IIJASS
IBN KHALDUN INTERNATIONAL JOURNAL OF APPLIED SCIENCES AND SUSTAINABILITY
e-ISSN : 0000-0000
p-ISSN : 0000-0000
https://ejournal.uika-bogor.ac.id/index.php/IIJASS Volume 1, Issue 1, pp.01-08

Development of Hexapod Fire Extinguisher Robot Navigation System Using LIDAR (Light Detection and Range)

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Received: May 29, 2023 Accepted: May 30, 2023 Published: June 03, 2023

ABSTRACT

Design of a navigation system on a hexapod robot for fire extinguisher using LIDAR (Light Detection And Range) are introduced in this paper. the LIDAR sensor used in this study is the Tfmini Lidar which functions as a detecting obstacle object and equipped with the 5 channel flame array sensor used to detect the presence of a fire source. The navigation system was designed to be able to find out fire existence. the robot has been carried out several tests to compare the speed performance of the navigation system with remote control (manually controlled) and autonomous control in fire source room. The results showed the Tfmini LIDAR reading test can read a distance of 0.15 -12 meters with average error of 0.51%. Tfmini LIDAR was not affected by light intensity but still cannot detect clear objects such as acrylic and mineral water bottles. The travel time obtained by the system with autonomous control in navigating to the room source of fire was 50.972 seconds and manually control was 40.07 seconds. Based on the results, the navigation system using LIDAR has been successfully designed and can be implemented for a hexapod fire extinguisher robot.

Keywords: 5 channel Flame array, navigation system, Tfmini LIDAR

INTRODUCTION

Robotics is evidence of human civilization that has progressed from time to time. Robot resembles not only a certain human or animal, but moved to resemble the shape it imitates. A robot is a mechanical device capable of carrying out physical tasks, either under human control and supervision, or one that is executed with a series of predefined programs or artificial intelligence (Kardha et al., 2019).

Research and development of robots were first carried out by Argone National Laboratories in Oak Ridge America in the 1940s to handle radioactive materials called master-slave manipulators. Currently, industrial robot technology was started to lag behind its development with mobile robot technology. Mobile robot technology widely used since 80s, its application is no longer related to industrial production processes, but more directed to help human tasks in various fields, for example the Pioneer Robot that used for missions to Chernobyl, Robot W for missions to Mars, Tour guide robot which is a type of robot that functions to avoid obstacles (Umam, 2013).

The ability to detect surrounding walls and obstacles, predict collision-free pathways automatically were the main features of autonomous mobile robots (Hutabarat & Et.all,

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2019). The robot must be able to navigate independently. To achieve robot with autonomous navigation, the proper posture of the robot in the environment must be obtained.the robot should be able to determine position coordinates and signs in that field. Therefore, navigation technology is a major problem in mobile robot research (Cheng & Wang, 2018). With advances in sensor and processor technology, the implementation of Light Detection and Range (LIDAR) sensors into the robot's navigation system has a significant impact on the robots perceive their surroundings. In particular, data input from the LIDAR sensor changed the robot's control behavior from a reactive approach to a deliberative approach (Anual et al., 2018).

Based on the description from the background above, this study intend to design a navigation system to be implemented in a hexapod fire extinguisher robot using LIDAR. The navigation system was designed to create more efficient and speed up the robot to navigate to a fire source room.

RESEARCH METHODS

Hardware Design

This study was designed the robot hardware including the following:

a) Sg-90 Servo Mount Bracket.

b) Microcontroller holder and DC Mini Fan

c) Circuit

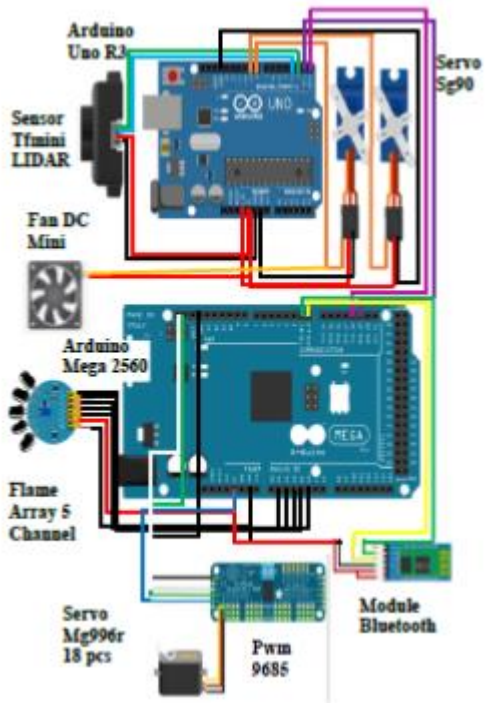

Figure 1. Navigation System's Circuit of Hexapod Fire Extinguisher Robot

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Software Design

The software design used logic thinking that manifested in the language of a program where all work orders will be designed.

Systen Testing

This test was carried out to convince the system work properly according to input. There are several system tests to obtain values according to input:

System testing per section

Testing TFmini Lidar

This test was carried out to ensure that the accuracy of the object distance reading on the sensor in accordance with the true value.

5 Channel Flame Array Sensor Testing

This test was carried out to ensure the accuracy of the fire sensor reading to work optimally so the robot can quickly detect the presence of fire.

Overall System Testing

Testing of the whole system was carried out after testing in parts has been carried out and there are no errors in coding (programming) and also in wiring.

Robot Walking Experiment

The performance of Robot walk was test in go straight and turn with various degree. The robot walk in to the room with distance 14 cm and the turn 900 and 1800. The 2D Sketch of robot testing path was showed in Figure 2.

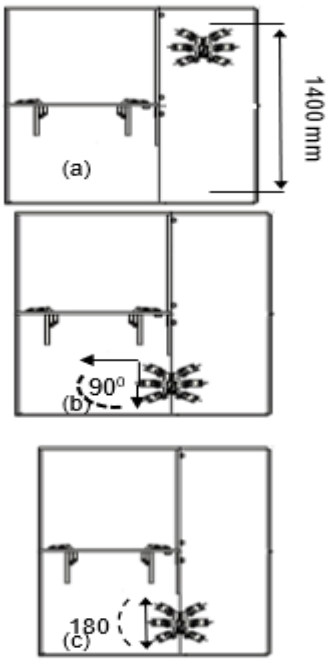

Figure 2. 2D Sketch of Robot Testing Path (a) Running Straight; ,(b) Rotating 90 degrees ; (c) Rotating 180 degrees 180 degrees

This robot was installed with Tfmini LIDAR sensor to avoid obstacles. Some obstacles used in this experiment such as plastic bottle, doll, wood, and transparant acrilic thing. The robot

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will encounter the obstacle by perform right turn or left turn. The response of the robot avoid the obstacle was test in 20 cm and 40 cm.

Robot in Navigating to The Fire Source Room

Figure 3 showed the fire source room. The navigation will test as the robot perform to find the fire source. Time and speed needs was analysis.

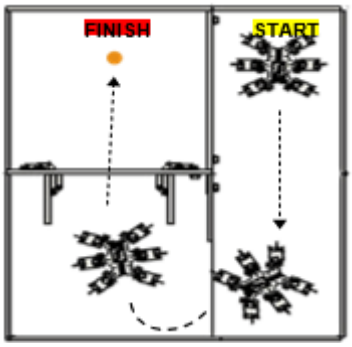

Figure 3. Robot Testing In Navigating Towards the Fire Source Room

Results & Discussion

The hexapod fire extinguisher robot has been developed with navigation system using LIDAR. This robot was equipped with LIDAR Sensor to navigate to the fire source room and able to avoid some obstacles such as dolls and wood object. Figure 4 showed the hexapod fire extinguisher robot.

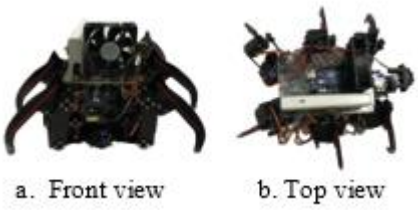

Figure 4. Hexapon fire extinguisher robot

Performance of Tfmini LIDAR Sensor

The TFmini Lidar test was carried out by directing the sensor to a solid object, where the Tfmini lidar sensor works by reflecting infrared rays on an object in front of it. The result showed the Tfmini lidar was able to read distances from 12 meters based on specifications obtained from the product datasheet made by DFrobot. Performance of Tfmini lidar was carried out with actual values ranging from 0-1200 cm. The lidar value was obtained from the analog digital serial monitor Arduino software, along with the test results of the Tfmini lidar showed in Table 1. The result showed the actual distance value with the tfmini lidar sensor readings is almost the same with the average error of 0.51%. The accuracy of Tfmini lidar was good enough to be used in distance measurement.

Table 1. Measurement of the TFmini Lidar Sensor

No	Distance (cm)	Lidar sensor reading (cm)	Error (%)
1	0	0	0,00
2	15	15	0,00
3	30	30	0,00
4	50	49	2,00

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5	150	147	2,00
6	250	250	0,00
7	350	350	0,00
8	450	448	0,44
9	550	547	0,55
10	650	645	0,77
11	750	748	0,27
12	850	848	0,24
13	950	947	0,32
14	1050	1045	0,48
15	1150	1146	0,35
16	1200	1190	0,83
Average			**0,51**

This test also used 2 variations in indoor light intensity to determine the performance of the Tfmini lidar sensor. The light intensity tested was 20 lux and 0 lux. It has been done to ensure that the Tfmini lidar sensor readings were not affected by the color of the object and also the intensity of the light. The test was carried out with several color objects including green, blue, red, yellow and brown. The results of the measurement of the Tfmini lidar reading was in Table 2.

Table 2. Results of Lidar Tfmini Sensor Readings at Room Light Intensity of 0 Lux and 20 Lux

0 Lux				
Object Color	**Sensor read objek in 50 cm distance**	**Error (%)**	**Sensor read objek in 100 cm distance**	**Error (%)**
Green	49	2,00	101	1,00
Red	49	2,00	101	1,00
Blue	49	2,00	101	1,00
Yellow	49	2,00	101	1,00
Brown	49	2,00	101	1,00
20 Lux				
Object Color	**Sensor read objek in 50 cm distance**	**Error (%)**	**Sensor read objek in 100 cm distance**	**Error (%)**
Green	49	2,00	99	1,00
Red	49	2,00	99	1,00
Blue	49	2,00	99	1,00
Yellow	49	2,00	99	1,00
Brown	49	2,00	99	1,00

The results of the error value for a room light intensity of 20 lux was 2% with an object distance of 50 cm while intensity of 0 lux light was 1% with an object distance of 100 cm. The Tfmini LIDAR sensor was not affected by light intensity and color of an object . it proved by Tables 2, 5 color variables has the same error value in different light intensity.

Performance of Channel Flame Array Sensor

Channel Flame Array Sensor was test in fire on and fire off condition. The results showed the 5 channel fire sensor work properly, proven by the result in Table 3. In fire on condition, ADC value higher when the sensor closer to the fire. The distance of sensor to the fire

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changed the ADC value from 440 to 810. In fire off condition, the sensor function not to detect fire with a constant ADC output value at a value of 23.

Table 3 Result of 5 Channel Flame Array Sensor When the Fire Off and Fire On

Distance (cm)	Fire Off		Fire On	
	Not Detect	ADC Value	Detect	ADC Value
20	√	23	√	810
40	√	23	√	778
60	√	23	√	560
80	√	23	√	540
100	√	23	√	440

Running Speed of the Robot

The robot was running straight for 1,4 m with autonomous and manually control. The robot speed in running straight with autonomous obtained an average speed value of 0.100 m/s and an average travel time of 14.02 seconds. With manually control, the average speed was 0.108 m/s with an average travel time of 12.94 seconds. The running speed by the autonomous system was lower because it detects surrounding objects automatically without human control.

Figure 5. Test of running speed in straight line

Tabel 4 Speed Test of Robot Rotating 90^0 and 180^0

Turning Degree	90^0		180^0	
Controll	Manual	Autonom	Manual	Autonom
N	0,25	0,25	0,5	0,5
Time (s)	4,484	6,056	7,754	9,644
Frekuen	0,056	0,041	0,065	0,052
Periode	17,936	24,224	15,508	19,288
Linier Speed	0,172	0,126	0,197	0,158

Another test was done for turning robot speed. Robot tested for turning in 90^0 and 180^0.Result of robot rotating 90^0 and 180° speed test showed in Table 4. The results of the robot speed when turning 90^0 with autonomous system obtained an average speed value of 0.126 m/s and an average travel time of 6,056 seconds. In manually control, the average speed was 0.172 m/s with an average travel time of 4.484 seconds. Based on Table 4, the result of the robot speed when rotating 180^0 with autonomous obtained an average speed value of 0.158 m/s and an average travel time of 9.644 seconds. The result with a manually control showed the average speed value was 0.197 m/s with an average travel time of 7.754 seconds. The speed of autonomous system is lower because automatically detecting surrounding objects without human control is different from remote

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control controlled by humans. If human control stops the robot will stop differently. with autonomous control the robot will keep moving.

Performance of Robot with Obstacles Object

The obstacles used in this test were clear bottles, dolls, wood and clear acrylic object. The robot navigation system was unable to read any obstacle objects such as clear bottles and clear acrylics because the laser beam from the LIDAR Tfmini sensor cannot reflect the laser and was not return to the Tfmini LIDAR receiver. Therefore the robot cannot respond the existence of an object in front. It was different with a wooden object and doll. A robot navigation system responds those obstacles from various distances because the Tfmini LIDAR laser was able to reflect laser light on the object so that the robot able to respond to objects in front of it.

Results of Robot Testing in Navigating to a Room with Fire Source

Figure 7 showed the testing of the Robot moved toward fire room and axtinguished fire. This test compared two navigation system such as autonomous and manually control. From 5 time trials, this test obtain datas of robot performance of extinguishing fire and travel time to reach the room. The result showed the average travel time when the robot navigates to the fire source room with autonomous control was 50.972 seconds while the manually control was 40.07 seconds. The value generated by the autonomous system is lower because it detects surrounding objects automatically without human control. It is different from a human-controlled remote control because decision was calculated by human process. The success of extinguishing fire with manually control 4 times out of 5 times, while control with autonomous was successful 3 times out of 5 times.

Figure 6. The Robot move to the fire source room

CONCLUSION

The navigation system using LIDAR has been successfully designed and can be implemented into a hexapod fire extinguisher robot. This experiment conclude as follows:

The reading distance of Tfmini LIDAR was 3-1190 cm with an average reading error of 0.51%. The performance of Tfmini LIDAR sensor was not affected by light intensity and object color. However, it cannot work well on objects such as clear acrylic and clear bottles.

The average speed of the robot in a straight line is 0.100 m/s with an average travel time of 14.02 seconds. The average speed of the robot while turning 90° is 0.126 m/s with an average travel time of 6.056 seconds and the speed of the robot while rotating 180° is 0.158 m/s with an average travel time of 9.644 seconds.

The robot with a navigation system using the Tfmini LIDAR based on the Arduino Mega 2560 microcontroller was able to navigate to a fire source room successfully with an average travel time to the room 50.972 seconds. This robot was able to detect fire and extinguish the fire. The system with manually controlled was able to navigate to the fire

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source room successfully with an average travel time to the room 40.07 seconds and extinguish the fire.

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