Evolution in Electrical and Electronic Engineering Vol. 3 No. 2 (2022) 979-986

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

System Identification and Control of Direct Current Motor

Muhammad Akmal Zaiton[1], **Rafidah Ngadengon**[1]*

[1]Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

* Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2022.03.02.115
Received 12 July 2022; Accepted 12 October 2022; Available online 30 October 2022

Abstract: The use of Direct Current (DC) motors today is very widely used whether in industry, hobby and education. At the industrial level, machines often use it to control things. The energy used by this DC motor is from electrical to mechanical energy. Process control is always used in industry, and motor speed is very important to control something. Proportional (P), Proportional Integral (PI), Proportional Derivative (PD) and Proportional Integral Derivative (PID) controllers are used to control the speed of the DC motor. The input data voltage and output data speed were taken to be used in the system identification to the mathematical model that will be used in the controller. In this project, MATLAB is used entirely to obtain data, and mathematical models, used in simulations and run-on DC motors. Based on the experiment, a comparison between P, PI, PD, and PID shows that the PID controller gives better performance.

Keywords: Direct Current (DC) Motor, System Identification, Proportional Integral Derivative

1. Introduction

In this new era of technology, the world in which society lives are changing and revolutionizing to further the nation's development. Using measurements of the system's Input/Output (IO) signals, a method known as System Identification (SI) is used to create mathematical models of dynamic systems from experimental data. A few steps are needed in SI, such as taking time or frequency domain measurements of the system's IO signals, selecting a candidate model structure, applying an estimation method to determine the values of the model's adjustable parameters, and validating and evaluating the estimated model to determine whether it is appropriate for the application's needs [1].

There are many controllers used to control the Direct Current motor's speed such as PID, fuzzy logic controllers, backstepping, and sliding mode controllers [2]-[5]. It is necessary to get a mathematical model of the system to be used by controllers. The advantages and disadvantages of using Proportional (P), Proportional Integral (PI), Proportional Derivative (PD) and Proportional Integral Derivative (PID) controllers were discussed by [6]. The P controller is normally used for the first order process and to decrease the steady-state error of the system. The PI controller is mainly used to

Corresponding author: rafida@uthm.edu.my

eliminate the steady state error resulting from the P controller. The advantage of using a PD controller is to increase the stability of the system by improving control because the PD controller can predict the future error of the system response. Lastly, the PIDD controller has the optimum control dynamics including zero steady-state error and fast response. The PID controller also can be used with higher-order processes including more than single energy storage [6].

The main objectives of this project are to integrate hardware using Arduino Mega 2560. After that, take the data of the voltage as input and revolution per minute (rpm) as output to obtain a mathematical model of the DC motor using system identification. Then, used P, PI, PD, and PID controllers that control the speed of the DC motor using a real-time application with the aid of MATLAB software.

2. Methodology

The objective of the project is to regulate the DC motor's speed, to obtain exact data, the technique must be followed correctly. At first, the experiment must be conducted, to get the voltage as an input and speed in RPM as output data. The input data is derived from the motor's voltage, while the output data is derived from the motor's RPM. Based on the data, a function called system identification in MATLAB toolbox is used to get the mathematical model, where a good system with the best fit nearest 100%.

The block diagram and the components for the hardware are shown in Figure 1. The Arduino Mega 2560 microcontroller is powered by 5V. Meanwhile, 12V is provided for motor driver L298N and connected to the DC motor. A DC encoder motor is used to collect data and the data will use to get a mathematical model using system identification. The mathematical model is used to design P PI, PD, and PID controllers.

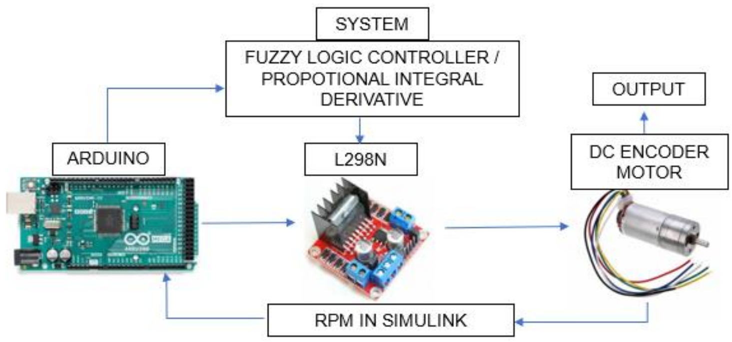

Figure 1: Block diagram of the overall project

Arduino may be used to construct digital devices and interactive things capable of sensing and controlling physical objects. Various microprocessors and controllers are incorporated into Arduino board designs. Expansion boards and other circuits are compatible with the board's digital and analog input and output pin configurations.

Electrical energy may be converted into mechanical energy by using a DC motor. DC motors may speed up or slow down by varying the supply voltage or the intensity of the current in their field windings. Small DC motors may be found in a wide variety of items, including tools, toys, and home appliances. Universal motors are small, direct-current brushed motors that are utilized in portable power gadgets and appliances. Larger DC motors are being used in electric vehicle propulsion, elevator and hoist drives, and steel rolling mill drive systems [7]. Direct current motors may be sped up or slowed down by varying the supply voltage or the intensity of the current in their field windings. Small DC motors may be found in a wide variety of items, including tools, toys, and home appliances. Universal motors are small, direct-current brushed motors that are utilized in portable power gadgets and appliances. Larger DC motors are being used in electric vehicle propulsion, elevator and hoist drives, and steel rolling mill drive systems [8].

The L298N is a dual H-Bridge motor driver that can control the speed and direction of two DC motors at the same time. Motors with a DC voltage range of 5V to 35V and a maximum peak current of 2 amps can be used with this module. In addition to the two screw terminal blocks for motors A and B, the module features a screw terminal block for the Ground pin, the VCC for the motor, and a 5V pin that may be used as an input or an output [9]. Consequently, by incorporating the PID controller into the DC motor, it's able to correct the DC motor's defect and modify the motor's speed. The L298 twin H-Bridge motor driver enables direction and position control of DC motors [10].

The PID controller's self-tuning capability is used to obtain the PID parameters. The updated PID controller is then implemented into the Hardware in the Loop (HIL) control system, and the response performance of the system is tested. The embedded C code is then generated automatically, and HIL tests are executed. The experimental results indicate that the proposed technique might shorten the design process control system [10].

2.1 Experimental Setup

The experimental setup is necessary to collect data. real hardware needs to assemble with the component that includes in this project. The component for the experimental setup is Arduino Mega 2560, motor driver L298N and DC encoder motor as in Figure 2. The encoder is used to measure the speed of the motor and connect with Arduino at pin 2. Then, the DC motor is connected with motor driver L298N. Motor driver L298N is connected with Arduino at pin 5. Meanwhile, for the voltage reading, the voltage pin connects with an analog pin that is pin A0. Figure 2 shows the experimental setup.

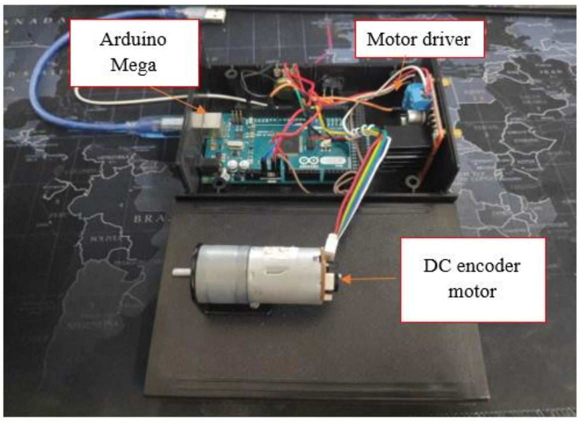

Figure 2: Experimental setup

2.2 Data collection

The hardware in the experimental setup is connected with MATLAB Simulink as in Figure 3. Data collection is important to obtain the mathematical model and also to design the controller. The purpose of the design in the Simulink block is to measure the voltage as input and the speed of the rotation motor as output. These two data are recorded and sent to the workspace in MATLAB. The simulation was performed without the use of a controller.

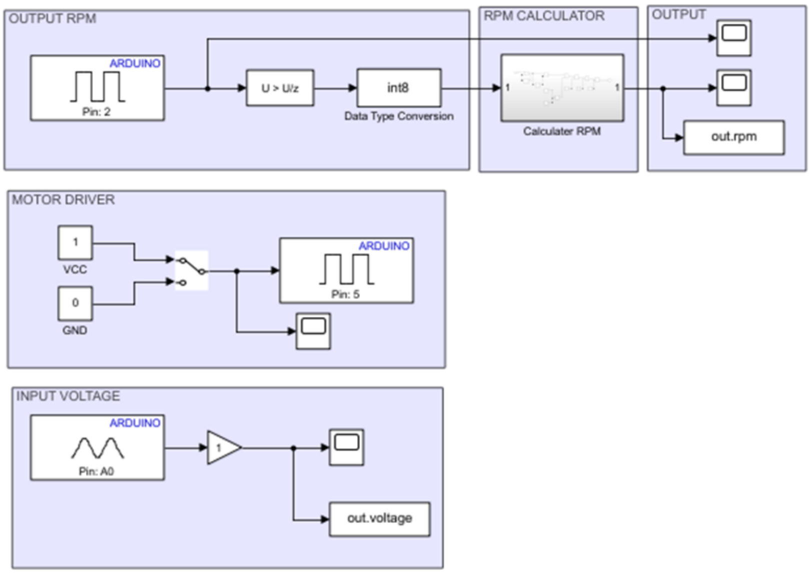

Figure 3: Simulink to collect data from hardware

The voltage of the DC motor that has been recorded to the workspace is shown in Figure 4. Meanwhile, Figure 5 shows the speed of the motor in RPM of the DC motor that has been collected as an output.

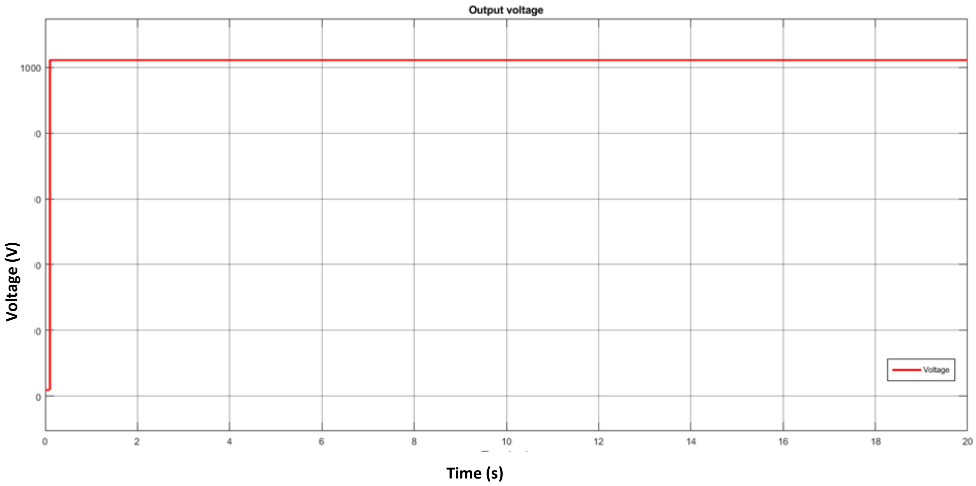

Figure 4: Voltage of the motor

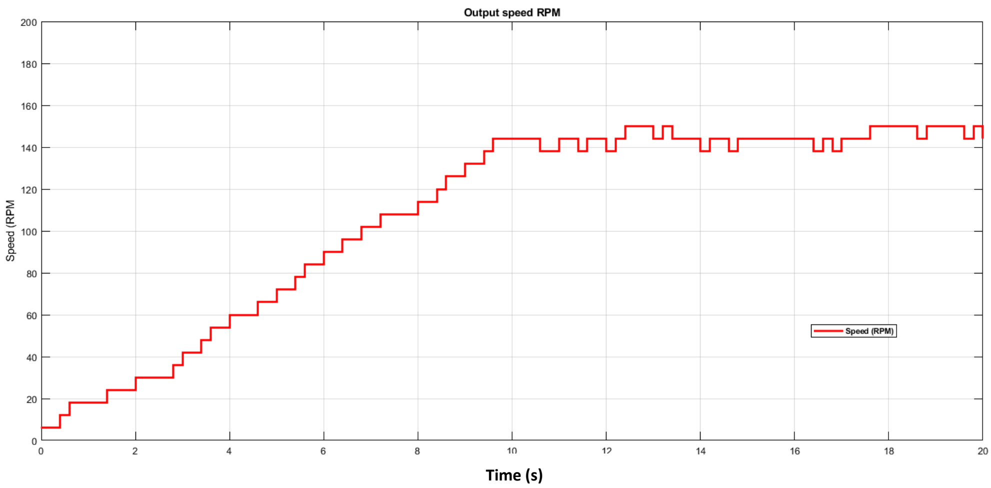

Figure 5: Speed of the motor

2.3 Model Output for System Identification

The mathematical model is structured by using system identification. Based on the data that had been collected from Simulink, several steps were taken in system identification. The process of model selection is the selection of suitable parameters for determining the data set upon which the model is evaluated. with an optimal fit of 92.29 %, the predicted transfer function model is produced. The best-fit model output is shown in Figure 6. The process of developing a mathematical model using experimental data is known as a model estimation. By specifying the relationship between these two data, the System Identification Toolbox can estimate the transfer function model of a dynamic system. Equation 1 generates a model of the calculated transfer function.

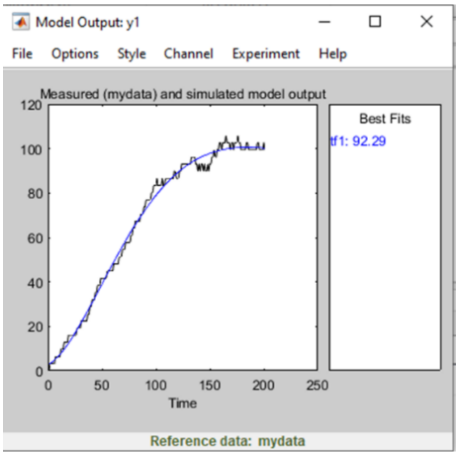

Figure 6: Best fit result

$$G(s) = \frac{-0.0001531s + 3.782e-05}{s^2 + 0.02477 + 0.0004194} \quad \text{(Eq 1)}$$

3. Real-time implementation of DC motor with P, PI, PD and PID controller.

To apply real-time implementation, the actual DC motor is connected to the personal computer. The Arduino mega board act as an interface between the DC motor and MATLAB Simulink. Then the DC motor is tested with four different controllers which are P, PI, PD, and PID controller. The PID controller as in Figure 7 will be replaced with P, PI, and PD controllers.

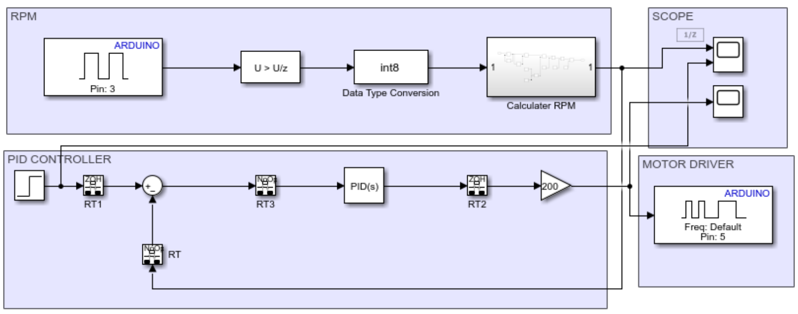

Figure 7: Proportional Integral Derivative with rpm block

The input reference for the system is 200 RPM and it is run for 200 seconds. At first, the P controller will connect to the motor driver that controls the DC motor. The result of the P controller is shown in Figure 8. The blue line is the input reference and the red line is the output for the speed of the DC motor.

Based on the result in Figure 8, the rise time is 8.900s, the slew rate is 14.498s, the overshoot is 16.265% and the undershoot of the system is 27.912%.

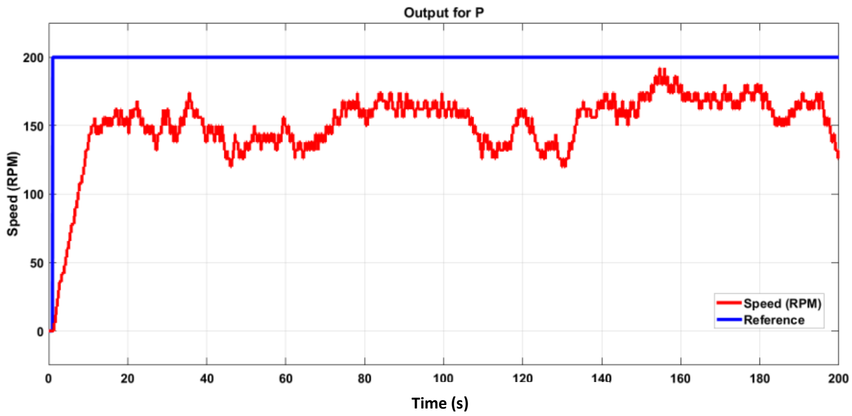

Figure 8: Speed of the DC motor using the P controller

The second experiment is run using a PI controller to control the speed of the DC motor. Figure 9 shows the result of the PI controller where the rise time is 8.400s, the slew rate is 13.532s, the overshoot is 21.791% and the undershoot of the system is 24.662%.

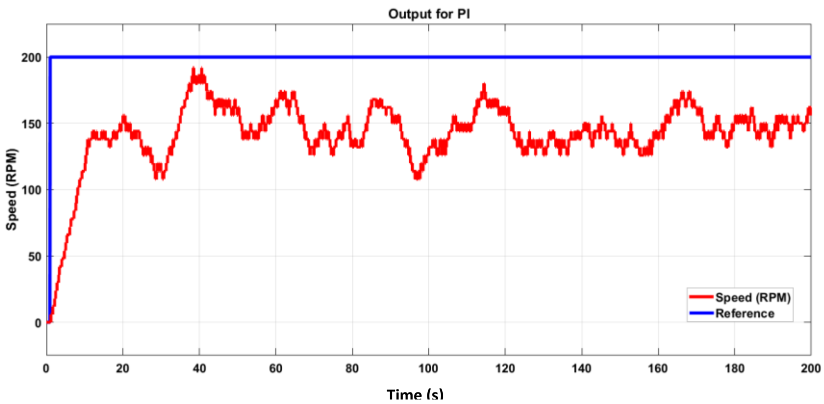

Figure 9: Speed of the DC motor using a PI controller

Figure 10 shows the result of the PD controller. From this figure, the rise time is 7.500s, the slew rate is 14.694s is 12.631% and the undershoot of the system is 26.568%.

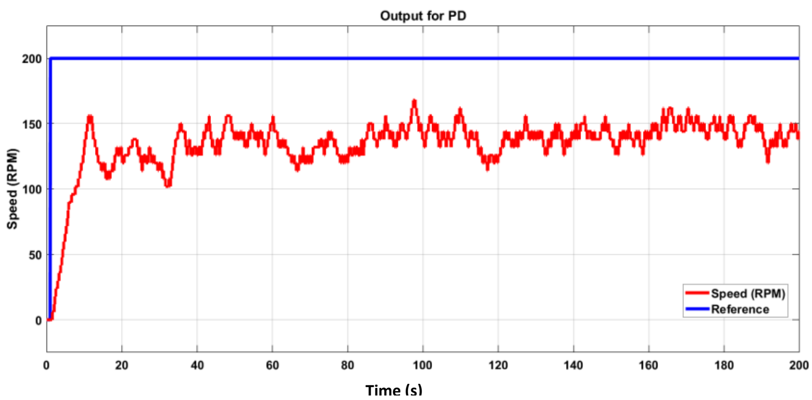

Figure 10: Speed of the DC motor using the PD controller

Lastly, the experiment was done using a PID controller. The result of the PD controller as in Figure 11 shows that the rise time is 5.900s, the slew rate is 16.174% and overshoot is 4.930% and the undershoot is of the system 15.191%.

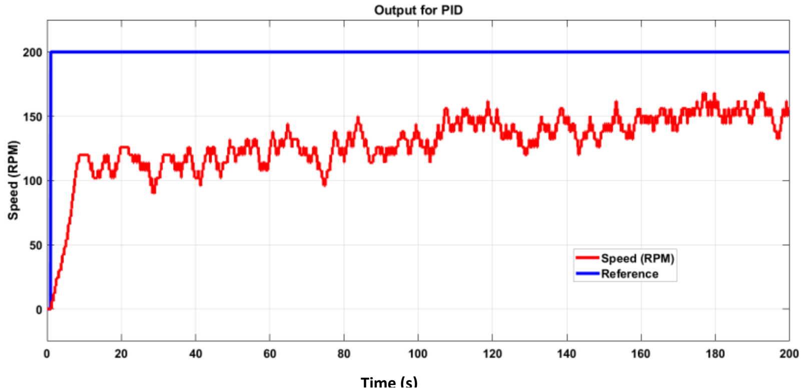

Figure 11: Speed of the DC motor using the PID controller

Table 1 provides a summary of the findings for all the controllers. The optimum controller for this transfer function model is a PID controller, according to a comparison of controller behavior. In other words, it has the least amount of overshoot while still achieving the desired speed. In addition, it responds quickly to rise and settle time.

Table 1: Result of the P, PI, PD, and PID

Parameter	P	PI	PD	PID
Rise Time (s)	8.900	8.400	7.500	5.900
Slew Rate (s)	14.498	13.532	14.694	16.174
Pre shoot %	0.595	0.676	0.610	0.704
Overshoot %	7.292	21.791	12.631	4.930
Undershoot %	18.750	24.662	26.568	15.191

4. Conclusion

The purpose of the project has been achieved. DC motors are becoming increasingly popular as a result of great efficiency, quick reaction, and low maintenance requirements. According to the previous chapter, the system identification was effectively created to acquire the transfer function, with a 92.29 % best fit. The design of the controller is also critical to the project. Aside from that, the Arduino Mega board is essential in the Data Acquisition System. The L298N is linked to a controller via a MATLAB Simulink block, and an Arduino Mega board serves as an interface between the controller and the MATLAB Simulink block.

The transfer function might be affected by the noise level. Due to the decreased proportion of overshoot, PID controllers outperform P, PI, and PD controllers. Based on the comparison from Table 1, the PID controller has the lowest rise time, and the overshoot rate is the lowest among all controllers which are 4.93 %. This result show PID controller is better than P, PI, and PD because the rise time, overshoot, and undershoot are the lowest compared to other controllers.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] M. S. Esteves, T. P. A.Perdicoúlis and P. L. D. Santos, "System Identification Methods for Identification of State Models" Proceedings of the 11th Portuguese Conference on Automatic Control, IEEE Lecture Notes in Electrical Engineering., vol. 321, pp. 417-427, 2014. .

[2] M.T Islam, S. M. R. Karim, A. Sutradhar and S. Miah, "Fuzzy Logic and PID Controllers for DC Motor Using Genetic Algorithm" IEEE International Journal of Control Science and Engineering., vol. 10 no. 2, pp. 37-41, 2020.

[3] Dr M. M. Shaker and Y.M.B. Ismeal Al-khashab, "Design and Implementation of Fuzzy Logic system for DC motor Speed Control" IEEE Iraq J. Electrical and Electronic Engineering., vol. 6, no. 2, pp. 123-130, 2010.

[4] L. Ardhenta, R.K Subroto and R.N Hasanah, "Adaptive backstepping control for Buck DC/DC converter and DC motor" International Conference on Renewable Energy (ICORE) 2019, pp.1-8, 2019.

[5] S.Yang, D.Shan and J. Zheng, "Sliding Mode Control for Brushless Direct Current Motor Drive Based on a New Reaching Law", IEEE International Conference on Artificial Intelligence and Computer Applications (ICAICA), pp. 1-6, 2021.

[6] V M Venkateswara Rao, "Performance Analysis Of Speed Control Of Dc Motor Using P, PI, PD And PID Controllers, International Journal of Engineering Research & Technology (IJERT)",vol. 2 no.5, pp.60-66, 2013.

[7] A. Hussein, K. Hirasawa, J. Hu and K.Wada, "Application of universal learning networks to PV-supplied DC motor drives." Research Reports on Information Science and Electrical Engineering of Kyushu University., vol. 8 no.2, pp.129–134, 2003.

[8] Z. Hou, H. Gao and F. L. Lewis, "Data-Driven Control and Learning Systems." IEEE Transactions on industrial electronics., vol.64, no.5, pp.4070-4074, May 2017.

[9] Munadi and M. A. Akbar, "Simulation of fuzzy logic control for DC servo motor using Arduino based on MATLAB/Simulink," 2014 International Conference on Intelligent Autonomous Agents, Networks and Systems, pp. 42-46, 2014.

[10] W. Tang, Z. Liu and Q. Wang, "DC motor speed control based on system identification and PID auto tuning," 2017 36th Chinese Control Conference (CCC), pp. 6420-6423, 2017.