CODAGE D'IMAGES PAR LA SUITE DES COURBURES DE LEURS CONTOURS

CODING IMAGES BY A SEQUENCE OF CURVATURES FROM THEIR CONTOUR

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RESUME

Il existe un grand nombre de pièces dans l'industrie pour lesquelles son contour constitue une information très significative de sa forme.

Une fois l'image isolée du fond il est possible de la décrire au moyen d'un code chaîne généré en suivant son contour. En prenant comme source cette information de nombreux descripteurs de contours on été utilisés.

Premièrement on montre un métode de description d'objets invariable avec la rotation dans laquelle les éléments descripteurs s'obtiennent de l'étude quantitative des courbures des segments du contour.

Visant à obtenir un compromis acceptable discrimination-filtrage du bruit de digitisation, une étude du nombre de points du contour à partir des quels on calcule chaque élément de la sequence de courbures, ainsi que del'algorithme à choisir est faite.

La description des contours à partir de cette sequence permet de distinguer des objets fort ressemblants utilisant un volume d'information très reduit.

La variation dans le nombre de points digitisés du contour en fonction de son orientation, entraîne une variation proportionelle dans la longueur de la sequence genérée qui renddifficile la comparaison avec le modèle. On présente un algorithme qui normalise la sequence de courbatures pour qu'elle soit invariable avec la rotation.

Pour que la sequence de courbures puisse se rapporter à une orientation, on ajoute l'information des coordonnées de certains points du contour ainsi quecelle de sa situation dans la sequence. Le choix des points est fait automatiquement de façon que l'erreur dans la détérmination de l'orientationsoit minimisée.

Le codage d'objets au moyen de la sequence de courbures proposée ainsi que des coordonnées de quelques points permet de reconnaître des objets de façon efficace, dans un court délai et a coût faible ce qui le rend utile pour des applications en robotique.

SUMMARY

For a wide number of industrial objects, the contour of their 2D image gives a very relevant information of their shape. Once the contour is extracted from its background, it is possible to describe the object's shape by a chain code, generated during contour tracking. Several different descriptors based on this information have been defined. In this paper, an object description invariant under rotation is described, in which the descriptor elements are obtained from a quantitative analysis of the curvatures from each contour segment.

In order to attain an acceptable compromise between discrimination and discretization noise reduction, a study is done about the number of contour points over which each element of the sequence is to be calculated, and also about the calculation algorithm to be used.

Describing contours by means of this sequence permits the differenciation among very similar objects, using a very reduced amount of information. The dependence of the length of the sequence of the object orientation on the plane makes difficult its comparison with the model. In order to obtain a sequence of curvatures invariant under rotation, a normalizing algorithm is used.

To reduce the sequence of curvatures to a given orientation, this sequence is complemented with the coordinates of two of the contour points, P1 and P2, and the position within the sequence of their respective curvature elements. These points are chosen in such a way that the resulting error in the orientation determination is minimized.

Coding objects in this way, permits their efficient recognition and calculation of its relative orientation in a very short time with a low cost system, makig it useful in robotics application.

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1- INTRODUCTION

On using a television camara to obtain images in the visual perception systems, a considerable amount of information is extracted, whose reduction would ease its future treatment. For this reason different coding techniques are used, either grouping the pixels in blocks or detecting the changes[1,2]. More notable reductions can be obtained on analysing only the image's zone of interest where the object can be found. For a large number of objects the contour constitutes enough significant information to permit its identification. The contour of an object allows a much more condense coding of information. Various techniques are used to extract the contour of a digitized image[3]. From this information a way of describing this contour consists in generating a chain-code which is generated in the tracking process. Since the descriptions of objects, done by Freeman[4] and based on this code, many variations have been used to describe and recognise objects from their contour. One of these consists of using a curvature function. Among others are the researches done by Rosenfeld and Johnson[5] that study the concavities and convexities of a contour to detect its vertices. Dessimoz[6] generates a sequence of curvatures detected like the gradient of the tangent in each defined segment. The standard deviation of this sequence together with other parameters is used to recognise objects. Bibriesca and Guzman[7] use the shape numbers to determine the forms of the arcs. On tracking a contour, a sequence of increases is generated which is variant under rotation[4], given that the length of these is 1 for verticals and horizontals and $\sqrt{2}$ for diagonals. Modifications have been made to Freeman's code obtaining invariable sequences[8] but the required transformations are excessivly complex for certain applications. The description system presented is based on the generation of a sequence of curvatures calculated for a determined number of succesive increases[9]. The sequence thus obtained becomes invariant under rotation through a normalisation done by segments. This simplified normalisation allows considerable reduction of calculating time. The identification of the coordinates of two points P1 and P2 on the contour permits the calculating of its orientation with respect to a reference position.

2- CONTOUR TRACKING

The tracking of the contour of an object obtained by the application of a gradient operator and then filtered to eliminate the noise and unite the possible discontinuities is begun through a scanning of the image. Once on the contour the tracking is effected analising from each point the state of the adjacent pixels and the trajectory tracked previously. The algorithm used is that of always taking the point of the contour which is farthest to the left of the preceeding point (if the tracking is done clockwise).

With the aim of minimising calculating time, the 2^{11} resulting combinations on considering the 2^8 states of the adjacent pixels and the 8 possible directions of source have been tabulated. This algorithm assures the correct tracking in contours of very different forms, except those which have singular points such as strangulations or multiple vertices. A memory capacity of 2K bytes enough to contain this table is very simple and fast to implement. An increase in the number of analised pixels, although it would require an excessive memory capacity to be processed simultaneously. An increase in the window's dimension of one pixel per side, for example would increase this capacity to 128 Mbytes.

3- GENERATION OF THE SUCCESSION OF CURVATURES

To make the calculation of the components of the radius of the circumference which passes through 3 consecutive points of the contour has been taken. With the aim being that the components Ci of the vector contain a lower noise level of digitisation, the number of curvatures which should average off to produce an attenuation and a reduced dispersion should be analised.

3.1 Calculation of the components of the succession

The expression of the calculation of the inverse of the radius of the circumference which passes through three points is

$$\frac{1}{R} = 4 \cdot \frac{\sqrt{p(p-a)\,(p-b)\,(p-c)}}{abc} \qquad (1)$$

with $a = \sqrt{\Delta x_1^2 + \Delta y_1^2}$

$b = \sqrt{\Delta x_2^2 + \Delta y_2^2}$

$c = \sqrt{(\Delta x_1 + \Delta x_2)^2 + (\Delta y_1 + \Delta y_2)^2}$

and $p = \frac{1}{2}(a+b+c)$

Δx and Δy are the components x and y of the effected increases. The curvature function thus defined is not completely adapted to the problem since the same three points may correspond to different curvatures depending on the followed order of tracking as shown in figure 1.

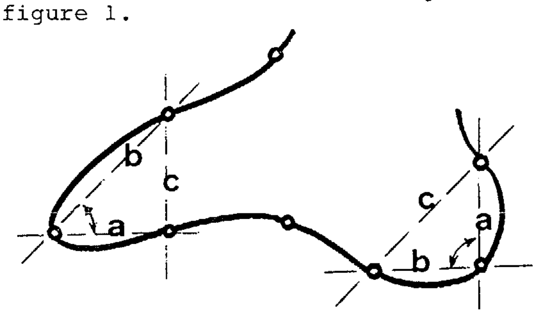

Fig. 1.- Different curvatures obtained from three points with the same relative position.

Without considering the sign it doesn't differentiates between concavities and convexities and therefore it doesn't distinguish forms like that shown in Fig. 2.

For these reasons certain modification to the expression (1) have been introduced. For that reason a higher weight is given to the side C, determined according to the order in which the three points are tracked and an adequate scaling is given. Also the sign is introduced. The new curvature expression is

$$\rho = 4\,\frac{\sqrt{p(p-a)(p-b)(p-c)}}{a^{3/4}\;b^{3/4}\;c^{3/2}}$$

taking $\sigma = \mathrm{SIGN}\ (\Delta x_2 \cdot \Delta y_1 - \Delta x_1 \cdot \Delta y_2)$

The calculated curvatures are indicated in table 1 as the discreet values noted, the nearest integer (except for the value ∞) for the distinct curvatures defined by three points.

Segment	↓↓	↓↘	↓→	↓↗	↓↑
Curvature (ρ)	0	4,78	12,33	16	∞
Nearest integer (C_i)	0	5	12	16	20

Table 1. Calculated curvatures and discret values noted.

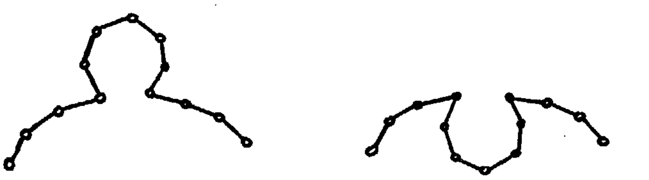

Fig. 2 Contour forms indistinguishable without considering the sign.

The value of K in the selected increases taken into account to realise the filtering in the calculus of each C_i, will produce a dispersion as shown in Fig 3. Its variation for different values of K is shown in Fig. 4. The selected value K which is considered an acceptable compromise between the effected filtering and the resulting dispersion has been 4.

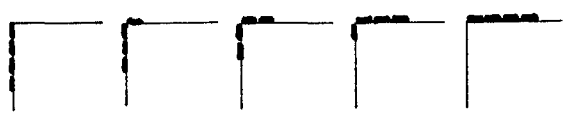

Fig. 3 Components C_i obtained through a vertex with $k = 4$.

3.2 Normalisation

To effect the normalisation of V_c make it invariant under rotation it is necessary to consider separately the form of each different segment of the contour. The variation in the number of increases which compose digitalised straight lines of the same real length oscillates between a relation of 1 and $\sqrt{2}$ in function to its orientation. In the same relation the dimension of the V_c would vary. This doesnot happen in a curved segment due to the continuous change in the direction of a curved segment which produces a continuous variation in the direction of the effected increases of the tracking process. The variation of the number of increases in relation to the orientation of a straight segment and a curved segment is shown in fig. 5.

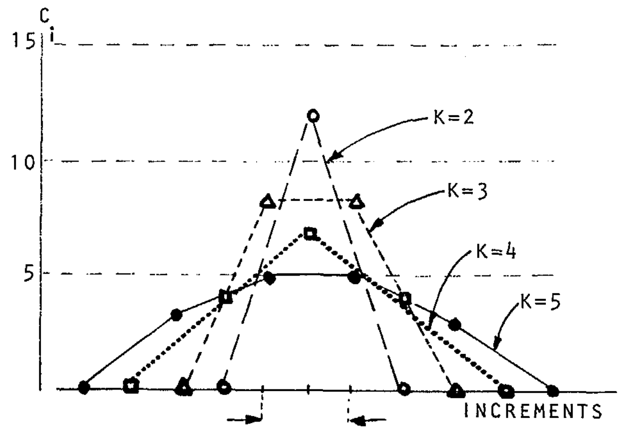

Fig. 4 Variations of C_i through a vertice with different values of k.

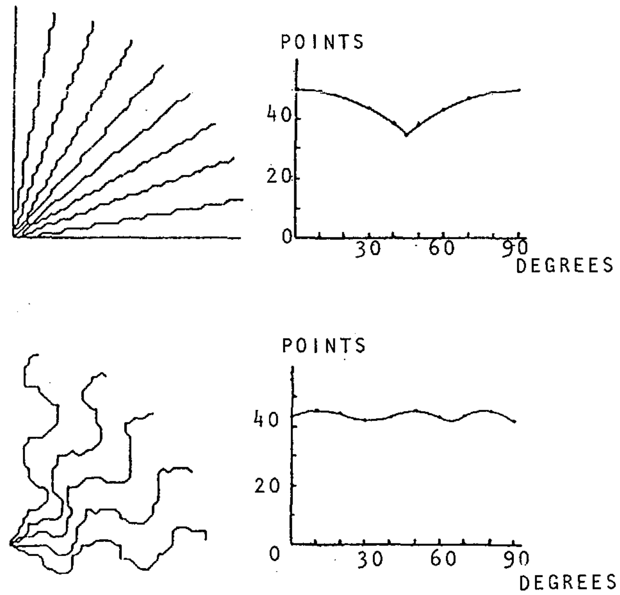

Fig. 5 Variation in the number of the components on turning a straight segment and another curved segment.

The process of normalisation will consist in detecting, firstly the vertices to enable the separation of the different segments of the contour, and to analise each one of those to see if they are straight or curved. A segment of the contour is considered as a vertex so that the components of the V_c surpass a determined value. To know if the comprised segment between 2 vertices is straight or curved it is necessary to compare the number of components of the succession Ni (the same as the number of effected increases) with the Np which would have the straight line which joins these vertices taken in a vertical or horizontal direction. In the segments considered as straight the normalisation consists in adding a number Na of zeros (components of nil curvatures) with Na=Np-Ni. The calculation of Na verifies $Na = Ni/\cos\alpha - Ni$, α being the angle that forms this straight line with the vertical or horizontal direction of the noted referred

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being $\alpha = \text{arctg}\,\frac{x}{y}$ or $\alpha = \text{artg}\,\frac{y}{x}$ in which x & y are the difference of co-ordinates (x,y) of the extreme points of the straight line and choosing one or other expression which thus verifies $\alpha \leqslant 45°$. The normalisation by segments does not secure the obtention of V_c of identifical size. The reasons are on one side the inexact division between the different segments on digitalising the image of an object in different orientations and on the other the non correcting in the curved segments. However the results obtained have shown that the dispersion of the dimension of the V_c obtained for the same object, codyfying it in different orientations is very low. This dimension gives additional information: the perimeter. At the same time as the dimension of the V_c is equalised, corresponding to the same object taken in different orientation, the normalisation by segments corrects the distribution of its components in the vector. The fig. 6 shows the number of those components corresponding to the different sides of a triangle before and after normalising and for different orientations.

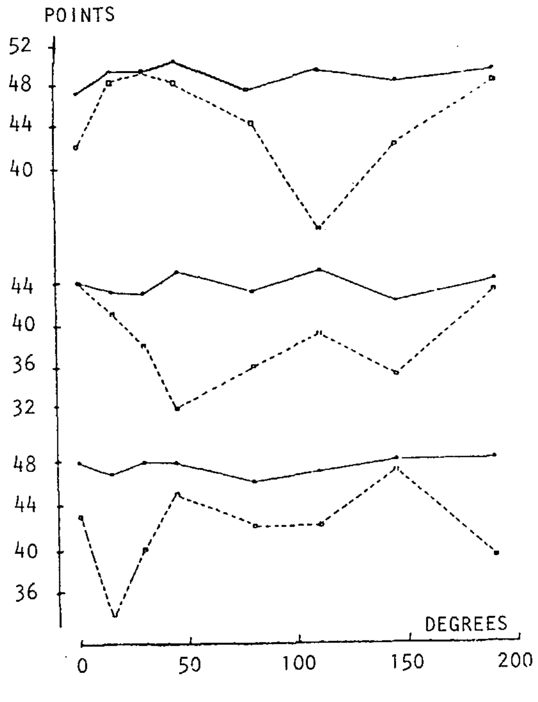


Fig. 6 Correction of the distribution of the components of the V_c of an object of triangular form on normalising it.

4- CALCULATION OF THE ORIENTATION

The condensed coding of an image should also contain information relating to its orientation on the plane.

This information is extracted from 2 points of its contour.

If only the vertices are used to define a reference direction, it is only necessary to memorise together with the components of V_c, the coordinates of the contour points which curvature surpasses a given threshold. This threshold is modified for each image in order to obtain a minimum number of vertices with a prefixed distance between them. With this information it is possible to determine an homologue axis that permits calculating the orientation of any part.

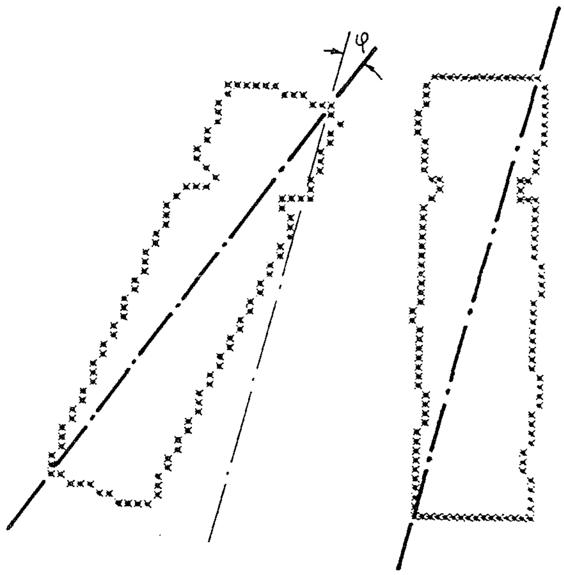


Fig. 7 Calculation of the orientation

With the aim of minimising the error obtained in the calculation of the angle it helps to choose the points P1 and P2 which determine the direction of reference, so that the distance between them will be maximum. The error can also be reduced by averaging more than only one axis.

5- RESULTS

The system of image coding, 2D, thus described can be applied to images taken with different levels of resolution. The used resolution is the minimum that allows the differentiation of distinct objects which can appear on the scene, that being for comparison of perimeters or for analisis of the position of the vertices in objects of similar perimeter.

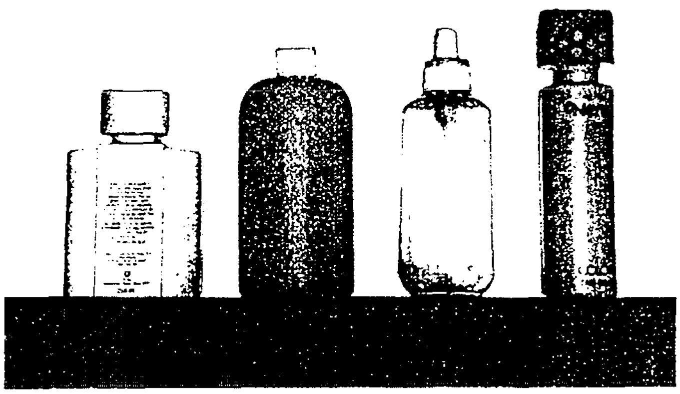
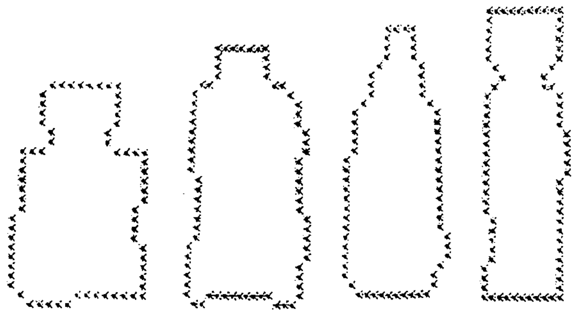


Fig. 8 Objects described.

For example, the objects presented in fig. 8 are differentiated without ambiguity with a resolution of 64x128 points (only when the object occupys at least a quarter of the scene). In fig. 9 the discretized image is shown an the V_c for each of these. With the information of the object thus condensed, its recognition are possible using a low power micro computer and in a very short amount of time. It's positioning is possible joining the vertices coordinates.



M1 M2 M3 M4

M_1 = [0,0,0,0,4,7,4,0,1,1,-2,-6,-4,-1,4,7,4, 0,0,1,1,-1,-1,-1,-1,1,1,0,0,4,7,4,0,-1, -1,1,1,1,1,-1,-1,0,4,7,4,0,-1,-1,1,1,1, 1,-1,-1,0,0,0,4,7,1,-1,-6,-2,1,1,0]

M_2= [0,4,7,4,-1,-4,-2,1,2,2,0,-1,1,2,1,-1, -1,0,0,-1,-1,1,1,0,1,1,-1,-1,1,4,4,2,1, -1,-1,0,-1,-1,2,6,4,1,0,0,1,1,-1,-1,0, 0,0,-1,-1,1,1,0,0,0,0,0,1,4,2,-2,-4,0]

M_3 = [4,7,4,-1,-1,1,1,-1,-2,0,2,1,0,0,0,1,1, -2,-2,1,1,0,-1,-1,1,2,2,0,-1,2,4,1,0, 0,0,1,2,2,2,1,0,1,1,-1,-2,-1,1,1,0,0, 1,1,-1,-1,0,1,2,0,-2,0,2,0,-2,0]

M_4 = [0,0,0,0,4,7,4,0,1,2,0,-4,-6,0,5,4,0,0, -1,-1,1,2,1,-1,-1,0,0,0,1,1,-1,-1,-1, -1,1,2,4,4,1,0,0,0,4,7,4,0,0,1,1,-1, -1,-1,-1,1,1,0,0,0,1,1,-1,-2,-1,1,2, 1,-2,-2,1,1,0,0,0]

Fig. 9 Discretised contours and V_c of the models shown in fig. 8.

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