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A PROPOSED ALGORITHM FOR THE RECOGNITION OF TWO DIMENSIONAL SOLID POLYGONS

By

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- Scene Analysis of digital Images
- Feature Extraction and Classification
- Pattern Recognition

ABSTRACT

Many image anlysis problems can be successfully performed by pattern recognition systems designed to classify an input pattern into one of several categories. This paper proposes an algorithm for the recognition of two dimensional solid polygons including those of variable dimensions and/or orientations. The introduced software of the proposed algorithm, in basic language, includes the subroutines for pattern creation, noise insertion, noise cleaning, feature extraction, and classification. The proposed algorithm is tested for more than 10 patterns and in all cases the results are satisfactory.

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1. INTRODUCTION

This work is intended for the analysis, classification, and identification of two dimensional solid polygon patterns according to a set of stored pattern classes. For the analysis of these patterns, the acquired image is first high frequency filtered through convolution with a difference operator mask, for extracting its contour. The histogram of the filtered image is then calculated and used for specifying a suitable threshold level for quantizing the image into a binary one. Finally, the associated noises are cleaned through filteration and masking.

The classification of patterns depends upon the selection of a suitable feature vector completely characterizing the pattern to be classified. This selection must satisfy simplicity, ease of calculation, time saving and efficiency. The identification of input patterns is performed through the comparison of its feature vector with those of the stored patterns and deciding whether it matches with one of them or not. In the latter case the feature vector of the examined pattern is saved as a new pattern for further classification.

2. PROPOSED ALGORITHM

Due to lack of an image acquisition system , the patterns to be classified and/or identified are created using computer simulation. The proposed algorithm, thus, comprises five stages for performing the allocated task, sequenced as follows:

1- Pattern creation
2- Noise insertion
3- Noise cleaning
4- Feature extraction
5- Classification and/or identification

2.1. Pattern creation:

The pattern is created by establishing the number and length of sides, the angles between sides, and the corresponding coordinates,(Fig.2.1).

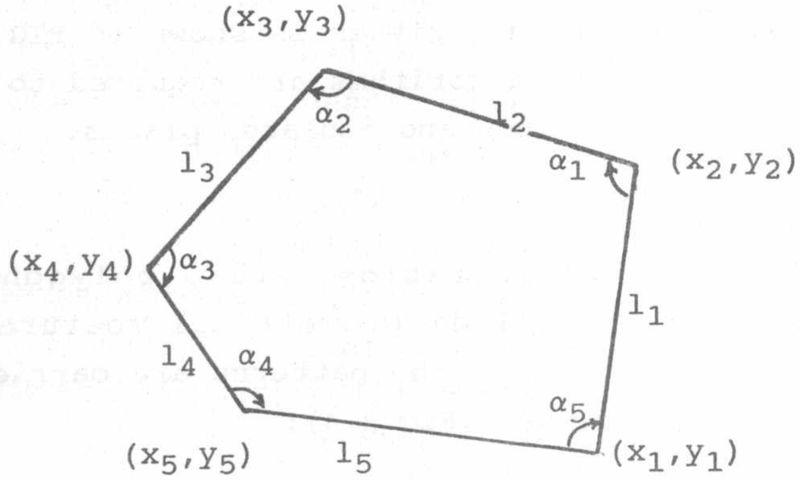


Fig.2.1

2.2. Noise Generation:

Image noise can be divided into several distinct categories, but it may occur as combination of these types in actual images. Two basic types are considered in this paper, namely random noise and isolated noise. Random noise, characterized by its statistical variation in gray level from pixel to pixel, may originate due to electronic components such as detectors and amplifiers. Isolated bad pixels or lines in digital images can be caused by bit loss in data transmission. The pixels affected by noise are either a zero-gray level, indicating data loss, or a maximum gray level, indicating saturation. This type of noise is simulated using a random noise generator.

2.3. Noise cleaning (Suppression):

Low-pass spatial filters can reduce random noise by averaging several pixels. If the noise is uncorrelated from pixel to pixel, its variance will be reduced by the low-pass filter. Isolated noise can be removed by comparing each pixel with its neighbours and deciding whether the pixel is bad or good according to its deviation from the neighbouring pixels. If a pixel or line is bad it can be replaced by the nearest good pixel or line, or by a gray level interpolated between the neighbours.

An example of noise cleaning algorithms is shown in FIG. 2.3 . Note that slightly different algorithms are required to remove bad vertical or horizontal lines and isolated pixels.

2.4. Feature Extraction:

The patterns under consideration, solid polygons, are generally characterized by their geometrical features upon which distinction and sorting of the patterns are carried out. The basic features may include, (Fig.2.4):

- number and length of sides (n, l_i)
- angles between sides (α_i)
- center of gravity of the pattern (COG)
- the ratio between the distance from the COG to the side and the length of the side (r_i/l_i)
- the angles whose vertix is COG (β_i)
- the angles Θ_i
- .... etc

Different feature vectors are used throughout this study, including :

$$\begin{bmatrix} l_i \\ \alpha_i \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} r_i/l_i \\ \Theta_i \end{bmatrix}$$

and it is found that the second one, although time consuming, outperformed the first in identifying patterns of varying magnification. The algorithm for extracting the general feature vector proceeds as follows:

1- Starting from the lower left hand corner, the image is scanned, horizontally from left to right and vertically up, for finding the first vertix and saving its coordinates

2- Using a contour tracing routine the other vertices are determined and saved. If this routine fails to determine all

(a) INDIVIDUAL PIXELS

GL1	GL4	GL7
GL2	5	GL8
GL3	GL6	GL9

AVE1 = (GL1 + GL3 + GL7 + GL9)/4

AVE2 = (GL2 + GL4 + GL6 + GL8)/4

DIFF = | AVE1 - AVE2 |

IF | GL5 - AVE1 | OR | GL5 - AVE2 | > DIFF

THEN GL5 = AVE2 OTHERWISE GL5 = GL5

(b) LINES

GL1	GL4	GL7
2	5	8
GL3	GL6	GL9

AVE1 = (GL1 + GL4 + GL7)/3

AVE2 = (GL3 + GL6 + GL9)/3

DIFF = | AVE1 - AVE2 |

IF | GL5 - AVE1 | OR | GL5 - AVE2 | > DIFF

THEN GL5 = (GL4 + GL6)/2

OTHERWISE GL5 = GL5

(c) COLUMNS

GL1	4	GL7
GL2	5	GL8
GL3	6	GL9

AVE1 = (GL1 + GL2 + GL3)/3

AVE2 = (GL7 + GL8 + GL9)/3

DIFF = | AVE1 - AVE2 |

IF | GL5 - AVE1 | OR | GL5 - AVE2 | > DIFF

THEN GL5 = (GL2 + GL8)/2

OTHERWISE GL5 = GL5

FIGURE 2.3 AN EXAMPLE OF NOISE CLEANING ALGORITHM other vertices (due to limited resolution), we resort to an error detection routine which is more powerful but not so fast.

3- The different features are calculated as follows :

- $l_i = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$

- $COG \equiv (\bar{x} , \bar{y})$

$$\bar{x} = \int x \, dA \Big/ \int dA \; ;$$

$$\bar{y} = \int y \, dA \Big/ \int dA \; ;$$

- $\alpha_i = \tan^{-1}\left(\dfrac{y_{i+1} - y_i}{x_{i+1} - x_i} \right) - \tan^{-1}\left(\dfrac{y_{i+2} - y_{i+1}}{x_{i+2} - x_{i+1}} \right)$

- $r_i = \min[\sqrt{(x_{COG} - x_{1i})^2 + (y_{COG} - y_{1i})^2}]$

- $\beta_i = \tan^{-1}\left(\dfrac{y_{COG} - y_i}{x_{COG} - x_i} \right) - \tan^{-1}\left(\dfrac{y_{COG} - y_{i+1}}{x_{COG} - x_{i+1}} \right)$

- $\Theta_i = \tan^{-1}\left(\dfrac{y_{COG} - y_i}{x_{COG} - x_i} \right) - \tan^{-1}\left(\dfrac{y_i - y_{i+1}}{x_i - x_{i+1}} \right)$

where

$i = 1,2,\ldots,n$

$(x_{n+1}, y_{n+1}) \equiv (x_1, y_1)$, $(x_{n+2}, y_{n+2}) \equiv (x_2, y_2)$

$(x_{1i}, y_{1i}) \in \{ l_i \}$

dA is an elementary area assuming homogeneous density

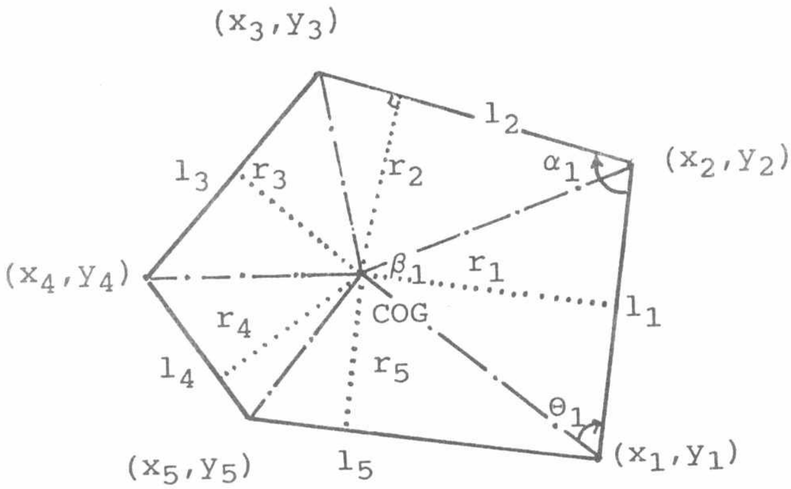


Fig.2.4

3. SOFTWARE IMPLEMENTATION

The implemented algorithm contains the following subroutines

(1) Acquisition of a set of images (creation of reference patterns)

(2) Noise treatment
   - a- Simulation of random noise.
   - b- Noise cleaning

(3) Feature extraction algorithm.
   - a- Finding first vertix
   - b- Line following to trace the contour.
   - c- Error detection.
   - d- Tabulation of the feature vector.

(4) Classification algorithm.
   - a- Saving the feature vector for each pattern.
   - b- Analysis of new patterns to extract the corresponding feature vector.
   - c- Comparison.
   - d- Decision making.

The complete flowchart of the proposed algorithm is shown in Fig.3.

Note: The software package is implemented using "BASIC" Language as an easy-to-learn, easy-to-use high level language,in addition to its availability for most of the personal and home computers

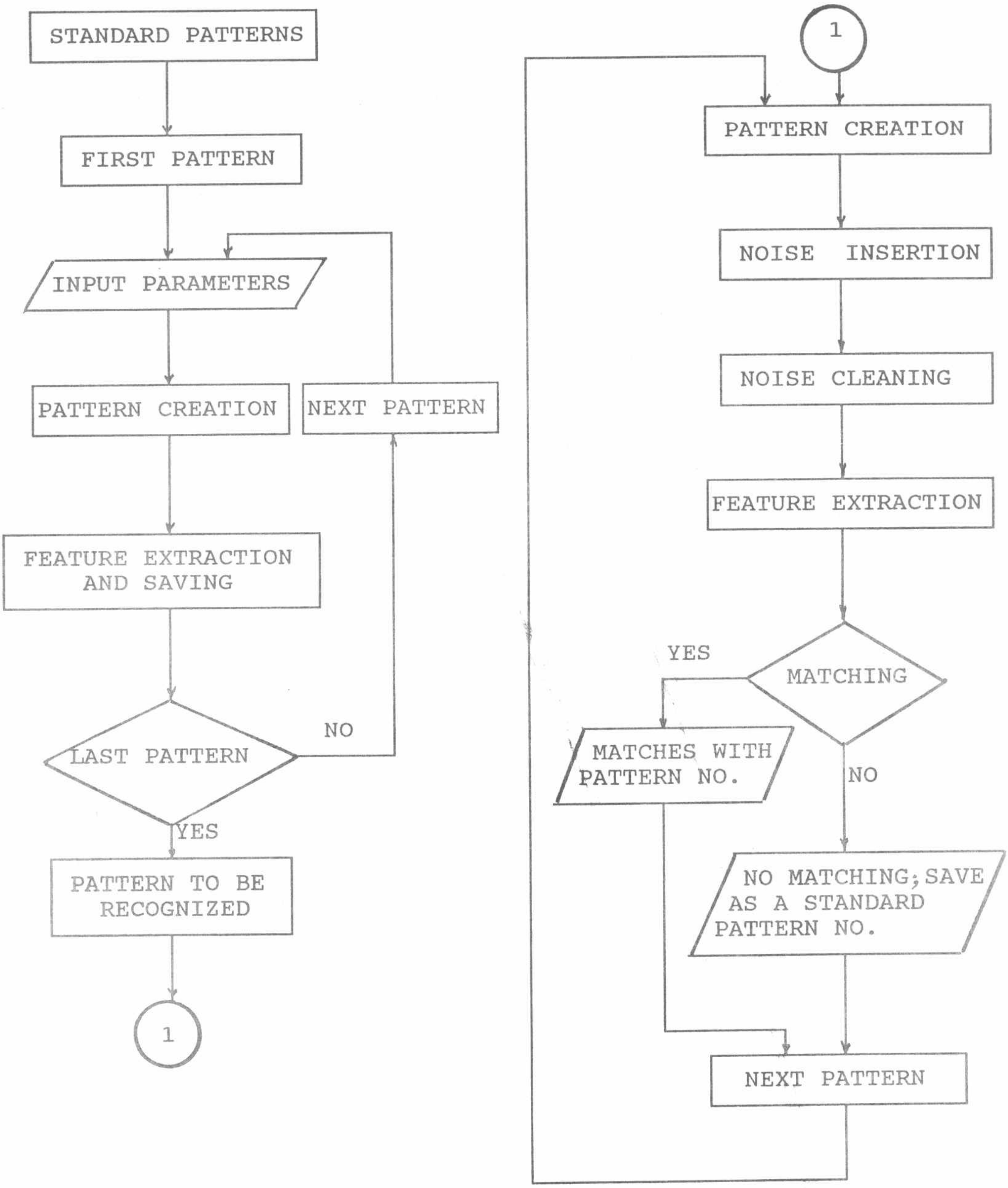
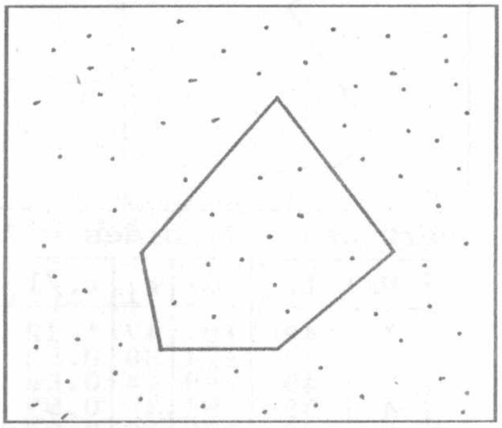


Fig. 3 Flowchart of the proposed algorithm.

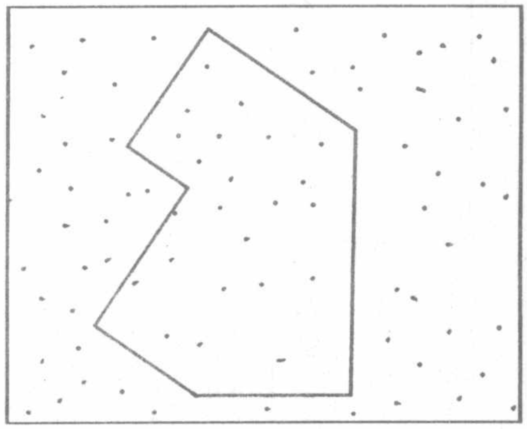
4. Computer Results

1-Creation of Standard Patterns

Pattern No. 1

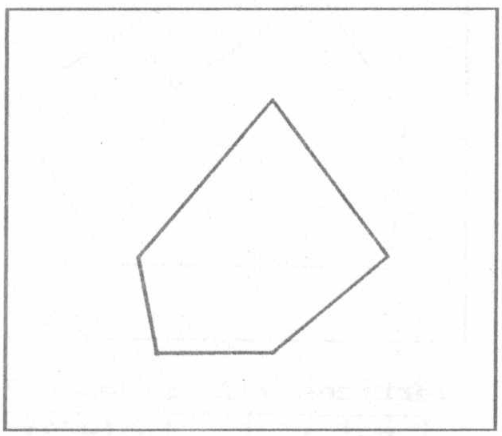


Pattern No. 2

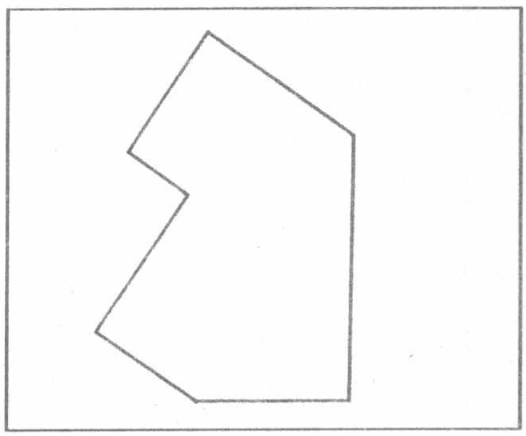


2-Noise Cleaning.

Pattern No. 1

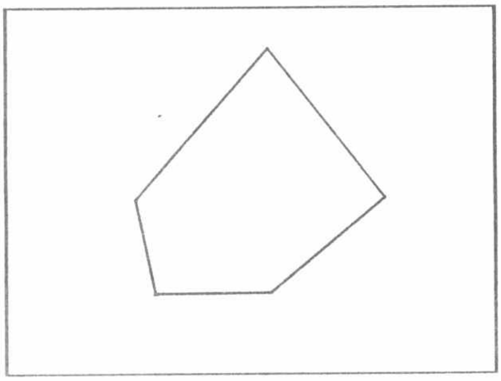


Pattern No. 2



3-Feature Extraction

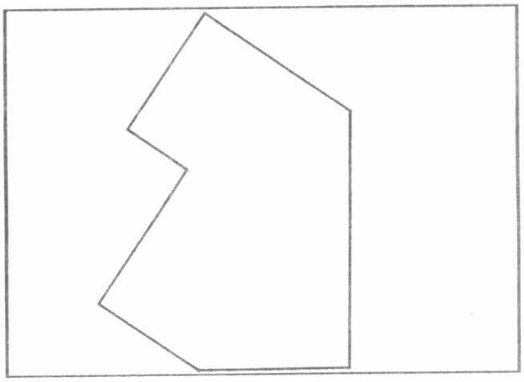
Pattern No. 1



vertices = 5 , sides = 5

Ns	l_i	α_i	r_i	r_i/l_i
1	30	140	28	0.91
2	39	93	26	0.65
3	50	78	30	0.59
4	53	128	21	0.39
5	25	101	31	1.20

Pattern No. 2

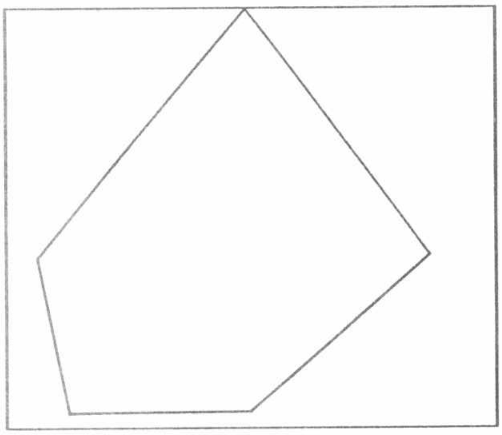


vertices = 7, sides = 7

Ns	l_i	α_i	r_i	r_i/l_i
1	42	101	47	1.12
2	72	124	38	0.52
3	49	89	44	0.88
4	39	91	39	0.99
5	20	270	19	0.97
6	51	90	19	0.36
7	40	135	46	1.16

4-Classification.

Pattern No. 1

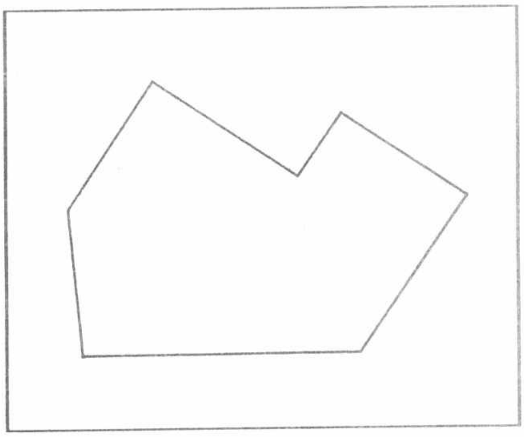


vertices = 5 , sides = 5

Ns	l_i	α_i	r_i	r_i/l_i
1	60	140	55	0.91
2	78	93	53	0.65
3	100	78	54	0.59
4	106	128	42	0.39
5	51	101	61	1.20

Matches with pattern #1

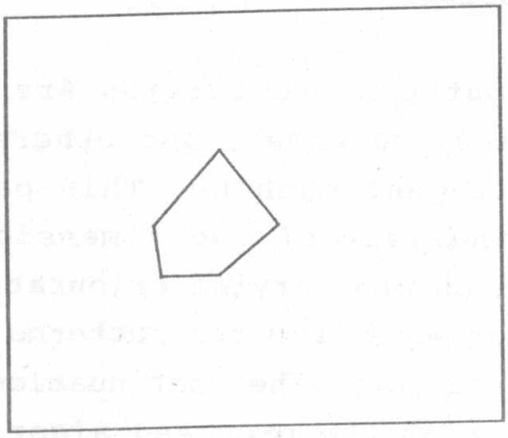
Pattern No. 2



vertices = 7, sides = 7

Ns	l_i	α_i	r_i	r_i/l_i
1	42	101	47	1.12
2	72	124	38	0.52
3	49	89	44	0.88
4	39	91	39	0.99
5	20	270	19	0.97
6	51	90	19	0.36
7	40	135	46	1.16

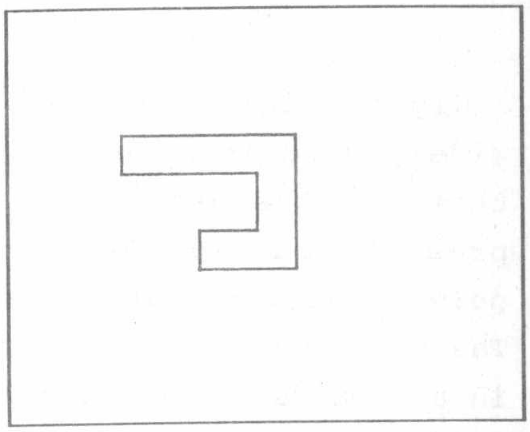
Matches with pattern #2



vertices = 5 , sides = 5

Ns	l_i	α_i	r_i	r_i/l_i
1	15	140	14	0.93
2	20	93	12	0.61
3	25	78	15	0.60
4	26	128	11	0.40
5	13	101	15	1.13

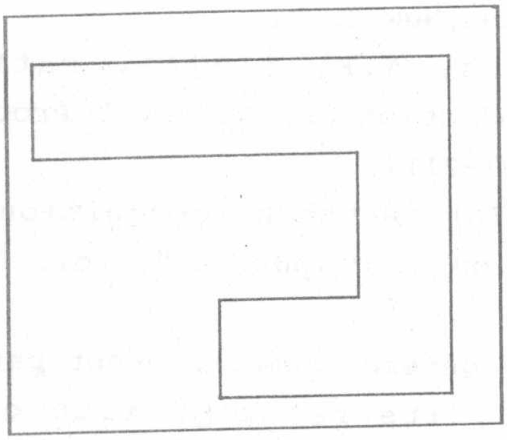
Matches with pattern #1



vertices = 8, sides = 8

Ns	l_i	α_i	r_i	r_i/l_i
1	25	90	20	0.80
2	35	90	18	0.51
3	45	90	15	0.33
4	10	90	28	2.75
5	35	270	5	0.13
6	15	270	8	0.52
7	15	90	10	0.67
8	10	90	12	1.23

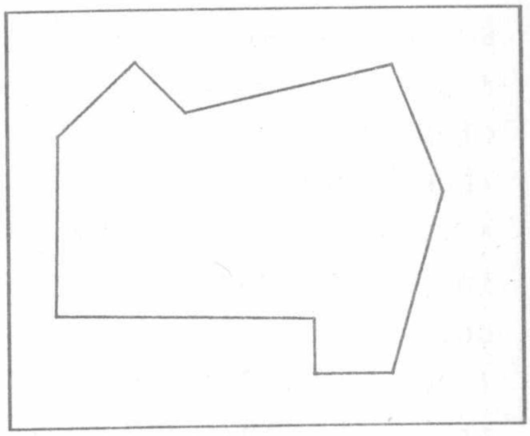
No matching stored as pattern #3



vertices = 8 , sides = 8

Ns	l_i	α_i	r_i	r_i/l_i
1	75	90	60	0.80
2	105	90	54	0.51
3	135	90	45	0.33
4	30	90	83	2.75
5	105	270	15	0.13
6	45	270	24	0.52
7	45	90	30	0.67
8	30	90	37	1.23

Matches with pattern #3



vertices = 9, sides = 9

Ns	l_i	α_i	r_i	r_i/l_i
1	30	106	66	2.19
2	73	142	79	1.08
3	54	98	76	1.4
4	82	239	45	0.54
5	28	90	46	1.64
6	42	135	74	1.73
7	70	90	75	1.06
8	100	270	41	0.40
9	20	90	48	2.39

No matching stored as pattern #4

5. CONCLUSION

digital image processing and pattern recognition are now widely used in industry , medicine, defence , and others as they are the heart of any intellegent machine. This paper presents an algorithm for the analysis of two dimensional polygon patterns of different scales and varying orientation. The proposed software is tested for more than ten patterns and in all cases the results are satisfactory .The continuation of this work includes the development of the proposed algorithm for the analysis of patterns with curved sections and/or with nonhomogeneous density (i.e. containing holes).

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