AN ALGORITHM FOR SCALE INVARIANT SEGMENT-MATCHING AND ITS APPLICATION TO A SILHOUETTE MATCHING PROBLEM

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ABSTRACT

This paper presents a method for scale invariant segment-matching of shapes. Segment-matching is important in image analysis if perfect contours of objects are not given. One of the methods for solving this problem is the Algorithm F proposed by L. Davis. However, since the method is not scale invariant, it encounters difficulties when matching an image and a model with different scales. By describing a distance measure in terms of Fourier descriptors, we have modified Algorithm F to be scale invariant. This modified method has been applied to a silhouette matching problem. The results show that the algorithm works successfully.

RÉSUMÉ

On présente une méthode d'adaptation de segments à invariance d'échelle des formes. L'adaptation des segments est importante pour l'analyse des images quand des contours parfaits des objets ne sont pas donnés. Une des méthodes de résolution du problème est l'algorithme F proposé par L. Davis. Mais la méthode n'étant pas à invariance d'échelle, elle pose des difficultés pour l'adaptation d'images et de modèles d'échelles différentes. En définissant une mesure de distance en termes de descripteurs de Fourier, les auteurs ont pu rendre l'algorithme F invariant de l'échelle. La méthode modifiée a été appliquée au problème d'adaptation de silhouettes, avec succès.

(SUMMARY).

INTRODUCTION

When identifying objects in a scene, shape features of object boundaries are an important key. In a real scene, however, perfect contours may not obtained, because of occlusion and/or poor condition of image acquisition. In such a case, partial segment-matching is a powerful tool for matching a model and a real image.

Algorithm F which was developed by L.Davis [1] for segment-matching, is based on a relaxation technique. It was shown that this method worked successfully when matching shapes of coastlines. All coastlines which were compared in his studies had almost the same scale. Because the algorithm is essentially scale-dependent, although it can accept a small range of scale changes. For the purpose of shape matching between a model and a real scene, a fully scale-invariant algorithm is required, since the model is defined independently of the real scene.

AN EXTENSION OF ALGORITHM F

The basic idea of Algorithm F is to represent the association of features, matching elements, as a node of graph (AG), to first generate possible associations, and to then reduce inconsistent matches by the constraints corresponding to the compatibility relations among matches using a relaxation scheme.

A shape is described by a sequence of vertices. Each vertex is expressed by an (x,y) coordinate and the bending angle at that point. The first step of the algorithm is to generate candidates for association between vertices of object and template to build a graph structure. This graph is called an association graph (AG). A node of AG represents an associated pair of vertices. An edge between two nodes means a relation between two pairs of associations exists. The condition to accept a pair of vertices is based on a simple criterion of their local similarity. That is,

if $| \theta_i - \theta_j | < t1$
(t1 : threshold) --- (C1)

(where θ_i is the angle at the vertex θi and θ_j is that of Tj), then the pair (Oi, Tj) is accepted as a node in AG. The condition to assign an edge between two nodes is the relative difference in length between two vertices of the object and the template (Fig.1) .

If $t1 < (|d1 - d2|)/d1 < t2$ --- (C2)
(t1, t2 : threshold)

(where d1 is the length between Oi and Ok , and d2 is the length between Tj and Tl), then an edge is assigned to the node (Oi,Tj) and the node (Ok,Tl). This condition allows a range of scale change and gives the limits.

To improve the scale variant characteristic of Algorithm F, a new evaluation function using Fourier descriptors (FD) is introduced instead of evaluating the scale dependent criterion (C2).

When a closed curve is expressed as a complex function $U(\ell)$, where $U(\ell) = X(\ell) + j\,Y(\ell)$, the Fourier descriptor is defined as

$$a = \frac{1}{L}\int_0^L U(\ell)\exp(-j\frac{2\pi}{L}n\,\ell)d\ell$$

(L : the total length of the curve) [2,3]. A new evaluation function for the acceptance of an edge in AG is constructed from these FDs. That is, if

$$\sum_{m=1}^{M}(|a_m| - |b_m|)^2 < tc$$
(tc : threshold),

where a_m is the FDs of the curve between the vertex Oi and Ok, b_m is the FD between Tj and Tl (Fig.1). Since the curve between two vertices is not closed, FDs are calculated by going from one vertex to another and then retracing to the initial vertex to make a closed curve.

AN APPLICATION TO A SILHOUETTE MATCHING PROBLEM

A silhouette matching experiment was performed to test the effect of the extension to scale invariance. Fig.2 shows a three-dimensional geometric model of a building generated by GEOMAP [4]. The problem is to estimate the position of the view point given a real image to this object. That is, shape matching is required between a silhouette of the real image and one of the model silhouettes generated by changing the position of the view point to the three-dimensional model.

In the silhouette of the real image, the length is scaled by pixel while, in the silhouette extracted from the geometrical model, the scale is determined by a combination of the actual length of the model and the camera parameters which are set at a specified view point. Thus, they have different scales.

The view points were assumed to be on a circle near the ground with fixed diameter from a specified center in the model. Thirty-six line drawing models were generated, changing the view point by 10 degrees on the circle. The real image, on the other hand, is a scene of a miniature object with 1/400 size of the actual length with an ITV camera being used as the input device. The image was 256x192 in size and digitized in 7 bits gray levels. The silhouette was extracted from the image by discriminant thresholding of the gray level histogram. The boundary was approximated by a polygonal curve.

Fig.3 is an image taken at the 240 degrees position and Fig.4 is the silhouette extracted from it. The results of matching this silhouette and the 36 model silhouettes are shown in Fig.5, where the vertical axis is the score of shape similarity, calculated as a reciprocal of the matching cost. The value zero means that the matching operation terminated in failure, deleting all nodes in the filtering process of the association graph. Therefore, the highest peak of the score means the best matching, indicating the estimated position where that image was taken. The results show good agreement with the true position. Fig.6 is the model silhouette of the best score, corresponding to the highest peak in Fig.5. The final associations left after matching between Figs.4 and 6 are also shown in Fig.7, and the pairs of vertices agree with the true correspondences.

CONCLUSION

We have modified Algorithm F to be scale invariant, describing a distance measure in terms of Fourier descriptors. Our algorithm has been applied to a silhouette matching problem, where the scene which best matches the given real scene is selected from many scene-templates generated by a geometrical model and the location of the camera is identified. The results showed that the algorithm works successfully.

REFERENCES

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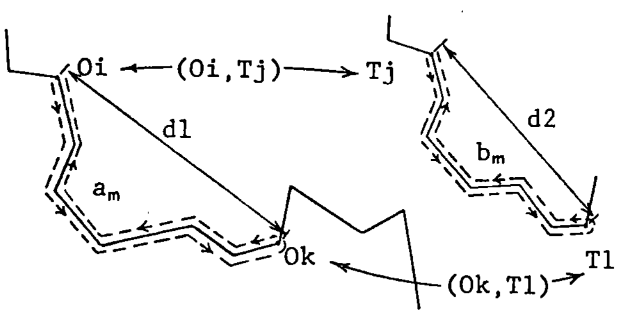

Fig. 1 Association of vertices and calculation of Fourier descriptors between vertices.

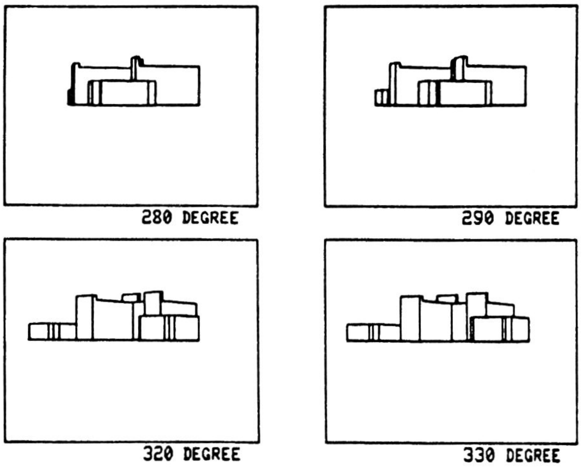

Fig. 2 Scenes generated from a three-dimensional model.

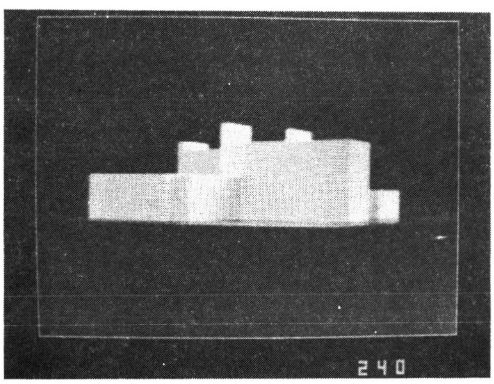

Fig. 3 An image taken at 240 degrees position.

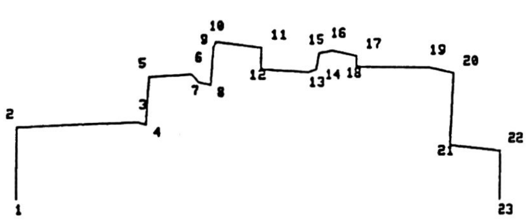

Fig. 4 Silhouette of the object in Fig.3.

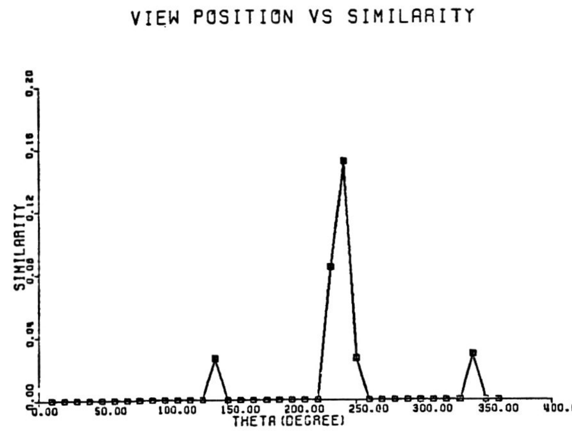

Fig. 5 Matching the silhouette in Fig.4 and models.

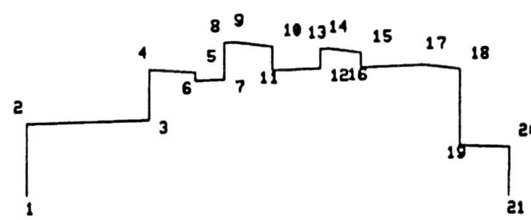

Fig. 6 Model silhouette of the best score in Fig.5.

** LIST OF FS **

(2, 2) (4, 3) (5, 4) (6, 5) (8, 7)
(10, 8) (11,10) (12,11) (14,12) (15,13)
(16,14) (17,15) (18,16) (19,17) (20,18)
(21,19) (22,20)

Fig. 7 Associations of vertices in the matching the silhouettes in Fig.4 and Fig.6.