Development of Miniature Range Image Sensor Using Multi-Slit Laser Projector and Endoscopy Camera

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In this paper, development of a miniature size range image sensor is presented. The sensor is designed for a robot hand by using an endoscopy camera and a multi-slit laser projector, which can obtain range images. The improvements over the previous sensor are size, accessibility and measurement range in close distance. The dimension of the sensor is 16×40×53 mm and its weight is about 28 g. By using a universal webcam chip, the computer can capture the image data without the driver. The sensor can measure the distance from 50-150 mm. The effectiveness of the sensor is verified by experiments.

1 Introduction

Distance data of the workpiece is necessary for grasping of a robot. However, when the range image sensor is set separately from the robot hand, a blind situation caused by the occlusion of the robot hand itself occurs. To avoid this, one of the measures is to directly install the sensor onto the robot hand [1]. Based on the former sensor we built [2], in this paper, we present the development of the new lightweight and compact sensor.

2 Method

By calculating the disparity between the coordinates of the multi-slit image of current and infinity, which is based on the triangulation method, the distance Z from sensor in the direction of the optical axis to the object is represented as

$$Z = \frac{b \cdot f}{p \cdot (k - k_\infty)} , \qquad (1)$$

where b is the baseline length, i.e., the distance between the center of camera and projector, f is focal length of the camera, p is the pixel width of the camera and $k - k_\infty$ is disparity of current and infinity. The measurement model is shown in Fig. 1 and the sensor model is shown in Fig. 2.

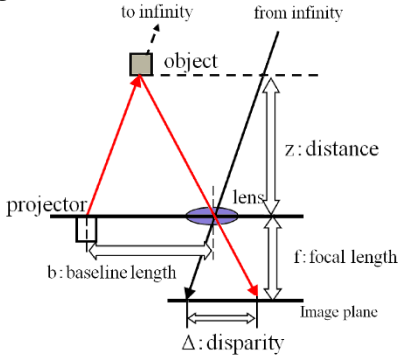

Fig. 1 Measurement model

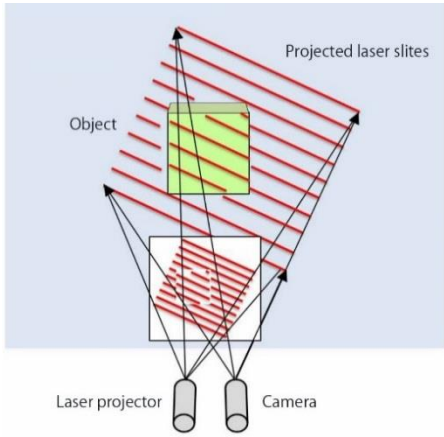

Fig. 2 Sensor model

3 Sensor Modification

Two main parts to assemble the sensor are the multi-slit laser projector and the endoscopy camera. The laser projector projects 15 slits of 690 nm wavelength red laser simultaneous on a 45° horizontal angle. The endoscopy camera has a 640×480 pixel resolution, the horizontal view angle is 45° and the minimum focus distance is 3 mm. For comparison, the resolution of former industrial camera is the same, but its view angle is 60° view angle and the minimum focus distance is 10 mm.

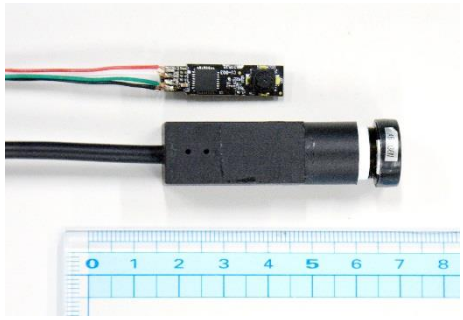

Fig. 3 Comparison between endoscopic camera (up) and former camera (down)

Table 1 Comparison between camera modules

	former camera	endoscopic camera
length	53 mm	28 mm
width	15 mm	7 mm
height	15 mm	5 mm
volume	11925 mm^3	980 mm^3
weight	15 g	1 g

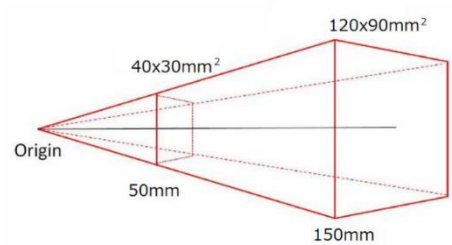

Fig. 4 Measurement space of the sensor

4 Sensor Specifications

The baseline length is 10 mm to match the close distance measurement. As shown in Fig. 4, the measurement range of the sensor is 45° for horizontal view angle and 50mm to 150 mm for measuring distance. The effective measurement space is from 40×30 mm^2 at 50mm to 120×90 mm^2 at 150mm depending on the distance of the object. The number of measuring points is about 2400, meanwhile the processing speed of the sensor is about 10 fps.

5 Experiments

To confirm the usability and property of the sensor, experiments of measurement of a flat wall and objects were carried out.

In the first experiment, the sensor was put against a white flat wall at a distance of 70 mm and the camera image shows straight multi-slits, as Fig. 5 shows. A clean point cloud of flat wall distance data can be obtained, as Fig. 6 shows.

In the second experiment, a white rectangular object (60mm×17mm×9mm) was put in the measurement space of first experiment, as Fig. 7 shows. Upon the clean flat background, a rectangular shape point cloud with distance data can be obtained as Fig. 8 shows.

The processing speed of the sensor is 8-10 fps. The possibility of range image measurement under such a close distance was verified.

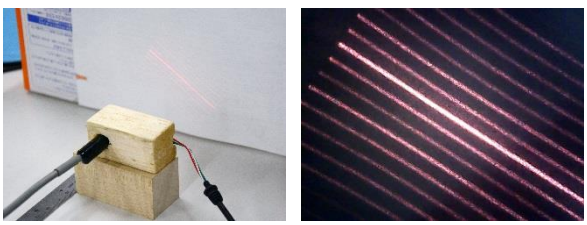
Fig. 5 First experiment scene and camera image

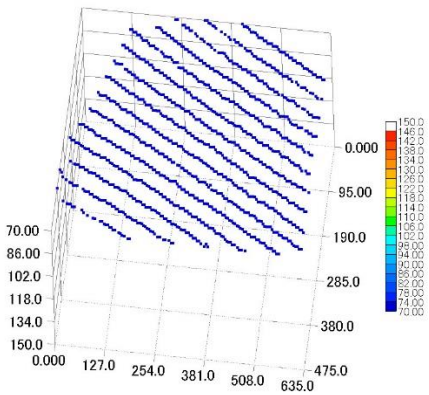

Fig. 6 Range image of flat wall

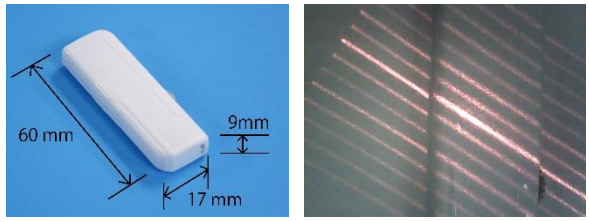

Fig. 7 Second experiment object and camera image

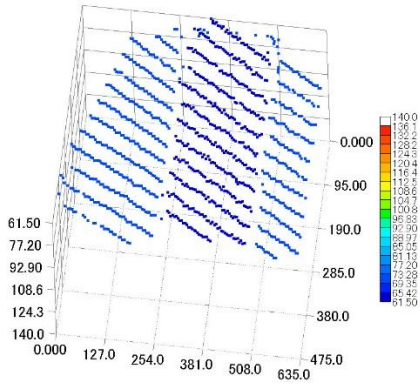

Fig. 8 Range image of a rectangular object

6 Conclusion

In this paper, we built a miniature range image sensor by using a multi-slit laser projector and an endoscopy camera. To downsize the sensor, a compact endoscopy camera has been used. The baseline length is also adjusted to as short as 10 mm, in order to have closer distance object measurability than the former sensor. The whole sensor size has been downsized by volume 20% and weight 30%, which makes it easier to install the sensor onto a robot hand.

The future prospects of the research are the further verification of detailed measuring accuracy, variable condition measurement, and installation to a robot hand.

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References

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