Signoff Request - April 18th, 2022 - Navigation (Lidar Sensor)

Thursday, April 7, 2022 12:17 PM

The SLAMTECH RPLIDAR A1 360 Degree Sensor:

This signoff request is for the SLAMTECH RPLIDAR A1 Sensor which will be used in the design for the Autonomous Crawl Space Inspection Robot. This lidar sensor resides in the "Navigation Subsystem" on our block diagram and will be responsible for obtaining distance measurements of the robot from walls and other obstacles within the crawlspace environment. A light detection and ranging (Lidar) sensor is a module which uses infrared (IR) lasing technology to determine the distance from objects in a surrounding environment. The capstone team will be utilizing a lidar sensor to obtain the distance of the autonomous robot from objects within the crawlspace environment such as walls, pillars, and other obstructions. While there are many lidar sensors available for purchase, the team believes that a spinning lidar sensor, which is capable of 360-degree rotation, is needed to construct a better visualization of the crawlspace environment. The lidar sensor will be mounted onto the top of the robot so that a full 360-degree view of the crawlspace can be obtained.

Team members believe that the 360 Degrees RPLIDAR A1 Sensor from SLAMTECH is an effective navigation sensor module for this project due to the high sampling frequency, distance range, and available ROS packages for the device. The RPLIDAR A1 sensor has a typical sampling frequency of 2,000 Hz (2kHz) or 5.5 samples per degree per second. Additionally, this lidar sensor has a distance range of 0.15 meters to 6 meters (0.45 feet to 18 feet) and has ROS libraries and packages already created for the device that team members can take advantage of later in semester two when programming the navigation protocol of the robot [1]. The cost of this lidar sensor is $99.99 and is available on websites such as Mouser, adafruit, and Amazon. This lidar sensor is composed of a laser housing, a DC motor, and a computational circuit to determine the distance of an object from the sensor. The needed technical information for why the chosen lidar sensor is a proper fit for this project, as well as techniques for properly mitigating the risks of using the selected lidar sensor, are discussed below.

RPLIDAR A1 Sensor and Raspberry Pi 4B Schematic:

The RPLIDAR sensor has seven connections, four of which are for the computational circuit on the lidar sensor and three which are for the DC motor used to rotate the lidar sensor housing. All seven connections of the lidar sensor can be connected to a USB adapter cable which is supplied with the sensor and then connected to the USB 2.0 or 3.0 port on the Raspberry Pi. While the DC motor (5V_MOTO) can be powered off an external 5 Volt power supply, the data sheet for the RPLIDAR states that the USB adapter is capable and safe for powering all aspects of the lidar sensor. Additionally, the motor speed and thus the sampling frequency of the sensor can be controlled through Python and ROS protocols on board the Raspberry Pi and then communicated quickly through the serial connections in the USB port [2].

Figure 1:

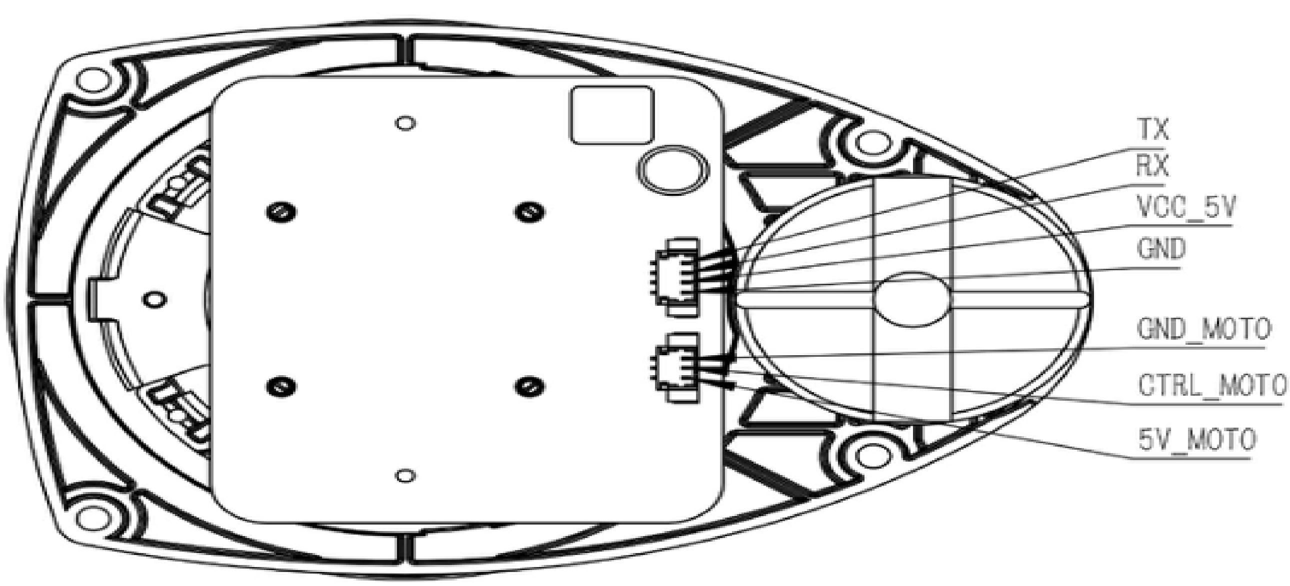
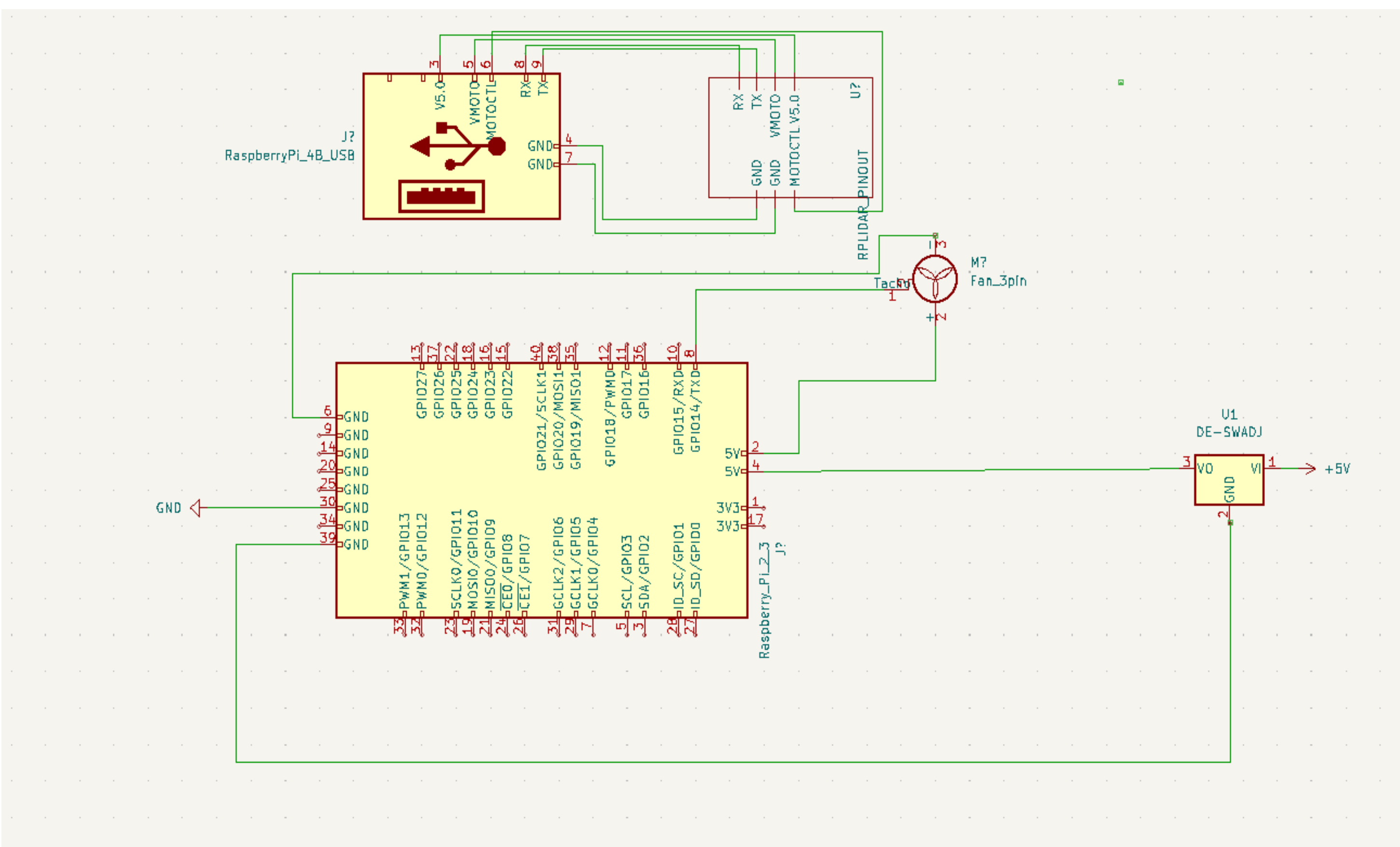


Figure 2:

Figure 3:



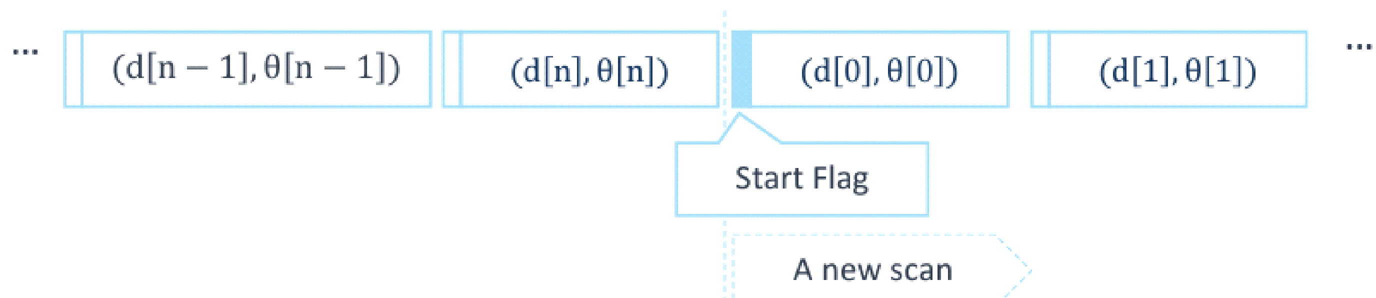
Data Outputs:

The data output by the RPLIDAR sensor is shown in figure 4. The distance measured by the sensor is output in the units of mm and the angle output by the sensor where reflection takes place is output in degrees. In figure 5, the string of information that is output to the controller is shown, as well as the order that the data is output. At the beginning of each data cycle, a start flag is created to communicate that the previous sample is complete and that the distance, angle, and quality of the current sample of the new sample are being sent [1]. While this data output by the sensor as well as the order of the output data are important, the ROS packages included for the sensor will automatically detect the format and display all the parameters in an easy to understand visual.

Figure 4:

Data Type	Unit	Description
Distance	mm	Current measured distance value between the rotating core of the RPLIDAR A1 and the sampling point
Heading	degree	Current heading angle of the measurement
Quality	level	Quality of the measurement
Start Flag	(Boolean)	Flag of a new scan

Figure 5:



3D Model (Position On Robot)

As stated in the datasheet, the dimensions of the RPLIDAR sensor are as follows: a height of 5.2 cm, a width of 9.68 cm, and a length of 7.03 cm (2 inches x 3.8 inches x 2.76 inches) [1]. In this initial design of the robot's structure, the RPLIDAR sensor will be mounted on the top of the device. Since the RPLIDAR has a height of roughly 2 inches, space will need to be allocated to allow for clearance of the robot to move throughout the crawlspace. As stated in our past design phase documents, the max height of the robot is hoped to be 16 inches. In order to accommodate for the needed size of the RPLIDAR sensor and other components, a rough estimate of the robots structure can be broken down into three main sections: the track base (4 inches), the robot internals (8 inches), and the upper portion of the robot containing the lidar sensor (4 inches). While the RPLIDAR sensor is only 2 inches tall, an additional two inches are being allowed for expansion and for the possibility of creating a higher platform or the robot if needed. As seen in figure 7, the lidar sensor will sit at the top plane of the robot which will allow for a view with the least obstructions present.

Figure 6:

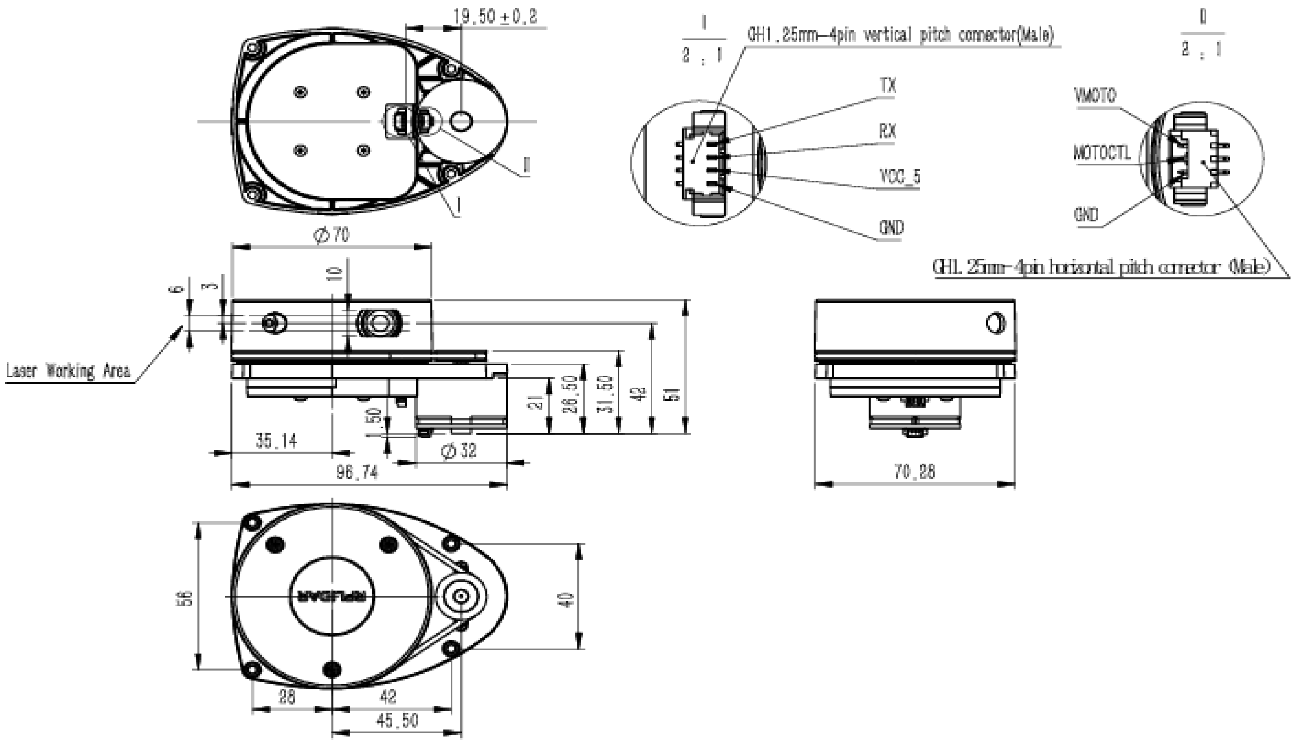
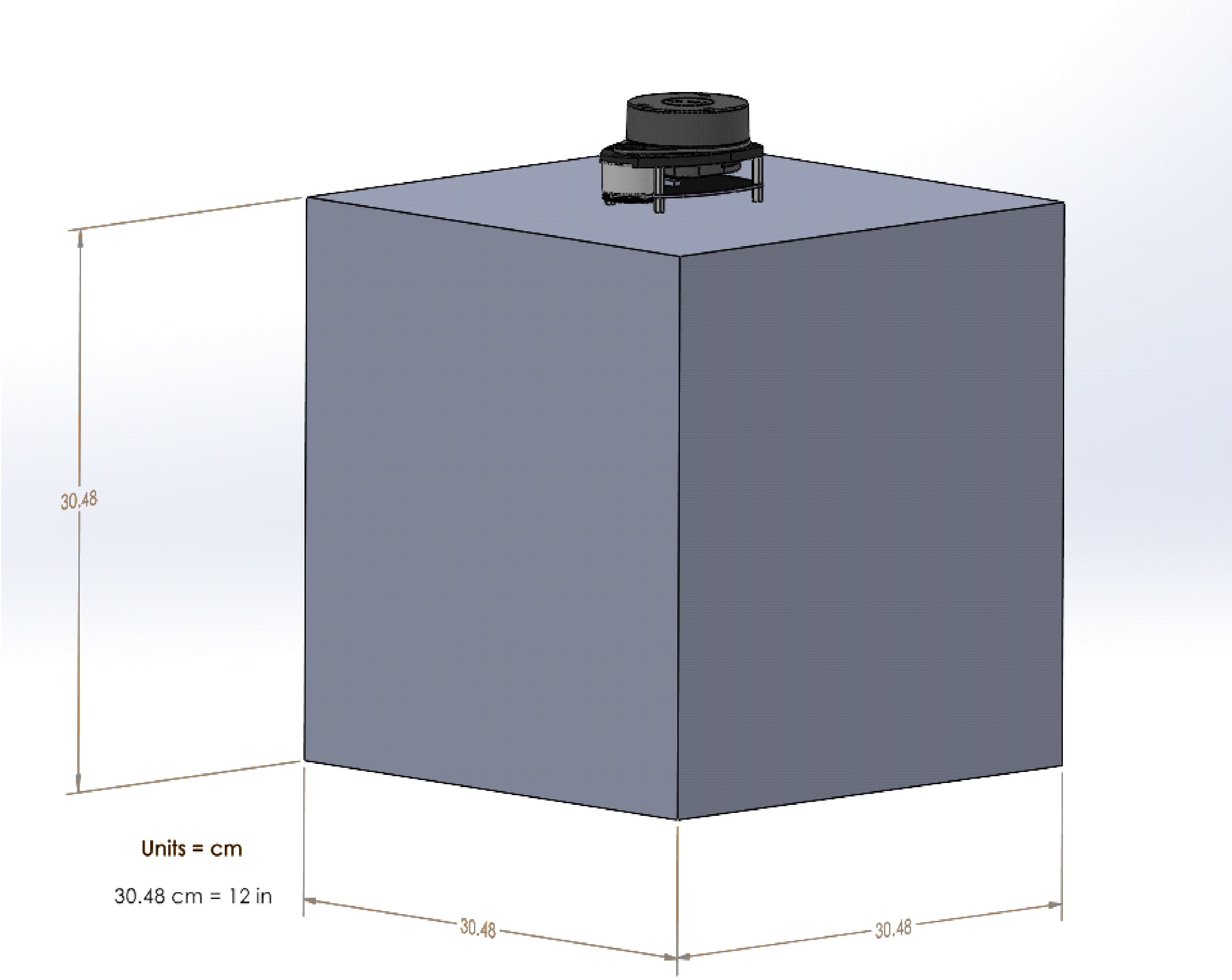

19.50±0.2
I
2 : 1
GH1.25mm-4pin vertical pitch connector(Male)
II
2 : 1
TX
RX
VCC_5
GND
VMOTO
MOTOCTL
GND
GH1.25mm-4pin horizontal pitch connector (Male)
II
I
Ø70
6
3
10
Laser Working Area
21
26.50
31.50
42
51
1.50
35.14
Ø32
96.74
70.28
56
40
28
42
45.50
RPLIDAR

Figure 7:



Notes On RPLIDAR Sensor Sampling Frequency and Distance Range:

The lidar sensor must be able to connect to and communicate with a Raspberry Pi 4B, which will serve as the main MCU of the Navigation Subsystem. The selected lidar sensor must be able to spin 360 degrees to create a full model of the crawlspace as the robot moves. If the lidar sensor is not sampling at an appropriate speed, long delay times in the navigation processing algorithms could lead to a failure of response time for the robot and thus generate potential hazards with the project. While a specific movement speed of the robot cannot yet be determined, due to the motor system not yet being designed, team members discovered that most of the available spinning lidar sensors have a very high sampling frequency, in the kHz range, which will relax the risk of not sampling fast enough for the robot's movement [2]. The lidar sensor that team members have chosen for this project has a typical sampling frequency of roughly 2,000 Hz (2 kHz) with 5.5 samples per degree per second [RP datasheet]. While the lidar sensor is capable of a higher sampling frequency, the datasheet for the module states that the previously stated frequency is more stable and power efficient. The selected lidar sensor has a distance range of 0.15 meters to 6 meters (0.45 feet to 18 feet). As the robot moves throughout the crawlspace environment, software applications within ROS will be used to store datapoints of the environment and construct a two-dimensional model of the crawlspace for the robot to see what areas have yet to be explored. It is important to note that SLAMTECH, the creator of this sensor module, has ROS packages and libraries already available which the capstone team will utilize when creating the navigation protocols for the robot.

When thinking of the crawlspace inspection robot, the team has been relating it to a household Roomba device due to some common distance determination components and algorithms such as Lidar and VSLAM. According to a datasheet from iRobot, a popular Roomba manufacturer, a typical iRobot Roomba can move at a max speed of 1.64 feet per second, with an average speed of roughly 1.25 feet per second [3]. If applying a rough estimation of the speed specification to the crawlspace inspection robot, a high lidar sensor sampling frequency is needed so that calculations within the navigation protocol can be performed fast enough for the robot to continually move on an accurate path. While manufacturers such as iRobot and Samsung do not specifically state the sampling frequency of the lidar sensors used on their vacuum Roombas, a paper from the University of Maryland states that the typical household vacuum robot utilizing lidar sensors has a rotation frequency of 5 Hz with each rotation collecting data points for each degree of rotation, thus establishing a common full rotation sampling frequency of 5 Hz times 360 samples per rotation for a total sample frequency of 1.8 kHz [4]. As previously stated, the spinning lidar sensor chosen by the capstone team has typical sampling frequency of roughly 2 kHz, making the chosen Lidar sensor sufficient for the design of the autonomous crawlspace inspection robot.

Filtering of the RPLIDAR Sensor:

One main concern of spinning lidar sensors is the possibility of noise and interference in the data retrieved by the sensor due to the presence of the DC motor attached to the housing. When choosing a lidar sensor for this project, the need for filtering was taken into consideration through the inspection of the given datasheets and user manuals, as well as direct communication with the manufacturer. The RPLIDAR sensor is designed with a filtering logic and circuits included in the overall design of the product. When reading through the datasheets, there is not a detailed circuit schematic which lists filtering components for the distance sampling. The datasheet does state that one component of the output data, as mentioned in the above output data section, is present to represent whether or not the measurements being received are clean and of good quality. In order to double check this information as well as confirm the presence of hardware filtering, the team members contacted the support office at SLAMTECH and received the following email from a hardware support specialist confirming the presence of filtering logic:

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Yuan Zixuan 回复道:

Hi Williams,
Do you refer to some noise data filtering?
If so, we have such logic in our rplidar.
There are three fields in the output scan data: Distance, Angle and Quality. Quality is used to check whether the scan data is valid or not. Zero means invalid, any other value bigger than zero means valid. The object beyond the detect range or of low reflectivity will create invalid data.
Best Regards,
Zixuan

Team members also called the support phone number and spoke to another specialist who confirmed that there was an included hardware filter circuit within the device that helped to create some error check against the logic software filtering. We hope that this is enough to confirm that clean and appropriate measurements can be received from the RPLIDAR sensor. In the rare case that some additional noise is created due to external interference, the team members feel confident in their abilities to mitigate this noise.

Sources:

[1] RPLIDAR Datasheet:
https://download-en.slamtec.com/api/download/rplidar-a1m8-datasheet/3.2?lang=en

[2] RPLIDAR User Manual:
https://download-en.slamtec.com/api/download/rplidarkit-a1m8-usermaunal/2.1?lang=en

[3] iRobot Roomba Datasheet:
https://www.irobotweb.com/~/media/MainSite/PDFs/About/STEM/Create/iRobot_Roomba_600_Open_Interface_Spec.pdf?la=en

[4] University of Maryland Robot Vacuum Lidar Research Paper:
http://icosmos.cs.umd.edu/images/2_publication/papers/LidarPhone_SenSys20_nirupam.pdf