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THE EVALUATION OF HOKUYO URG-04LX-UG01 LASER RANGE FINDER DATA

J. Krejsa [*], S Vechet[*]

Abstract: *Laser range finders are essential sensors in mobile robot navigation tasks, such as robot localization, or simultaneous localization and mapping. As the probabilistic approach is commonly used to fuse the robot motion model with sensor data, the knowledge of the sensor parameters, such as linearity, variance, etc. is essential for fusing algorithms to perform correctly. This paper presents the results of extensive tests on performance of Hokuyo URG-04LX-UG01 range finder, that becomes nowadays popular among robot designers due to its reasonable cost, compact dimensions and low weight. The influence of obstacle color, error distribution and offset drift are examined.*

Keywords: Laser range finder, Mobile robot, Localization.

1. Introduction

There are several essential issues in mobile robot navigation task, such as localization and simultaneous localization and mapping (SLAM). While sensors based on various physical principles can be used as environment description measurement component for fusion of robot dynamic model with such data (Krejsa, 2010), the direct determination of the distances from surrounding obstacles is necessary to handle the obstacle detection and avoidance issue. Moreover, the scan matching based techniques (Vechet, 2007) and most of SLAM algorithms are solely based on laser range finder observations. To correctly utilize measured distances in fusion algorithms, it is necessary to know the properties of the sensor in order to identify its probability model.

There are two major types of laser range finders (LRF) differing in measurement principle. The first one, represented by SICK LMS200 sensor (Ye, 2002), is based on time-of-flight principle. This type of LRF intended for larger outdoor robots is hard to beat in terms of precision and reliability. However, the second group, based on phase shift measurement principle, is much more suitable for most indoor robots, as compact dimensions, low weight and low power consumption can be reached. Hokuyo URG-04LX-UG01 sensor by Hokuyo, Japan (see Fig. 1-left), is currently the most wide spread representative of such a sensor mainly due to its low cost.

2. Sensor evaluation

Hokuyo URG-04LX-UG01 sensor (Hokuyo Automatic) specifications are given in Tab. 1. The sensor has combined power source and communication interface through USB. It is intended for indoor use, due to its compact dimensions it is ideal for smaller autonomous robots navigating in office spaces, hospitals, etc. The example of LRF sensor mounted on mobile robot Breach by Bender Robotics is given in Fig. 1. The evaluation of the sensor was therefore performed on surfaces that are typical for environments the robots equipped with the sensor are likely to be used, in particular the painted walls and highly reflective metal and plastic panels.

The sensor was mounted on a linear drive enabling to change the distance between the sensor and obstacle in the range of 250 – 4000 mm. Scan frequency used was 10 Hz, the maximum the sensor allows. Only a single beam measurement located in the axis of the sensor and thus perpendicular to the

[*] Assoc. Prof. Jiri Krejsa, PhD., Assoc. Prof. Stanislav Vechet, PhD.: Institute of Thermomechanics AS CR, v.v.i., Technicka 2, 616 69, Brno, Czech Republic, krejsa@fme.vutbr.cz, vechet.s@fme.vutb.cz

obstacle was taken into account and analyzed. First the stability of the measurement was evaluated (see below), followed by the influence of measured distance and materials the obstacles are made of.

Tab. 1: Sensor data sheet specifications.

Variable	**Value (range), unit**
Measuring distance	20 – 5600 mm
Angular range	240 degrees
Distance resolution	1 mm
Angular resolution	0.36 degree
Scan frequency	10 Hz
Dimensions	50 x 50 x 70 mm
Weight	160 g

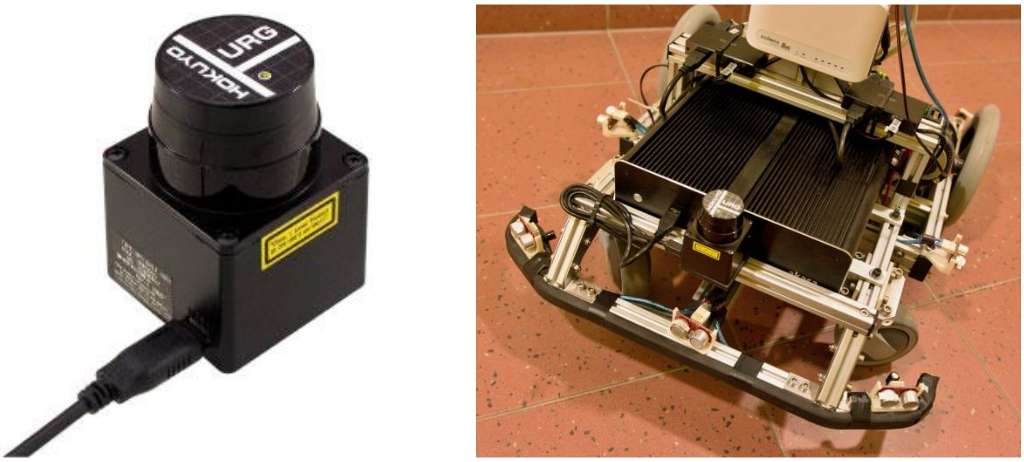

Fig. 1: Hokuyo URG-04LX-UG01 scanner (left), scanner mounted on Breach mobile robot (right).

2.1. “Warm-up” mean drift

Time stability of the measurement is the key factor. The scanner of ambient room temperature was positioned into the distance of 1000 mm from the white painted wall and measurement was performed for 2 hours. The results are shown in Fig. 2, the raw measurement values together with the filtered data calculated by floating average filter with the length of 1000 samples, that corresponds to 100 seconds. One can see obvious drift of the mean, it takes about 50 minutes for the readings to become stable. As the only factor that changes during the test is the temperature, another experiment was evaluated, with the scanner precooled to 0 °C prior to the measurement. The results are shown in Fig. 2-right. One can see, that the dependency on sensor internal temperature is a complex process, as the measured distance for the cooled sensor starts as far as 20 mm below the nominal value, rises and then follows the previous experiment course.

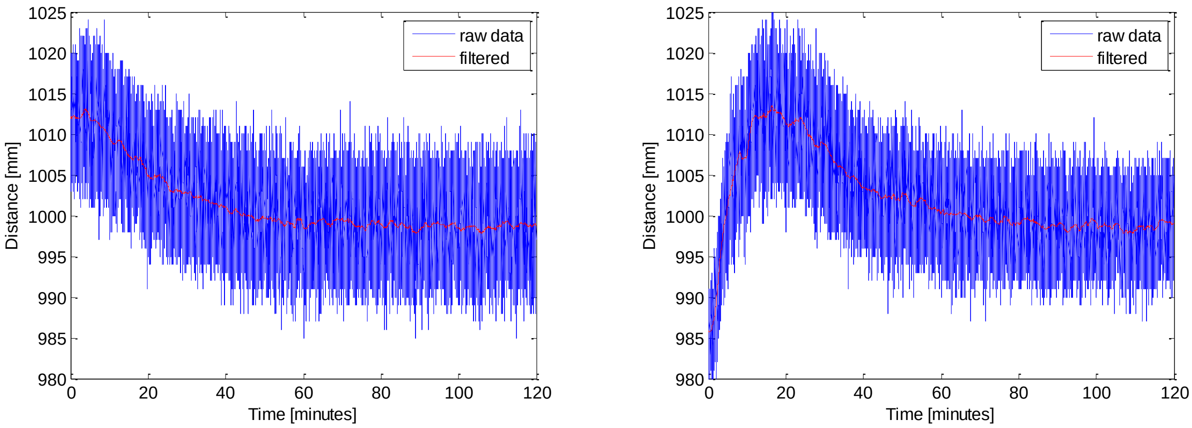

Fig. 2: Mean “warm up” drift. Room temperature scanner (left), scanner cooled to 0 °C (right).

2.2. Measured distance related errors and variations

The consistency of measurement along measured distance was tested with following setup. The sensor was positioned against the white wall in defined set of distances in the range of 250 – 4000 mm and data was collected for 30 seconds (300 samples). The mean error and standard deviations are shown in Fig. 3. One can see that standard deviations are about the same in the whole range of measurement, the error of the mean does not exhibit relation to the distance measured. All the measurements were obtained using sensor that was warmed up for 60 minutes prior to the test. The same holds for all further measurements.

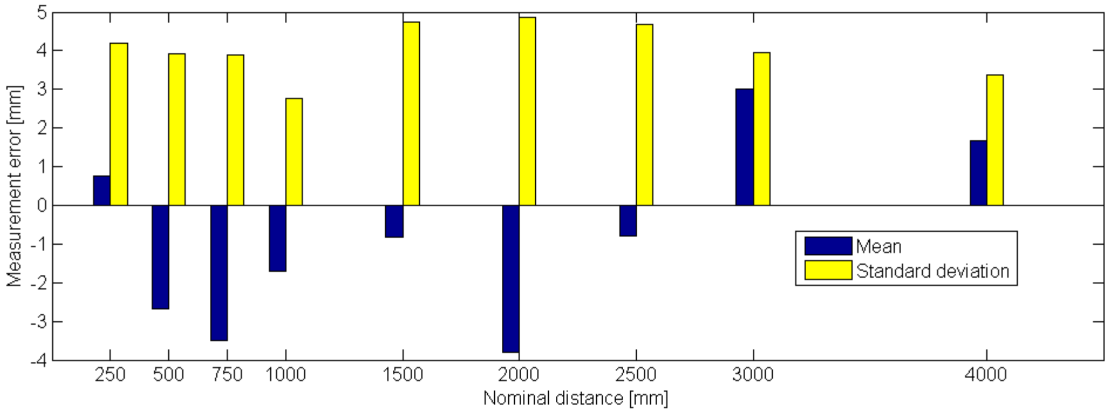

Fig. 3: Linearity test results, mean error and standard deviation of measured data.

2.2. Sensor manufacturing differences

The repeatability of the measurement when using different sensor units of the same type was tested. Three units were available with different manufacturing date (sensor A - 2013, sensor B - 2015 and sensor C - 2016). The tests were performed in following manner. Value of 1000 mm was selected as nominal distance. The sensor was positioned against the white painted wall and data were measured for 500 seconds (5000 samples). The experiment was repeated under the same conditions for all three sensor units. The results are shown in Fig. 4. The normal distribution of the measurement noise is apparent from the measurements, however, one can see that there are significant differences in mean, with older sensors giving smaller values. Whether it is caused by sensor degradation in time is yet unknown, larger set of sensors is currently being collected.

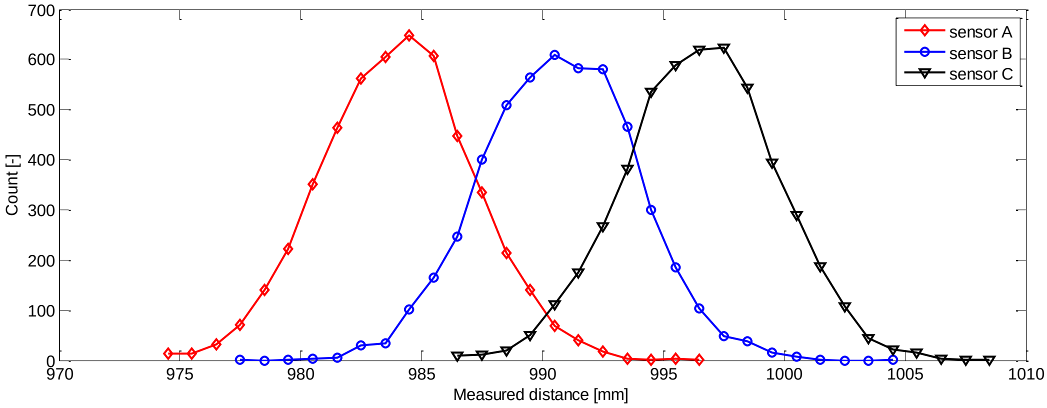

Fig. 4: Measurement of different sensor units.

2.3. Obstacle color and material

The influence of obstacle color and material was tested in following manner. Value of 1000 mm was selected as nominal distance. The sensor was positioned against the wall and data were measured for 50 seconds (500 samples). The experiment was repeated for several wall colors and materials, with the emphasis on reflexive materials commonly available in office spaces where the robot equipped with the sensor is intended to be used. The results are shown in Fig. 5. One can see that the variance of measurements is substantial. The difference in mean between the green and red painted walls is 11.5 mm.

The influence of material gives interesting results, note in Fig. 5 that the measurements for aluminum and reflexive foil are almost identical, while the stainless steel measurement is not too different from the white painted wall. The reason is yet to be found.

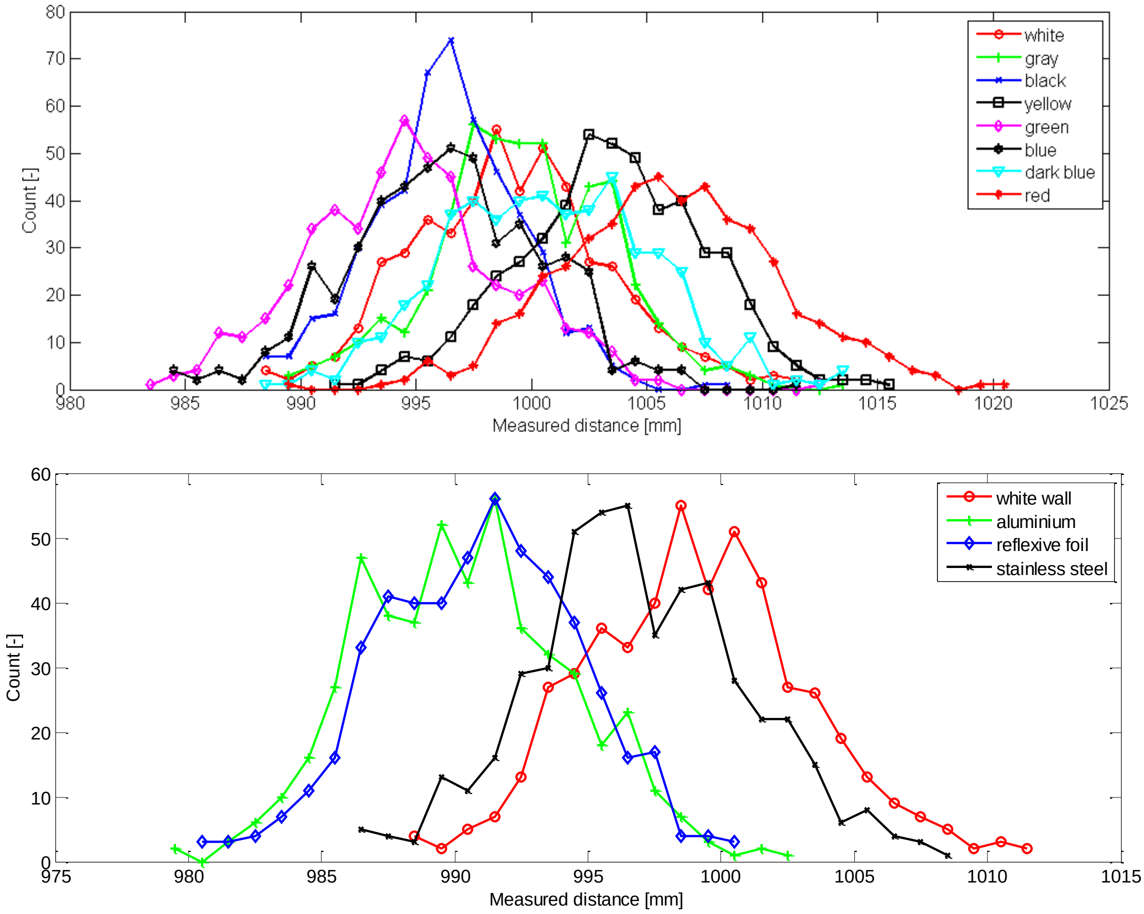

Fig. 5: Influence of obstacle color (top) and material (bottom).

3. Conclusions

Number of experiments was performed with the Hokuyo URG scanner. Mean drift was observed that is dependent on the initial sensor temperature. Measured distances errors are not influenced by the actual distance of the obstacle both in terms of mean and variance. Repeated measurements proved the normal distribution of the measured distance. The influence of obstacle color and material is significant.

Acknowledgement

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