Feasibility analysis for the use of Light Detection and Ranging Scanners in rooms with high energy ionization

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Abstract

The objective of this study is to explore the feasibility in using a Laser Imaging Detection and Ranging Scanners (LIDAR Scanners) implemented in a mobile robot to perform mappings of rooms with high energy ionizing radiation present. Usually when building a robot whit Simultaneous Localization and Mapping (SLAM), complex scanners as global positioning systems (GPS) or inertial measurement units (IMU) are commonly used, however these scanners are useful in outdoor environments, for indoor places the most used election are the LIDARs, for this reason the present analysis is made. Through the use of a commercial LIDAR, the SLAMTEC RPLIDAR – A2, connected to a raspberry pi 3b + with UBUNTU and Robot Operating System (ROS) installed on it, a geometric configuration was made using the LIDAR and a known barrier at a distance of one and a half meter between the two, thirty measurements were made, five without ionizing radiation present in the treatment room and twenty-five with the most common photon and electron beams used for day-to-day clinical practice, later, the different measurements thrown by ROS were evaluated and compared in the graphic interface and in the numerical matrix. Experimental results show a difference of less than 5 millimeter only in 1% of the whole evaluated points in the numerical matrix this in the measurements with the same room conditions. The results of comparing the measurements between the room without ionizing radiation present and the same room with a photon beam present, shows a difference of less than 15 millimeters only in 2.5% of the whole evaluated points in the numerical matrix. Finally, the results of comparing the measurements between the room without ionizing radiation present and the same room with an electron beam present, shows a difference of less than 10 millimeters only in 1% of the whole evaluated points in the numerical matrix.

Keywords: Light Detection, Ranging Scanners, Ionizing radiation present, SLAM on mobile Robots.

Resumen

El objetivo de este estudio es explorar la viabilidad del uso de escáneres de rango y detección de imágenes láser (escáneres LIDAR) implementados en un robot móvil para realizar mapeos de habitaciones con radiación ionizante de alta energía presente. Por lo general, cuando se construye un robot con localización y mapeo simultáneo (SLAM), comúnmente se usan escáneres complejos como sistemas de posicionamiento global (GPS) o unidades de medición inercial (IMU), sin embargo, estos escáneres son útiles en ambientes exteriores, para lugares interiores la elección más utilizada son los LIDAR, por ello se hace el presente análisis. Mediante el uso de un LIDAR comercial, el SLAMTEC RPLIDAR - A2, conectado a una *raspberry* pi 3b + con UBUNTU y *Robot Operating System* (ROS) instalado en él, se realizó una configuración geométrica utilizando el LIDAR y una barrera conocida a una distancia de metro y medio entre las dos se realizaron treinta mediciones, cinco sin radiación ionizante presente en la sala de tratamiento y veinticinco con los haces de fotones y electrones más habituales utilizados para la práctica clínica del día a día, posteriormente, las diferentes mediciones arrojadas por ROS fueron evaluadas y comparadas en la interfaz gráfica y en la matriz numérica. Los resultados experimentales muestran una diferencia de menos de 5 milímetros solo en el 1% del total de puntos evaluados en la matriz numérica esto en las mediciones con las mismas condiciones de la habitación. Los resultados de comparar las medidas entre la habitación sin radiación ionizante presente y la misma habitación con haz de fotones presente, muestra una diferencia de menos de 15 milímetros solo en el 2.5% del total de puntos evaluados en la matriz numérica. Finalmente, el resultado de comparar las medidas entre la habitación sin radiación ionizante presente y la misma habitación con haz de electrones presente, muestra una diferencia de menos de 10 milímetros solo en el 1% del total de puntos evaluados en la matriz numérica.

Palabras clave: Detección de luz, Escáneres de rango, Radiación ionizante presente, SLAM en robots móviles.

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I. INTRODUCTION

LIDAR is the acronym of Light Detection and Ranging, it is a laser system the allows us to measure the distance between a point of emission of a laser to an object or surface, the time it takes for the laser to reach and return from its target can be converted easily in the distance between bot [1].

LIDARs are commonly used for Simultaneous Localization and Mapping (SLAM) in mobile robots for many indoor and outdoor applications, the frequent use of this device in new and numerous mobile robot prototypes, makes it implementation viable [2].

The main characteristics that make a 2D LIDAR ideal for SLAM in mobile robot are: 1- Low noise problems, 2- Omnidirectional scanning of 360 degrees, 3- Laser range, 4- Simple generation of contour maps, 5- Possibility to choose between low cost or high cost devices, 6- mapping of numerous samples per second, 7- High measurement resolution (less than 0.5 millimeters) and 8- compatibility with many SLAM algorithms [3].

Radiotherapy treatment rooms are places with very specific characteristics, its walls can be up to meters in order not to let in or out electromagnetic waves [4, 5], for this reason the use of devices such as Global Positioning System (GPS) or inertial measurement units (IMU) are not possible, other characteristic of these rooms is that they are commonly found in isolated, tidy and object free facilities, which makes them a good environment for a mobile robot to walk through using a LIDAR for its SLAM.

The biggest problem about this treatment rooms is the high energy ionizing radiation is present most of the time, due to this, a search was made of the behavior of the LIDARs in presence of ionizing radiation in the specifications of the commercial and accessible manufacturers available on the market. Since the LIDAR manufacturers specifications do not specify anything about this behavior, the following study is carried out.

II. MATERIALS AND METHODS

A. Slamtec Rplidar A2

This lidar is a low cost lidar with the custom special parts and the carefully designed internal mechanical system, the RPLIDAR A2 keeps its excellent performance while cut the thickness to only 4 cm It is ideal for all kinds of mobile robot.

The core of RPLIDAR A2 runs clockwise to perform a 360 degrees omnidirectional laser range scanning for its surrounding environment and then generate an outline map for the environment.

The sample rate of LIDAR directly decides whether the robot can map quickly and accurately with a range radius of 18 m, RPLIDAR improves the internal optical design and algorithm system to make the sample rate up to 8000 times, it measures distance data 8000 times per second and also has an excellent performance in a long distance.

The RPLIDAR A2 system adopts the low power infrared laser light as its light source and drives it by using modulated pulse. The laser emits light in a very short time frame which can ensure its safety to human and pets. Table I, shows RPLIDAR A2 measurement performance [3, 6].

TABLE I. SLAMTEC RPLIDAR A2 measurement performance.

Item	*Unit*	*Min*	*Typical*	*Max*
Measurement range	Meter(s)	Not Applicable	0.15 – 12/18	Not Applicable
Angular Range	Degrees	Not Applicable	0 – 360	Not Applicable
Measurement resolution	mm	Not Applicable	<0.5	Not Applicable
Angular resolution	Degrees	0.45	0.9	1.35
Measurement frequency	Hz	2000	>4000	8000
Scan frequency	Hz	5	10	15

B. Linear accelerator Varian Vital beam

A Linear Accelerator (LINAC) is a medical device that accelerates electrically bound particles like electrons to produce high energy ionizing radiation beams to treat diseases like cancer [7].

To make this analysis we used a treatment room of the oncology hospital in “Centro Médico Nacional Siglo XXI” belonging to the “Instituto Mexicano del Seguro Social”, this treatment room has a VARIAN brand linear accelerator. This LINAC has two photon energies beams and five electrons energies beams. Table II shows the beams energies available in this treatment room [8, 9].

TABLE II. Beams energies available in treatment room.

Beam energy	Type
6 MV	Photons
10 MV	Photons
6 MeV	Electrons
9 MeV	Electrons
12 MeV	Electrons
15 MeV	Electrons
18 MeV	Electrons

C. Raspberry Pi 3 B+ and LCD Screen

Raspberry pi is a small single board computer usually used for porpoises like robotics or research project because of its low cost and portability, the specifications of this raspberry pi are shown in table III [10].

TABLE III. Beams energies available in treatment room.

Processor	Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
RAM	1GB LPDDR2 SDRAM
Wireless	2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
Ethernet	Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps)
I/O	Extended 40-pin GPIO header, Full-size HDMI, 4 USB 2.0 ports, 4-pole stereo output and composite video port.
Storage	Micro SD port for loading your operating system and storing data.
Power supply	5V/2.5A DC power input

For the correct control and reading of the LIDAR, SLAMTEC recommends the use of its packages in Robot Operating System (ROS) [11, 12], for this reason UBUNTU 15 was installed on the raspberry pi 3 b+. To display the interface of the operating system and ROS a 7-inch LCD screen was added to the raspberry pi 3 b+ [13].

To make the measurements more compact and simpler, we integrate the LIDAR, LDC and Raspberry into a module to be handled as a single piece; Figure 1 shows the module integrated.

Once the measurements have been made, the different results thrown by ROS were evaluated and compared in the graphic interface and in the numerical matrix [14, 6]. Figure 3 shows a frontal picture of the geometrical configuration made and figure 4 shows a side view of the same.

D. Geometric configuration and the measurements

A geometric configuration was made using the LIDAR and a known barrier at one and a half meter between the two, in the middle of them an ionizing radiation beam with different configurations is activated or deactivated. Figure 2 graphically shows the geometric configuration.

FIGURE 1. RPLIDAR A2 Connected to a RASPBERRY 3b+.

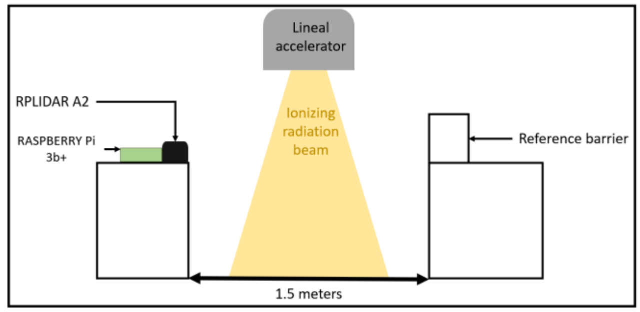

FIGURE 2. Geometric configuration.

Thirty measurements were made, five without ionizing radiation present in the treatment room and twenty-five with the most common photon and electron beams used for day-to-day clinical practice, the details of the measurements taken are detailed in Table IV.

TABLE IV. Beams energies available in treatment room.

Measurement	Beam energy	Beam type	# of measurements
1 - 5	NO BEAM	NO BEAM	5
6 - 10	6 MV	Photons	5
11 - 15	10 MV	Photons	5
16 - 20	6 MeV	Electrons	5
21 - 25	9 MeV	Electrons	5
26 - 30	12 MeV	Electrons	5

FIGURE 3. Frontal view of the configuration.

FIGURE 4. Side view of the configuration.

III. RESULTS

The results thrown by LIDARs ROS graphic interface [14] are shown in the Figure 5, surrounded in green we can see the barrier in front of the RPLIDAR A2, in the same way we realized that it was not going to be possible to analyze the difference between the different measurements only with the graphic results, because all the images obtained in the 30 measurements looked the same.

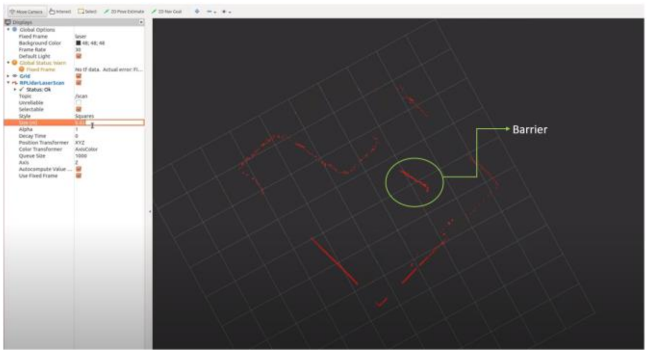

FIGURE 5. ROS graphical interface result.

To carry on an accurate analysis, we chose to consult the data thrown by the message laser scan on ROS package sensor messages [15], Figure 6 shows an example of a single sequence made by the LIDAR.

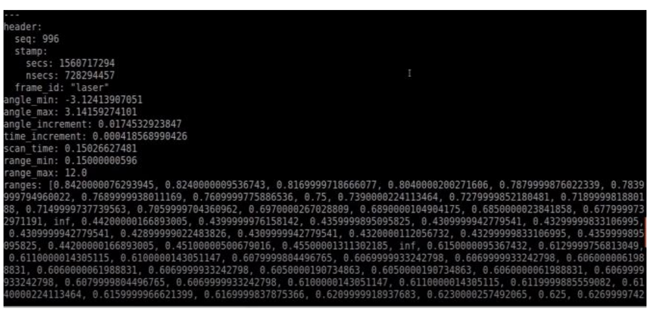

FIGURE 6. ROS numerical interface result.

We take the data sequence shown in figure 6 the contains the following measurement parameters: frame id, angle min, angle max, angle increment, time increment, scan time, range min, range max and the ranges vector.

The ranges vector was taken from each sequence and they were compared to each other with a simple, vector comparing function, in MATLAB [16].

The results of measurements with the same treatment room conditions are shown in table 5, note that we take five measurements per treatment room condition.

TABLE V. Results of measurements with the same treatment room conditions.

Measurements Parameter	Value
Scan time	0.150266274810000
Time increment	0.000418568990426
Number of samples	359
Device resolution	0.5 mm
Samples with the same value	355
% of Samples with the same value	99%
Samples with difference in the measure	4
% Samples with difference in the measure	1%
Maximum difference value	5 mm
Minimum difference value	0.5 mm

The results of the comparison between the measurements made in the room without ionizing radiation present, the room with photon beams present and electrons beams present are shown in table 6, it's important to note that the measurements of the room without radiation present were taken as reference.

TABLE VI. Results of measurements.

Measurements Parameter	No ionizing radiation (Reference)	Photon beam 6MV	Photon beam 10 MV	Electron beam 6 MeV	Electron beam 9 MeV	Electron beam 12 MeV
Scan time	0.15026627481					
Time increment	0.00041856899					
Number of samples	359					
Device resolution	0.5 mm					
Samples with the same value	355	351	352	355	355	356
% of Samples with the same value	99%	98%	98%	99	99	99
Samples with difference in the measure	4	9	8	4	4	3
% Samples with difference in the measure	1.1%	2.5%	2.2%	1.1%	1.1%	<1%
Maximum difference value	5 mm	15 mm	12 mm	10 mm	9 mm	5 mm
Minimum difference value	0.5 mm	1 mm	1 mm	1 mm	0.5 mm	0.5 mm

VI. CONCLUSIONS

Analyzing the result tables, we note that the photon beams alters more the lectures obtained by the LIDAR, that is because the photon beams nature is the same has the LIDAR laser, in other words, a laser is a coherent beam of photons with high intensity but low energy. In the same way in the photon beams that are used in clinical practice, the low energies photons are eliminated by filters, from this idea we can conclude that the photon beams slightly alter the readings obtained by the LIDAR, but not enough, so that its use is recommended since only between 2% and 3% of the total samples were affected.

If we refer the electron beams, less significant differences are noted in the readings and these differences are probably attributed to the leakage radiation in the treatment room and also to the photons generated by the compton and photoelectric effects produced by the electron beam when interacting. with the material from the room. Since the differences obtained do not go further than 1% of the samples taken, nothing different from the above is concluded.

In conclusion, the use of RPLIDAR A2 is highly recommended in clinical environments where there is the presence of ionizing radiation, since it was proved that very few readings of all the samples taken are affected by them, 1 % – 3 % depending of the beam type, and also that those readings that were affected show differences not beyond 15 millimeters of with those taken as reference readings.

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