

International Conference on
COMPUTER INTEGRATED MANUFACTURING
Internationale Konferenz über
RECHNERINTEGRIERTE FERTIGUNGSSYSTEME
Zakopane, March 24-27 1992

G. Graziano, M. Orlando, G. Podda

Dipartimento di Sistemi di Produzione ed Economia dell' Azienda.
Politecnico di Torino, Torino, Italy.

RECOGNITION OF CONCAVE SHAPES WITH INTERNAL HOLES

SUMMARY. We are given an extension of an optimized method of recognizing plane figures with holes in a bilevel scene.

In a previous paper [1] we developed an automatic method in order to recognize plane figures in a bilevel scene. Such a method is not affected by translation, rotation and scaling. It can be used for either convex or concave figures, but not for figures with interior holes. The figures are extracted from the scene by a contour following algorithm, which associate a different grey level with each contour.

In this paper we extend that algorithm to figures with interior holes: figures and holes may be either convex or concave.

1) Extraction of figures with holes from the scene.

Suppose we are given an image from a camera, and suppose we have chosen a threshold so that this image has only two grey levels: white for the background and black for the figures (fig. 1).

We make a raster scan of the display until the grey level of the analyzed pixel is different from that of the previous one. In this case we have three possibilities:

- 1) The analyzed pixel is black, whereas the previous pixel is white.

This means we have met a first contour pixel of a figure. After having extracted the contour pixels by a following contour algorithm [2], we save their display coordinates into an array and we set their colour in a certain gray level.

Then we calculate the contour barycenter G and, the number A of the pixels inside the contour [3].

- 2) The analyzed pixel is white, whereas the previous pixel is black.

This means we have met a first pixel of an hole inside the figure. After having extracted the contour pixels of the hole in the same way as above, we set their colour in the same grey level

as the contour of the figure. Then we calculate the barycenter H of the hole contour, the number S of pixels inside and the distance L between the hole contour barycenter H and the barycenter G of the figure. Moreover we calculate the clockwise angle α between the horizontal left axes through the barycenter G of the figure contour and the line from this point to the hole contour barycenter H (fig. 2).

3a) The analyzed pixel is grey, whereas the previous pixel is white.

In this case we enter a figure we have already met or we exit from a hole we have already met.

3b) The analyzed pixel is white whereas the previous pixel is gray.

In this case we exit from a figure we have already met or we enter a hole we have already met.

In both case 3a) and 3b) we set a variable "attribute" to the value of the grey level which belongs to figure or to hole.

Of course we continue the raster scan of the display until the last pixel is reached.

II) Comparison of the figure to the model and recognition

We compare each figure with model in the following way:

1) We explore (fig. 3a, fig. 3b) the contour of both the figure and the model (the model is a particular figure extracted from a scene in the same way as in I) in order to find the scale $S = \sqrt{A_m/A_f}$, (A_m is the number of the pixels inside the contour of the model, A_f is the number of the pixels inside the contour of the figure) and the possible angles θ_k ($k=1, \dots, t$) of rotation.

In particular, if both the contour are circular then the angle θ is not determined. For, the similitude between figure and model is always possible for any angle.

2) For any hole $i = 1, 2, \dots, n$ ($n =$ number of holes) of either the model or the figure, we make a list whose items are the quantities α_i, L_i, A_i already calculated in I.

3) We order every list of 2) so that the α_i 's are increasing; if two or more of the α_i 's are equal, then we order the corresponding items so that their L_i 's are increasing. Similarly, if two or more items have equal α_i 's and also equal L_i 's, then we order them so that their A_i 's are increasing.

4) For $i = 1, \dots, n$ we calculate (fig 2) the differences $\beta_i = \alpha_i - \alpha_{i-1}$ between each angle of the ordered list and the previous one, where $\alpha_0 = \alpha_n$.
If $\beta_i < 0$ then we consider $360 - \beta_i$.

5) We compare the list of the holes of the model with all possible cyclic permutations of the list of the holes of the figure. In such a way we can find, if any, the r permutations of the second list which are equal to the first list ($0 < r < n$). (Notice that the two lists must have

the same number of items, that is the figure and the model must have the same number of holes. Otherwise the comparison is not possible and so the figure is different from the model). Then we calculate in the model the vector V_0 between the barycenter G of the contour and the barycenter of a fixed hole, say the first hole (fig 4a). At last, for each of the found permutations, we calculate the vector V_i ($i = 1, 2, \dots, r$) from the barycenter G of the contour to the barycenter of the hole corresponding to the fixed one. For $i = 1, 2, \dots, r$, let ϕ_i be the clockwise angle between V_0 and V_i (fig. 4b).

6) We consider the common values among the θ_k 's ($k = 1, 2, \dots, t$), and the ϕ_i 's ($i = 1, 2, \dots, r$). If θ_k is not determined, then we consider all the ϕ_i 's. For every common value $\theta_k = \phi_i$ (or for any ϕ_i if θ is not determined) we transform the first point of the contour of each hole of the figure by the following operations:

- a) A scaling $S = \sqrt{A_m/A_f}$ so that the area A_f of the figure become equal to the area A_m of the model.
- b) A translation so that the barycenter of the figure coincide with the barycenter of the model.
- c) A clockwise rotation around the common barycenter of angle $\theta_k = \phi_i$.

7) We choose the point of the contour of the hole of the model, closer to the transformed point in 6) of the contour of the corresponding hole of the figure.

8) For every hole of the model we consider the cyclic permutation of the list of the contour polar coordinates $d = f(s)$ starting from the chosen point in 7).

9) We multiply by a scale factor $S = \sqrt{A_m/A_f}$ the lists of polar coordinates of the holes of the figure.

10) We compare the lists of the holes of the figure with the lists of the corresponding holes of the model.

11) If all the lists are pairwise equal (and we consider them as equal when their difference is less than a small fixed error), then the figure is declared to be similar to the model. The recognition is therefore done.

III) Example

We consider a bilevel scene containing the model (fig. 5a) and another scene containing some figures (fig. 5b).

The triangles in the model and in the figures are all equilaterals and the holes have the same area. Their barycenters are vertices of an equilateral triangle which edges are parallel to the edges of the figure and barycenter coincident to the barycenter of the figure.

The figures A and B are similar to the model M, while the figure C has a triangular hole d which is rotated with respect to one of the corresponding holes of the model. The results we obtained are written in Table 1 directly from the computer.

The algorithm, from the beginning to the end of the raster scan, runs in 11 seconds.

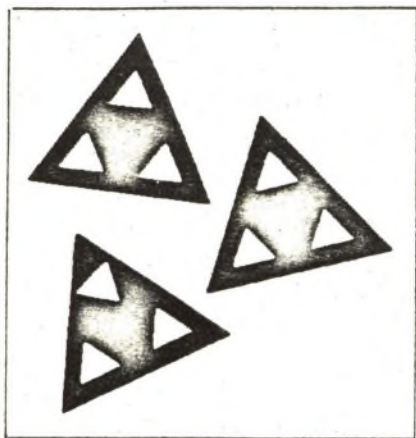


Fig. 1

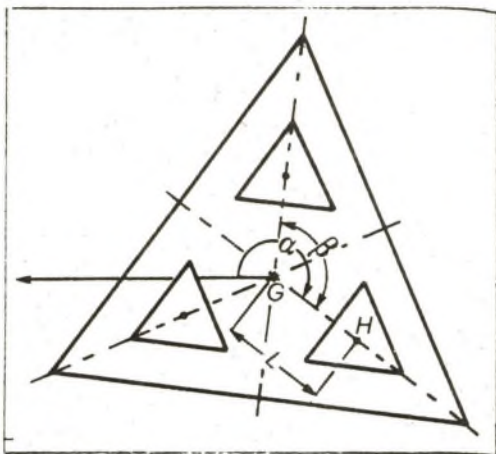


Fig. 2

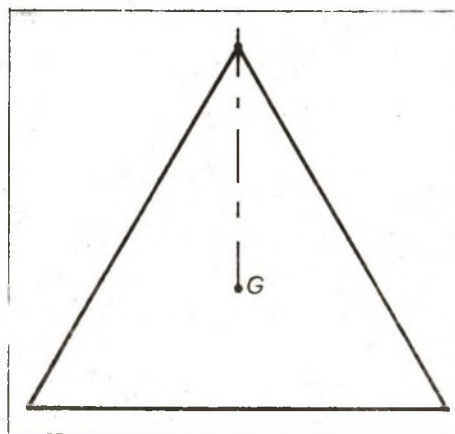


Fig. 3a

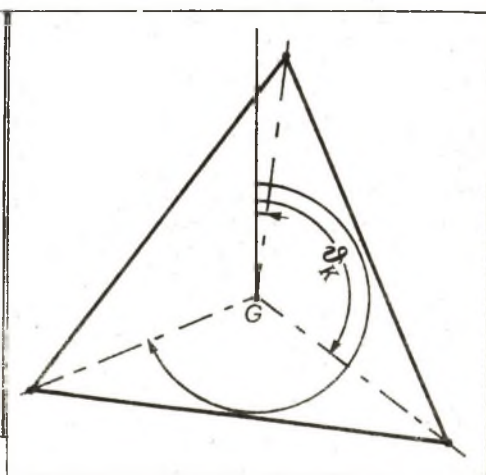


Fig. 3b

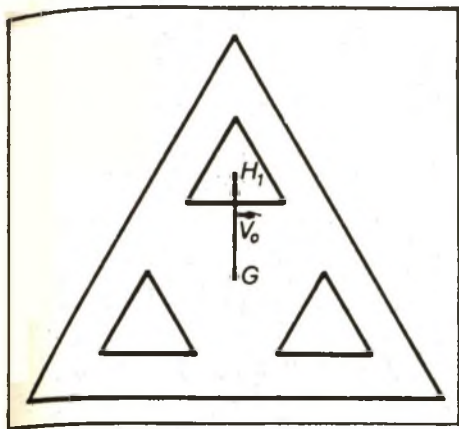


Fig. 4a

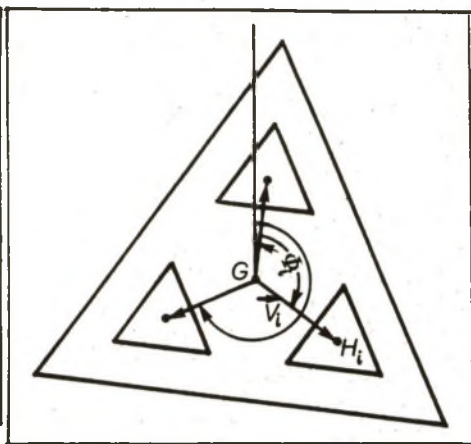


Fig. 4b



Fig. 5a

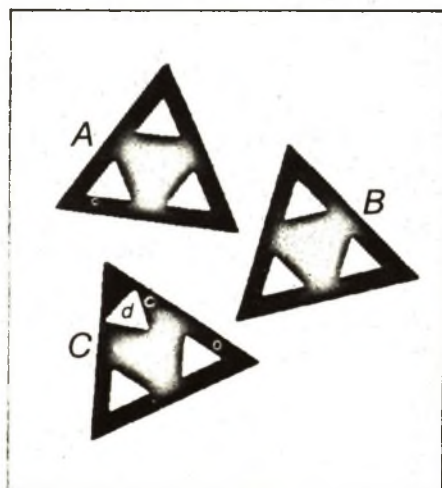


Fig. 5b

name of the file model : TRI.DAT

tri.dat

name triangle area 18790.000000 barycenter 140,126

hole: xbb 140 ybb 73 area 1004.500000

hole: xbb 185 ybb 150 area 1031.500000

hole: xbb 95 ybb 150 area 1078.500000

repeat? n

contour fig. n. 1

area 20133.50

barycenter 129,136

scale factor 0.96606

contour fig. n. 2

area 20499.50

barycenter 311,229

scale factor 0.95740

contour fig. n. 3

area 19950.00

barycenter 124,350

scale factor 0.97049

figure n. 1

hole: xbb 134 ybb 82 area 1050.500000

hole: xbb 78 ybb 154 area 1138.000000

hole: xbb 170 ybb 166 area 1101.500000

figure n. 2

hole: xbb 298 ybb 173 area 1056.500000

hole: xbb 362 ybb 239 area 1016.000000

hole: xbb 273 ybb 261 area 1065.000000

figure n. 3

hole: xbb 101 ybb 301 area 1135.500000

hole: xbb 177 ybb 351 area 1084.500000

hole: xbb 94 ybb 391 area 1104.000000

fig. n. 1

recognition performed

rotation = 6.065262 degrees

fig. n. 2

recognition performed

rotation 347.583496

fig. n. 3

figure not recognized

total scanning and recognition time: 11 s.

Table 1.

IV) Hardware

- 80286 IBM PC/AT
- CCD camera
- Overlay Frame Grabber, Imaging Technology
- Image Processing Accelerator, Imaging Technology.

REFERENCES

- [1] G. Graziano, M. Orlando, G. Podda: "Ottimizzazione di un' algoritmo polare per l' individuazione di una figura generica". 9 ° SAMUTIC , Napoli, 6-10 Novembre 1991.
- [2] G. Podda: "Algoritmo di contorno per inseguimento". Atti VII Convegno Nazionale A.D.M., Trento 1991, pp. 23-31.
- [3] M. C. Fairhurst: "Computer Vision for Robotic Systems". Prentice-Hall, N. Y., 1988, pp. 74-78.

ERKENNUNG VON MIT INNEREN LOECHERN KONKAVFORMEN

ZUSAMMENFASSUNG. Eine Ausdehnung von einem verbesserte Erkennungs_ verfahren für mit Löchern Flachformen wird gestellt.

Eine automatische Methode für die Erkennung von in einer auf zwei Hönen Szene Flachformen ist in einer vorherigen Arbeit entwickelt worden. Solche Methode ist im Verschiebung, Rotation und Skala Fall unveränderlich und sie kann sowohl für konkav als auch für Konvexformen benützt werden, aber nich für mit inneren Löchern Formen.

Eine Ausdehnung solcher Methode an die mit inneren Löchern Formen wird in dieser Arbeit gestellt; die Formen und die Löcher können sowohl konkav als auch konvex sein.

AUTOMATYCZNE ROZPOZNAWANIE FIGUR PŁASKICH Z OTWORAMI

Streszczenie

W artykule podano rozszerzenie metody optymalizacji rozpoznawania figur płaskich z otworami. W poprzednim artykule [1] podano rozwój metody automatycznego rozpoznawania figur płaskich. Metoda ta może być użyta zarówno dla figur wypukłych jak i dla wklęsłych ale nie dla figur z otworami wewnętrznymi. Figury zostały wyróżnione ze sceny przez kontury wg algorytmu, każdemu z konturów przypisuje się inny poziom szarości. W tym artykule algorytm został rozbudowany dla figur z otworami wewnętrznymi. Figury i otwory mogą być wklęsłe lub wypukłe.

Wpłynęło do redakcji w styczniu 1992r.

Recenzent: Wojciech Cholewa