

A binocular robot vision system with quadrangle recognition

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Abstract: A binocular robot vision system having an autonomously moving active viewpoint is proposed. By using this active viewpoint, the system constructs a correspondence between the images of a feature points on the right and left retinas and calculates the spatial coordinates of the feature points. The system incorporates a function of detecting straight lines in an image. To detect lines the system uses Hough transform. The system searches a region surrounded by 4 straight lines. Then the system recognizes the region as a quadrangle. The system constructs a correspondence between the quadrangles in the right and left images. By the use of the result of the constructed correspondence, the system calculates the spatial coordinates of an object. An experiment shows the effect of the line detection using Hough transform, the recognition of the surface of the object and the calculation of the spatial coordinates of the object.

Keywords: binocular robot vision, active viewpoint, Hough transform, shape recognition

1. INTRODUCTION

The stereopsis is the ability to get the three-dimensional information of a scene [1]. This ability is realized by the combination of several functions of our right and left eyes such as accommodation, vergence motion, parallax and so on. Like a human being, the stereopsis is achieved by a binocular robot vision system using parallax and vergence motion. Fundamental difficulty of such vision system is to get correct correspondence between right and left images. Many methods to know the correspondence between the right and left images have been proposed, e.g. a method to make a correspondence directly extracted feature points between right and left images [1], and the partial image matching method [3]. To construct a correct correspondence between the right and left images easily, we have proposed a binocular robot vision system, which uses both active and passive vision techniques [3].

The proposed binocular robot vision system has two CCD cameras; the right camera has two laser-line-markers. The laser-line-markers are attached on the top and to the right side of the camera. The laser lines from both markers make cross-line on an object. Then the intersection of both laser lines indicates the right cameras' viewpoint actively, therefore we call this intersection an "active viewpoint"[2]. By using the vergence motion of both cameras, the system makes agreement with the centers of both cameras' view fields in agreement. Thus, the active viewpoint becomes a fixation point of the binocular robot vision system. Since the viewpoints of the right and left cameras are agreed mechanically, the fixation point is the first correspondence. Then, without complex image processing and computation, the distance from the binocular vision to the fixation point on the object is calculated by triangulation. After the calculation of the distance from the binocular vision to the object, the system extracts the edges of the object from image data. Then straight lines are detected from the extracted edges. The system finds out a region surrounded by 4 straight lines. The region is recognized as a quadrangle by the system. The quadrangle is categorized into six kinds. By the use of the categorized result, the system constructs a correspondence between right and left quadrangles and calculates the spatial coordinates of the object.

2. BINOCULAR VISION

The arrangement of the binocular vision proposed by us is illustrated in Fig.1, where the point O on an object is the

active viewpoint, and O_L and O_R are the images of O projected on the left and right retinas. By the vergence motion of the both eyes (CCD cameras), O_L and O_R are placed at the centers of both retinas. The vergence angles of left and right cameras are θ_L and θ_R , respectively. Thus the point O becomes the first fixation point of the system. The procedure of finding the corresponding images of a feature point P_1 on the object in the left and right retinas is shown in Fig.1. After the agreement of the viewpoints of the both cameras, the distance from the vision system to the viewpoint is calculated by using the vergence angles and the length of the base line. Then the image of the feature point P_L in the left view is extracted by image processing technique. To determine the corresponding point for this feature points P_L , the system searches the candidates on the epipolar line in the right retina. Plural candidates P_{R1} , P_{R2} may be picked up on the epipolar line, then, correct correspondence among these candidates is determined by using the active viewpoint. The distance and the direction from O_L to P_L in the left retina are similar to those from O_R to the true correspondent point in the right retina. Consequently, the system selects the P_{R1} as the correspondence of P_L . In spite of such a simple and optimistic assumption, this procedure is effective to find out the correspondences where the feature points are distributed scarcely on the object. However it is difficult to know the correspondences when the object has many similar feature points distributed densely. Fig.2 shows the flow chart of the measurement using the active viewpoint.

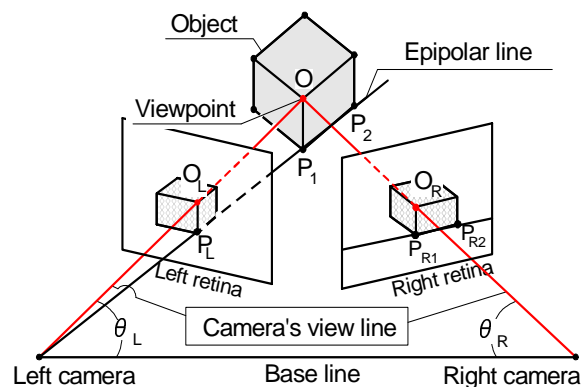


Fig.1 Simplified arrangement of a binocular vision

3. IMAGE PROCESSING

To develop the intelligent robot vision system which has the recognizing function of various solid bodies, we introduce simple method. The method is the combination of followings:

- 1) Color detection.
- 2) Straight lines detection.
- 3) Quadrangle recognition.

Fig.3 shows the flow chart of image processing to extract the features.

3.1 Color detection

For extracting the features of an object from an image data, the system uses the color information of the surface of the object. In order to reduce the influence of noise, an image data are converted by using the equations (1) and (2) from RGB color [3] to HLS color space [4] (H:Hue, L:Light, S:Saturation).

$$Y = 0.587G + 0.114B + 0.299R$$

$$C_1 = R - Y \tag{1}$$

$$C_2 = B - Y$$

$$H = \tan^{-1} \left(\frac{C_1}{C_2} \right) \tag{2}$$

$$S = \sqrt{C_1^2 + C_2^2}$$

Fig.4 illustrates the HLS color space. By the use of the values of H and S, particular color on the object is able to extract from the image data easily.

3.2 Straight lines detection

From the extracted object, the edges of the object are detected. The system finds out the straight lines from the edge data. The straight lines in the image are detected by the Hough transform [5]. The Hough transform is useful method to detect global patterns like straight lines, circles, etc. The Hough transform is to transform all pixels on a straight line to a single point in the $\theta - \rho$ plane. Hence, this transform requires the computational cost of transforming into the $\theta - \rho$ plane from the image data. The Hough transform is made by using following equation,

$$\rho = x \cdot \cos \theta + y \cdot \sin \theta \tag{3}$$

If the straight line is transformed from image data to the $\theta - \rho$ plane, the all points on the same line have the same ρ and θ value. Then the Straight lines are detected from the transformed result. The detected lines are converted to the source image using following equation

$$y = -\frac{1}{\tan \theta_p} x + \frac{\rho_p}{\sin \theta_p} \tag{4}$$

3.3 Quadrangle recognition

Fig.5 illustrates the flow chart for the process to recognize a quadrangle and to calculate the 3D coordinate of the quadrilateral surface. At the beginning of the process, the system extracts the surface of the object by using the values of Hue and Saturation. The edges are detected from the extracted surface of the object.

Straight lines are found out by the Hough transform. The system searches the area which is surrounded by 4 straight

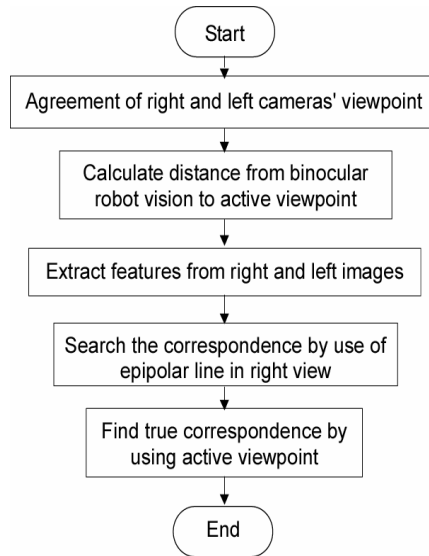


Fig.2 Flow chart of measurement using active viewpoint

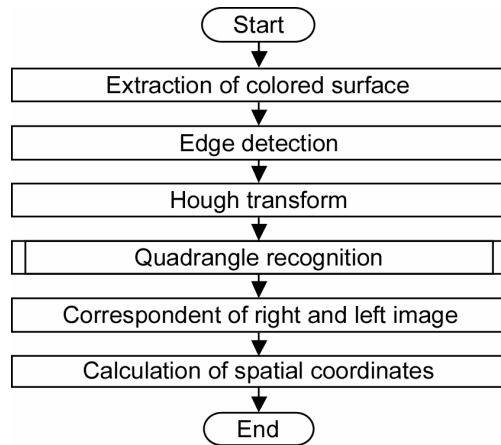


Fig.3 Flow chart of image processing to extract the features

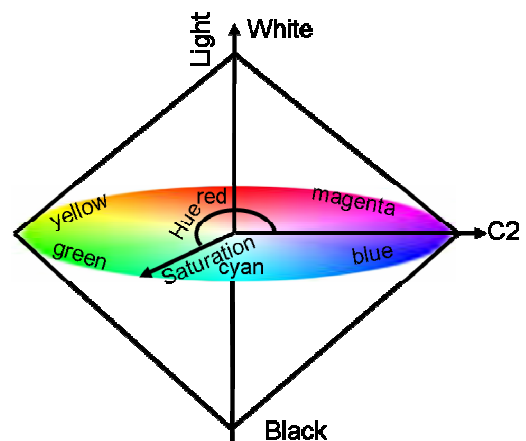


Fig.4 HLS color space

lines. Then the system recognizes the area as a quadrangle. The recognized quadrangle is categorized into the following kinds.

- | | |
|------------------|--------------|
| 1) Quadrangle | 2) Trapezoid |
| 3) Parallelogram | 4) Lozenge |
| 5) Rectangle | 6) Square |

To categorize a quadrangle, two features of quadrangle are used. The first feature is the parallelism of an opposite sides edges and the second feature is an internal angle between adjacent edges. If there are no parallel pairs of the opposite sides edges, the quadrangle is a categorized as quadrangle. If there is a one parallel pair of the opposite sides edges, the quadrangle is categorized as a trapezoid. If there are two parallel pairs of the opposite sides edges, the quadrangle is categorized as parallelogram. At this point, by the use of internal angle, the parallelogram is categorized as parallelogram or rectangle. In parallelogram and rectangle, if the aspect ratio is 1:1, it is categorized as lozenge or square. In this way, the system recognizes six kinds of quadrangle.

In six kinds of quadrangle, the parallelogram and rectangle are categorized into wide variation by aspect ratio. Fig.6 shows the relation of aspect ratio and yellow parallelogram. The yellow parallelogram is a projection of a surface of a cube that is rotating from 0 degree to 80 degree. From this graph and by the use of integer aspect ratio, the parallelogram and rectangle are categorized into 3:1, 5:2, 2:1 and 3:2 respectively. The system recognizes the 14 kinds of quadrangles. The recognized quadrangles become features that are utilized to construct a correspondence between the right and left images. To construct a correspondence for each feature in the left image, the candidates that are recognized quadrangle as same shape in the right image are searched. In the searching process, plural candidates may be found out as same shape. Then the true correspondent among these candidates is determined by using the rotation angle of the quadrangles and the position of the center of gravity of the quadrangles. The gradient of the bottom edge that is calculated by equation (4) is used as the rotation angle.

4. SYSTEM COMPONENTS

The components of the binocular vision system are shown in Fig.6. In this figure, the dashed lines indicate the flow of information into the system. The solid lines are the control signals from the system. The system consists of two parts, i.e. the mechanical part and the intelligent part. The mechanical part has a binocular vision mounted on a multi-joint robot with six joints. In binocular vision, the right camera has two laser line markers. The markers are attached on the top and to the right side of the camera. The laser lines from both markers make cross-line on the object. Then the cross point of both beams indicates the right cameras' viewpoint. For the vergence motion of each camera, a stepping motor and a rotary encoder are used.

The intelligent part consists of a personal computer that has several I/O interfaces such as image processors, D/A converters and pulse counters. The tasks of this part are as follows: control of the vergence motion of the both cameras, process of the images, construction of the correct correspondence between the right and left images, recognition of the quadrangles, decision of the autonomous movement of the fixation point of the system and control of the multi-joint robot.

5. EXPERIMENT

To confirm the ability of measurement of the system, we measured a specimen shown in Fig.8. The specimen is two cubes (length of a edge=83mm). Three surfaces of the each cube are painted in red, yellow and white, respectively. These cubes are set 1000mm away from the baseline of the binocular robot vision system. Fig.9 shows the procedure for

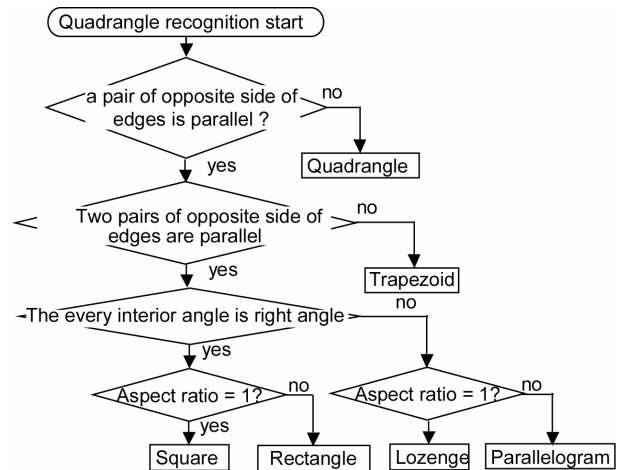


Fig.5 Flow chart of quadrangle recognition

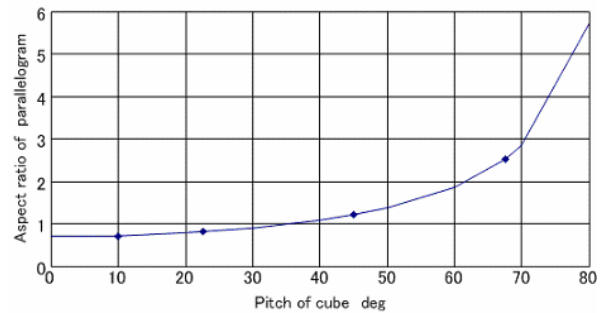
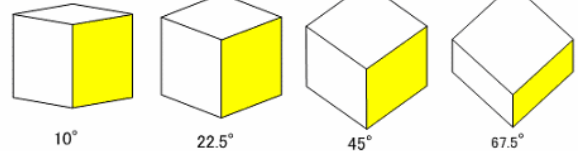


Fig.6 Relation between rotation angle of cube and aspect ratio in image

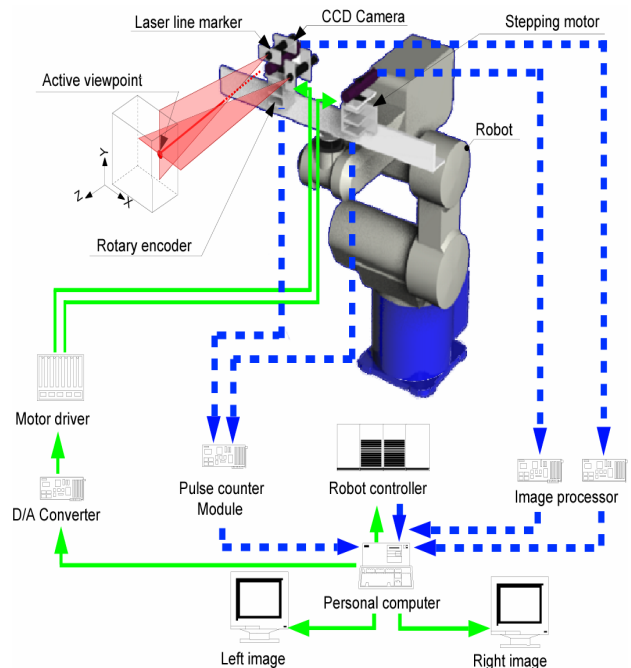


Fig.7 Binocular robot vision system

recognizing the red surface as a quadrangle. In the measurement, the system makes the agreement of the viewpoints of the right and left cameras by using the active viewpoint. Then the image data are captured from both cameras. The captured image data are processed along the procedure illustrated in Fig.3. The “Extracted red surfaces” in the middle of Fig.9 shows the extracted red surface by using the HSL color space. Each extracted surface is labeled. For each labeled surface, the system processes the edge detection and the Hough transform to recognize the quadrangle. The “Detected lines” of Fig.9, the system recognizes the region surrounded by 4 straight lines as quadrangles. The two pairs of opposite side of edges of all red surfaces are parallel. Then these quadrangles are recognized by the quadrangle recognition as lozenge respectively.

Similarly, the yellow surfaces are recognized as parallelogram that aspect ratio is 2:3. The white surfaces are recognized as lozenge. The result of the quadrangle recognition is summarized in Table1. The system constructs a correspondence between recognized surfaces in the right and left images. By use of the constructed correspondence, the spatial coordinates of the object’s vertices are calculated. The result of measurement is shown in Fig.10. The dots indicate the vertices of the specimen. The average of the length is 82mm and the standard deviation is 5mm. In this experiment, the function of quadrangle recognition incorporated to the system works effectively.

6. CONCLUSIONS

We incorporate the function for recognizing quadrangles into our binocular robot vision system. The experimental results obtained by this system are as follows:

- 1) The system is able to distinguish the colored surfaces of the object.
- 2) The straight lines are detected from the edge data by the use of Hough transform. Then the system recognizes the quadrangle.
- 3) The system classifies the recognized quadrangles into the 14 categories.

By the use of the function of the quadrangle recognition, our binocular robot vision system succeeds in recognizing the shape of an object and calculating the spatial coordinates of the object.

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 [4] http://msdn.microsoft.com/library/default.asp?url=/library/en-us/icm/icm_6yib.asp
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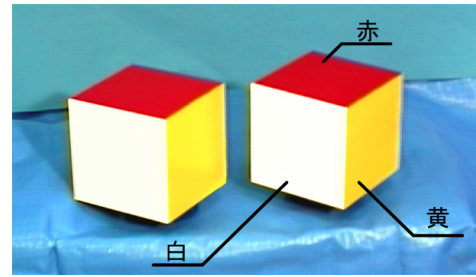
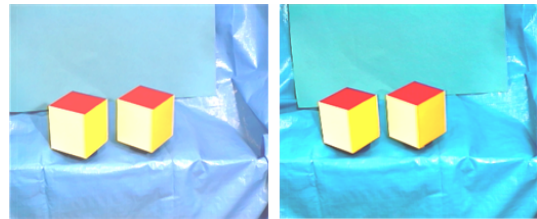
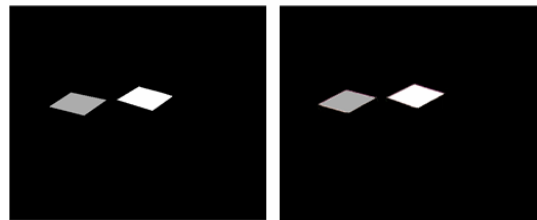


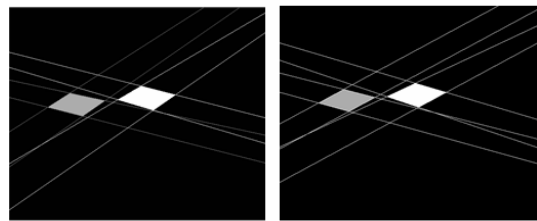
Fig. 8 Specimen



Source image



Extracted red surfaces



Detected lines

Fig. 9 Processed red surfaces

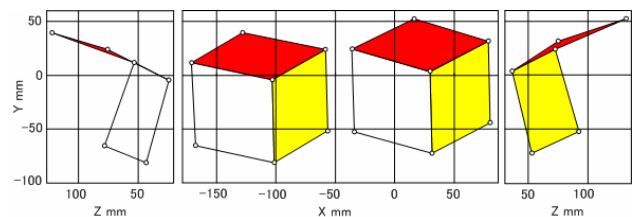


Fig.10 Measurement result

Table 1 Recognized surface

	Left image	
	Cube (left)	Cube(right)
Red	Lozenge	Lozenge
White	Lozenge	Lozenge
Yellow	Parallelogram(2:3)	Parallelogram(2:3)
	Right image	
	Cube (left)	Cube(right)
Red	Lozenge	Lozenge
White	Lozenge	Lozenge
Yellow	Parallelogram(2:3)	Parallelogram(2:3)