Characterization of Neato Lidar

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I. ABSTRACT

The Light Detection and Rangings (Lidars) are very useful sensors in many robotic applications. The problem is that the price of these sensors are quite expensive. A cheap version of these sensors is the Neato[1] Lidar. In this report we will present different experiments that had been done to characterize this device. Also discuss the possibilities that can be done to improve its performance in the robotics applications.

II. INTRODUCTION

Neato Lidar is a low cost 360 degree 2D laser scanner. The system can perform 360 degree scan within 6 meter range. The produced 2D point cloud data can be used in mapping, localization and object/environment modelling. It's scanning frequency reached 5.5 Hz when sampling 360 points each round and it can be configured up to 10 Hz maximum. It is basically a laser triangulation measurement system. It can work in indoor environment and outdoor environment without sunlight. It emits infra-red laser signal and the laser signal is then reflected by the object to be detected. Distance to an object is measured by the angle of the reflected light. Fig. 1 shows a simplified diagram of the triangulation method. There is no accurate information about the camera, however, reverse engineers believe that the camera has 2080 pixels of resolution. Each pixel is $4\mu m \times 4\mu m$, it is expected to be able to resolve the laser dot to within 0.1 pixel using the centroid algorithm [1]. It measures the distance x between the dotted line that is parallel to the laser beam and the ray reflected from the object. The similarity between the big and small triangles gives the equation

$$\frac{q}{s} = \frac{f}{x} \tag{1}$$

where q is the perpendicular distance to the object, s and f are constants from the geometry of the Lidar and x is the distance returned by the camera. It is clear from (1) that x is inversely proportional to q. The range sensitivity $\frac{dq}{dx}$ grows quadratically with distance q

$$\frac{dq}{dx} = \frac{q^2}{fs} \tag{2}$$

Longer distances are measured by few pixels in the camera while smaller distances are measured by tens of pixels, therefore, the resolution for short distances is much higher than the resolution for long distances.
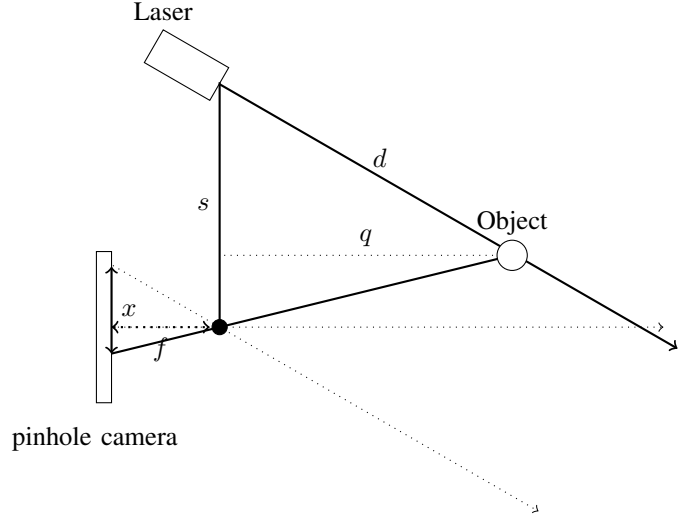
[1]Neato Robotics, Inc. https://www.neatorobotics.com/company/

Fig. 1. A simplified diagram of the triangulation method.

III. SOME PROBABLE SOURCES OF ERROR

A. Laser and lens pointing angles

Low-cost laser modules have typical pointing accuracies of at best 6 degrees. The physical linkage between lens elements, camera, laser, and laser optics must be rigid and have low thermal distortion. Any relative movement of the chassis that causes the laser dot to deviate more than a fraction of a micron can cause large distance errors, especially at larger distances.

B. Lens distortion

For a low-cost 16mm lens, the distortion will be at least a few percent at the edge of field, even when optimizing for a single wavelength. This is enough to be the major error in distant readings, and must be compensated.

C. Laser dot localization on the sensor

To reduce errors at larger distances, the image of the laser dot must be localized to sub-pixel precision. A simple centroid algorithm were used for localization [1]. First, the rows in 10-pixel horizontal band are summed. The resultant line image is then differentiated and smoothed, and the center of the dot is found using the maximum value. A better sub-pixel localization can be achieved using more advanced techniques.

Saturation

An interesting phenomenon is that the errors do not go down very much below 0.5 meter. This is because the apparent size of the laser dot grows, and more pixels become saturated at closer distances. Thus, it is more difficult to localize the dot accurately.

IV. THE EXPERIMENTS

A. Device warming-up

Fig. 2 shows the recorded measurements for a target fixed at 2 meters. The measurements recorded for about 1 hour. Both the recorded distance and recorded intensity are stabilizing after about 2000 seconds. These changes could be due to the temperature effect.
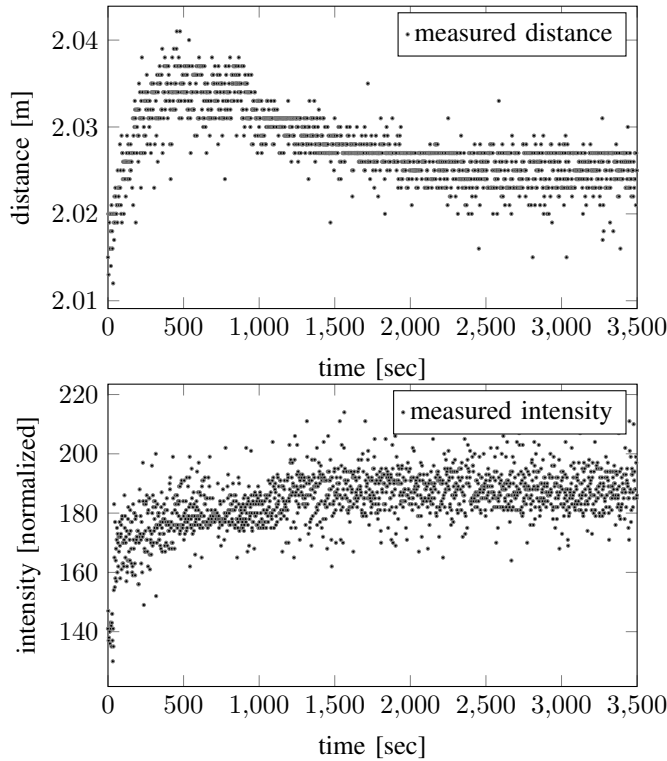

Fig. 2. Device warm-up effect on the measured distance and the measured reflected laser intensity.

B. Distance error

The distance error curve is shown in Fig. 4. We did three different experiments in different places and during different day time. In each experiment the same target was used. we move the target along the detection range from 0 to 3 meters in 20cm step. We noticed that the probability of detection for the target is decreasing greatly for distances longer than 3 meters. Negative distance error means that the measured value is larger than the actual value.

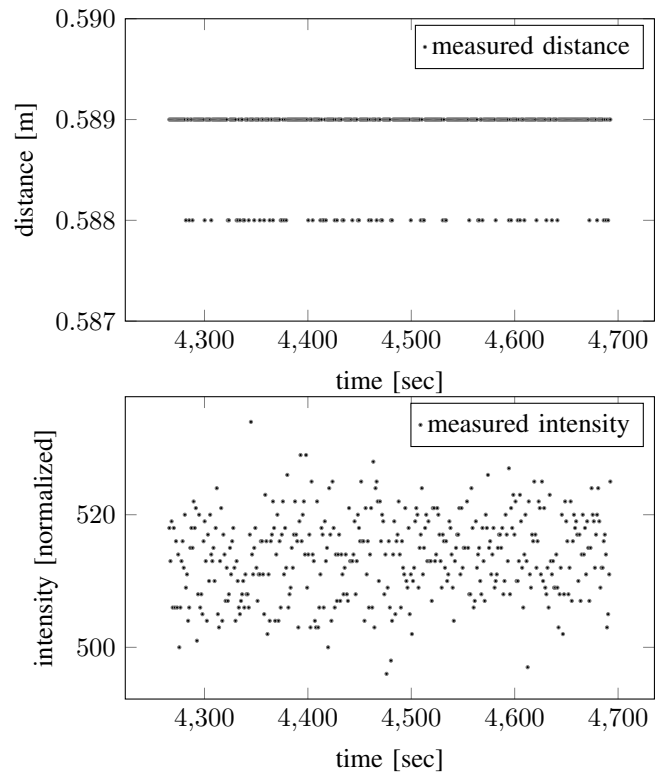$$distance\ error = actual\ distance - measured\ distance \tag{3}$$

Fig. 3. Device warm-up effect on the measured distance and the measured reflected laser intensity for 0.6 meter target distance.

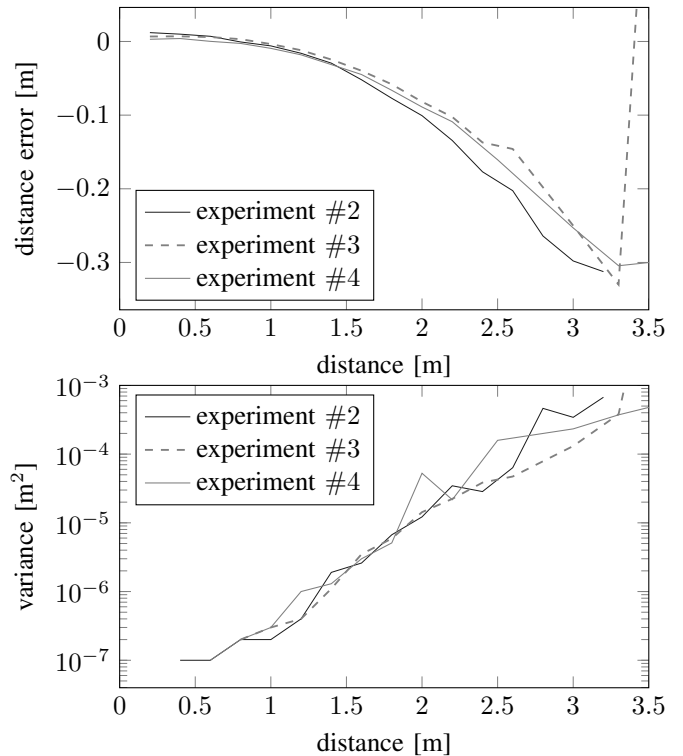

Fig. 4. Distance error mean and variance verses distance for three independent experiments.

C. Measurements variance and intensity

The box-plot for the distance error and the intensity is shown in Fig. 5 for three different targets for both 1 meter and 2 meters distances. We noticed that there is a direct relation between the intensity and distance error. Also there is inverse relation between the error variance and the measured intensity. Finally, these relations become more clear at longer distances.
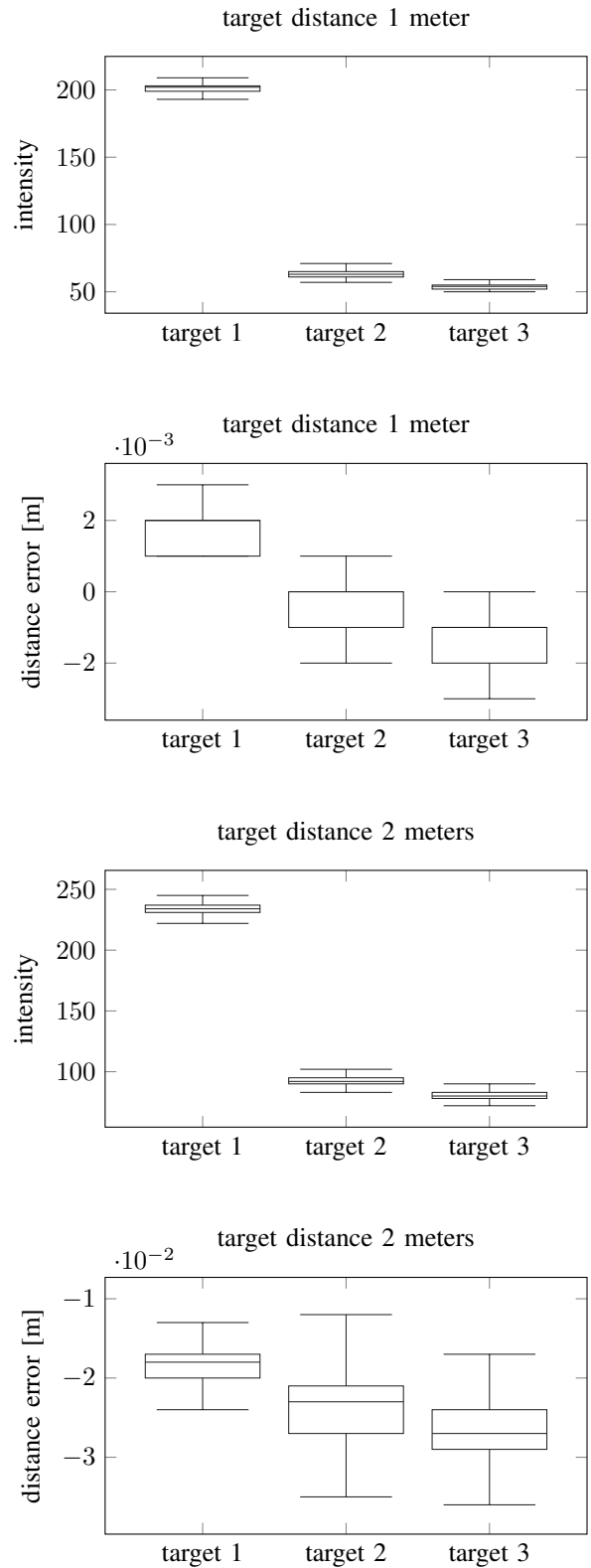
Fig. 5. The intensity and distance error box-plots for three different targets.

V. Research Questions

1) The noise variance is not fixed and increasing non-linearly with the distance. The same thing with the measurement bias. Can we propose a calibration or linearisation procedure to get the best performance from the device.
2) Is it possible to do warm-up (or temperature) compensation ? and how much it will be useful?
3) A very clear problem is the missing measurement or maybe a false measurement especially at longer distances. Is it possible to detect and remove these measurements?
4) It is more accurate (has law variance) for distances between 0.2m and 1.2m which makes it not very useful for fast moving platforms (like quad-rotor for example). Is it possible to make it more useful for such applications?
5) Specifying the robot mapping and localization applications, Is it possible to optimize the device to give the best possible performance in the application?

References

[1] K. Konolige, J. Augenbraun, N. Donaldson, C. Fiebig, and P. Shah, "A low-cost laser distance sensor," in *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*. IEEE, 2008, pp. 3002–3008.