Obstacle Avoidance System Using LiDAR on Robot Turtlebot3 Burger

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Abstract. The Burger Robot Turtlebot3 series is a standard platform from Robotics Corporation's ROS, which is used as a learning medium and as a prototype in a robot delivery project. The Turtlebot3 Burger robot is used as a learning medium in the application of the goods delivery robot system. In this research, a Turtlebot Robot which can be controlled manually and automatically, was developed. Automatic controllers can work based on the location of the coordinate points that have been determined. The Turtlebot's automatic controller also features an obstacle avoidance system. The obstacle avoidance system is one of the behaviors that bring the Turtlebot to move freely without collision. The sensor used for this system is Light Detection and Ranging (LiDAR). LiDAR is a long-range technology that uses the property of scattered light to find the distance and information of an object from the intended target. LiDAR used is 360 Laser Distance Sensor LDS-01. LiDAR will be processed on Raspberry then LiDAR data will be included in the obstacle avoidance method so that the success rate will be higher. This research resulted in the success rate of the obstacle avoidance system. It is hoped that this obstacle avoidance system will help the Turtlebot avoid a collision with an object when it goes to a predetermined waypoint position.

Keywords: LiDAR, Turtlebot, Obstacle avoidance.

1 Introduction

Along with the times, the need for companies to provide products to serve consumers is increasing. Products must be produced in sufficient quantities over a certain period of time. This requires the company team to work faster with optimal results. The distribution of goods is an important part of making a product. But this will take more time and energy if done personally and repeatedly. Therefore, an automatic device is needed to distribute goods, such as a delivery robot.

In this research, a Turtlebot robot that can be controlled manually and automatically was developed. Automatic controllers can work based on the location of the coordinate points that have been determined. The Turtlebot's automatic controller also features an obstacle

ICAE 2022, October 05, Batam, Indonesia
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DOI 10.4108/eai.5-10-2022.2327479

avoidance system. The obstacle avoidance system is one of the behaviors that bring the Turtlebot to move freely without collision. One of the main challenges that robots have is to avoid obstacles and perform path planning in dynamic environments. Robots should be able to understand the surrounding environment for potential threats, be able to identify new forces in the scene, and modify or plan trajectories with the latest knowledge, ideally also achieving optimality in multiple flavors at low cost on memory and computational space[1]. Many sensors can be used to detect an obstacle, such as infrared, ultrasonic, and even cameras. Each of these sensors has advantages and limitations. For example, in cameras, it is very clear that computer vision alone is not enough to provide an efficient vision for autonomous vehicles. This motivates to propose LiDAR-based detection and evasion systems that can be integrated into autonomous systems [2]

Due to the lack of each sensor, a device that can meet the obstacle avoidance system on the Turtlebot is needed. Light Detection and Ranging (LiDAR) is a remote sensor technology that uses the property of scattered light to find the distance and information of an object from the intended target. This technology can be added to the obstacle avoidance system in Turtlebot because LIDAR has several advantages, such as an accurate level of precision with a wide detection distance and can use of various angles. The focus of this research is to design an obstacle avoidance system on the Turtlebot using LIDAR.

2 Literature Review

2.1 Turtlebot3 Burger

TurtleBot3 is a small, affordable, programmable, ROS-based mobile robot for use in education, research, hobby, and product prototyping. The goal of TurtleBot3 is to dramatically reduce the size of the platform and lower the price without having to sacrifice its functionality and quality while at the same time offering expandability. The TurtleBot3 can be customized in various ways depending on how you reconstruct the mechanical parts and use optional parts such as the computer and sensor. In addition, TurtleBot3 is evolved with nn st-effective and small-sized SBC that is suitable for robust embedded system360-degree distance sensors and 3D printing technology[3].

2.2 Light Detection and Rangging (LiDAR)

LiDAR is a remote sensor technology that uses the property of scattered light to find the distance and information of an object from the intended target. The method for determining the distance of an object or surface is to use laser pulses [4]. The basic principle of the LiDAR sensor is that the sensor emits laser light on the object, and then it is reflected by the sensor, the reflected light is then captured and analyzed by the detector. Changes in the composition of light received from a target are defined as objects. Based on the distance measurement method, LiDAR is divided into two parts, the first is triangulation. The way LiDAR triangulation works is by utilizing the calculation of triangular equations. The laser emits an infrared laser which is then reflected by the detected object. The light passes through the pinhole lens and hits the CCD camera sensor. This means that the distance to the object is proportional to the angle of the reflected light, and it is possible to estimate the actual distance using the concept of trigonometric equations of triangles. Second Time of Flight (ToF). The way LiDAR Tof works is by emitting a laser beam towards the object, and then the reflection of the light will be received by the receiver. The travel time from the time the light is emitted until it is received back will be the divisor of the speed of light. The comparison between the speed of light and time will produce distance data [5].

2.2.1 Specifications LiDAR.

LiDAR specifications are important information for selecting the most suitable product for the application. This can be broken down into four levels, as depicted in the image below see **Figure 1**. The first specification in the hierarchy includes range-related information such as maximum and minimum detection range, resolution, accuracy, and update frequency. The second specification in the hierarchy relates to physical parameters such as size, weight, and power consumption which can be found in the product manual. Because LiDAR uses a laser, related information such as wavelength, emitted power, and laser class is included in the specification as part of safety compliance in the third hierarchy. In the fourth hierarchy, examples of optical specifications commonly found in the product manuals include lens focal length and beam divergence[2].

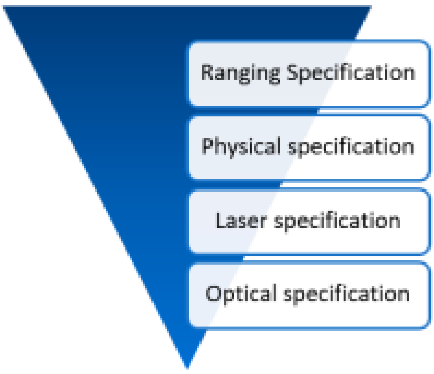

Fig. 1. LiDAR Hierarchy Specifications

In this study, the turtlebot3 Burger robot uses a 360 Laser Distance Sensor LDS-01 Sensor. The following are the specifications of LiDAR on the robot:

Table 1. General Specifications 360 Laser Distance Sensor LDS-01.

No	Items	Specifications
1	Operating supply voltage	5V DC ±5%
2	Light source	Semiconductor Laser Diode(λ=785nm)
3	LASER safety	IEC60825-1 Class 1
4	Current consumption	400mA or less (Rush current 1A)
5	Detection distance	120mm ~ 3,500mm
6	Interface	3.3V USART (230,400 bps) 42bytes per 6 degrees, Full Duplex option
7	Ambient Light Resistance	10,000 lux or less
8	Sampling Rate	1.8kHz
9	Dimensions	69.5(W) X 95.5(D) X 39.5(H)mm
10	Mass	125g

Table 2. Measurement Performance Specifications.

No	Items	Specifications
1	Distance Range	120 ~ 3,500mm
2	Distance Accuracy (120mm ~ 499mm)	±15mm
3	Distance Accuracy(500mm ~ 3,500mm)	±5.0%
4	Distance Precision(120mm ~ 499mm)	±10mm
5	Distance Precision(500mm ~ 3,500mm)	±3.5%
6	Scan Rate	300±10 rpm
7	Angular Range	360°
8	Angular Resolution	1°

2.3 Obstacle Avoidance System

The way the obstacle avoidance controller works is to avoid obstacles or moving people to ensure the safety of the robot moving during the movement. Considering the speed and wide range of scanning capacity, we adopted the same LiDAR sensor used to detect obstacles. In this design, the distance and direction of the laser measurement are represented as vectors for calculation. The laser scanner scans the 360-degree environment in front of it. With the obstacle position vector, obstacle avoidance behavior is developed. If the robot wants to perform the obstacle avoidance function when navigating itself to a destination, it needs to know information about its surroundings. With the obtained laser scan, the system will scan the distance between the robot and the direct obstacle. In this design, the surrounding resistance is represented by a simple resistance vector with direction and distance [6].

3 Method

This research was conducted so that the robot can avoid obstacles that are in front of it, and this study uses a LiDAR sensor to detect obstacles and where the data from the LiDAR sensor will be processed. To know how the obstacle avoidance system work sees **Figure 2**.

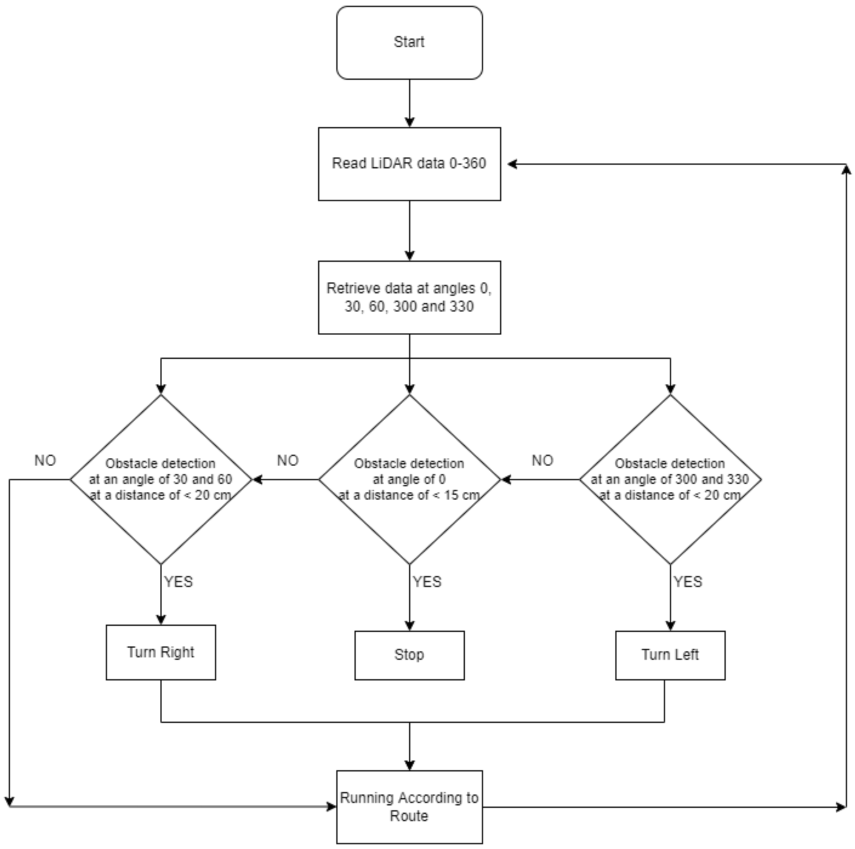

Fig. 2. Obstacle Avoidance Flowchart on Turtlebot3 Burger

The flowchart above shows that when the robot is turned on, LiDAR will read data from 0 degrees to 360 degrees. Then LiDAR will take data at angles of 0 degrees, 30 degrees, 60 degrees, 300 degrees, and 330 degrees to detect whether there is an obstacle at that angle. If LiDAR detects an obstacle at an angle of 0 degrees or in front of it with a distance of 15 cm, the robot will stop until the obstacle is gone or not. If LiDAR detects an obstacle at an angle of 30 degrees and 60 degrees to the left of the robot with a distance of 20 cm, the robot will turn right to avoid the obstacle (the wall on the field). If LiDAR detects an obstacle at an angle of 300 degrees and 360 degrees to the right of the robot with a distance of 20 cm, the robot will turn left to avoid the obstacle (the wall on the field). If LiDAR does not detect the obstacle at angles of 0, 30, 60, 300, and 330 degrees according to the conditions that have been made. Then the robot will continue to walk according to its path until it reaches the robot's destination point. To know the point of view from the top of LiDAR with five angles, see **Figure 3.**

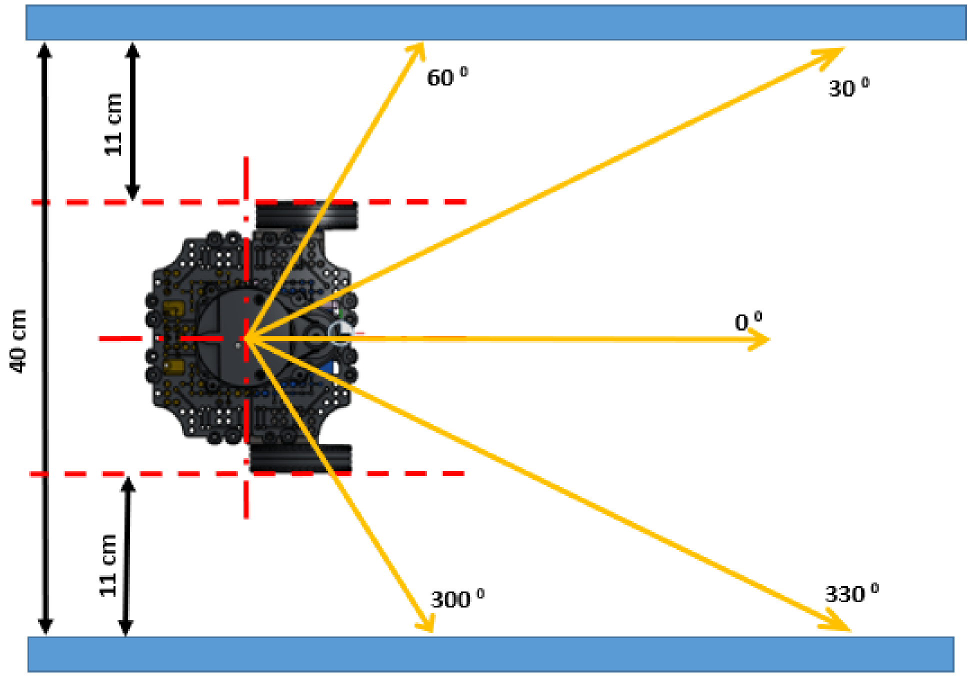

Fig. 3. Point of view from the Top of LiDAR with 5 Angles

The location of the test in this study was carried out according to regulations and requests at the Company and this test was carried out in the field that had been made according to the request of the Company.

4 Result and Discussion

4.1 LiDAR Sensor Testing

This test is carried out to determine the comparison of the LiDAR distance readings from each corner with the actual distance.

Table 3. LiDAR Sensor Testing.

No	Angle	Actual Distance (cm)	LiDAR Reading Distance (cm)	Error (%)
1.	0	10	9	10.00
2.	20	15	14	6.67
3.	40	20	19	5.00
4.	60	25	24	4.00
5.	80	30	29	3.33
6.	100	35	34	2.86
7.	120	40	39	2.50
8.	140	45	44	2.22
9.	160	50	49	2.00
10.	180	55	54	1.82
11.	200	60	59	1.67
12.	220	65	64	1.54
13.	240	70	69	1.43
14.	260	75	74	1.33
15.	270	80	79	1.25
16.	280	85	84	1.18
17.	290	90	89	1.11
18.	300	95	94	1.05
19.	310	100	99	1.00
21.	330	120	119	0.83
22.	340	130	129	0.77
23	350	140	139	0.71
24.	360	150	149	0.67

See equation (1) for the formula for finding the error value is as follows :

$$\text{Error (\%)} = \frac{(\text{reference value}) - (\text{trial value})}{(\text{reference value})} \times 100\ \% \quad (1)$$

From the test data that has been carried out, it can be concluded that the comparison of the actual distance with the distance of the lidar reading has an average error value of 2.389%, where the error value does not have a major effect on the actual conditions.

4.2 Robot Testing Against Obstacles

Obstacle avoidance testing using a LIDAR sensor. The purpose of this test is the robot is able to avoid obstacles that are around it. This test will be carried out in as many as three trials to test how the system is hindered.

Testing of this sensor is needed because the output of this sensor will determine whether there is an obstacle in front of the robot or on the other side of the detected robot, so this test will be carried out on the robot against the obstacle with a different angle and near the robot.

This test uses a constant speed of 0.14 m/s, and this experiment will be carried out with variations in the distance between obstacles with different angles. This test is carried out in the field that has been determined by the company.

Testing on the left side of the robot

In the first test, the robot is given a navigation command from coordinate A to coordinate C. The success parameter of this test is that the system is able to avoid obstacles that are on the left of the robot's path. The robot is observed in how its avoidance pattern and begins to respond to obstacles. The test results can be seen in **Table 4**. The results of the first test are the robot can dodge without experiencing a collision with the obstacle. The robot avoidance pattern is turning right because the obstacle given is in the robotic path area to the left.

Table 4. Testing On The Left Side Of The Robot.

No	Distance (cm)	Angle Detection					Action
		10^0	15^0	30^0	45^0	60^0	
1	150	✓	✓	✓	✓	✓	Running Forward
2	100	✓	✓	✓	✓	✓	Running Forward
3	50	✓	✓	✓	✓	✓	Running Forward
4	30	✓	✓	✓	✓	✓	Running Forward
5	20	✓	✓	✓	✓	✓	Turn Right
6	10	✓	✓	✓	✓	✓	Turn Right
7	9	✗	✗	✗	✗	✗	Running Forward
8	8	✗	✗	✗	✗	✗	Running Forward
9	2	✗	✗	✗	✗	✗	Running Forward
10	1	✗	✗	✗	✗	✗	Running Forward

Note :

✓ = *Detected*

✗ = *Undetected*

Data output on the robot test terminal on the obstacle on the left side of the robot see **Figure 4** to see the actual appearance of the robot against the obstacle, see **Figure 5**.

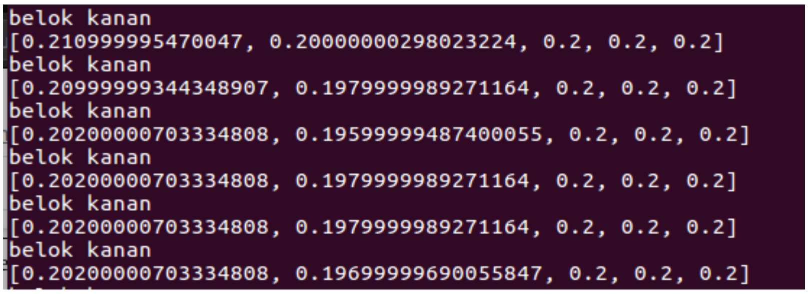

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Fig. 4. LiDAR Test Terminal Display on Robot's Left Side

Fig. 5. Position of Obstacle Detection Robot on the Left Side of Robot

Testing on the right side of the robot

In the second test, the robot is given a navigation command from coordinate A to coordinate C. The success parameter of this test is the system is able to avoid obstacles that are on the right side of the robot's path. The robot is observed in its avoidance pattern and begins to respond to obstacles. The test results can be seen in **Table 5**. The results of the first test are that the robot can dodge without experiencing a collision with an obstacle. The robot avoidance pattern is to turn left because the obstacles given are in the robotic path area to the right.

Table 5. Testing On The Right Side Of The Robot.

No	Distance (cm)	Angle Detection 350^0	355^0	330^0	315^0	300^0	Action
1	150	✓	✓	✓	✓	✓	Running Forward
2	100	✓	✓	✓	✓	✓	Running Forward
3	50	✓	✓	✓	✓	✓	Running Forward
4	30	✓	✓	✓	✓	✓	Running Forward
5	20	✓	✓	✓	✓	✓	Turn Left
6	10	✓	✓	✓	✓	✓	Turn Left
7	9	×	×	×	×	×	Running Forward
8	8	×	×	×	×	×	Running Forward
9	2	×	×	×	×	×	Running Forward
10	1	×	×	×	×	×	Running Forward

Note :

✓ = *Detected*

× = *Undected*

Data output on the robot test terminal on the obstacle on the right side of the robot see **Figure 6** to see the actual appearance of the robot against the obstacle, see **Figure 7**.

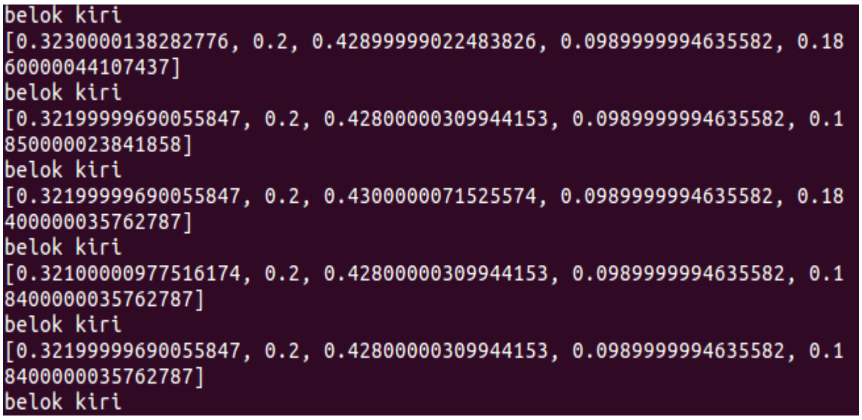


Fig. 6. LiDAR Test Terminal Display on Robot's Right Side

Fig. 7. Position of Obstacle Detection Robot on the Right Side of Robot

It can be concluded from the table and this test that the robot will decide if it detects an obstacle at a distance of 20 - 10 cm. The LiDAR sensor cannot detect objects at a distance of below 10 cm, so testing at a distance from 9 cm with different angles the robot can no longer detect and cannot make decisions and keep running until the robot can hit an existing obstacle. The change in the speed of the robot does not affect the LiDAR readings and the actions to be carried out by the robot.

Testing on the front side of the robot

The third test, the robot is tested how the robot is able to avoid obstacles in front of the robot when navigating. The robot will be tested by navigaton ing and given an obstacle in the middle of the robot. Navigation is carried out as far as 10 cm by being given the right obstacle between the coordinates of the departure point and the coordinates of the destination point. The system is given a navigation command from coordinate A to coordinate C. The success parameter of this test is the system is able to avoid obstacles that have been prepared at location B, which is 1.5 meters from coordinate A. The robot is observed in how the avoidance pattern and the robot responds to obstacles. The test results can be seen in **Table 6**. The results of the first test are that the robot can dodge without experiencing a collision with an obstacle.

Table 6. Testing On The Front Side Of The Robot.

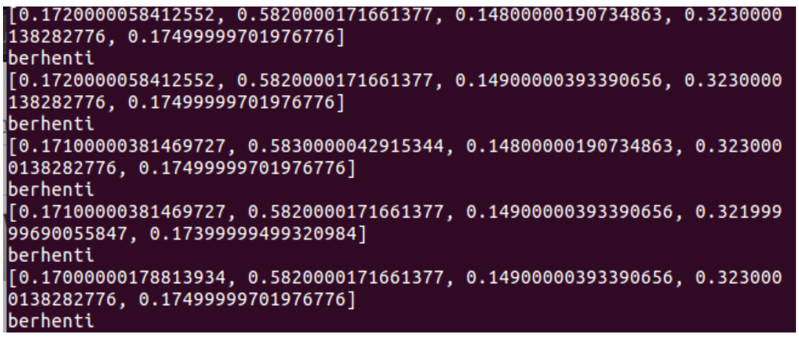
No	Distance (cm)	Sensor	Action
1	150	✓	Running Forward
2	100	✓	Running Forward
3	50	✓	Running Forward
4	20	✓	Running Forward
5	15	✓	Stop
6	10	✓	Stop
7	9	✗	Running Forward
8	8	✗	Running Forward
9	2	✗	Running Forward
10	1	✗	Running Forward

Note :

✓ = *Detected*

✗ = *Undected*

Testing the robot on an obstacle with a distance of 15 cm for an angle of 0 degrees produces output data at the terminal see **Figure 8** to see the actual appearance of the robot against the obstacle see **Figure 9**.



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berhenti
```

Fig. 8. Display of LiDAR Testing Terminal Obstacle detection distance 15 cm

Fig. 9. Position of Robot Detection obstacle distance 15 cm at Angle 0^0

Testing the robot on an obstacle with a distance of 10 cm for an angle of 0 degrees produces output data at the terminal see **Figure 10** to see the actual appearance of the robot against the obstacle see **Figure 11**.

```
[0.11400000005960464, 0.1809999942779541, 0.10000000149011612, 0.256000
01215934753, 0.125]
berhenti
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001215934753, 0.125]
berhenti
```

Fig. 10. Display of LiDAR Testing Terminal Obstacle detection distance 10 cm

Fig. 11. Position of Robot Detection obstacle distance 10 cm at Angle 0^0

It can be concluded from the table and this test that the robot will decide if it detects an obstacle at a distance of 15 - 10 cm. But the LiDAR sensor cannot detect objects at a distance of below 10 cm, so testing at a distance of 5 cm with an angle of 0 degrees is no longer able to detect and cannot make decisions and keep running until the robot can hit an existing obstacle. The change in the speed of the robot does not affect the LiDAR readings and the actions to be carried out by the robot.

5 Conclusion

Based on the results of research on the Obstacle Avoidance System Using LIDAR on the Turtlebot3 Burger Robot, the robot can detect and avoid obstacles according to the command. However, the LiDAR sensor cannot detect at a distance of less than 10 cm, so the robot does not make a decision and continues to run until it hits an obstacle. However, if faced with an obstacle at a distance of more than 10 cm, LiDAR can detect the obstacle and make decisions according to the conditions that have been made. The actual experiments and results also validated the feasibility and advantages of our sensor in contrast to other state-of-art solutions for this problem.

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