SCENE SEGMENTATION BY VELOCITY MEASUREMENTS OBTAINED WITH A CROSS-SHAPED TEMPLATE

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Abstract

This paper presents a method of segmenting a scene into its basic objects on the basis of motion. The velocities of points are approximated by associating them to sets of reference edges in the scene. These measurements are then used to group the points, A basic tenant of this work is that all points of a single object have the same velocity values. Accordingly, points with the same velocity measurements are grouped together. Since the motion of an object is independent of its other visual characteristics, whole objects (not surfaces or edges) are initially included in one segment. The program successfully grouped points from internally generated scenes with 100% accuracy. Points from real test scenes were grouped correctly 90% of the time on the average. The poorest result was 42% accuracy The best was 100%.

Introduction

One of the most important steps in processing digitized scenes is the segmentation of the scene into its basic objects ("Basic objects" in the sense used here correspond roughly to the common nouns that refer to three dimensional objects which would normally be used in the description of a scene), Guz.man [1968] segmented line drawings into objects on the basis of vertex configurations, Brice and Fennema [1970] segmented scenes directly into surfaces on the basis of the gray scale values of the picture elements. It is the author's belief that the motion of objects in a scene can be profitably used for segmenting a scene into its component objects. Potter [1975] proved the feasibility of such an approach. The process envisioned here is not intended to solve the problem of segmentation by itself, but instead provide a powerful method of dividing a scene into a set of fundamental divisions which correspond to the scene's basic objects, A basic consideration in the design of the system was that it should be compatible with other segmentation schemes. The author hopes to integrate this system with other systems so as to achieve more complete and accurate scene segmentation.

The use of motion for scene segmentation results in two subproblemsi first, how to extract motion information: second, how to use motion information for segmemtation. This paper discusses a method of motion extraction more general than that presented by Potter [1975]. and a simple but effective system of scene segmentation based on the motion information obtained.

Motion Extraction

Motion can be extracted from a scene by processing sequentially related pictures Several articles dealing with cloud motion have been published, Leese, Novak ana Taylor [1970] presented a system of "binary matching," The gray scale values of satellite pictures of cloud cover were converted into binary to emphasize edges. The pictures were then divided into "sectors," Sectors from the first picture served as templates to be "looked for" in the second picture. The sector from the second picture that most nearly matched the template was associated with it. The displacements between the sectors of the second pictures and their associated templates were used to calculate the amount and direction of motion of the cloud banks, Endlich, Wolf, Hall and Brain [1971] described a method of motion detection which used "centers of brightness." The "centers of brightness" were determined by a clustering algorithm, A cross-correlation technique was used to match centers. The motion of the clouds was calculated in the same manner as by Leese et al. Smith and Phillips [1972"] also used a cross-correlation analysis to track clouds and determine their motion.

The goal of these processes was the precise determination of wind velocity from apparent cloud motion. Thus the procedures developed are specific to that purpose and must accommodate "unusual" conditions. For example, the pictures are normally taken hours apart. The recognition of "objects" is of no concern. Finally, the scenes generally contained known "objects" (i.e. land masses) which enabled precise picture alignment.

Potter [19751 developed procedures which are more useful for motion extraction from general scenes. He assumed that pictures could be taken arbitrarily close in time, that the exact determination of velocity is not essential as long as all parts (or points) of an object have the same velocity value, and that since segmentation is a preliminary step in object identification there is no advanced knowledge of scene content which can be used for comparing two pictures.

Potter's approach to motion extraction wap bps^d on the measurement of +** mrwo_ment of "edges." He assumed that since

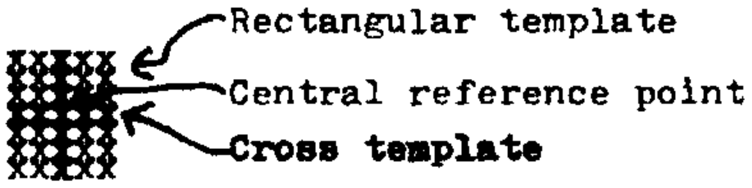
The research reported in this paper was completed by the author while a student nt the University of Wisconsin - Madison, the pictures were taken only a few moments apart, the edges could be correlated between the pictures by their spatial position alone. A motion measurement was obtained by determining the displacement of the edges between pictures from a given point on a superimposed absolute reference grid.

These same general assumptions and approaches are taken here, however instead of determining the x- and y-motion comfonents seperately as was done in Potter [1975], a "cross-shaped template" i6 used to determine the actual velocity in one step.

The "Cross-shaped Template"

The basic concept of velocity extraction to be used here is to find a feature in one picture, find the corresponding feature in a second picture and use the observed displacement as a measure of motion. The major problem with feature matching is that a feature has to be initially found (and identified). One way of circumventing this problem is to extract templates from one picture and in this manner, generate features. This approach was first discussed by Uhr and Vossler [1966]. Their templates were rectangular and of a fixed size. If such a template happens to be defined in an area of the picture that contains little information, then there is little significance in its matching or failing to match in a subsequent picture.

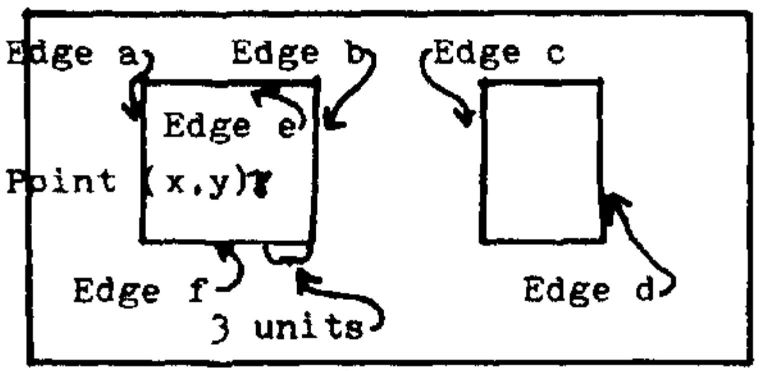
The "cross-shaped" template (hereafter referred to as simply the cross template) contains two advantages for motion extraction purposes over the Uhr and Vossler template generation scheme. First, the template is cross-shaped as opposed to rectangular. This results in a considerable reduction of points that need to be processed for matching. In figure 1, for example, a five-by-seven rectangular template contains 35 points. But the five-by-seven cross template contains only \\ points. Second, the cross template is of variable size. The length of an arm of the cross is determined by the distance from the central reference point (or simply center of the template) to the nearest edge. The variable size of the template greatly increases the likelihood that it contains useful information.



Comparison of Rectangular and Cross Templates

Figure 1

The cross template is defined by taking the point at the intersection of the arms as the center point of the template and the distance from the center to the closest edge in four given directions as the length of the corresponding arms. That is, an association of distance and direction forms the basis for the cross template. The association operates on the assumption that every point of a superimposed absolute reference grid is surrounded by edges in the picture. In any one picture, a reference point of the grid may be surrounded by any number of edges. A unique association is established between a reference point and an edge by picking a direction and recording the distance from the point to the nearest edge. In figure 2, the point (x,y) is surrounded by the edges a, b, c, d, e and f. By restricting the direction of association to the positive x-axis, the number of edges is reduced to three : edges b,c and d. This number is reduced to one (and therefore a unique association) by choosing the closest edge. In figure 2, the point (x,y) and edge b are associated uniquely by the positive x-axis direction and the distance between them, three units.



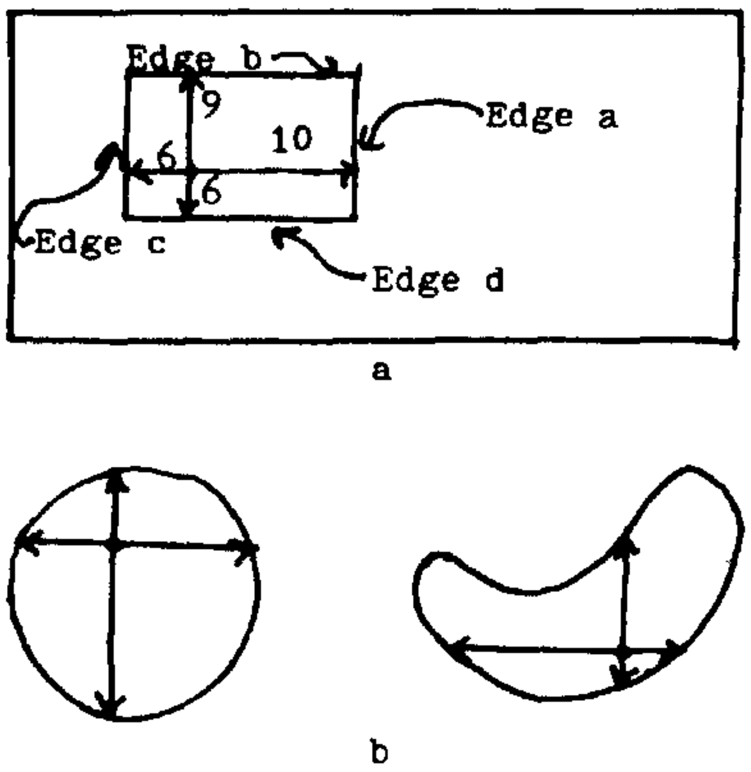
The point (x,y) and the edge b are uniquely associated by the positive x-axis direction and the distance of three units.

Unique Association of a Reference Point and a Reference Feature

Figure 2

A template must be sufficiently unique that "false matches" do not occur. An effective design for a unique template consists of four orthogonal arms. Thus a "cross-shaped" template is defined by a set of four rays parallel to the positive x-, positive y-, negative x-, and negative y-axes. In figure 3a, the cross template is

•More accurately, discontinuities in gray scale values were used instead of edges. However, since "edge" is a more easily understood term, it will be used in this paner. It should be kent in mind however, that wherever "edge" is used, discontinuity in gray scale value should be used. See Potter [1975] for a more complete discussion defined by uniquely associating the point (x,y) with the closest edge (edge a) in the positive x-axis direction by the distance value of 10 units, with the closest edge (edge b) in the positive y-axis direction by the distance value of 9 units, with the closest edge (edge c) in the negative x-axis direction by the distance value of 6 units, and with the closest edge (edge d) in the negative y-axis direction by the distance value of 6 units



Cross Template Definition for Various Objects

Figure 3

In figure 3a, the cross template is defined by the edges of a rectangular object. Figure 3b illustrates the fact that cross templates can be used with any arbitrarily shaped rigid figure. It should be kept in mind that although most of the examples in this paper are rectangular and have straight edges, the only requirement for application of the cross template is that the object does not change shape between pictures.

Velocity Determination

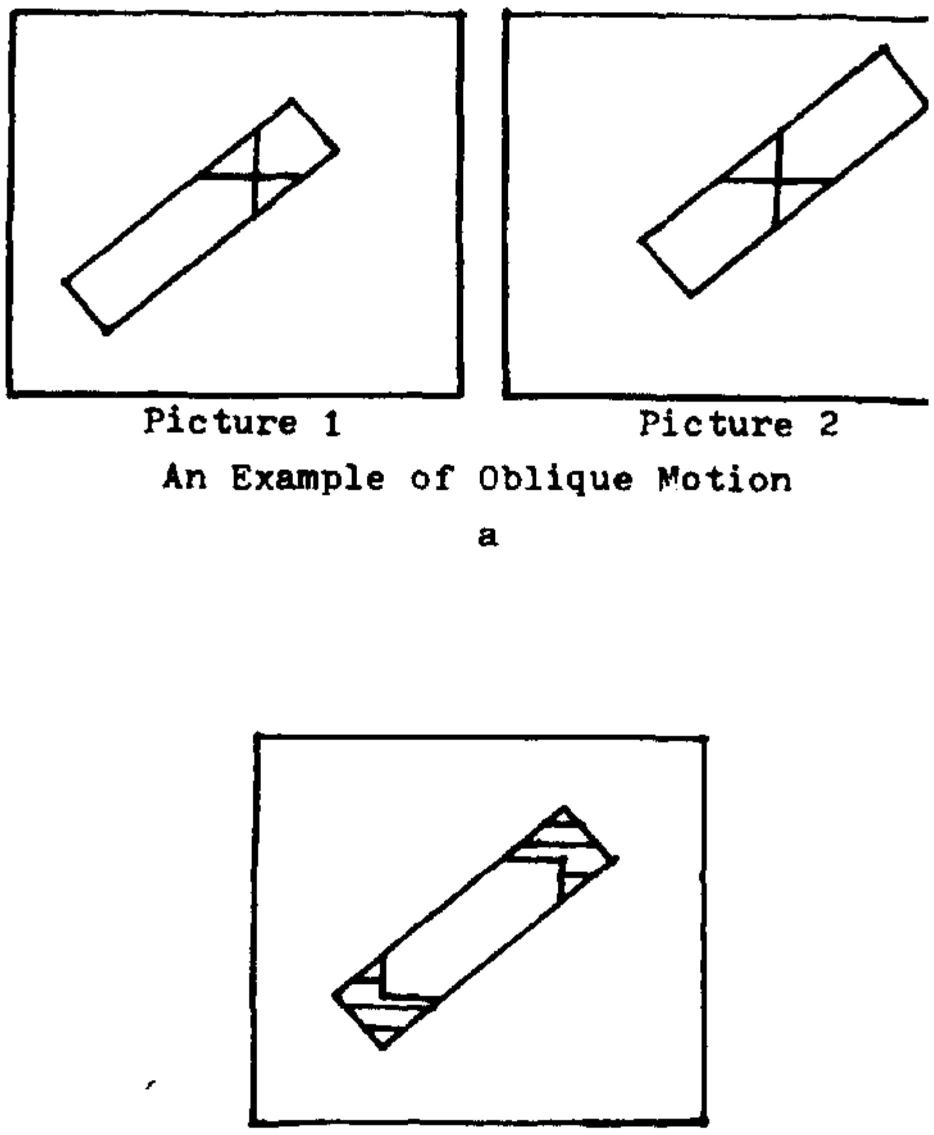
After the cross template has been defined in one picture, it is moved around the second picture until an exact match is found. The cross template is sought in a regular manner. Each of the absolute reference points in the neighborhood of the reference point used as the center of the defining template is tested as the center point of a matching template. First the points along the positive x-axis are tested, then the points along the negative x-axis, then the points along the positive y-axis and finally along the negative y-axis. Each axis is searched until a search length parameter is exceeded. This parameter is set by the user and reflects the maximun number of absolute reference units an object can move between pictures.

The search along the axes is a heuristic approach to finding a matching template since the actual movement of the object may be oblique to both axes. The searching routine looks for a match of the total length of the perpendicular arms of the template (i.e. total y-arms length, if searching along the x-axis). If a total length match is found, the true y-displacement can be easily calculated. The search along the perpendicular axis (y-axis in this case) is then started from this newly calculated reference point. When (or if) a total x-arm match is found, the x-displacement is calculated. The absolute reference point obtained by calculating the x- and y-displacements, is tested as the center of a matching template. If successful, the x- and y-displacement values are used as a measurement of the x- and y-axes component velocities. If the template does not match, the search continues. Points for which no matching template can be found are assigned a "null" (not to be confused with zero) velocity value.

The velocity value obtained from this process is associated with the corresponding reference point in the last picture taken. The reason for associating the velocity with the reference point is that if the reference point corresponds to some physical point of the object, then that physical point does have a velocity. Moreover, at an initial level of processing, there may not be any other entity (edge, corner or feature of any type) that the motion value can be meaningfully associated with.

The main advantage of this approach to velocity extraction is that it is object independent. It can be used on any size or shape of object. The only requirement is that a number of spatial discontinuities in gray scale be associated with the object. Every visible object meets this requirement. Perhaps more important is the property that this procedure can be applied to any point of a scene without any prior knowledge of the nature of the object which is at that point. Therefore, the information obtained by this procedure is available to be used at all levels of scene processing.

Unfortunately, this velocity extraction procedure does not always detect the correct velocity, Under certain circumstances it can not detect motion parallel to an edge. The situation arises when the extracted template is not unique, Figure 4a shows an example of such a situation. The condition illustrated in the figure is complicated. First, the object must have two parallel sides. Second, the two sides must be long enough and of such an orientation that they constitute the defining discontinuities for all of the arms



Picture 1 Picture 2

An Example of Oblique Motion

a

The Areas of Valid Cross Template Motion Extraction

b

Figure 4

Figure k

of the template. Third, the motion of the object must be parallel to the two sides. All of these conditions are expressed in' the phrase "oblique motion parallel to two edges" or "oblique motion" for short.

The problem of oblique motion is more theoretical than practical. Since it arises from the relationship between the orientation of the arms of the template and the two parallel sides of the object, whenever the situation is detected, a new template can be constructed which avoides the problem. The new template need only to be constructed with one set of arms parallel to the parallel sides. This newly definded template will extract the correct velocity. Unfortunately, this is a somewhat ad hoc solution to the problem.

The theoretical problem of oblique motion can be eased slightly by the observation that a human can not directly detect motion under similar conditions either. Instead, motion of the parallel sides seems to be inferred from the observed motion of the ends (or "remainder") of the object. Therefore, a less ad hoc but perhaps more difficult solution is to rely on the knowledge of the real world and deductive capability of a monitor. For example, all of the points in the'shaded areas of the object in figure 4b will have accurate motion measurements, A "smart" monitor should be able to infer that points with zero motion values which lie between the shaded areas are the result of oblique motion and should be given the same motion values as the bracketing points

Scene Segmentation

The points of a scene are grouped into segments on the basis of the computed x- and y-axis velocity components. The avowed purpose of this procedure is to obtain a crude first approximation of the basic object segments in a scene. Accordingly it is not essential and in fact wasteful to process every absolute reference point. Instead, every n-th point (a system parameter) is processed. The points are processed in serial. Thus, after the velocity values of a point have been determined, they are compared with the velocity values of previously processed points which have been divided into groups on the basis of their velocity measurements. If an exact match of velocity magnitude and direction of both the x- and y-axis components exists between the point and a group, the point is added to the group. If there is no match, a new group is created with the present point as its first member. This process is repeated until all of the points selected have been processed. In this elementary algorithm, points with "null" velocity values are grouped with points which have zero velocity values (This group corresponds roughly to the background of a scene).

Results

The velocity extraction and scene segmentation program(VESS) was implemented in FORTRAN IV on a DATACRAFT computer. The program required 24k memory locations (16 bit words). The pictures were taken by a KGM 113TM television camera connected via a Zeltex analog-to-digital converter to a PDPll/20 computer. Each 5000 byte picture was transmitted from the PDP11 to the DATACRAFT by an asychronous interface unit.

The VESS program was tested on various scenes. It was completely effective on internally generated scenes of rigid, nonoccluded objects. These scenes contained three or four rectangular and triangular objects with various types of motion. The upper limit of four is due to the convenience of displaying a scene if the gray scale levels are limited to a single digit. Figure 5 is an example of an internally generated scene of three objects.

Starting from point (5.5) every 10th point was processed That is, the 50 points - (5,5). (5.15), ... (5.95), (15.5), ... (15.95) . . . . . (45.95) - were put into segments on the basis of their motion. Of the fifty points processed for the scene shown in figure 5, all were correctly grouped. Four groups were formed, one for each object and one for the background. Every point in every group was from the same object (background being an "object").

Four different real scenes of one or two rigid, non-occluded objects were used for testing the basic segmentation program. The first scene is shown in figure 6, Table 1 shows the results of four runs. Three of the runs used the same 50 point sample used to test the generated scenes. Two parameters were used to accommodate noisy data. They were varied from zero to two. One of the two parameters determined the discrepancy in gray scale value allowed before an edge was "detected." The other parameter determined the tolerance in velocity values allowed in grouping points. As can be seen the best results were obtained when the "deltas" were set to 1.

The poor results for object 1 in scene 1 were due to the lack of contrast between the right hand surface (orange) and the background (yellow), A second scene was taken with the right side of object 1 black with an orange insert, A ninety point sample ((2,5). (2,15). ,.. (2.95). (7.5). ... (7.95). . . . . .(47,95>> was used for this test. The change in color resulted in an improvement to 61% correctly classified as shown in the scene 2 column of table 1.

A third test scene was made with the entire right face of object 1 contrasting with the background. The results of this test run were approximately the same as the previous one. Apparently the shadowy area between the objects in the second scene caused a decrease in contrast, so a fourth test scene (not shown) was taken of a single multi-colored object. The results were considerably better as shown in the scene 4 column of table 1, The averages of all tests (with "deltas" set to 1) are given in the last column of table 1.

A major problem in these tests with real data was the noise present in the pictures. The edge noise was such that "large" objects were required, Large objects can only be moved slightly before being outside of the field of view of the TV camera. The scenes used constituted a compromise of these aspects and consisted of moderately sized objects (4 to 7 inches long) in a field of two feet by one and a half feet. These limitations prevented using scenes with more than two objects.

During these test runs, the segmentation program processed on the average one point every 5.5 seconds. The fastest processing was one point every 2,4 seconds on the generated scene data. The real scene data was processed at one point every 6 seconds.

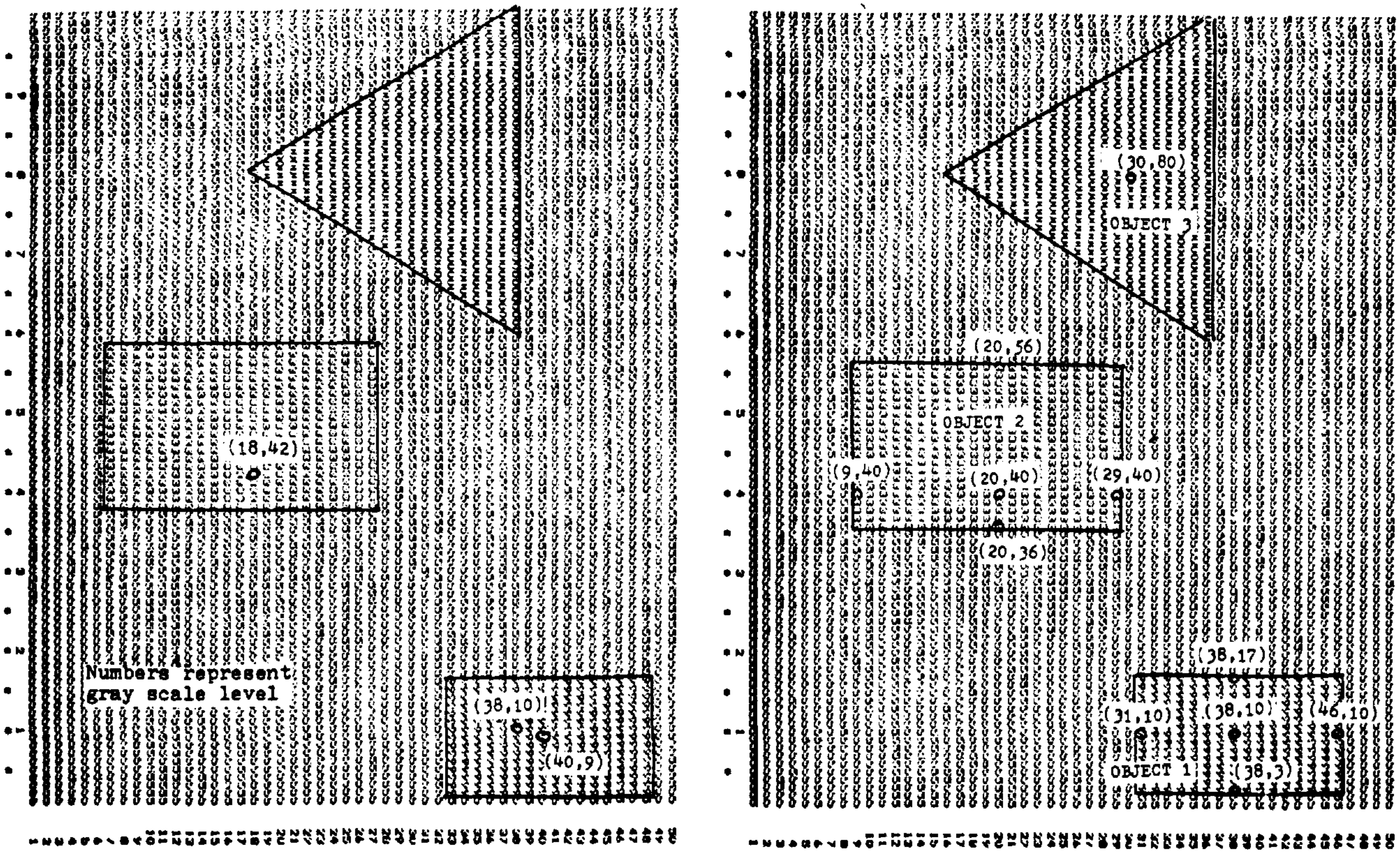
Conslusion

This paper shows that the use of motion for scene segmentation can be applied to quite general scenes. The cross template can be used to extract the motion of any arbitrarily shaped, rigid, non-occluded object. The motion values so obtained can be effectively used to segment a scene into its moving components and "background"" Although the scenes in this paper were restricted to non-occluded objects, the approach presented here seems applicable with slight modifications to scenes with occluded objects. This problem is currently under investigation and results should be forthcomming shortly. The primary drawback of the cross template is its failure to detect "oblique motion," However, on the whole, this process seems to be quite promising as a first step in the segmentation of complex scenes since the groupings are independent of the color (or gray scale value) of the objects in the scene.

		Scene						
		1 (Figure 6)			2	3	4	Average
	Deltas	0	1	2	1	1	1	1
Object 1	Correct	0%	25%	17%	61%	67%	89%	46%
	No Value	92	25	17	17	33	11	25
	Incorrect	8	50	67	22	0	0	29
Object 2	Correct	33	100	33	89	80	-	89
	No Value	67	0	67	11	0	-	6
	Incorrect	0	0	0	0	20	-	6
Background	Correct	75	100	100	100	-	-	100
	No Value	25	0	0	0	-	-	0
	Incorrect	0	0	0	0	-	-	0

Results of Tests on Real Data

Table 1

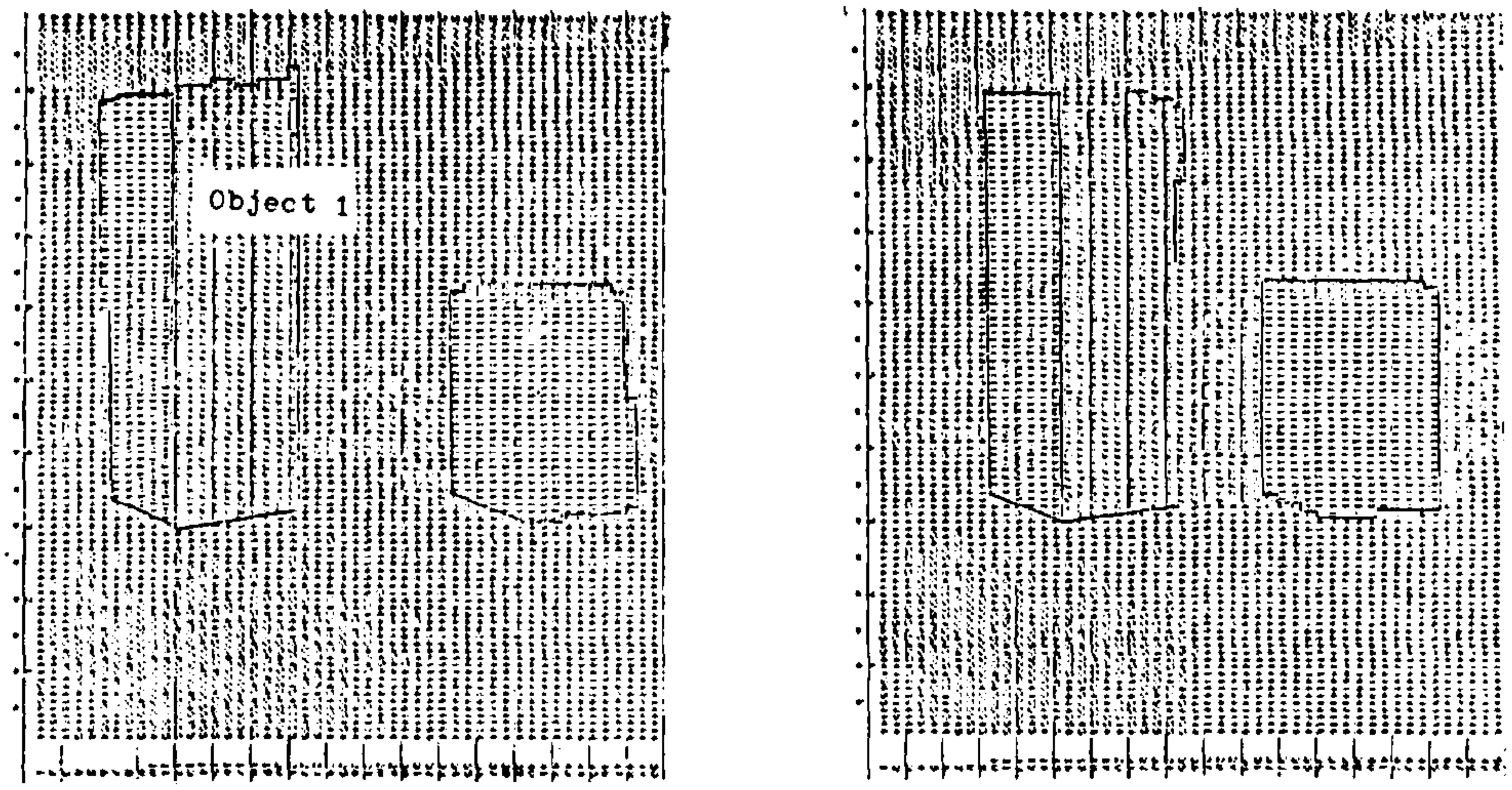


Picture 1

Picture 2

Typical Scene

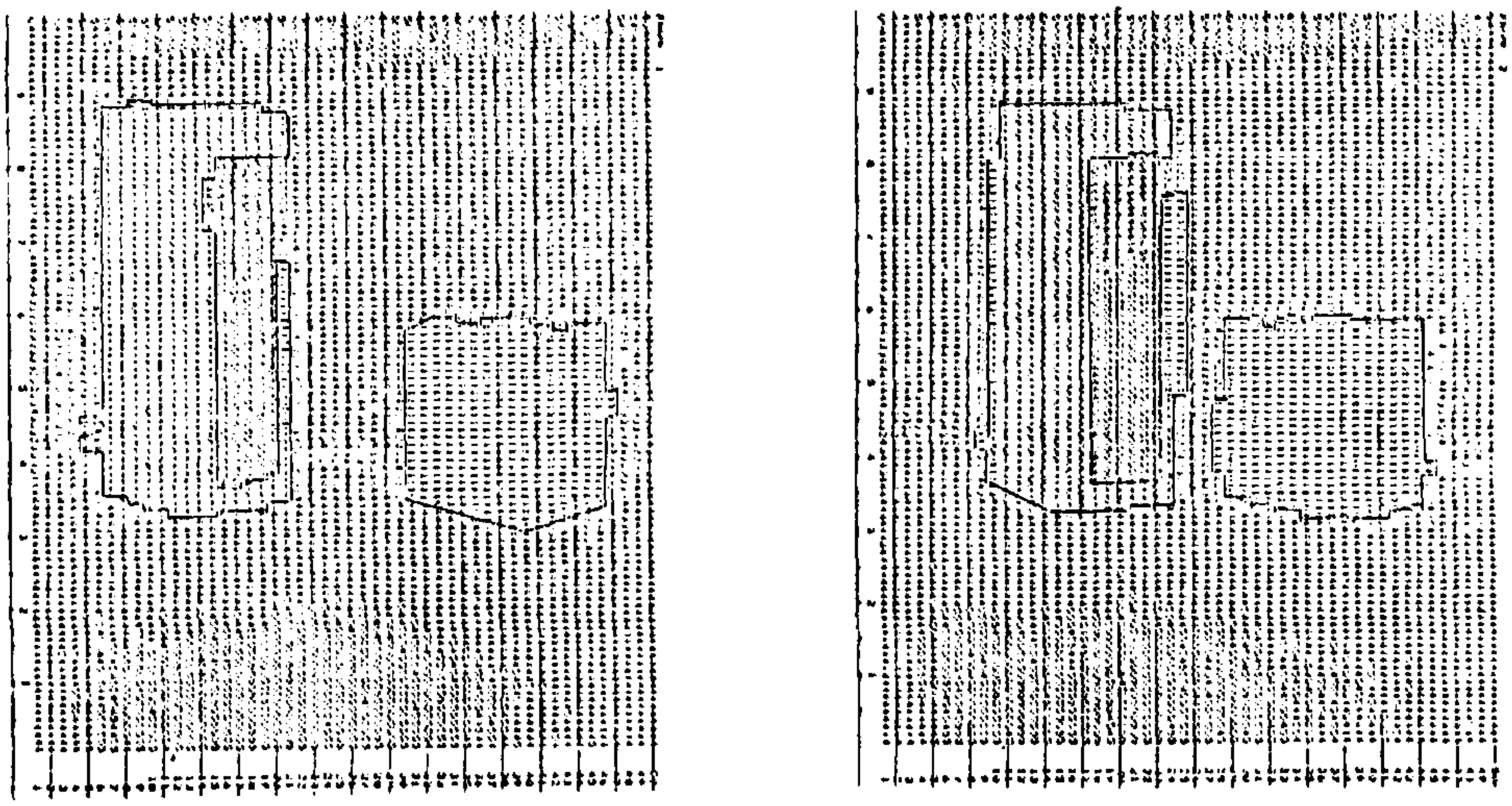
Figure 5



Picture 1

Picture 2

Velocity Extraction - Real Data #1



Picture 1

Picture 2

Velocity Extraction - Real Data #2

Figure 6

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