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Mathematical Approach for the Removal of Specular Reflection of Laser RangeFinder

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Abstract— **In order to make autonomous machines or robots it is very essential to measure the distance of neighboring objects. There are various types of errors which occurred while measuring the distance. In this paper we have focused on specular reflection error which occurs in the case of distance measurement using lasers. In this paper presents a mathematical approach for the removal of specular refraction of Hokuyo UBG-04LX-F01 Laser Rangefinder when a laser beam incident on a highly refractive material like mirror at an angle 90^0.When a laser beam strike on a highly refractive material the laser rangefinder always shows a variation in the measurement i.e. wrong reading. The experiment result shows that the measurement error can be strongly removed by this approach.**

Keywords-component; Hokuyo UBG-041LX-F01; Specular Reflection; Range Finder

I. INTRODUCTION

The distance measurement system in 2-D and 3-D environment is essential to develop an autonomous mobile robot [1-2, 4]. The laser rangefinder (LRF) is a good choice for acquiring the accurate distance to an obstacle. The LRF provides an accurate range with high angular resolution over a long distance rather than infrared rangefinder investigated by Alwan et al.[1].however the LRF considered a major limitation that is Specular refraction. It's generally occur when a highly refractive material put in front of a laser beam due to its refractive nature the laser beam diverts in another direction. This can be removed by this approach very easily.

Hokuyo LRFs Since there is no research on the error comes during the measured data by UBG for practical use. Some LRFs as Hokuyo UBG-04LX-F01(UBG) and URG-04LX(URG) shown in Fig. 1,use the phase shift measurement principle to detect the distance to a target. The characteristics and the calibration model of URG were proposed by Okubo et al [3, 5].

UBG is the new and small LRF produced by Hokuyo Automatic Co. Ltd. And it has improved specification compared to the earlier Hokuyo LRFs. Since there is no research on the error comes during the measured data by UBG for practical use.

Fig. 1: Hokuyo UBG-04LX-F01

II. OVERVIEW OF THE HOKUYO UBG-041LX-F01

Firstly, the man specification of the UBG and URG are the compared in Table 1.Some specifications of the URG and UBG is the same, but the main difference between them is scan, frequency, external dimensions, weight and power source. Although UBG is slightly larger and heavier, it has fast scan frequency to detect the shape of the target in a short time.

The distance measurement system with LRF [2] is the fast and cost efficient solution when the accurate distance to a target is required for a robot UBG consist of a laser diode, a photo diode, a mirror, a lenses and an actuator. The actuator rotates the mirror and the lens with the speed of 2140 rpm, due to the rotation period of 28 ms and the photo diode measure 682 steps on the 240 per one rotation and therefore the angular resolution is 0.352^0 .Note that the minimum measured distance is 20 mm and the data, less than 20, are error code resulting from certain circumstances.

TABLE 1. Specifications of the Laser range finder

S.No	specification	URG-04LX UBG-04Lx-F01
1	Measured distance	20-5600mm
2	Measurement resolution	1mm
3	Measurement error	Up to 1m: +/- 10mm
4	Scanning angle	240^0
5	Angle resolution	0.36^0
6	Scan frequency	100hz 36hz
7	External dimension	50x50x70mm 60x75x60mm
8	Power source	DC 5V DC 12V

III. SPECULAR REFLECTION

Specular reflection is the mirror-like reflection of light (or of other kinds of wave) from a surface, in which light from a single incoming direction is reflected into a single outgoing direction, for this we placed a mirror in front of the laser scanner at the distance of 2000mm and note down the few reading at the same position and get the result on the graph as shown in fig.2

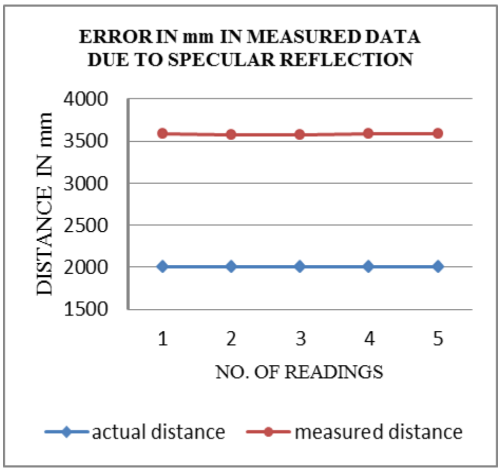

Fig. 2: Error Measured

As shown in fig.2, the measured data consist of errors. The actual distance is 2000mm but when we measured with the LRF it shows the reading more than 3500mm, hence it shows the error more than 1500mm. This error is due to specular reflection. When laser ray falls on the plane mirror is gets reflected and we get error in the measured readings. In this paper we use a mathematical approach for removing this error. Fig.3 shows how the laser ray reflected when it falls on the reflected surface.

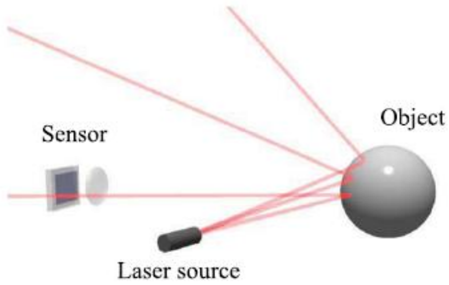

Fig. 3: Reflection of the laser Ray from Reflected surface

IV. EXPERIMENTAL SETUP

As shown in fig 4. The experiment consist of a LRF, 3 mirror, sliding arrangement for the sliding of two mirror at an angle 45^0 .mirror 1 and 2 are fixed on a sliding arrangement to move them at 45^0 w.r.t. LRF. Mirror 1 is the obstacle in front of LRF .the distance between them is unknown; we have to measure the distance between them. If we placed a non-refractive obstacle in front of LFR it shows the actual distance but if we placed a refractive material the LRF will show variation in reading that is error. X is the actual distance that has to be measured by using laser rangefinder.

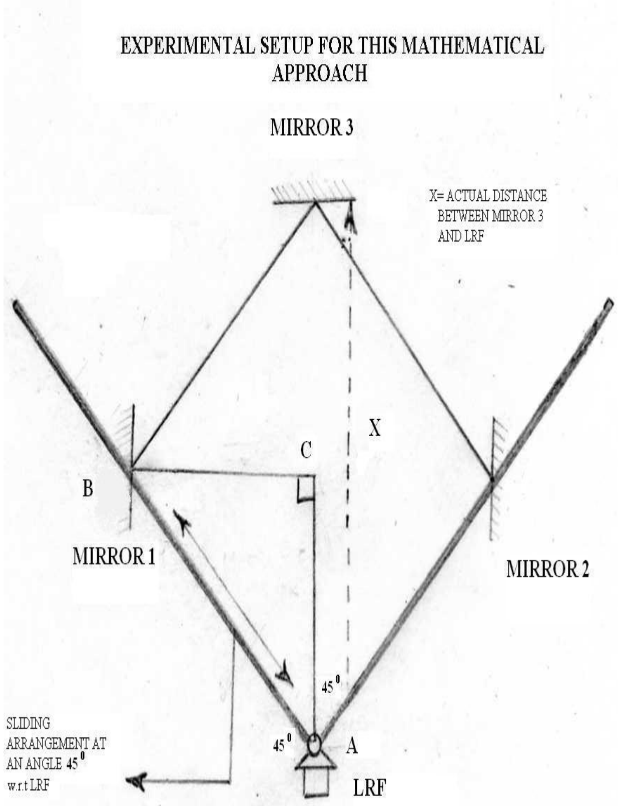

Fig. 4: Experimental Setup for the range finder

A. Communication Interface

To connect the sensor with a host computer, both USB and the RS-232 are provided. The maximum transfer of USB interface is 9mbps and the maximum transfer rate of RS-232 varies from 115.2Kbps to 750 Kbps.

To transfer the measured data to a host computer, two transfer protocols SCIP 1.1 and SCIP 2.0 are available. Since SCIP 2.0 supports more functions to improve the performance of the sensor, it is preferable .therefore SCIP 2.0 and the USB is selected in this paper for measured distance to a target

B. Drift Effect of the Sensor

Drift effect is known characteristic of the LRF and it has a different name as “warm up time”. In order to observe the drift effect, the distance of a white colored target, which is at 2000 mm in front of the sensor, was performed for approximately two hour and result is seen in the Fig. 5 as the time goes on, the measured distance is decreasing during the first 40 minutes, then stabilizes, this phenomenon is called the drift effect.

V. REMOVING OF SPECULAR REFLECTION

In this section, we will present the experiment result and the approach for removing the error. First of all the mirror 3 is placed in front of the laser rangefinder at an unknown distance and the two mirror 1& 2 is at on the sliding arrangement at angle 45^0.Now selected the laser beam which incident on the mirror 1 at an angle 45^0.

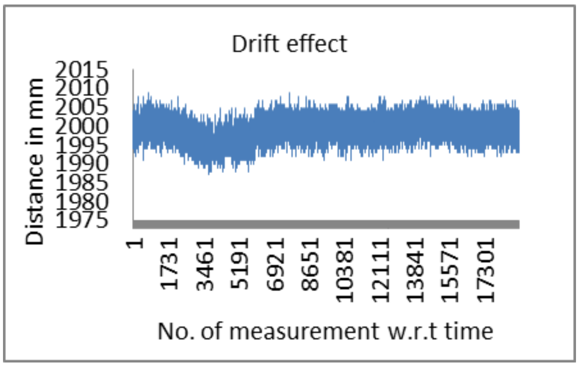

Fig. 5: Figure showing the drift effect of sensor

now slide the mirror 1 and 2 on the sliding arrangement parallel .When the obstacle is not in the path of the laser beam the LRF shown reading more than 4 meter that is wrong, now when we slide the mirror 1 &2 ,then we reach a point when the laser beam strike the mirror 3 at an angle 45^0 .As we know that laser light has a property that is angle of incident is always equal to angle of reflection.

This property is used in this mathematical approach so when the laser beam strike the mirror 3 at angle 45^0 it also reflect as the same angle that is 45^0 .when it strike at mirror 3 it again reflect at an angle 45^0 and strike on the mirror 2. Mirror 2 is positioned in that way that it reflect the laser beam at an angle 45^0 finally it reached the LRF hence it cover the distance 4 time the distance between LRF and mirror 2.

Now divide the measured reading by 4 we get the distance between mirror 2 and the LRF that is AB .now we have to find the distance BC that is half of the distance between mirror 2 & 3 for this we have to multiply the distance between the mirror 2 and the LRF that is AB by 0.7 that is (AB*2) where 0.7 is a constant, from here we get the distance between BC. As shown in diagram a right angle triangle ABC is formed. We have the value AB and BC from the previous measurements and we have to find the distance between CA. This can be calculated by using phythagorous theorem.

$$(\text{Hypotenuse})^2 = (\text{base})^2 + (\text{perpendicular})^2 \quad \text{----} \quad (1)$$

$$(AB)^2 = (AC)^2 + (BC)^2$$

We have the value of AB and BC (as shown in the figure 2).

By using the above equation (1), we can find out the AC .now multiply the AC with 2 that is (AC* 2) that will give the actual distance X that is between the mirror 3 and the LRF that is required.

VI. CONCLUSION

In this paper, the Hokuyo UBG-04LX-F01 is studied and the specular reflection is removed by using a mathematical approach. UBG can measure the distance up to 5600mm, however if we placed a highly refractive material in front of it will give error in the measurement but by using this approach we can easily get the actual distance for an highly refracted surface which is put in front of a LRF.

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