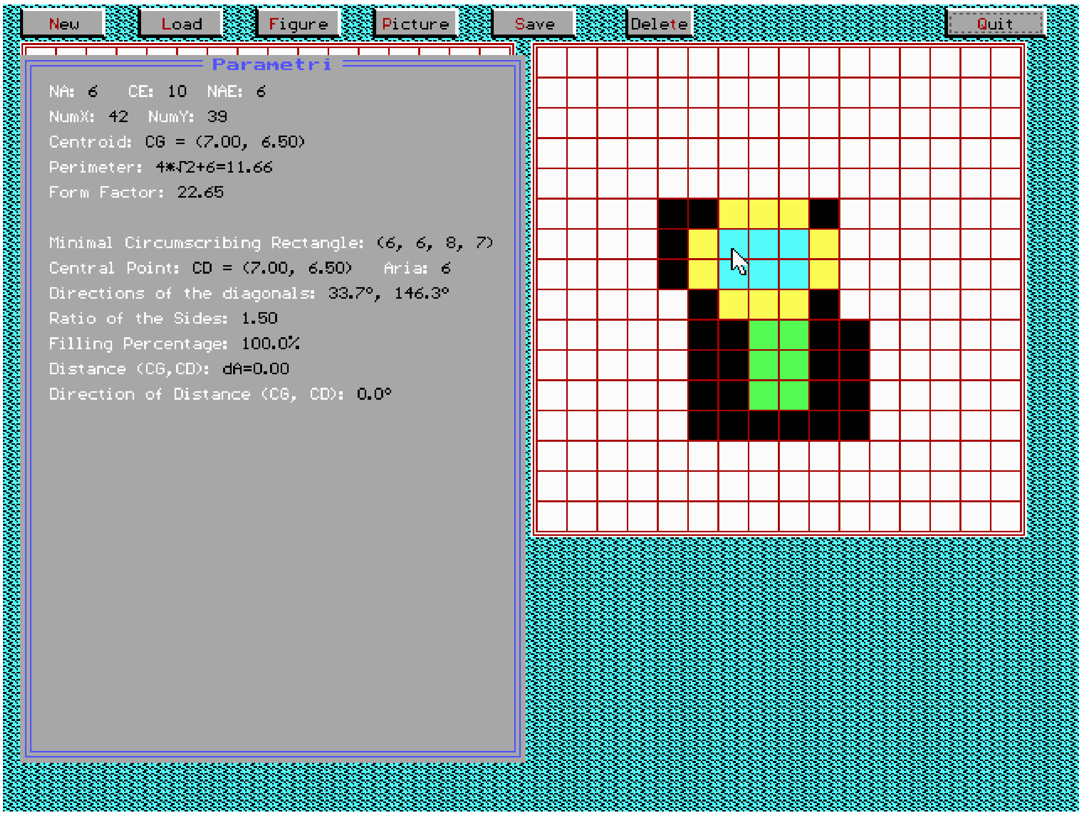

Fig. 4. The resulted binary imprint of the shape from Fig. 3 and the descriptors of the selected hole.

The processed binary imprint (selected with the mouse) can be the binary shape limited by the exterior outline of the imprint or an internal cavity. The parameters (displayed in Fig. 2 and Fig. 4) are the following:

- area of the binary imprint – represented by the number *NA* of the taxels 1 (attached to all activated sensory cells) from the binary imprint;
- area of the binary shape limited by the exterior outline - represented by the number *NAE* of the taxels 1 from this binary shape;
- the length of the binary outline – represented by the number *CE* of the taxels 1 from the binary outline of the selected binary shape;
- the sum *NumX* of the x-coordinates and the sum *NumY* of the y-coordinates of the sensory cells which form the binary imprint;
- the perimeter of the binary outline – represented by the relative length *P* of the polygonal curve generated by the centers of the successive taxels 1 from the binary outline;
- the form factor *F* of the analyzed shape,

$$F = \frac{P^2}{NAE}; \quad (1)$$

- the geometrical parameters of the minimal rectangle circumscribing the binary shape:
  - position in the sensory space – represented by the coordinates of the vertices of this rectangle;
  - coordinates of this central point *CD*;
  - area of this rectangle (denoted *Area* in Fig. 2) – represented by the number of the taxels from the rectangle;
  - directions of the rectangle diagonals;
  - ratio of the sides;
  - filling percentage of the rectangle (the ratio *NA/Area*);
  - distance between the points *CG* and *CD*;
  - direction of the segment (*CG, CD*).

The program computes all these characteristics for the binary imprint resulted using options *Figure*, *Load* or *Picture*. The selection of the size and location parameters, presented in Fig. 1, generates the binary imprint and its characteristic parameters shown in Fig. 2. For the shape from Fig. 3, the descriptors are presented in Fig. 4.

Observation

The computed values are

- absolute for *NumX, NumY, CG, FF*, coordinates of the vertices of minimal rectangle circumscribing the binary shape, *CD,* directions of the rectangle diagonals, ratio of the sides, filling percentage of the rectangle, distance between the points *CG* and *CD*, direction of the segment (*CG, CD*) and
- relative for *NA, NAE, CE, P, Area.*

4 Conclusion

This paper presents a program for the generation and description of binary imprints resulted by simulating the touch of each analyzed shape with a tactile matrix sensor. The touched shape can be a geometrical one, a shape created by the user or a previously learned shape. Almost all-possible binary imprints can be generated for each analyzed shape because the program enables the change of the shape size, position and orientation in the sensory plane. Each binary imprint can be memorized or deleted. Many geometrical parameters are computed for the binary imprint description.

This method for the generation and description of binary imprints enables the testing of many description, classification or decision algorithms, necessary for shape recognition in robotics. The program is also very useful for students, in the shape description study.

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