UTILIZATION OF A STRIPE PATTERN FOR DYNAMIC SCENE ANALYSIS

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ABSTRACT

This paper describes a new idea to project a stripe pattern onto a time-varying scene to find moving objects and acquire scene features in the consecutive frames for estimating 3-D motion parameters. At first, a simple temporal difference method detects objects moving against a complex background. A 2(1/2)D representation of moving objects at each frame is then obtained by estimating surface normals from the slopes and intervals of stripes in the image. The 2(1/2)D image is further divided into planar or singly curved surfaces by examining the distribution of the surface normals in the gradient space. Then, the rotational motion parameters of the objects are estimated from changes in the geometry of these surfaces between frames. Determining translational ones is also discussed.

1. INTRODUCTION

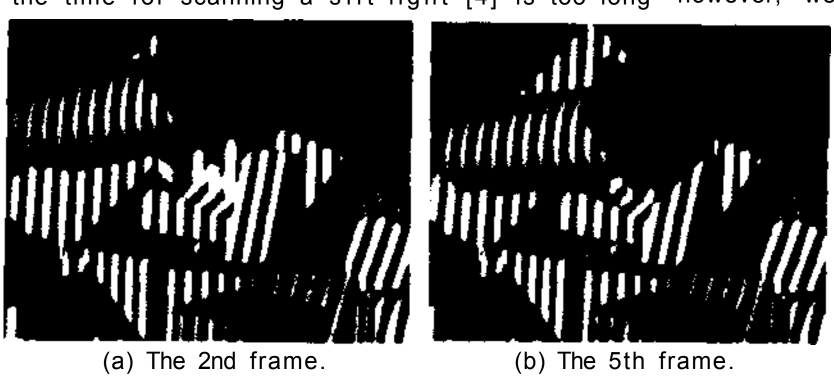
Determining of 3-D motion parameters in a time-varying scene is a current problem in computer vision. Interesting theories have been presented to estimate 3-D motion of objects from a sequence of images taken by a camera [1-3]. They, assuming the rigidity of objects, analyze changes in geometry of object's images in the consecutive frames to obtain 3-D motion cues. The results of applying these theories to real scenes, however, are very sensitive to noise and unsatisfactory in most cases. We, therefore, need a reliable method to obtain scene features from each frame in the image sequence.

A method useful for acquiring 3-D information is to project the structured light to the scene. Since the time for scanning a slit light [4] is too long for the dynamic scene analysis, we use a dense stripe pattern as the structured light. One advantage of this method is that a simple temporal difference method can easily detect objects moving against a very complex background, saving a considerable computing time.

If the stripe is dense, finding of correspondence between each stripe pattern in image and light stripes in scene is difficult, especially when the scene contains many concave objects or discontinuous boundaries. As a result, our method cannot provide with the range information at each image point. Surface normals as important scene features, however, are available at a number of points distributed densely in the image.

The image acquisition system is arranged such that all light stripes in scene are almost parallel and the projection from scene to image is orthographic. Thus, we can obtain a 2(1/2)D representation of the moving objects at each frame by estimating the surface normals from the slopes and intervals of the stripe.

The 2(1/2)D image is further segmented into planar or singly curved surfaces by finding and examining clusters of the surface normals mapped onto the gradient space. Although the estimate of each surface normal is somewhat inaccurate, we can obtain much better estimates of geometrical parameters of these surfaces by utilizing the continuity in each surface. The rotational movements of the objects are determined from changes in these parameters between consecutive frames. The estimation of the translational components from these changes is difficult, however, we could utilize cues to get the range



(a) The 2nd frame. (b) The 5th frame.

Fig.l Examples of input images.

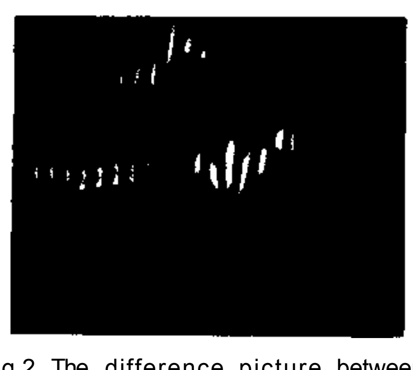


Fig.2 The difference picture between (a) and (b) in Fig.l.

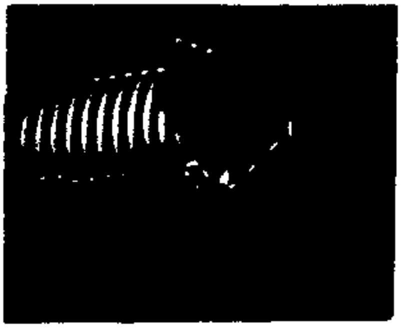


Fig.3 The moving object at the 5th frame.

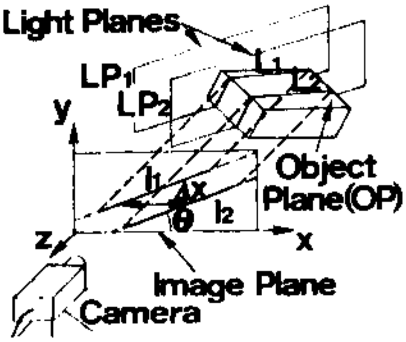


Fig.4 The principle of measurement.

Fig.5 Edge picture of Fig.3.

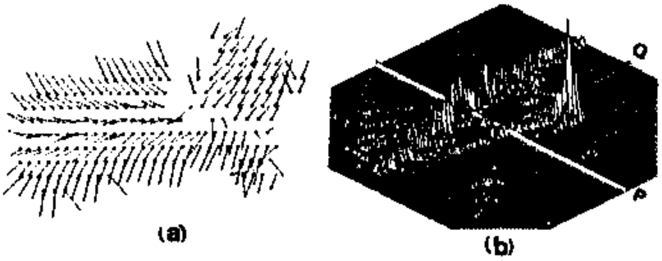


Fig.6 The obtained surface normals, (a) needle map and (b) histogram of them on the gradient space.

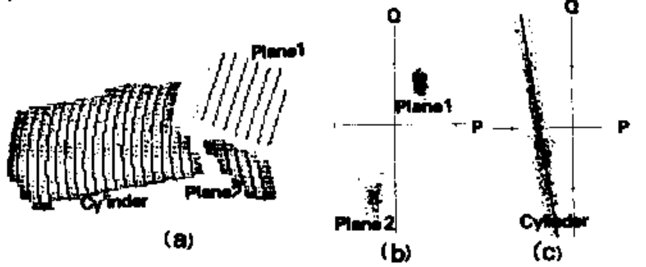


Fig.7 The result of segmentation, (a) region map, (b) planar and (c) cylindrical surfaces on the gradient map.

information as discussed in the final chapter.

2. METHODS

We apply the method to a real scene shown in Fig.I. Input images consist of 256*240 pixels, 8bits/pixel. Many blocks are stacked up, and a cylinder with a wedge is moving above them. It seems difficult to extract moving objects because of complexity of background.

2.1 Extraction of Moving Objects

The first step of dynamic scene analysis is to separate non-stationary portions from the stationary background. In our case, a difference picture of gray values between two consecutive frames shows most parts of moving objects, because the stripe pattern on an object surface is changed in its position, slope or intervals in image by the object motion in most cases.

Fig.2 shows a difference picture of gray values between the 2nd and the 5th frames, which displays the absolute value of difference. We can see the region covers almost whole parts of moving objects while, by ordinary lighting, overlapping part of moving objects in those frames will not be detected. In order to extract the moving object at the 5th frame, we take one more difference picture between the 5th and the 8th frame, and take the AND picture of two difference pictures, then the region of moving object at the 5th frame is left (frame interval is arbitrarily chosen). Small holes and cracks are eliminated by region growing. As a result, the moving object at the 5th frame is extracted (See Fig.3).

2.2 Determination of Surface Orientation

The surface orientation is determined locally from the slope and intervals of each stripe in image.

Fig.4 shows the geometrical relations among light planes and an object plane in the camera-centered coordinate system. We define the equations of two light planes LP1 and LP2 parallel to each other and of an object plane OP on which a stripe pattern is projected, as

$$LP1 : PsX + QsY + Z = D1,$$
$$LP2 : PsX + QsY + Z = D2,$$

and

$$OP : PoX + QoY + Z = C,$$

where Ps and Qs are parameters which represent the direction of light source in a projector and (Po,Qo) is the surface orientation. The object plane OP and the light plane LP1 (LP2) intersect in a line L1 (L2). The projection of two lines L1 and L2 onto the image plane (the x-y plane) are defined as l1 and l2, respectively. The slope of these lines ($\tan\theta$) and the distance between them (Δx) in the x-direction are easily measured in image since we assume the orthographic projection.

The geometrical relation among these variables leads to the following equations,

$$\tan\theta = -(Qs - Qo) / (Ps - Po),$$
$$\_x = (D2 - D1) / (Ps - Po).$$

From these equations,

$$Po = (D1 - D2) / \Delta x + Ps$$

and,

$$Qo = -(D1 - D2) / \Delta x * \tan\theta + Qs.$$

That is, the surface orientation (Po,Qo) of a point on an object is calculated locally from the slope ($\tan\theta$) and intervals (Δx) of the stripe in the image.

In order to obtain the surface normal, the system detects edge segments from the striped image of moving objects (See Fig.5). The location of edge point is estimated in a sub-pixel order by using the Linear Mixing Model [5] of intensity around the boundary between dark and bright regions to reduce the effect of digitizing error. The system fits a line segment to seven successive edge points. Those segments whose fitting error exceeds a threshold are discarded as discontinuous boundaries. From the slope and intervals of these line segments, we can calculate the surface orientations. Fig.6 (a) shows sampled surface normals on the moving objects obtained at the 5th frame. A histogram of these surface normals in the gradient space are shown in Fig.6 (b).

23 Motion Analysis

Let us consider how we can utilize the 2(l/2)D images to estimate the 3-D motion parameters. At first, we map the obtained surface normals onto the gradient space in order to segment the 2(1/2)D image into planar or singly curved surfaces (see Fig.6 (b)). Surface normals on a plane make a cluster in the gradient space. By mapping them from the gradient space into the 2(1/2)D image reversely, we obtain the planar region. Its orientation is precisely estimated by calculating again with longer line segments and wider intervals.

Also, surface normals on a singly curved surface, for example, a cylindrical surface make a line-like cluster in the gradient space. The line parameters obtained by fitting a line to the cluster gives us the orientation of generating line of the cylindrical surface. Its orientation makes the surface parameters more precise.

Since the lower surface of wedge is parallel to the generating line of the cylindrical surface, the cluster corresponding to it is merged in a line-like cluster (See Fig.6 (b)). Therefore, we cannot detect the lower surface of wedge in the gradient space at first. The line--like cluster, however, is segmented into two surfaces by examining the surface continuity on the 2(1/2)D image. Fig.7 shows the results of the segmentation.

Since each 2(1/2)D image is segmented into planar or singly curved surfaces, it is easy to find correspondence of these surfaces between consecutive frames. Table 1 indicates the angles between the surfaces at the 4th and the 5th frames. The orientation of cylindrical surface is represented as the direction of generating line. Little changes of them between frames shows the rigidity of object. Assuming it, we determine the accurate rotation parameters from the precisely obtained surface properties at each frame.

3. DISCUSSIONS

We have determined the rotational movement of object from the changes of surface geometry between frames. They, however, can provide us with little information on the translational movement. Thus, let us consider how we can get the range information from such images as shown in Fig.l to determine the translation.

Shadow parts give us a very important cue to extract the depth information. Utilizing the projections of light lines onto the image plane, which are equivalent to the epipolar line in stereo vision, we can label each stripe in image between two surfaces which are discontinuous as shown *in* Fig.8. This figure displays the upper surface of the wedge and its shadow on the back wall in Fig.l (b). Then, the relative distance between them is obtained from the equations of light stripes in scene.

If two surfaces are continuous, stripe edges in image are connected across their boundary. Therefore, we hypothesize that the range is continuous between two surfaces where stripe edges *in* image are connected, although it is not always true.

Most parts of the image would be interpreted by propagating the consistent labeling of stripes with the shadow information and the cue of surface continuity. There would remain several candidates *of* interpretation for unknown portion of the image.

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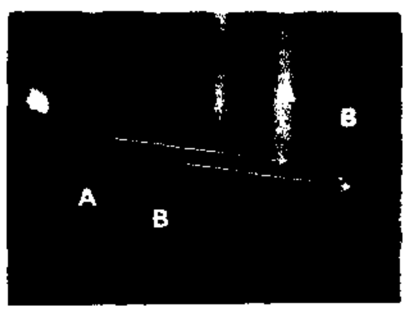

Fig.8 Consistent labeling of stripes with shadow information.

inter-surface \ frame	4th	5th
Planel <-> Cylinder	40.9(deg.)	40.9
Cylinder <-> Plane2	89.7	88.1
Plane2 <-> Planel	89.5	88.6

Table 1 Angles between the surfaces.