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13—21 A Range Finder by Using a Rotary Cubic Mirror

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Abstract

The slit light scanning method is a conventional method of range finder. But according to this method, it is impossible to measure the three dimensional shape when the object is too large, because camera is fixed against the observation field. In this paper, we propose a new active range finder with a rotary cubic mirror to solve these problems. In this sensing system, slit light and view of camera are moved to the same direction simultaneously by using a rotary cubic mirror. This method is able to obtain the slit light image which dose not include distortion. On the other hand in the proposed sensing system, the image of slit is projected on near the center of the image plane all the time by moving the slit light and the view of camera simultaneously. The experiments were performed to demonstrate the efficacy of this sensor by using this system. As a result, the proposed method can measure the three dimensional position of the object and effectiveness was shown.

1 Introduction

Range finder is an effective method for obtaining the three dimensional information of objects [1][2][3]. Then, slit light method is the conventional method of range finder that based on the principles of active triangulation [4][5][6].

But according to conventional slit light scanning method, because camera is fixed to the observation field, it cannot obtain the information of distance when the object is larger than the field of view[3]. When the object exists near the edge of the observation field, the distance is not able to be measured correctly. Because a slit image with distortion is obtained when the image of slit is projected near the edge of image plane.

To solve these problems, follow method has been proposed[7]. Two motors are attached at the camera and the slit projector respectively. Therefore slit light and view of camera are moving same direction simultaneously. In this care, observation field becomes wide because view of camera is moved by revolving motor. And slit light moves with view of camera to same direction simultaneously, so image of slit is projected near the center of image plane all the time. But this system has some problems. It will become complex system composition because it uses two motors. And to operate the two motor at the same time together, strict calibration is in need.

We propose a new active range finder with simple system component, and no need a strict calibration to move slit light and view of camera simultaneously. This sensor uses swinging mirror that has a cubic shape. This mirror is located between CCD camera and slit light projector. The two units are opposite from each other. Thus, only swinging cubic mirror can realize to move slit light and view of camera simultaneously to the same direction, as a result, there is no need strict calibration.

In this paper, we describe the principle of measurement, system component, calculation of 3D position, and results of experiment to verify the efficiency of this method.

2 System Composition

System composition is shown in **Fig.1**. Laser pro-

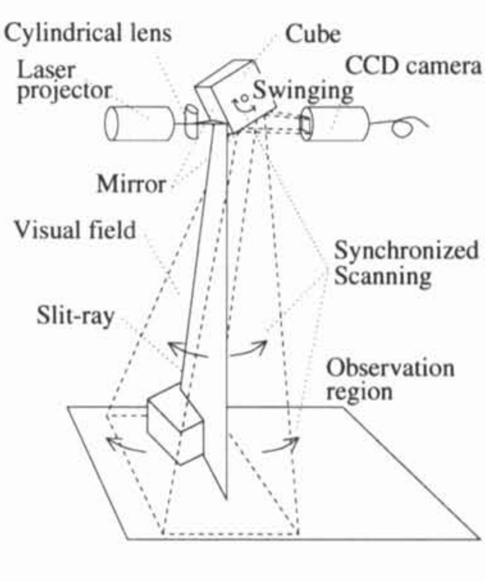

Fig.1 Overall system

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jector and CCD camera are opposite from each other on the optical axis, and the cube is located between them. The surface of this cube is put over the mirror. The motor is attached at the bottom of the cube, due to swinging the cube, the slit light is scanning on the object area one dimensionally, and view of camera is moved to the same direction simultaneously.

The feature of this scanning method is described as follows.

First, this method can obtain the image of slit light that dose not include distortion. According to conventional slit light scanning method. the camera is fixed to the object and slit light is moved one dimensionally on the object area. So the image of slit light is moved on the image plane edge to edge. The image of slit will be distored when the image is projected on near the edge of image plane. It is necessary for the image of slit to be projected at the center of the image plane all the time. The proposed method can do above, because slit light and view of camera are moved to the same direction simultaneously by using the swinging cube.

Second, this method can get wide observation field than conventional slit light method. In conventional method, field of view was limited by fixed camera, but proposed method is able to get wider observation field because view of camera can be moved by swinging cubic mirror.

Third, the system of the proposed method has a simple structure. There was a method that slit light and view of camera moves simultaneously to the same direction, but the structure of the measurement system becomes complex because it needed two motors for scanning laser projector and the CCD camera. But the proposed method uses only one motor. So it realizes a simple structure of the measurement system.

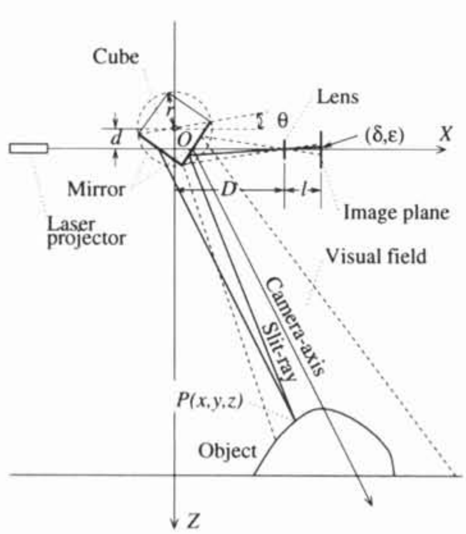

Fig.2 Optical schematics of the sensor

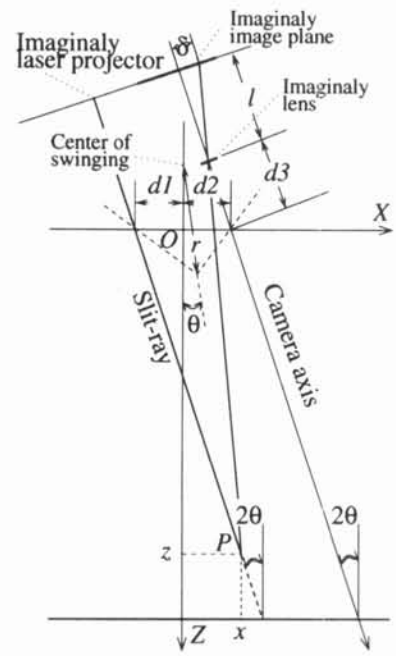

Fig.3 Imaginaly optical scheme (for calculating z and x)

3 Three dimensional Position

The slit light is projected on the object, the image of the object is obtained by using CCD camera. The gravity of slit is detected from the image sequence, and the three dimensional position is calculated.

The optical scheme of the sensor is shown in **Fig.2**. The CCD camera and laser projector are opposite from each other on the optical axis, and the cube is put between them. The imaginary optical scheme is shown in **Fig.3** and z and y are represented as follows,

$$z = \frac{l}{\delta}(d_1 + d_2)\cos 2\theta - d_3 + (d_1 + d_2)\sin 2\theta \cos 2\theta, \tag{1}$$

$$x = \frac{\cos 2\theta}{\sin 2\theta} z - d_1. \tag{2}$$

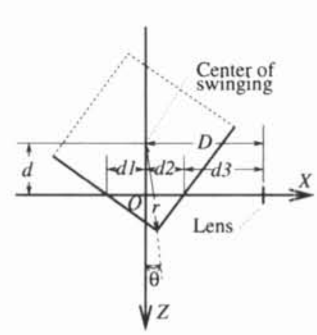

Fig.4 Parameters about a swinging cube

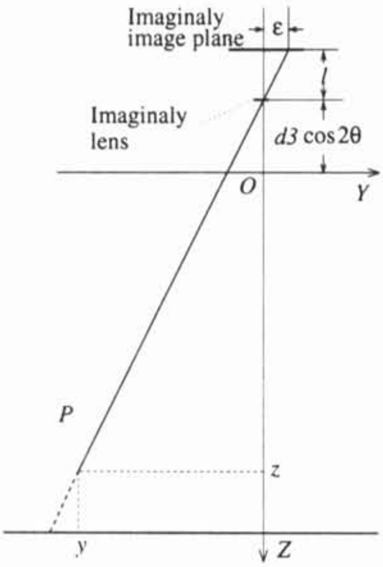

Fig.5 Imaginaly optical schematics (for calculating y)

where δ and ϵ are the position of the slit projected on the image plane, *ell* is a distance between the center of lens and image plane, θ is a angle of the rotary cube, and r is a length at the side of cube. d_1, d_2 and d_3 are parameters about the cube, as shown in **Fig. 4** There parameters are represented as follows,

$$d_1 = \frac{r - d(\cos\theta + \sin\theta)}{\cos\theta - \sin\theta}, \tag{3}$$

$$d_2 = \frac{r - d(\cos\theta - \sin\theta)}{\cos\theta + \sin\theta}, \tag{4}$$

$$d_3 = D - d_2. \tag{5}$$

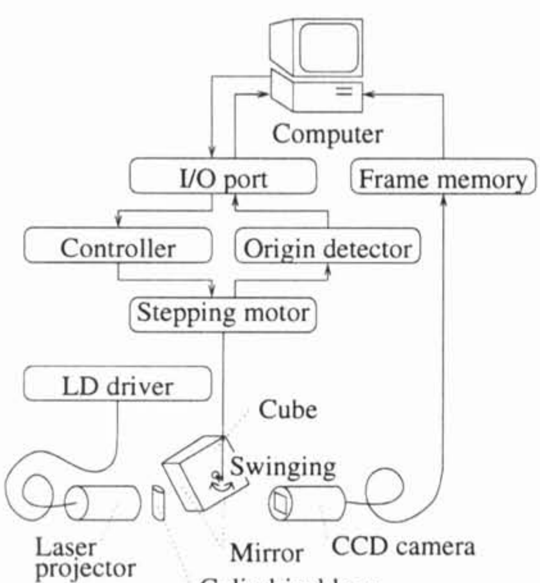

Fig.6 Scheme of an experimental system

The imaginary optical scheme for calculating y which is one axis of the three dimensional position is shown in **Fig.5** and y is represented as follows,

$$y = \frac{\epsilon}{f}(z + d_3 \cos 2\theta) \tag{6}$$

4 Experiments

4.1 Experimental system

The experiments by using the experimental system were performed to demonstrate the efficacy of this method. The experimental sensor system was composed of a laser projector(810nm in wavelength and 30mW in output), ,a cubic mirror and CCD camera, as shown in **Fig.6**. Image data obtained by CCD camera is stored in frame memory (512 pixel 128 pixel, 256 shadings), and processed by a computer. In addition, in order to reduce the effect of external light disturbances, the CCD camera is furnished with a light-band filter (light of 760nm in wavelength permeates at a rate of over 90%).

Fig.7 shows the part of range finder. There are the rotary cube between the CCD camera and the slit light projector.

4.2 Experiment results

Fig.8 shows an example of the relationship between the real distance and the measurement distance. In this experiments, the sensor was placed at each position of 400mm, 410mm, 420mm, 430mm and 440mm from the large plane. Each plot indicates the average and the standard deviation of z measurement value. A satisfactory results of plane measurement is attained.

Fig.9 shows an example of the three dimensional data obtained by the experimental sensor system. A coffee cup is placed about 400mm from the sensor system on the observation region. The oblique axes in the diagram indicate the x value of the three dimensional data, the horizontal axes show y value and the vertical axes give Z value. The three dimensional shape of the coffee cup is reconstructed.

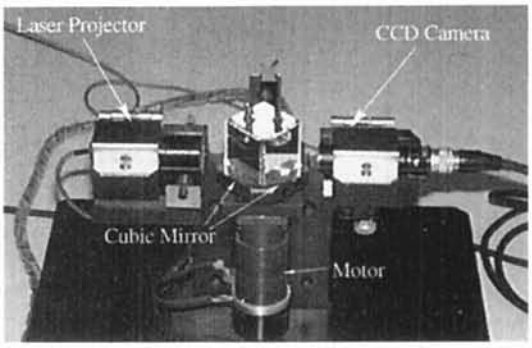

Fig.7 Photograph of the head of the measurement system

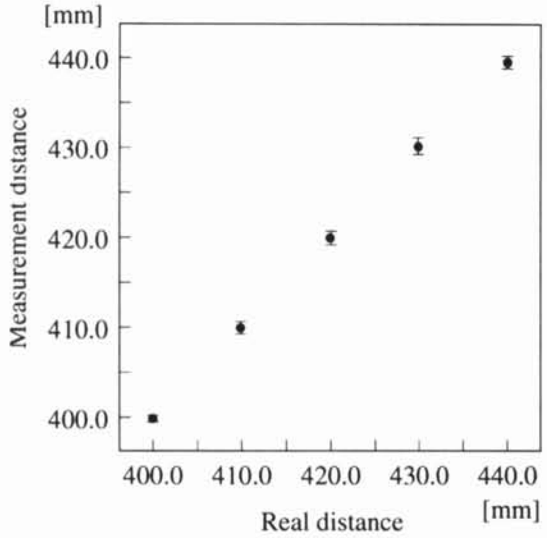

Fig.8 Relationship between real distance and measurement distance

Fig.10 shows an example of the three dimensional facial data obtained by the experimental sensor system. A subject person placed his face about 400mm from the sensor system. The three dimensional facial shape is reconstructed.

5 Conclusion

In this paper, we have described the new active range finder using the rotary cubic mirror. The experiments were performed to demonstrate the efficacy of this method.

The range finder has a feature that is its optical arrangement. The CCD Camera and laser projector are placed opposite to each other on the optical axis, and the cube which has mirror on the surface is placed between them. By rotating the cube by using the motor attached at the bottom of cube, The slit light and the view of the CCD camera are moving same direction simultaneously. This sensor has advantage: the image of slit light is obtained without distortion; the observation field is wider than conventional light slit method; the sensor system is very simple.

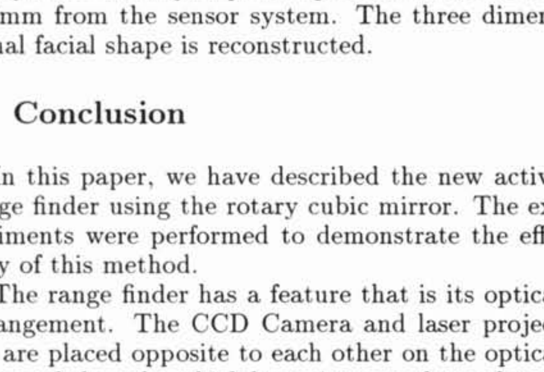

Fig.9 An example of the three dimensional data of the cup in the experiments

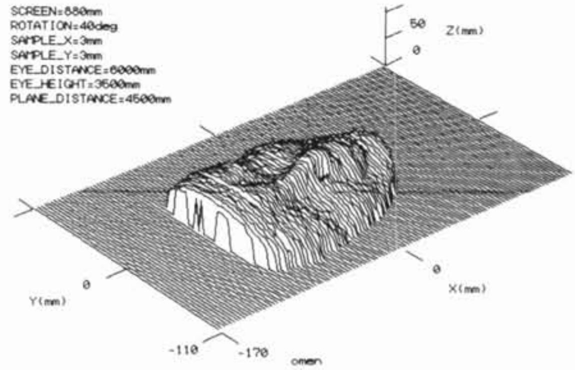

Fig.10 An example of the facial three dimensional data in the experiments

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