Investigate The Performance of Line Following Robot with Different IR Sensor Position Mounted

Mohd Nazrul Effendy Mohd Idrus[1,*], Mohd Khairul Anuwar Mohd Khairi[1], and Kamarul Ariff Abu Mansor[1]
[1]Department of Electrical Engineering, Politeknik Mersing, Jln Felda Nitar Timur, 86800 Mersing, Johor, Malaysia
*Corresponding author: nazrul@pmj.edu.my

Abstract

Line following is one of the methods used in mobile robotic to navigate to other places. Commonly, infrared (IR) sensors were used to sense the line with its black line on a white surface. There are several methods to improve performance in line following navigation such as by using advanced algorithm line sensor detection, improving sensor configuration strategy, and vision-based approached. However, the previous studies are limited to investigate the effect of the different positions of IR sensors on the performance of line following robots. Determination of line following sensor position is important to improve the navigation performance. This study aims to investigate the performance of line following robots with different IR sensor positions mounted. Different lines following circuit track which are circle and rectangle shape were tested. Results indicated that location 2 ($L2_{20}$) and location 1 ($L1_{25}$) were the best locations mounted for rectangle and circle track respectively. The finding shows that location 3 ($L3_{15}$) can be declared as the best position with 12.10 s and 13.60 s of mean time for rectangle and circle circuits. Therefore, an appropriate IR sensor position tends to give an optimum performance of the line following the robot to navigate.

Keywords: - line following robot; sensor position; IR sensor; circuit track

1. Introduction

Line following robot having the ability to detect and follow a particular line to complete the purpose task autonomously. The previous study shows that line following robots can be applied in various applications such as delivery (Opeyemi, 2019), industrial (Pathak et al., 2017), transportation (Mostafa et al., 2019), and car parking (Younus et al., 2019). Furthermore, some line following robots are commonly used for educational purposes (de Lima et al., 2018) and competition (Pakdaman et al., 2010).

Many studies were conducted on the developed line following robot and improve the performance of line following navigation. In order to move forward, turn left, and turn right, the line following robot was designed with different types of wheels base. For example, two main wheels connected with geared motor combined with a freewheel were used to navigate on the line following (de Lima et al., 2018 and Tian and Du, 2019). Then, 4-wheels autonomous control of line following robot was used for the line following competition (Nikolov, 2018). Two main wheels combined with 2 freewheels were used on a restaurant serving Robot (Thanh, 2019). Therefore, the different number of wheels used in line following navigation depends on its task application.

There are two common methods were used to detect line namely optical-based and vision-based approached. Infrared sensors or light-dependent resistors were the most commonly used sensors for the line following robot navigations (Nikolov, 2018). The previous result shows that the mobile robot was successfully able to navigate using a vision-based method throughout the provided path (Ismail, 2009 and Ma'arif and Nuryono, 2020). Therefore, these optical-based and vision-based approaches can be used in line following detection. However, this method requires an advanced algorithm and a high-speed processor. Generally, more than three infrared photo reflectors were used to detect the line following the track by capturing the line position with optical sensors mounted (Pakdaman et al., 2010). However, there are certain study used 2 number an infrared sensor to detect the line following (Hasan and Al Mamun, 2012). Eight sensors to detect line following were used (Nikolov, 2018). Therefore, a different number of sensors can be used to navigate on the line following path.

In addition, there are also studies developed different algorithm in line following detection. By using three variables which are proportional, integral, and derivative (PID) that gives feedback continuously looping control system which helps keep the robot on track (Dumitrache, 2020). This method improves the performance of the line following robot goes fast and on track without slip. Then, the fuzzy logic was implemented shows high accuracy capability to detect different line colors

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which represent different routes (Nugraha, 2015). The studies indicate that different types of algorithms can be used on the line detection navigation.

To fulfill the purpose of the line following task, different alignment of sensor position has been studied. Line sensor configuration methods to place sensors for junction tracking and junction turning were proposed successfully to navigate (Baharuddin et al., 2005). Then, double line sensors position which is front and back located on robot body was successfully developed of a restaurant serving robot (Thanh, 2019). In addition, a robot with a three-level alignment of eight infrared sensors on the bottom to detect the line was successfully designed (Pakdaman et al., 2010). These indicate that different alignment of line following sensor can be used to detect line following.

However, there is no specific study was conducted to investigate the effect of different locations of line following sensors on the performance of line following robots. Therefore, this study aims to measure the performance of the line following robot with six location positions mounted from the center of the main wheel.

2. Methodology

2.1. Sample and Performance Evaluation

During this study, 30 attempts (n) for six positions mounted of line following sensor has been recorded which is the interval time (I_t). This process is done in two different types of track which are rectangle and circle track. Therefore, 360 number of the sample has been recorded during the study. Maximum (max), minimum (min), mean (μ), and standard deviation (σ) as Equation 1 and Equation 2 were computed to measure the performance of different locations of the line following sensor. Where N is the total number of samples and x_i data samples.

$$\mu = \frac{\sum_{0}^{x_i} It}{N} \qquad (1)$$

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}} \qquad (2)$$

2.2. Sensor Arrangement Location Mounted

In this study, the line following sensor is located at a different distance from the center of wheels up to the front of the robot.The sensor located with 6 different location from the center of the wheel which is location 1 ($L1_{25}$), location 2 ($L2_{20}$), location 3 ($L3_{15}$), location 4 ($L4_{10}$), location 5 ($L5_{5}$), and location 6 ($L6_{0}$) as shown in Figure 1((a), (b), (c), (d), (e) and (f)) respectively. The nearest distance is 0 cm where it is on the center of the wheel increasing with 5 cm each location until the far location is 25 cm. The position of the sensor will be changed after 30 complete rounds for the circle line following track. This procedure was repeated for the rectangle line following track.

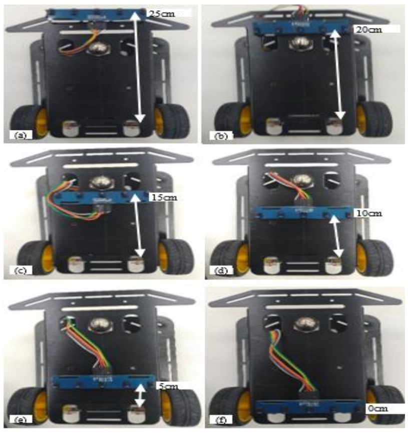
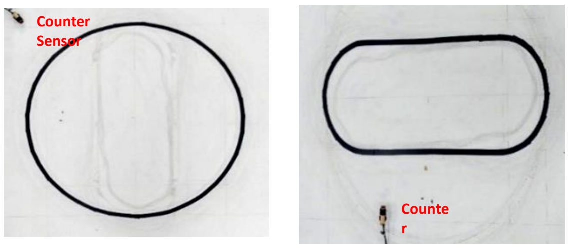


Figure 1: Line following sensor mounted

2.3. Line Following Track

There are two lines following tracks that were used in this study which are circle and rectangle rounded corner as shown in Figure 2. Many types of line following track such as T-junction, or any 90^0 angle, and curvy path has been used for previous studies (Opeyemi, 2019). The black line is 3cm wide was placed on the white surface which the robot has to follow. Circle track with 35cm of radius and 220cm of circumference used to provide a continuous rounded shape line following track. While rectangle rounder corner with 15cm of radius and 200cm of circumference provides a straight and continuous shape line following track. An infrared sensor was located 10cm beside the tracking line used to count the time consumed for the line following robot navigation to complete each round.



(a) (b)

Figure 2: Line following track for (a) circle and, (b) rectangle rounded corner.

2.4. Simple Line Following Algorithm Detection

In this study, 5 infrared sensors were used which are infrared sensor left 2 (IRS_{L2}), infrared sensor left 1 (IRS_{L1}), infrared sensor center (IRS_{C}), infrared sensor right 1 (IRS_{R1}), infrared sensor right 2

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(IRS_{R2}). A simple movement algorithm was used to navigate the robot movement as shown in Table 1. High and Low signal indicates that the sensor detects white and black colour respectively which is black is the line path to be followed by the robot.

Table 1: Robot movement reaction with the different conditions of the sensor.

IRS_{L2}	IRS_{L1}	IRS_{C}	IRS_{R1}	IRS_{R2}	Movement
High	High	Low	High	High	Forward
High	Low	Low	High	High	Left
Low	Low	High	High	High	Left
High	High	Low	Low	High	Right
High	High	High	Low	Low	Right

There are 5 conditions of line following sensor that could be occurred during the navigation. First, when only IRS_C is Low where the robot is in the center of line following. In this situation, the robot will move forward with the left and right of the motor will rotate at high speed. Second, when IRS_C and IRS_{L1} are Low indicate the robot is in the left of line following. Therefore, the robot has to move to the left to recorrect the position of the robot until getting the first position. To do so, the robot has to slow down the left motor speed and keep the right motor at the highest speed. The third condition where IRS_{L1} and IRS_{L2} are low indicates the robot is in the outer left of line following. In this condition, the robot will execute the movement the same as the second condition. Then, the fourth condition where IRS_C and IRS_{R1} Low indicate the robot is in the right of line following. Therefore, the robot has to move to the right to recorrect the position of the robot until getting the first position. The fifth condition where IRS_{R1} and IRS_{R2} are low indicates the robot is in the outer right of line following. In this condition, the robot will execute the movement the same as the fourth condition. The robot will continuously navigate the line following track base on the given condition as above. However, there will be a condition where the robot will detach from the line following tracking may cause from the sensor condition is not stated as above or the sensor location may not appropriate mount.

3. Finding and Analysis

3.1 Performance on Rectangle Track

Figure 3 shows the line following performance with different location sensors mounted for rectangle track. There are 30 number of testing for each sensor location were performed. The data with 20 s indicate that the robot failed to complete that round. Location 1 ($L1_5$) tends to reach the best performance with 7.70 s of minimum time interval on the 11 attempts of testing. However, there were 4 attempts failed on 5th, 7th, 22nd, and 26th attempt. The second-best performance is obtained when the line following sensor is located at location 2 ($L2_{20}$) with 10.10 of the minimum time interval. Meanwhile, location 3 ($L3_{15}$) tends to obtain 11.68 s of minimum time interval which is slower than $L1_5$ and $L2_{20}$. This indicated that $L1_5$ achieved 3.98 s fastest than $L3_{15}$. After that, location 4 ($L4_{10}$) tends to obtain 12.39 s of minimum time interval at the 10th attempt. Then, location 5 ($L5_5$) tends to achieve lower performance with 13.07 s of minimum time interval compared to $L4_{10}$. However, location 1 ($L6_0$) failed to complete any testing of 30 attempts with more than 20 s of time interval indicated that $L6_0$ is not an appropriate position of line following sensor because the sensor is located parallel with the canter of wheels.

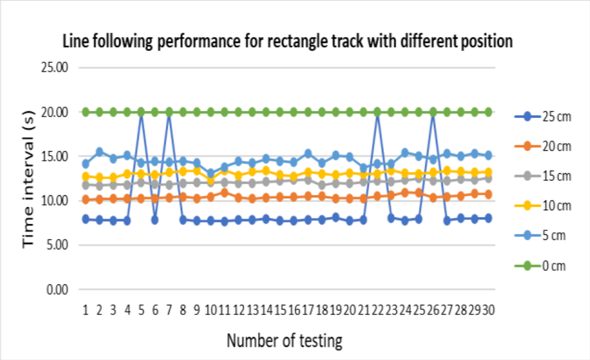

Figure 3: Line following performance with different location sensor mounted for rectangle track

3.2 Performance on Circle Track

Figure 4 shows the line following performance with different location sensors mounted for the circle track. There are 30 numbers of testing for each sensor location that was performed equally with a rectangle track. The data with 20 s also indicate that the robot failed to complete that round. Location 5 ($L5_5$) tends to achieve the best performance with 12.11 s of minimum time interval at the first 1st attempt. Location 1 ($L1_{25}$) tends to reach the second best performance with 11.27 s of minimum time interval on the 16 attempts of testing. Robot succeeded to completed every 30 attempts compared with the same Location 1 ($L1_5$) in the rectangle track with only 26 number of attempts succeeded. This result indicated that $L1_5$ is not suitable used on rectangle line following track. The third best performance is obtained when the line following sensor located at location 4 ($L4_{10}$) tends to obtain 12.60 s of the minimum time interval. Meanwhile, location 3 ($L3_{15}$) tends to obtain 13.11 s of minimum time interval which is slower than $L1_{25}$, $L5_5$, and $L4_{10}$. This indicated that $L5_5$ achieved 1.84 s fastest than $L3_{15}$. After that, location 2 ($L2_{20}$) tends to obtain 13.66 s of minimum time interval at 1st attempt. However, location 1 ($L6_0$) failed to complete any testing of 30 attempts with more than 20 s of time interval indicated that $L6_0$ is not an appropriate position for circle and rectangle track.

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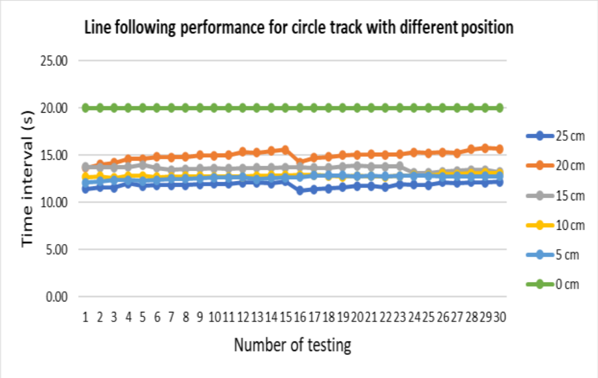

Figure 4: Line following performance with different location sensor mounted for circle track

Table 2: Line following performance for rectangle and circle track.

Track	Sensor location	max	min	μ	σ
Rectangle	location 1 ($L1_{25}$)	20.00	7.70	9.47	4.13
	location 2 ($L2_{20}$),	10.96	10.10	10.43	0.23
	location 3 ($L3_{15}$),	12.54	11.68	12.10	0.23
	location 4 ($L4_{10}$),	13.42	12.39	13.06	0.26
	location 5 ($L5_{5}$),	15.51	13.07	14.60	0.56
	location 6 ($L6_{0}$)	20.00	20.00	20.00	0.00
Circle	location 1 ($L1_{25}$)	12.23	11.27	11.84	0.25
	location 2 ($L2_{20}$),	15.77	13.66	14.98	0.48
	location 3 ($L3_{15}$),	13.98	13.11	13.60	0.21
	location 4 ($L4_{10}$),	13.13	12.60	12.83	0.13
	location 5 ($L5_{5}$),	12.88	12.11	12.63	0.21
	location 6 ($L6_{0}$)	20.0	20.00	20.00	0.00

Table 2 shows the maximum (max), minimum (min), and mean (μ) of the time interval for rectangle and circle track with different locations of the sensor. The results show that location 2 ($L2_{20}$), location 3 ($L3_{15}$), location 4 ($L4_{10}$), and location 5 ($L5_{5}$) tend to achieve a good result 0.23, 0.23, 0.26, and o.56 of standard deviation (σ) respectively. These results indicated that $L2_{20}$, $L3_{15}$, $L4_{10}$, and $L5_{5}$ are the reliable location the line following sensor can be mounted because all of 30 numbers of testing for rectangle and circle track were successful in completed without fail. Then, $L2_{20}$ can be declared as the best location position followed by $L3_{15}$, $L4_{10}$, and $L5_{5}$ with 10.43, 12.10, 13.06, and 14.60 of μ respectively for rectangle track. After that, $L1_{25}$ can be declared as the best location position followed by $L5_{5}$, $L4_{10}$, $L3_{15}$, and $L2_{20}$ with 11.84, 12.63, 12.83, 13.60, and 14.98 of μ respectively for circle track. $L1_{25}$ shows the best location for line following sensor on circle track but not on rectangle track cannot be declared as the best location for both tracks. Therefore, $L3_{15}$ can declare as the best position for both tracks with 2nd and 4th best positions for rectangle and circle track. However, the result of location 6 ($L6_{0}$) where the line following sensor located on the center of the wheel show that every attempt for rectangle and circle were failed. This indicates that this location is not an appropriate location for the line following sensor to navigate. In addition, $L1_{25}$ shows 4.13 of standard variation (σ) because there are 4 attempts from 30 attempts robot failed to complete the task for rectangle circuit. This indicated that $L1_{25}$ is not a suitable location for a certain line following track.

4. Conclusion

This study investigates the performance of line following robot with different infrared sensor positions mounted on rectangle and circle line following track. Results indicated that location 2 ($L2_{20}$) and location 1 ($L1_{25}$) were the best locations mounted for rectangle and circle track respectively. The finding shows that location 3 ($L3_{15}$) can be declared as the best position with 12.10 s and 13.60 s of the average time for rectangle and circle circuits. Therefore, an appropriate line following sensor is important to ensure an optimum performance of line following robot to navigate. Nevertheless, different algorithm line following detection methods may be investigated to improve the line following robot navigation.

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