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A Method of Cubic Object Feature Extraction

Hong GAO*, Tsutomu WADA**, Toshiro NORITSUGU**

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ABSTRACT

How to reduce and simplify the calculation for image recognition is a very attractive and important issue in order to realize the real time control of a robot based on the image recognition results. This paper describes a method of extracting 2-dimensional geometrical features of cubic objects based on the normal vector distributions from the visual information obtained with the laser range finder to reduce the calculation of the image recognition. In this research a laser beam is scanned in the horizontal plane to which the cubic objects stand vertically and the laser spot is detected with a TV camera every sampling time. These spots make an intermittent locus which includes some special lines corresponding to the cubic objects.

To extract the features of the cubic objects, we utilize the normal vectors formed on the locus. If some normal vectors distribute in the same direction and the origin of the normal vectors are very close to

* The Graduate School of Natural Science and Technology
** Department of Industrial and Mechanical Engineering

their neighbor's, these normal vectors can be classified into the same class, -the straight line class. Because the normal vectors on the neighbor surfaces of the cubic objects are vertical to each other, we use this property to determine the pair of straight lines which belong to the cubic objects. Making the histogram based on the normal vectors with the same direction, we obtain the peaks which are supported by the points on the cubic object surfaces. Then, the points can be extracted from the set of points on the whole locus inversely according to the relations with the peaks and the features of the cubic object can be extracted by applying method of least square to these extracted points.

The experiments proved the availability of the proposed processing algorithm.

1. INTRODUCTION

Now, the research on the vision system is an active branch in robotics to develop an intelligent robot which will be able to deal with various tasks. As well known in this field, the 2-dimensional brightness information is not sufficient with so-called under-constraint problems. Meanwhile, because the binocular stereo vision system also can not decisively solve the problem of the corresponding points on the left image and on the right image, the method has not been used in practices. The laser range finder, an active measurement of the range data of a scene, is being used in many image recognition tasks because its reliability and simplicity for obtaining the absolute coordinate information[1].

This paper describes a method of extracting the 2-dimensional geometrical features of cubic objects from the visual information obtained with the laser range finder.

A laser beam is scanned in a horizontal plane to which the cubic objects stand vertically and the laser spot is detected with a TV camera every sampling time. These spots make an intermittent locus which includes some special lines corresponding to the cubic objects. The problem is how to extract the features of the cubic object. A typical method is the Hough transformation for finding straight line[2]. The method of the Hough transformation needs much time and many memories during calculating procedure. Here, we propose a method which utilizes the normal vectors on the locus consisting in the intermittent spots and the index information of the range data obtained with the laser range finder to simplify the recognition procedures.

The experimental results prove the availability of the proposed processing algorithm.

2. TRIANGULATION GEOMETRY OF LASER RANGE FINDER

Let us explain the meanings of the symbols and the parameters used in the Fig.1 before starting the analysis with the triangulation geometry of the laser range finder.

X-Y: Cartesian coordinates of the scanning plane

(x, y): Coordinate of a light spot.

(-D, d): Coordinate of rotating axis of the stepping motor on which the laser emitter is fixed.

(-D, y_r): Reference point for the system calibration.

O : Origin of the Cartesian coordinates of the scanning plane. A lens (not shown) is arranged at this point.

f : Focal length of the lens used in TV camera.

u_r: Image position of reference point(-D, y_r).

u : Image position of a light spot (x, y).

θ : Angle between the straight line x = -D and the scanning line.

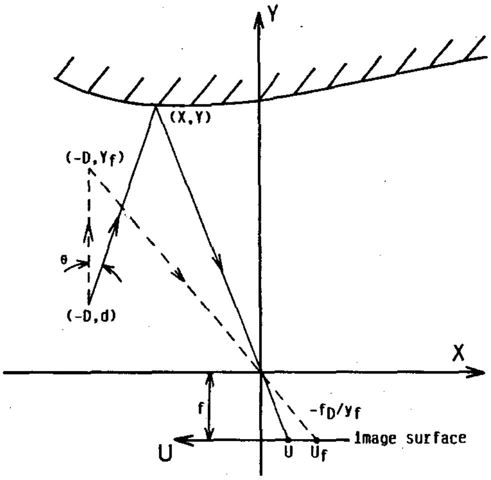


Fig.1 Triangulation geometry of the laser range finder

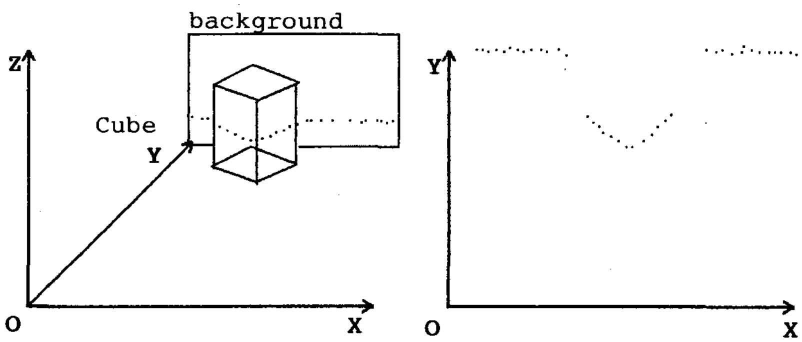
Here, the image plane(line) is parallel to the X-coordinate. First, the laser beam is projected at an angle of 0^{o} with the line x=-D to the reference point (-D, y_r) to check whether the image position u_r equals to $-fD/y_r$. If it is true, the calibration of the system at the original state is finished. Then, under the movement of laser head rotated by the stepping motor, the laser beam rotates to another angular position θ . The spot of light on the image moves from fD/y_r to a new position u due to the intersection of the projected laser beam with the object surface at a point (x, y). From the triangulation, we obtain the relations between the image position u and the coordinate (x, y) according to the parameters of geometry in this system as following:

$$x = u\, s;\ y = f\, s; \qquad (1)$$

where $s=(D+d\tan\theta)/(f\tan\theta - u)$. The rotating angle θ changes 0.2^{o} at one step and ranges from 0.0^{o} to 20.0^{o} in the experiments. In order to achieve higher resolution of the image and reduce the cost of the visual system, we fixed the laser emitter directly on the top of the rotating axis of stepping motor instead of utilizing the reflecting mirror.

3. FEATURE EXTRACTION OF CUBIC OBJECTS

The scene we deal with in this research is shown in Fig.2(a). To get the vertical pair of straight lines it is necessary to ensure that the scanning plane is vertical to the cubic object.



(a) (b)

Fig.2 The sketch of obtaining intermittent locus

In Fig.2(b), we can see the projection of the intermittent locus of the light spot on the X-Y scanning plane. It is obvious that the pair of vertical straight lines correspond to the cubic object. The objective is to extract the discrete points belonging to the surface of cubic object from the set of points of the whole locus and to deduce the features of the cubic object, e.g, (1) side orientation; (2) vertex position(intersection of the two sides which can be seen from both camera and the laser emitter); (3) side length. The following properties are the fundamental of the cubic object feature extraction:

A. All normal vectors on the same surface are parallel to each other;

B. The normal vectors on one side are vertical to the normal vectors of the neighbor side;

C. One origin of normal vectors is close enough to the next origin of the normal vectors on the same surface (continuity).

3.1 Investigation of the normal vector distribution

The normal vector of the i_{th} point $P(x_i,y_i)$ is expressed in $V_i(k_i,x_i,y_i)$, the value of the k_i is determined in the following equation:

$$k_i = -(x_{i+1} - x_{i-1})/(y_{i+1} - y_{i-1}) \qquad (2)$$

where k_i is the direction parameter and (x_{i-1}, y_{i-1}), (x_{i+1}, y_{i+1}) are the neighbor points of the P_i. The distribution of the normal vectors on the locus(needle map) is shown in Fig.3.

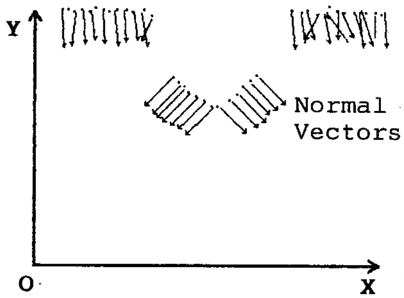


Fig.3 Distribution of normal vectors

3.2 Making histogram

To extract the points on the cubic object surface, we accumulate those points with the above-mentioned properties by making histogram. Because the normal vectors on the straight lines have the same direction, they form a cluster with the same direction parameter. Therefore, the number of the points in the cluster appear a peak value on the histogram, the peak may relate to the points on the cubic object surface. Let us consider the calculation of the j-th peak value, $H_j(k_i,x_i,y_i)$, on the histogram.

$$H_j(k_i,x_i,y_i)=\sum a_{ij} \quad i=1,2 \cdots\cdots N. \quad (3)$$

where,

$$a_{ij}=\begin{cases} 1, & D_j <= Th_1 \text{ and } E_j <= Th_2 \\ 0, & D_j > Th_1 \text{ or } E_j > Th_2 \end{cases}$$

$$D_j=[(x_i-x_j)^2+(y_i-y_j)^2]^{1/2} ;$$

$$E_j=|k_i-k_j| .$$

a_{ij} is the element of the unit accumulator. Th_1 and Th_2 are the thresholds determined in the experiment conditions. Whenever a point is counted in the value H_j, we attached mark "j" to the point. Therefore, as soon as the H_j is selected the points with index "j" can be acquired inversely. The sketch of the histogram is shown in Fig.5.

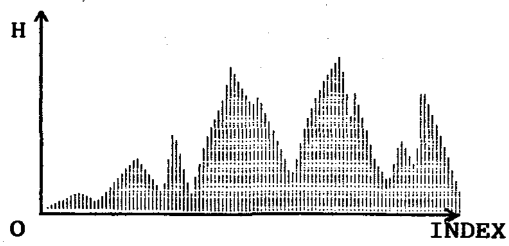


Fig.5 Histogram of the points with the same properties

To determine which peaks represent the two sides of the cubic object, we use the equation (4) to extract the pair of peaks with the vertical direction parameter to each other:

$$k_i + 1/k_j <= Th_3 \qquad (4)$$

where Th_3 is a threshold. From the pair of peaks, the points belonging to the two sides of the cubic objects are acquired.

3.3 Feature Calculation

We apply the least square method to the points related to one peak and another respectively to obtain the straight line equation (5),(6):

$$y-y_i= k_i' (x-x_i) \quad (5)$$

$$y-y_j= k_j' (x-x_j) \quad (6)$$

The k_i' and k_j' are the side orientation of the cubic object; the intersection of the equation (5), (6) is vertex position (x_s, y_s). We search the two most far points(x_{p1},y_{p1}), (x_{p2},y_{p2}) belonging to the two different peaks from the vertex position(x_s,y_s). The side length of the cubic object is determined in the equation (7):

$$L= \max \{ L_1, L_2 \} \quad (7)$$

where $L_1= ((x_{p1}-x_s)^2+((y_{p1}-y_s)^2)^{1/2}$;

$L_2= ((x_{p2}-x_s)^2+((y_{p2}-y_s)^2)^{1/2}$.

In this way, we extract the features of the cubic object based on the visual information.

4. EXPERIMENTS AND DISCUSSION

Under the condition of natural illumination, we put cubic objects at several positions and in various orientations in the scene to check the availability of the proposed algorithm. The secnes and the histograms are shown Fig.6(a)-(e). The Table 1 show the experimental results. Comparing the case 1 with case 2, we see that though the cubic object side length are the same, because of the differences of the orientations, the accuricy of the feature extraction is also different. We consider that the sight field of camera and laser emitter appear different, so sometimes, they could not see the object well at the same time. Comparing case 3 and case 1, we see that the larger the object, the easer the object could be extracted. Comparing case 4 and 5, we see that the closer the object to the camera, the more the data about the object can be collected, therefore, the more reliable the extracted features.

5. CONCLUSION

The experiments have been carried out under natural illumination conditions in the laboratory. The results of experiment described here indicate that the proposed algorithm is effective for extracting the 2 dimensional geometrical features of cubic objects. From the algorithm, the quantity of the processed information is in proportional to 2N (N is the range data number) in stead of processing the information proportional to N^2 in the case we use the Hough transformation method. Although the extracted features have some errors, we think that they are because of the inaccuricy of laser range finder.

6.ACKNOWLEDGEMENT

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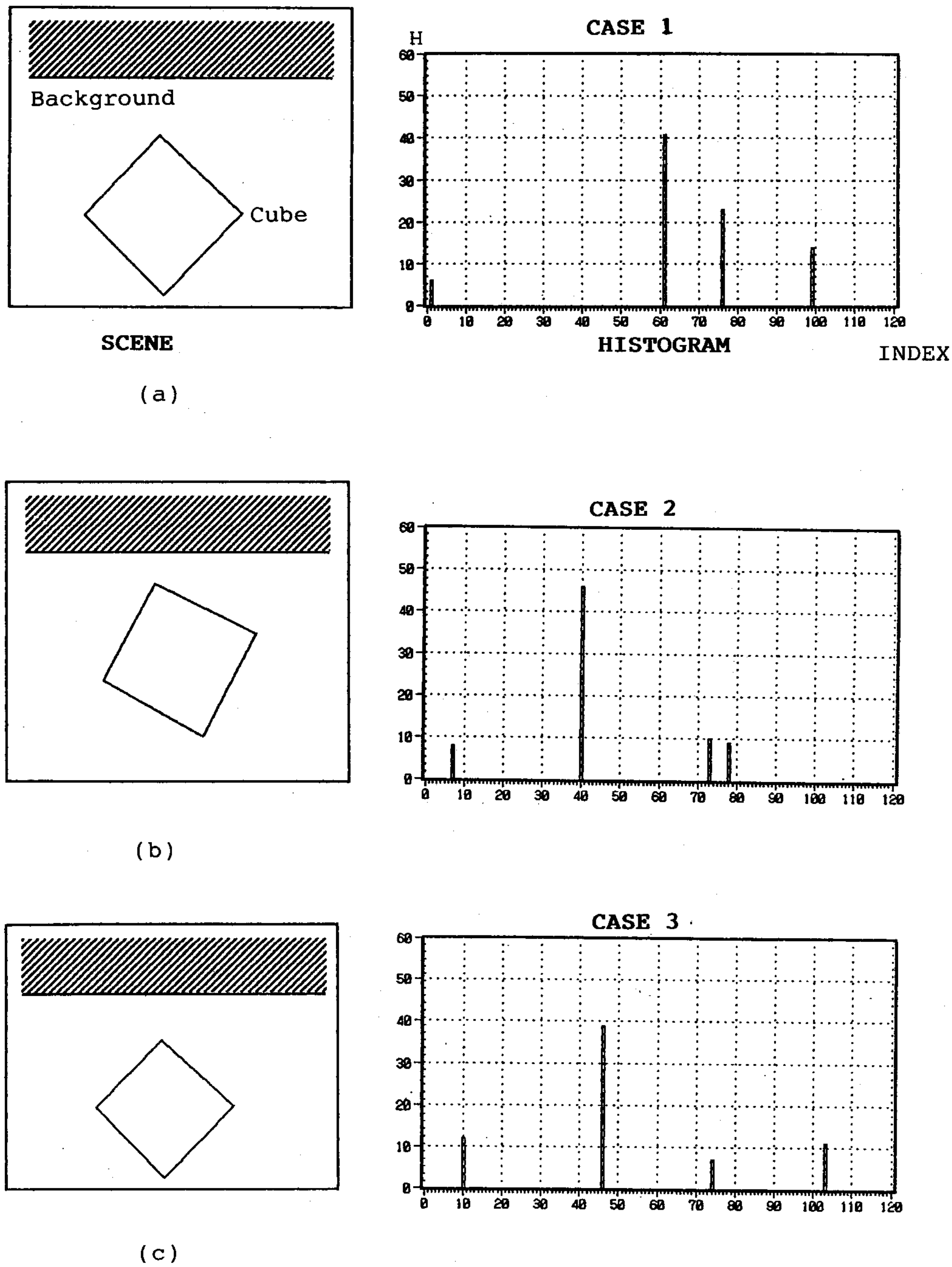
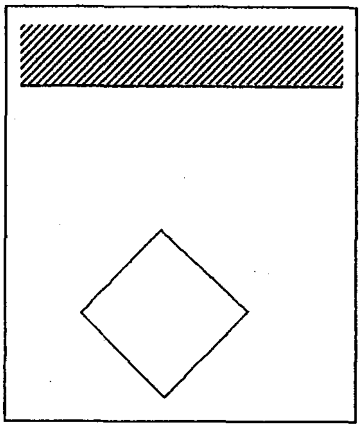
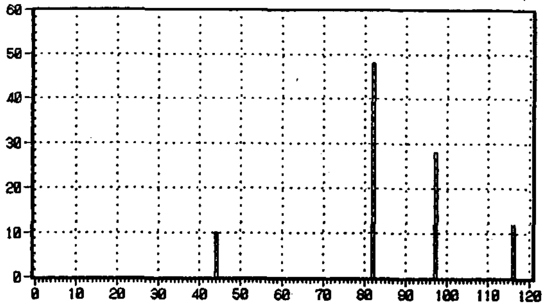
Fig. 6 Scene and histogram

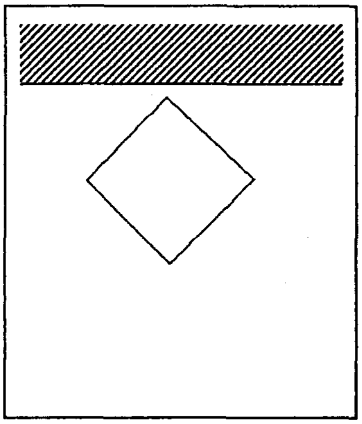




(d)

CASE 4





(e)

CASE 5

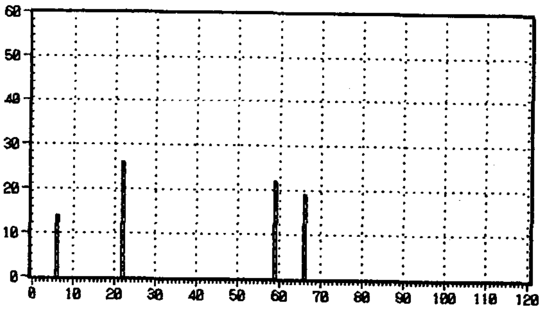


TABLE 1

	REAL DATA				MEASURED DATA				ERROR			
CASE	X mm	Y mm	L mm	α	X mm	Y mm	L mm	α	E_x	E_y	E_l	E_α
1	0.0	607.0	60.0	1.25	4.34	601.9	63.8	1.43	4.34	-5.1	3.8	0.18
2	0.0	607.0	60.0	1.00	4.5	599.5	60.7	0.91	4.5	-7.5	0.7	-0.09
3	0.0	607.0	50.0	1.25	3.49	602.2	48.3	1.56	3.49	-4.8	-1.7	0.31
4	0.0	507.0	60.0	1.25	3.3	490.7	64.9	1.25	3.3	-16.	4.9	0.0
5	0.0	690.0	60.0	1.0	7.0	695.7	57.5	1.1	7.0	5.7	-2.5	0.1