A Method for Estimation of Lightness of Objects with Intensity Data from SOKUIKI Sensor

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Abstract— **Recently, SOKUIKI sensor is used in various fields including robotics. SOKUIKI sensor "URG-04LX" can take distances by measurement. And by using special mode of the firmware, Received Light Intensity and AGC Voltage Level can be obtained. This paper describes a method to estimate Gray Level of scanned objects by using Received Light Intensity. The method uses AGC Voltage Level for accurate estimation.**

I. Introduction

A lot of laser range finders (SOKUIKI sensor) can output laser's intensity data[1]-[3]. In general, the intensity data itself has two different meanings by each SOKUIKI sensor. One is the strength of received optical signal, the other is the strength of reflected optical signal. The latter data is calculated from the former data by removing the influence of distance and inclination. In this paper, the former data is called received intensity, and the latter one is called reflected intensity. The main purpose to use such intensity data is to make and indicate a laser intensity image of the scanned environment by SOKUIKI sensor. Though reflected intensity is more suitable for more accurate purposes e.g. Intensity ICP[4]. Though the SOKUIKI sensor "URG-04LX"(URG) of Hokuyo Automatic Co., Ltd.[5] which was used in the work can output only received intensity.

In this paper, we describe our work for getting reflected intensity from URG.

Fig. 1 SOKUIKI Sensor URG-04LX"

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TABLE I
SPECIFICATIONS OF URG-04LX

Range	0.02 – 5.6 m
Resolution	1 mm
Scan Angle	240 deg
Angle Resolution	0.352 deg
Optic source	Laser (λ=785nm)
Laser Safety Class	Class 1 (Eye safe)
Scan Rate	100 msec/scan
Dimension	50×50×70 mm
Weight	160 g
Environment	indoor

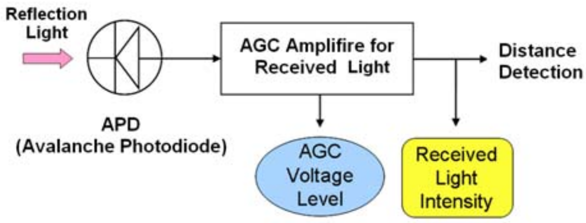

Fig. 2 Flowchart of Data Processing in URG-04LX

II. Acquisition of Variable data from URG

As mentioned in Kawata et al.[6], URG has Auto Gain Control Circuit (AGC) for high dynamic range. As shown in Fig.2, AGC control saturation of amplifier when Avalanche Photodiode (APD) receives strong light. Then the gettable intensity variable is signal intensity which the amplifier outputs. Thus real received intensity variable is not equal to output received intensity. Their relation is not in linear proportion. This fact indicates that it is important to remove the influence of AGC for estimating reflected intensity.

URG also can output voltage (0-3.3V) value of AGC. The value is output from 10-bit AD converter. The AGC voltage value keeps high level when the real received intensity is under certain value. Though the value decreases when the real receive intensity is over the certain value by AGC's function, that is to say, AGC reduces the gain of signal which is input to amplifier. The value range of AGC voltage value is from 500 to 1,023.

III. Characteristic of Variable Data from URG

In this chapter, the investigation result of characteristic of received intensity and AGC voltage value is described.

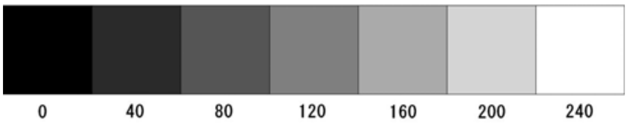

Fig. 3 Samples of Lightness

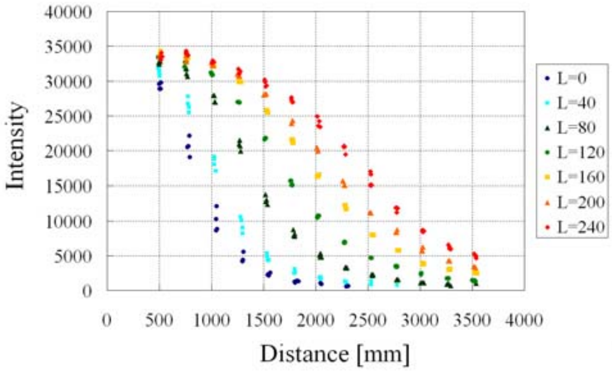

Fig. 4 Distance vs Intensity

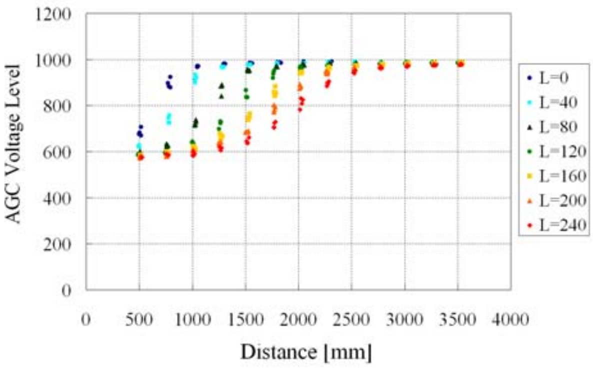

Fig. 5 Distance vs AGC Voltage Level

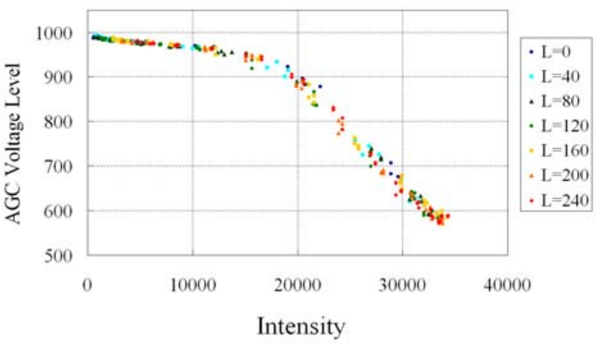

Fig. 6 Intensity vs AGC Voltage Level

Firstly a sheet of paper to which seven colors are printed is prepared as measured object (Fig.3). These colors are made as below. Lightness value of HLS color spaces was changed from 0 to 240 in spaces of 40 keeping Hue and Saturation as zero. Here, the lightness has similar mean to reflected intensity. Thus to recognize the lightness from received intensity is one of this work's goal. Then

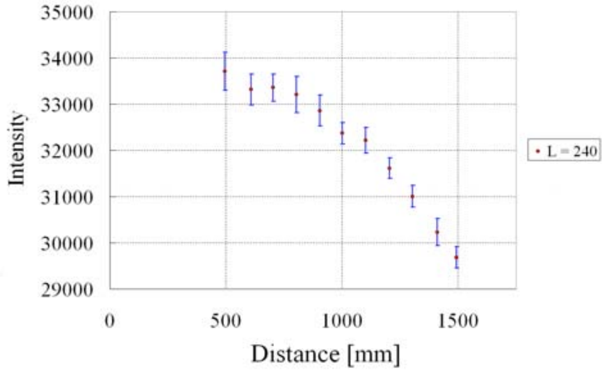

Fig. 7 Distance vs Intensity with s.d.

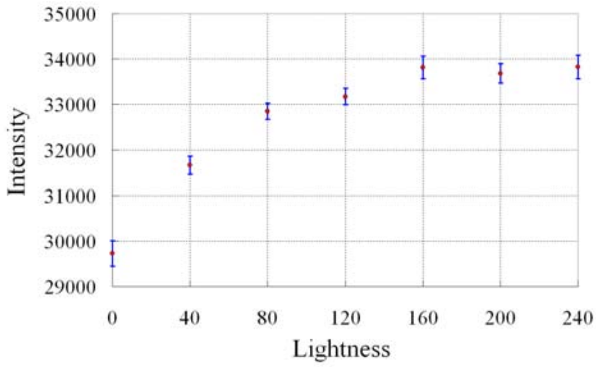

Fig. 8 Lightness vs Intensity at dist. = 500 mm

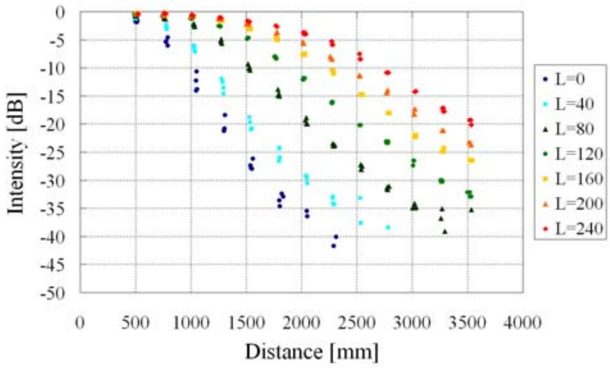

Fig. 9 Distance vs Intensity [dB]

three data (distance, received intensity and AGC voltage) were measured four times at each position with changing the distance between URG and the object. Here, transmit system and receive system are completely separated in the optical system of URG. As a result, reflected light is hard to be received when the object is close to URG. Therefore the changing distance was done each 250mm from 500mm to 3,500mm. Furthermore the object is set as an entrance angle of transmitted laser is 0 degree. This investigation was done for every seven colors.

Fig.4, Fig.5 and Fig.6 show the results. Fig.4 shows the relation between distance and intensity, Fig.5 shows the relation between distance and AGC voltage and Fig.6 shows the relation between intensity and AGC voltage. As

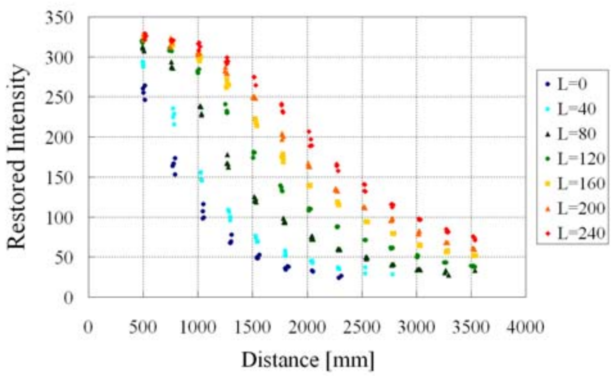

Fig. 10 Distance vs Restored Intensity

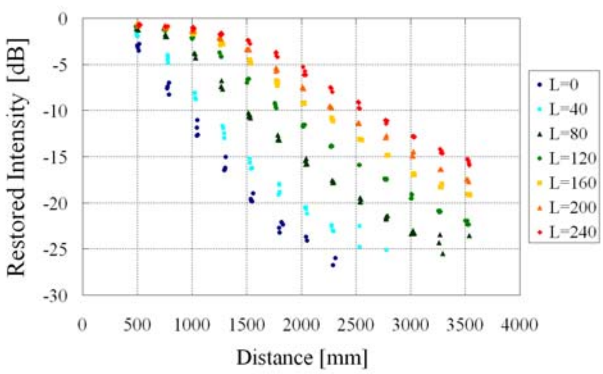

Fig. 11 Distance vs Restored Intensity [dB]

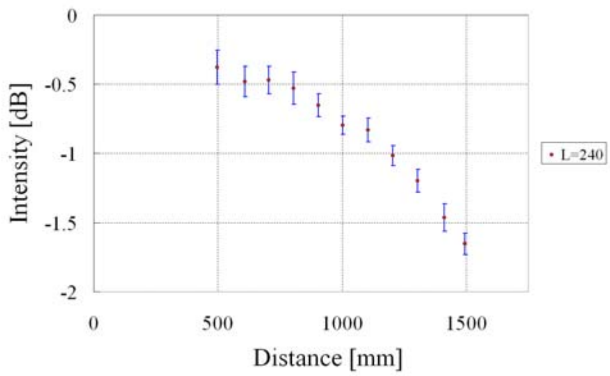

Fig. 12 Distance vs Intensity [dB] with s.d.

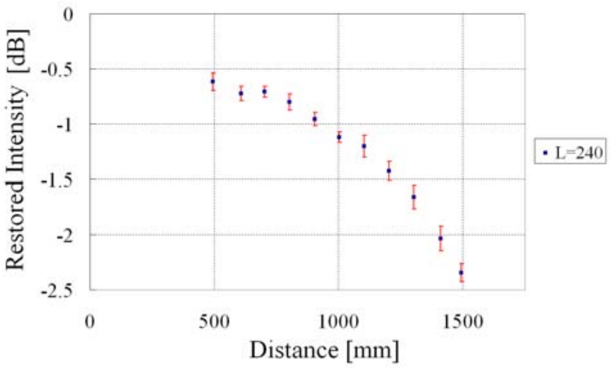

Fig. 13 Distance vs Restored Intensity [dB] with s.d.

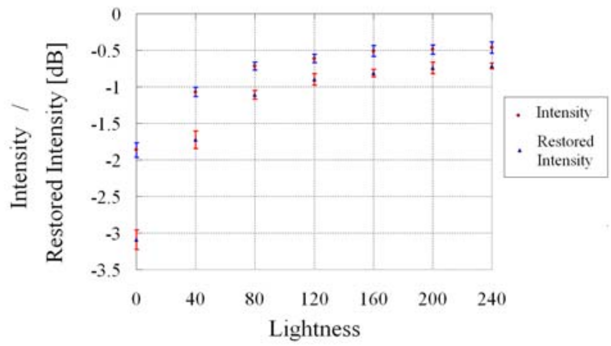

Fig. 14 Lightness vs Intensity / Restored Intensity [dB] at dist. = 500 mm

mentioned in previous chapter, AGC voltage value becomes lower when intensity value exceeds certain threshold.

In Fig.4, it seems that received intensity data in case of L=240 from 500mm to 1,500mm are similar and hard to be found their difference. To verify that, more detail data was measured, that is, standard deviation (σ) of received intensity value was calculated by changing measured distance each 100mm from 500mm to 1,500mm. As a result, Fig.7 was obtained. In this figure, each plots indicate average of received intensity and each top [lower] of the bars are +σ [-σ]. Then Fig.8 shows that the relation between Lightness and received intensity at the point measurement distance is 500mm. This figure also includes standard deviation.

Each sensor's maximum value of received intensity is different from one of each other. Then, to signify the value of received intensity, decibel was considered for normalization. In case of URG which was used in this work, 35,000 is its maximum value of received intensity and was set as reference level. Fig.9 shows Intensity of Fig.4 was re-expressed by decibel.

These figures indicate that every value of received intensity in case that Lightness of object is high and measured distance is near, are similar to max value. That means it is very hard to estimate object's Lightness from received intensity and distance.

IV. Estimation of Intensity

A. Restored intensity

From the results obtained in previous chapter, it was clear that to remove the influence of AGC from received intensity which URG output was important process to estimate reflected intensity. The principle for measuring distance of URG is AM phase-differencing. Therefore amplitude of received laser signal is output as received intensity. However, its value itself is not original amplitude, but the second power of the original. AGC voltage value is output from 10-bit Ad converter, so its max range is 1,023.

Finally, the following expression was defined to calculate estimated original received intensity (restored intensity).

$$Ir = \frac{\sqrt{Io}}{Va/1023} \qquad (1)$$

Here,

Io : received intensity

Ir : restored intensity

Va : AGC voltage

B. Evaluation

Experiments were conducted to evaluate the proposed expression. Restored intensity was calculated from received intensity in Fig.4 and Fig.9. These results are shown in Fig.10 and Fig.11. In Fig.11, reference level for decibel was set to 350. From these figures, it seems that synthetic linearity of relation between distance and intensity was improved

Fig.12 shows the same relation as in Fig.7 but transforming the received intensity from original data to decibel. Then Fig.13 shows the case of restored intensity of Fig.12. From these figures, it can be seen that standard deviation was also improved. This suggests that reliability of received intensity to difference of distance was also improved.

Fig.14 shows the relation between lightness and received intensity which are same used in Fig.8. The figure also indicates the case of restored intensity. As this figure shows, the restored process makes the difference of received intensity more distinct, and recognizing the difference of lightness easier.

V. CONCLUSION

In this paper, the method for estimating lightness of objects which is detected using on URG-04LX was discussed. Intensity data were obtained from URG, though the value is not reflected one but received one. Moreover the output received intensity data was not the original received intensity data.

Firstly, we investigated and cleared the characteristics of some parameters. Then a method to estimate original received intensity was proposed. Finally the method's validity was confirmed by evaluation.

As future works, we will consider more suitable method for estimate received intensity.

REFERENCES

[1] Marc Rioux, J. Angelo Beraldin, M. S. O'Sullivan, and L. Cournoyer, "Eye-safe laser scanner for range imaging," Appl. Opt. 30, 2219-2223. (1991)

[2] Jafar Amiri Parian, Armin Gruen:" INTEGRATED LASER SCANNER AND INTENSITY IMAGE CALIBRATION AND ACCURACY ASSESSMENT," ISPRS WG III/3, III/4, V/3 Workshop "Laser scanning 2005",, (Sep. 2005)

[3] Devrim AKCA:" FULL AUTOMATIC REGISTRATION OF LASER SCANNER POINT CLOUDS," Optical 3-D Measurement Techniques VI, pp.330-337(Sep. 2003)

[4] Yoshitaka Hara, Hirohiko Kawata, Akihisa Ohya and Shin'ichi Yuta: "Mobile Robot Localization and Mapping by Scan Matching using Laser Reflection Intensity of the SOKUIKI Sensor", IECON'06 The 32nd Annual Conference of the IEEE Industrial Electronics Society Proceedings, pp.3018-3023 (Nov. 2006)

[5] Hokuyo Automatic Co., Ltd. http://www.hokuyo-aut.jp/

[6] Hirohiko Kawata, Wagle Santosh, Toshihiro Mori, Akihisa Ohya and Shin'ichi Yuta: "Development of ultra-small lightweight optical range sensor system", Proceedings 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp.3277-3282 (Aug. 2005).