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Application of Proportional Integral Derivative system as speed control on Mobile Robot Line Follower

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Abstract

Abstract In today's world, the use of robots to assist with work is becoming increasingly common. One such example is the Line Follower robot, a type of mobile robot that uses lines to navigate to a predetermined location. In this line-following robot, sensors are a crucial component that determine the robot's speed and accuracy. The robot uses infrared (IR) line-following sensors to detect black lines, enabling it to follow the predetermined line as quickly as possible. Time serves as a benchmark for the robot's speed in completing a path. The Arduino Uno microcontroller in this robot design acts as the control system. In this design, the Arduino Uno is used as the microcontroller to control the IR sensors. The robot's operating system works as follows: it is operated by activating the power button on the back of the robot. The number of sensors, power, and PID accuracy values can affect the robot's travel time comparison from the starting point to the end of the test on the two tested tracks. The results obtained are 4 IR LF sensors with an average travel time of 6.7 seconds on the first track and 13.5 seconds on the second track, which is better than 2 or 3 IR LF sensors with a difference of 0.64 seconds on the first track and 0.7 seconds on the second track. The above values may vary depending on the specifications of the components, conditions, and environment of the robot during testing.

Keywords: *PID; IR Sensor; Line Follower; Time; Microcontroller*

1. Introduction

The development of robotics in Indonesia has grown rapidly compared to a few years ago. Robotics competitions are held almost every year by the Ministry of Research, Technology, and Higher Education (Kemenristek DIKTI), both for schools and public and private universities. With these various competitions, research in the field of robotics has also increased. This robot is designed to follow a predetermined path. One type of robot with special capabilities that has recently attracted significant attention from experts for development is the line-following robot[1]. Navigation is a crucial component in robotics applications. To complete certain tasks, robots must follow specific paths. Line-following robots equipped with a reflectance sensor array can be used to transport specific loads from one point to another. The objective of this research is to develop a differential wheel control algorithm for following a specific path. There are two main objectives in this research. The first objective is for the robot to complete its path perfectly. The second objective is for the completion time to be as short as possible. During this study, only commercially available and affordable components were used. Proportional Integral Derivative (PID) controller is an acronym for proportional, integral, and derivative. PID controllers are closed-loop control systems widely used in industry. These systems attempt to bring the system to a state determined by the input by calculating the error[2].

In the development of line-following robots, improving speed control performance is essential to ensure accurate navigation and responsive reactions to changes in the path. The Proportional-Integral-Derivative (PID) control system has been widely applied in various robotics applications to regulate speed and position with high precision.[3] This indicates that the use of the PID system in line-following robots can produce quick and stable responses to lane changes, as well as dynamically adjust the robot's speed according to environmental conditions. However, despite the proven effectiveness of the Proportional Integral Derivative system, challenges in its implementation lie in optimizing the Proportional Integral Derivative parameters according to conditions, the ability to handle external disturbances, and the compatibility of sensor value calculations with uncertainties in changing environments. To address this, the application of the Proportional Integral Derivative system is an intriguing approach worth exploring. By integrating these elements, the robot can plan an optimal path to follow, enabling the Proportional Integral Derivative system to be tuned more efficiently to achieve better navigation performance and sensor value readings. Therefore, this study aims to explore the application of the Proportional Integral Derivative system as a speed controller for a line-following robot to enhance the navigation capabilities of the IR line-following sensor [4].

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Seeing The lack of research in the field of robotics at Pakuan University, particularly regarding line-following robots, poses problems such as a lack of knowledge resources about line-following robots, including the sensitivity of sensors to line colors, the field used for robot trajectories, and the proper placement of line sensors on robots, as well as the application of Proportional Integral Derivative (PID) in robot control. Therefore, I conducted a final project research titled “Application of the Proportional Integral Derivative System as a Speed Controller for a Line-Following Robot Car” to enable the robot to follow a predetermined line in the shortest possible time by attempting an approach using multiple sensors.

2. Metode

2.1. Stages of Research Implementation

The stages of this research are based on the research method used, namely the Hardware Programming method, in this method there are several stages that need to be carried out including:

1. **Planning.** In the design of a research project, the design determines how the system runs from the beginning to the final goal that has been set.
2. **Reference Study.** This reference study uses journals with a period of 5 years before this research was carried out.
3. **Electrical Design.** Electrical design is important to know the voltage source and voltage requirements needed in the tool being made.
4. **Component Procurement.** This stage is to prepare the tools and materials needed in this research.
5. **Component Testing.** This stage is to test the work function of the components that have been provided.
6. **Electrical Implementation.** This stage is carried out to stabilize and control the current used according to the needs of the system.
7. **Software Design.** Software design is carried out, in order to find out the system design so that it gets according to the objectives made.
8. **Software Implementation.** This stage aims to complete the software system that has been determined in the previous design.
9. **Test Software.** This stage aims to ensure that the software is in accordance with its uses.
10. **Mechanical Design.** Mechanical design is aimed at knowing the placement of components, the placement of these components is done with efficiency and the right arrangement.
11. **Mechanical Implementation.** This stage is carried out to prepare and complete a series of research tools and check all components that have been determined in the previous design.
12. **Integration.** Performing unification between software design and mechanical design to carry out overall test tests on the system made.
13. **Overall Test.** This overall test is carried out to find out whether all system functions in the design that have been determined according to the concept. If the system does not run well, an inspection will be carried out on the system implementation.
14. **Application.** This stage is where to improve a system that has been designed in such a way as to further maximize and optimize it so that the system made is much better.

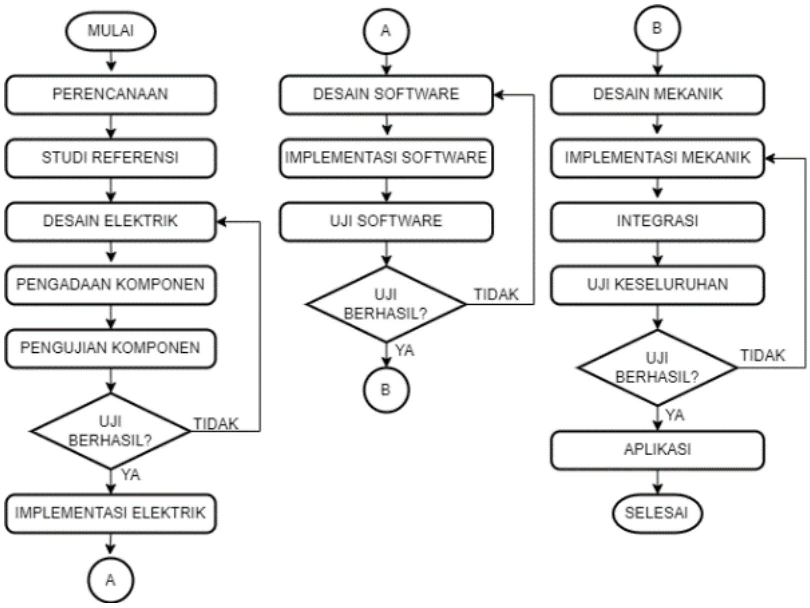

Figure 1. Hardware Programming Research Methods

2.2. Theoretical foundation

PID (Proportional Integral Derivative) controller system is a feedback mechanism controller commonly used in control systems. Proportional Integral Derivative control is a control method used to regulate the precision of instrumentation systems by utilizing feedback on the system. The main components of Proportional Integral Derivative control consist of three types: Proportional (P), Integrative (I), and Derivative (D). These controllers continuously calculate the error value as the difference between the desired setpoint and the measured process variable[5].

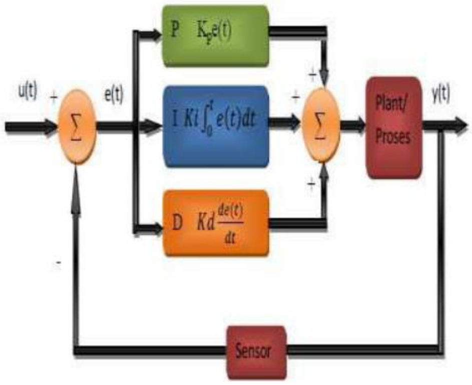

Figure 2. Block Diagram of PID Controller[6]

The output of the PROPORTIONAL INTEGRAL DERIVATIVE controller in Figure 2 can be calculated using the equation :

$MU(t) = Pout + Iout + Dout$

Where :

$M_{U(t)}$ = Controller Output
P_{out} = Proportional Controller Output
I_{out} = Integral Controller Output
D_{out} = Derivative Controller Output

The variable whose parameter value can be set is called the operating variable (MV) which is usually equal to the controller output (t). The output of the Proportional Integral Derivative controller will vary in response to changes in sensor measurement results and the specified setpoint.[7]

PID control or Proposional Integdral Derivatife control is a system used to regulate or control the output of the system used. The PID control system can also be referred to as a close loop control system because it has feedback. PID control is useful for calculating the error of the measured variable value and the specified setpoint and trying to minimize the existing error value [8]

Line sensors are often used in line-tracking robots, which can detect black and white line colors. To distinguish between black and white colors, these sensors are usually made of photodiodes or LEDs that function as light emitters and are then attached to a voltage divider circuit. Line sensors can be connected directly to a comparator or to a microcontroller with the adc feature. Know the properties of Photodiode and LDR sensors before discussing how line sensors work.[9] The LED in the line sensor sends light to the line, which is then reflected and read by the photodiode or LDR. The light-reflecting properties of different colors are used. The principle is that when an LED emits light onto a white field, most of the light is reflected by the white field. Conversely, when an LED emits light onto a dark or black colored field, the dark field will absorb a lot of light, so the amount of light reaching the sensor (photodiode or LDR) will be small. This is because the different light received by the sensor will cause different resistance in the sensor.[10] The line detection sensor uses infrared to detect the presence of a line. Therefore, this sensor can be used in line follower robots. [11]

DC motor is a device that converts electrical energy into kinetic energy or DC motor movement is also called a direct current motor. As the name suggests, a DC motor has two terminals and requires a direct current voltage to be able to move it.[12] This electric DC motor is usually used in electronic devices and devices that use DC power sources such as fans, electric drills and others. This visual aid the author uses a DC motor to rotate the wheels on the robot.[13]

The L298N Motor Driver Module is a high-power motor driver module for driving DC and Stepper Motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. The L298N module can control up to 4 DC motors, or 2 DC motors with direction and speed control.[14]

The controller used in this line follower robot is an arduino uno microcontroller, why use arduino uno, because arduino is one of the new breakthroughs in the world of microcontrollers. Many electronics and robotics projects use Arduino. This is because Arduino has high flexibility both in terms of software and hardware. Arduino is a single-board microcontroller that is opensource. Arduino has many advantages compared to other microcontrollers. The advantages include having a code library and many modules that support Arduino. This reason makes novice users easy to operate Arduino so that the user is very much[15]

3. Results and Discussion

The research results obtained are based on the existing research stages. The research stages use the hardware development method used, namely the Hardware Programming method. Design and manufacture of Line follower robot prototypes using PID and IR Line follower to get a short travel time at Pakuan University as follows:

3.1. Needs Analysis Results

The results of this needs analysis produce specifications of the needs of the design and development of the system and the mechanism of the tool to be designed.

1. The tools and materials used in this research are Microcontroller/Arduino Uno, Motor Driver and Actuator/L298N, Sensor/IR TCR 5000, Arduino Jumper Cable, Wheel, Mica Glass, dc motor, computer and supporting software Draw.io, Microsoft Office, Google Chrome, Arduino IDE, Figma, and Tinker cad.
2. In the previous stages, the design process to implementation of the Arduino Uno-based line follower robot has been explained. This robot does not need a place that is so large, this tool can be used on a track or without a track, but requires a battery with sufficient voltage to be able to move the robot.
3. The testing method is carried out not only when the tools and systems have been made, but components that have not been put together will be tested to determine the function and performance of these components. Overall system testing will be carried out from the hardware function is running properly, then continued testing the robot running on the path that has been provided and record the time and the match of the PID value to the robot and the environment.
4. Design analysis is related to how the work flow of the tools and systems. In this study, a block diagram was made to make it easier to read how these tools and systems work.

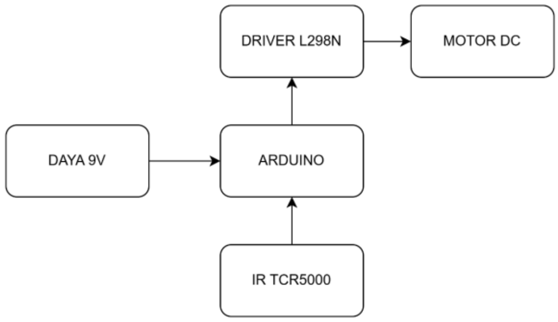

Figure 3. Block diagram of the relationship between components

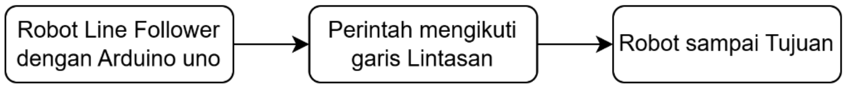

Figure 4. Block Diagram of line follower robot

3.2. Design result

The design results of this research refer to the prototype of the application of the Proportional Integral Derivative system as a speed control on the Mobile Robot Line Follower in accordance with the system block diagram. In this study there is an electrical design form of a line follower robot and components that are already interconnected in electrical form can be seen in Figure 5.

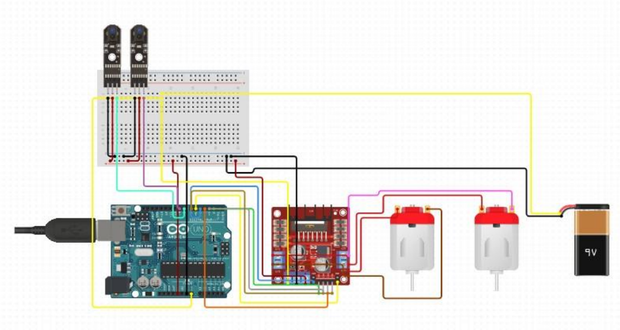

Figure 5. electrical design

In accordance with Figure 5, the following are the needs of the tools used in the design of this research :

a) Arduino Uno is used to read and process data from the IR Line Follower sensor, L298N Driver and DC Gearbox Motor. Then Arduino Uno is used to give instructions to the Relay to disconnect or connect the electric current connected to the power supply and wheels. The data obtained and processed in Arduino Uno.

b) This L298N driver is used and focused on receiving data from Arduino Uno. The data will be channeled to the DC motor so that the motor moves according to the direction of the Arduino Uno.

c) Sensor IR Line follower this sensor is a reader sensor that utilizes the difference in infrared light reflection between lines and surfaces to generate a signal that is then processed to control the movement of the robot.

3.3. Software design

The software used in this study uses Arduino IDE as the main function of the system as shown in Figure 6, in this application logic and PID commands will be input so that the robot can read the path and logic when the robot moves.

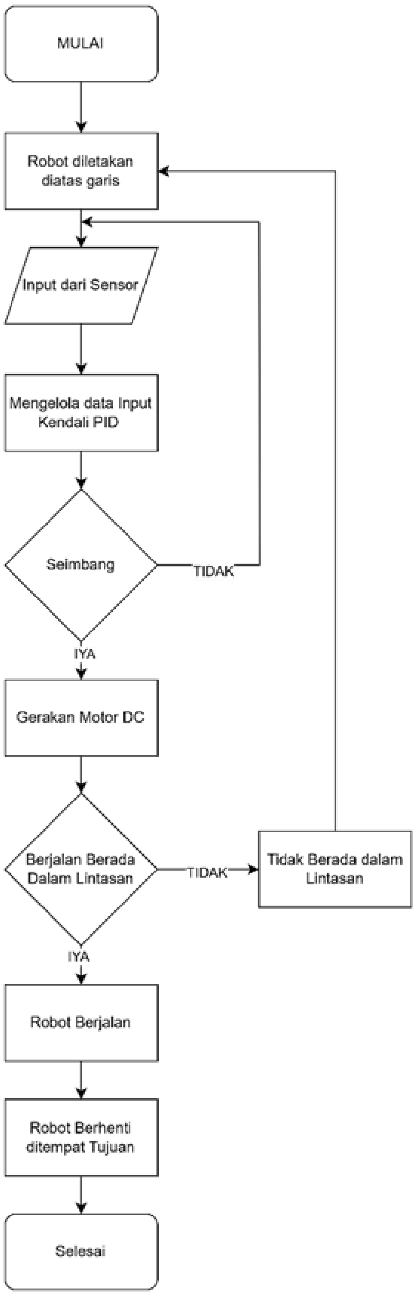

Figure 6. System Flowchart

3.4. Component Testing

This stage is carried out to test the components that will be used in this system model. In this testing, testing of component functions is carried out using a multimeter to determine the input and output voltages that exist in the component.

1. **Arduino Uno Microcontroller Testing**

For testing the Arduino Uno used has been given a voltage of 6V and 9V using a power supply. After that the voltage is checked on the 5V pin which is connected to the positive phobe and the GND pin is connected to the negative on the multimeter.

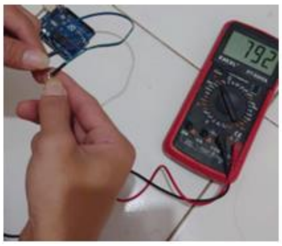

Figure 7. Arduino Uno Testing

Tegangan Masukan	Tegangan Keluaran
6V	5.74V
9V	7.92V

2. L298N Driver Testing

For testing the L298N Driver used has been given a voltage of 6V and 9V using a power supply. After that the voltage is checked on the 5V pin which is connected to the positive phobe and the GND pin is connected to the negative on the multimeter.

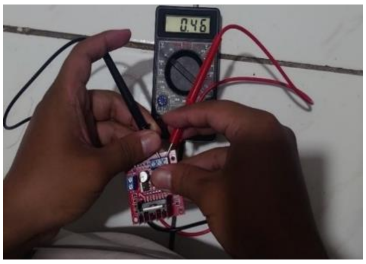

Figure 8. L298N Driver Testing

Tegangan Masukan	Tegangan Keluaran Pin 5V
6V	4,6V
9V	6,9V

3. IR Line Follower Sensor Testing

For testing the IR line folllower sensor used has been given calibrated using a multimeter. After that the voltage is checked on the VCC pin which is connected to the positive phobe and the GND pin is connected to the negative on the multimeter.

Figure 9. Line Follower Sensor Testing

Tegangan Masuk	Keluaran
865 ADC	4.23 V
995 ADC	4.86 V

3.5. Development/ implementation results

Results and implementation will be carried out on the floor of a plain colored house or room and given a black line using black duct tape. In this test, 2 examples of paths with different shapes will be used, the first path has a length of 1 meter and a width of 500 cm with a letter U shape with a few turns, while the second path has a length of 2.7 meters and a width of 1 meter with a rectangular shape with an imperfect circle and several sharp turns that can be seen in Figures 11 and 12, and the results of the robot shape can be seen in the figure 10.

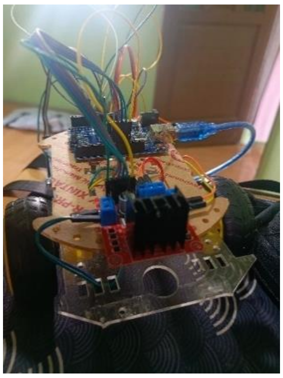

Figure 10. LF robot result form

Figure 11. First Line and second line

3.6. Test Result

At this test stage, the speed of the robot in reading the line from start to finish will be tested. Before starting the test here there is a value test table on the IR line follower sensor which can be seen in table 1 to get the value of Infrared sensitivity to black and non-black colors, after getting the test value on the sensor the robot will read both lines with a comparison test when the robot uses 2, 3 and 4 sensors.

Table 1. Voltage value on IR sensor on 4 sensors

Sensor 1		Nilai Tegangan (Volt)		Nilai ThresHold
Hitam	Putih	Hitam	Putih	
987	47	4,82V	0,23V	517
987	47	482V	0,22V	517
Sensor 2		Nilai Tegangan (Volt)		Nilai ThresHold
Hitam	Putih	Hitam	Putih	
1010	35	4,94V	0,17V	522
1011	36	4,,94V	0,17V	523
Sensor 3		Nilai Tegangan (Volt)		Nilai ThresHold
Hitam	Putih	Hitam	Putih	
1012	45	4,95V	0,22V	528
1011	45	4,94V	0,22V	528
Sensor 4		Nilai Tegangan (Volt)		Nilai ThresHold
Hitam	Putih	Hitam	Putih	
938	73	4,54V	0,36V	505
939	74	4,55V	0,36V	506

Table 2. Testing Results of LF Robot Using PID Control and without PID Control with 2 Sensors on the Letter U Path

Dengan Kontrol PID						Tanpa Kontrol PID		
Waktu Pengujian	Nilai PID			Waktu Yang Ditempuh(Detik)	FINISH	Waktu Pengujian	Waktu Yang Ditempuh(Detik)	FINISH
	P	I	D					
13.10	8.0	0.02	0.4	6,51	Berhasil	14.26	11,91	Berhasil
13.11	8.0	0.02	0.4	7,36	Berhasil	14.28	13,54	Berhasil
13.12	8.0	0.02	0.4	7,88	Berhasil	14.30	10,34	Berhasil
13.13	8.0	0.02	0.4	7,50	Berhasil	14.32	13,73	Berhasil
13.14	8.0	0.02	0.4	7,25	Berhasil	14.34	12,79	Berhasil
13.15	8.0	0.02	0.4	7,21	Berhasil	14.36	12,32	Berhasil
13.16	8.0	0.02	0.4	7,30	Berhasil	14.38	11,34	Berhasil
13.17	8.0	0.02	0.4	7,48	Berhasil	14.40	11,51	Berhasil
13.18	8.0	0.02	0.4	7,64	Berhasil	14.42	12,41	Berhasil
13.19	8.0	0.02	0.4	7,08	Berhasil	14.44	12,68	Berhasil
13.20	8.0	0.02	0.4	7,38	Berhasil	14.46	12,34	Berhasil
13.21	8.0	0.02	0.4	7,88	Berhasil	14.48	11,38	Berhasil
13.22	8.0	0.02	0.4	7,26	Berhasil	14.50	11,65	Berhasil
13.23	8.0	0.02	0.4	7,34	Berhasil	14.52	13,36	Berhasil
13.24	8.0	0.02	0.4	7,30	Berhasil	14.54	12,89	Berhasil
Rata - rata				7,4 Detik		Rata - rata	12,28 Detik	

Table 3. Testing Results of LF Robot Using PID Control and without PID Control with 2 sensors on Imperfect and Winding Circle Paths

Dengan Kontrol PID						Tanpa Kontrol PID		
Waktu Pengujian	Nilai PID			Waktu Yang Ditempuh(Detik)	Finisih	Waktu Pengujian	Waktu Yang Ditempuh(Detik)	FINISH
	P	I	D					
15.36	8.0	0.02	0.4	13,10	Berhasil	15.02	17,86	Berhasil
15.40	8.0	0.02	0.4	14,65	Berhasil	15.05	18,98	Berhasil
15.44	8.0	0.02	0.4	14,44	Berhasil	15.11	18,32	Berhasil
15.48	8.0	0.02	0.4	14,23	Berhasil	15.14	19,62	Berhasil
15.52	8.0	0.02	0.4	13,78	Berhasil	15.17	18,63	Berhasil
15.56	8.0	0.02	0.4	14,02	Berhasil	15.20	20,53	Berhasil
15.60	8.0	0.02	0.4	13,85	Berhasil	15.26	19,27	Berhasil
15.64	8.0	0.02	0.4	15,20	Berhasil	15.29	20,01	Berhasil
15.68	8.0	0.02	0.4	15,46	Berhasil	15.38	21,61	Berhasil
15.72	8.0	0.02	0.4	14,29	Berhasil	15.41	21.42	Berhasil
15.76	8.0	0.02	0.4	13,34	Berhasil	15.08	19,15	Gagal
15.80	8.0	0.02	0.4	14,23	Berhasil	15.23	05,71	Gagal
15.84	8.0	0.02	0.4	13,69	Berhasil	15.32	23,14	Gagal
15.88	8.0	0.02	0.4	14,03	Berhasil	15.35	05,47	Gagal
15.92	8.0	0.02	0.4	13,76	Berhasil	15.44	04,81	Gagal
Rata - rata				14,14		Rata - rata	19,43	

Table 4. Average result of testing 2 sensors

Lintasan	Nilai Rata - Rata PID	Tanpa PID	Nilai Selisih
Pertama	7,4 detik	12,28 detik	4,88 detik
Kedua	14,14 detik	19,43 detik	5,29 detik

Table 5. Testing Results of LF Robots Using PID Control and without PID Control with 4 Sensors on the Letter U Path

Dengan Kontrol PID						Tanpa Kontrol PID		
Waktu Pengujian	Nilai PID			Waktu Yang Ditempuh(Detik)	FINISH	Waktu Pengujian	Waktu Yang Ditempuh(Detik)	FINISH
	P	I	D					
01.00	8.0	0.02	0.4	6,81	Berhasil	01.01	8,34	Berhasil
22.37	8.0	0.02	0.4	6,5	Berhasil	01.02	7,87	Berhasil
22.38	8.0	0.02	0.4	7,57	Berhasil	01.03	7,85	Berhasil
22.39	8.0	0.02	0.4	7,06	Berhasil	01.04	7,86	Berhasil
22.40	8.0	0.02	0.4	6,79	Berhasil	01.05	7,69	Berhasil
22.41	8.0	0.02	0.4	6,72	Berhasil	01.06	7,89	Berhasil
22.42	8.0	0.02	0.4	6,71	Berhasil	01.07	7,42	Berhasil
22.43	8.0	0.02	0.4	6,02	Berhasil	01.08	7,60	Berhasil
22.44	8.0	0.02	0.4	6,89	Berhasil	01.09	7,67	Berhasil
22.45	8.0	0.02	0.4	6,74	Berhasil	01.10	7,68	Berhasil
22.46	8.0	0.02	0.4	6,92	Berhasil	01.11	7,58	Berhasil
22.47	8.0	0.02	0.4	6,80	Berhasil	01.12	7,56	Berhasil
22.48	8.0	0.02	0.4	6,83	Berhasil	01.13	7,36	Berhasil
22.49	8.0	0.02	0.4	6,38	Berhasil	01.14	7,12	Berhasil
22.50	8.0	0.02	0.4	6,42	Berhasil	01.15	8,05	Berhasil
Rata - rata				6,7 Detik		Rata - rata	7,7 Detik	

Table 6. Testing Results of LF Robot Using PID Control and without PID Control with 2 sensors on Imperfect and Winding Circle Paths

Dengan Kontrol PID						Tanpa Kontrol PID		
Waktu Pengujian	Nilai PID			Waktu Yang Ditempuh(Detik)	FINISH	Waktu Pengujian	Waktu Yang Ditempuh(Detik)	FINISH
	P	I	D					
17.50	8.0	0.02	0.4	13,18	Berhasil	17.24	11,98	Gagal
17.51	8.0	0.02	0.4	13,42	Berhasil	17.20	12,42	Gagal
17.52	8.0	0.02	0.4	13,87	Berhasil	17.16	15,32	Berhasil
17.53	8.0	0.02	0.4	14,65	Berhasil	17.17	14,21	Berhasil
17.54	8.0	0.02	0.4	13,98	Berhasil	17.18	13,42	Berhasil
17.55	8.0	0.02	0.4	13,74	Berhasil	17.19	14,92	Berhasil
17.56	8.0	0.02	0.4	13,64	Berhasil	17.21	14,74	Berhasil
17.57	8.0	0.02	0.4	13,33	Berhasil	17.22	13,70	Berhasil
17.58	8.0	0.02	0.4	13,12	Berhasil	17.23	15,46	Berhasil
17.59	8.0	0.02	0.4	13,98	Berhasil	17.25	13,80	Berhasil
17.60	8.0	0.02	0.4	13,74	Berhasil	17.26	13,90	Berhasil
18.00	8.0	0.02	0.4	13,07	Berhasil	17.27	14,67	Berhasil
18.01	8.0	0.02	0.4	12,57	Berhasil	17.28	14,72	Berhasil
18.02	8.0	0.02	0.4	12,47	Berhasil	17.29	13,58	Berhasil
18.03	8.0	0.02	0.4	13,24	Berhasil	17.30	15,32	Berhasil
Rata - rata				13,5 Detik		Rata - rata	14,4 Detik	

Table 7. Average result of testing 4 sensors

Lintasan	Nilai Rata - Rata PID	Tanpa PID	Nilai Selisih
Pertama	6,7 Detik	7,7 Detik	1 detik
Kedua	13,5 Detik	14,4 Detik	0.9 Detik

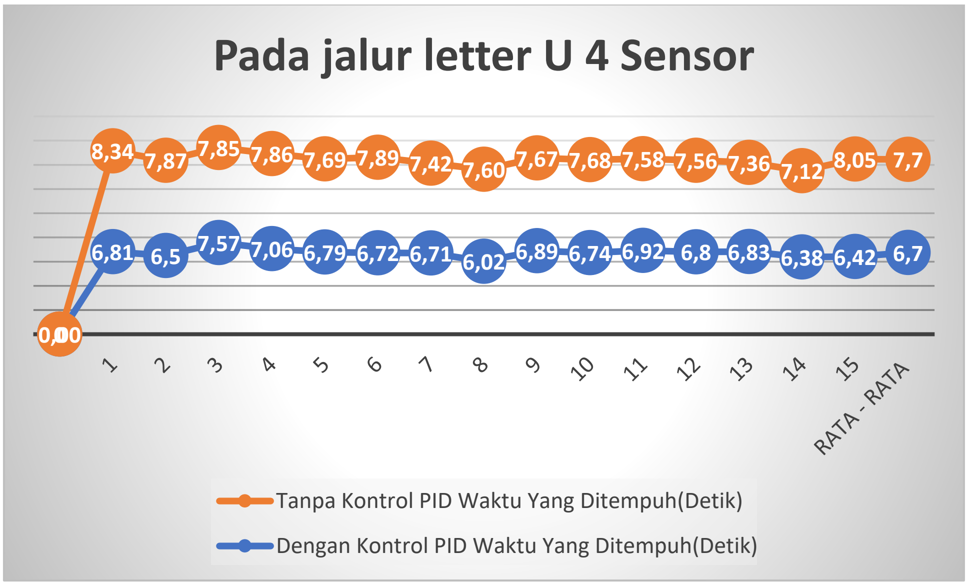

Figure 12. Graph of LF Robot Data using PID Control and without PID Control with 4 sensors on the Letter U Path

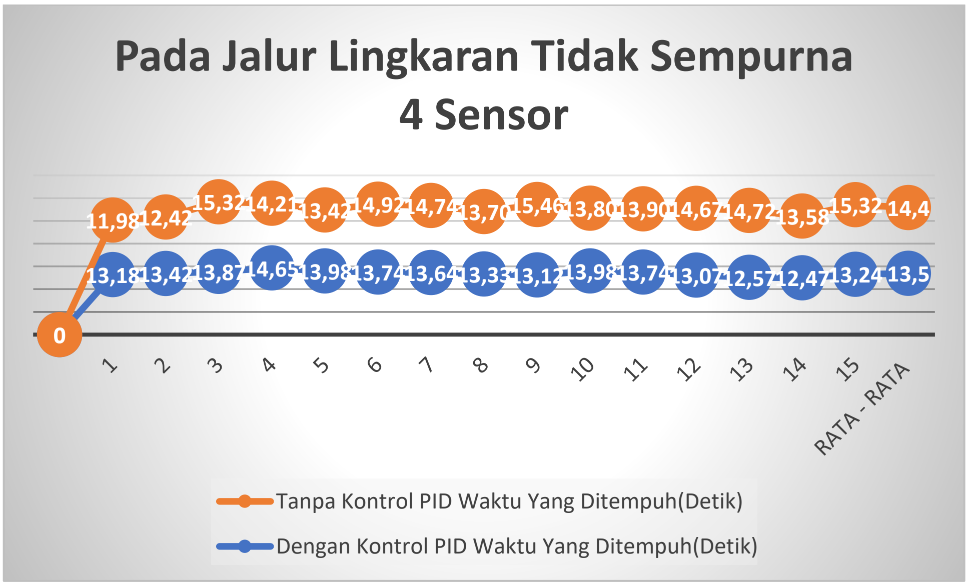

Figure 13. Grafik Data Robot LF dengan Menggunakanan Kontrol PID dan tanpa Kontrol PID dengan 4 sensor pada Jalur Lingkaran Tidak Sempurna dan berliku

4. Conclusion

In the study "Application of Proportional Integral Derivative (PID) System as a Speed Controller in Mobile Line-Following Robots," this was done to obtain a line-following robot that could travel the shortest distance along a given path through optimization of the PID values. This study also compared the use of several sensors to see if this could affect the robot's travel speed, and it turned out that the number of sensors had a small effect on the robot's performance. In this study, data was obtained showing that 4 sensors were more efficient in terms of travel time, with efficiency here referring to a shorter time. With a difference of 0.7 seconds on the first path and 0.64 seconds on the second path, 4 sensors are better than 2 or 3 sensors. 4 sensors achieved an average value of 6.7 seconds on the first path using PID and 13.5 seconds on the second path with PID. These values may vary depending on the position/type of components, sensor sensitivity determination by setting the threshold value, and the environment during testing. This study demonstrates that PID and the number of sensors used influence the travel time of the line-following robot. For this study, the researcher investigated the application of PID on a line-following robot by examining the effect of the number of sensors, and the researcher hopes this study can be further developed by investigating the influence of the power used by the robot and its weight on the robot's speed in completing the track.

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mobile robots that use line follower sensors so that they can provide significant benefits for the development of science at Pakuan University and society in general.

References

[1] K. Joni, M. Ulum, Z. Abidin, T. Elektro, U. Trunojoyo Madura, and J. P. Raya Telang BOX, "Robot Line Follower Berbasis Kendali Proportional-Integral-Derivative (PID) Untuk Lintasan Dengan Sudut Ekstrim," Jurnal Infotel, vol. 8, no. 2, 2016.

[2] S. Oguten and B. Kabas, "PID Controller Optimization for Low-cost Line Follower Robots," Nov. 2021, doi: 10.13140/RG.2.2.22102.98886.

[3] S. Fatimah Anggraini, A. Ma, and R. Dwi Puriyanto, "Pengendali PID pada Motor DC dan Tuning Menggunakan Metode Differential Evolution PID Controllers on DC Motors and Tuning Using the Differential Evolution Method," TELKA, vol. 6, no. 2, pp. 147–159, 2020.

[4] P. Prasetyo, R. Maulana, and E. Setiawan, "Sistem Kontrol PID pada Purwarupa Robot Pembawa Barang berbasis Line Follower menggunakan Algoritma Path Planning," 2022. [Online]. Available: http://j-ptiik.ub.ac.id

[5] O. Erbay, A. B. Doğan, and E. Devecioğlu, "Line Follower Robot with PID Control." [Online]. Available: https://www.researchgate.net/publication/377666058

[6] H. Jurnal, S. Sibuea, A. Rahmaddoni, B. Widodo, U. Mohammad, and H. Thamrin, "JURNAL INFORMATIKA DAN TEKNOLOGI KOMPUTER PERANCANGAN ROBOT PEMADAM API DENGAN PENGONTROLAN GERAK METODE PROPORTIONAL INTEGRAL DERIVATIVE (PID) MENGGUNAKAN SENSOR SONAR BERBASIS MIKROKONTROLLER," vol. 1, no. 3, pp. 1–14, 2021.

[7] Muhardian, R. (n.d.). JTEV (JURNAL TEKNIK ELEKTRO DAN VOKASIONAL)Kendali Kecepatan Motor DC Dengan Kontroller PID dan Antarmuka Visual Basic. http://ejournal.unp.ac.id/index.php/jtev/index

[8] S. Fatimah Anggraini, A. Ma, and R. Dwi Puriyanto, "Pengendali PID pada Motor DC dan Tuning Menggunakan Metode Differential Evolution PID Controllers on DC Motors and Tuning Using the Differential Evolution Method," TELKA, vol. 6, no. 2, pp. 147–159, 2020.

[9] A. Putri and F. Maspiyanti, "ROBOT LINE FOLLOWER PENGANTAR SURAT MENGGUNAKAN METODE FUZZY LOGIC STUDI KASUS FAKULTAS TEKNIK UNIVERSITAS PANCASILA," Jurnal Teknologi Terpadu, vol. 3, no. 1, 2017, [Online]. Available: www.ardino.cc

[10] P. Pendidikan, T. Elektro, F. Tarbiyah, and D. Keguruan, "PENGEMBANGAN PROTOTIPE ROBOT BERBASIS SENSOR."

[11] Prasetyo and S. Tinggi Manajemen Informatika dan Komputer Dumai Jalan Utama Karya Bukit Batrem Kota Dumai kode, "I N F O R M A T I K A PROTOTYPE ROBOT LINE FOLLOWER ARDUINO UNO MENGGUNAKAN 4 SENSOR TCRT5000," Jurnal Informatika, Manajemen dan Komputer, vol. 11, no. 2, 2019.

[12] E. Hasan, M. Daud, H. M. Yusdartono, and K. Kartika, "Desain Kontrol Motor Brushless Direct Current (BLDC) Menggunakan Boost Converter," Jetri : Jurnal Ilmiah Teknik Elektro, pp. 117–134, Feb. 2023, doi: 10.25105/jetri.v20i2.14945

[13] M. Rifhaldy Rizky Jusman, A. Mashinton, F. Jilan Aqilah, M. Nur, and P. Bosowa, "Rancang Bangun Robot Avoider Berbasis Arduino Uno Menggunakan Satu Sensor Ultrasonik."

[14] Peerzada, Pirah, Wasi Hyder Larik, and Aiman Abbas Mahar. "DC motor speed control through arduino and L298N motor driver using PID controller." *International Journal of Electrical Engineering & Emerging Technology* 4.2 (2021): 21-24.

[15] Sarimuddin, "Cara Mudah Kuasai Mikrokontroler Arduino Teori dan Praktek. Jawa tengah: EUREKA MEDIA AKSARA" (2023).