Jurnal Scientia
Volume 13, Number 04, 2024, DOI 10.58471/ scientia.v13i04
ESSN 2723-7486 (Online)
https://infor.seaninstitute.org/index.php/pendidikan

An Analysis Of Geogebra Method For Visual Design PID Control System

Nimas Deria Wijayanti[1], Parlin Siagian[2], Zuraidah Tharo[3]
[1,2,3]Universitas Pembangunan Panca Budi, Medan, North Sumatera, Indonesia

Article Info	ABSTRACT
Keywords: GeoGebra, PID, control system, visualization, parameter tuning.	The design of Proportional-Integral-Derivative (PID) control systems is a critical aspect of control engineering to achieve system stability and optimal performance. How-ever, tuning PID parameters often poses challenges due to the complex analytical ap-proaches required. This study analyzes the application of GeoGebra, a dynamic mathe-matics software, in designing PID control systems visually. GeoGebra is utilized to model control systems, visualize system responses, and perform interactive PID parameter tun-ing. The study involves simulations of simple linear systems, such as actuator position control, to evaluate the effectiveness of the GeoGebra method compared to traditional approaches. The analysis focuses on performance parameters, including rise time, peak time, and steady-state error. The results demonstrate that GeoGebra simplifies the PID parameter tuning process through intuitive visualization, enhancing concept comprehen-sion and design efficiency. Furthermore, GeoGebra proves to be an effective tool for edu-cation and training in control engineering.
	Corresponding Author: Nimas Deria Wijayanti, Universitas Sumatera Utara, Medan, North Sumatera, Indonesia, nimasderia44@gmail.com

INTRODUCTION

PID controller is a controller that is widely used in industry and PID is described ideally. PID description for industry by Setiawan , Implementation of PID controller to control plant is done by Rosada. Ali implementing PID using matlab. Implementation of PID using arduino is done by [7][8]. Students in making projects with PID controllers often have difficulty in understanding the processes that occur in the PID controller.

Geogebra is a web-based mathematical tool for learning and visualizing mathematics. Through this tool, users can share their work in the form of ggb files. With the existence of a forum for GeoGebra users, the GeoGebra site is becoming more and more complete. In this research, visualization will be carried out on each stage in the PID controller starting from the SP and PV signals as well as the calculation process in the PID controller and signal adjustment output. Visualization is done using GeoGebra. Suwarno [9] used GeoGebra to visualize the Thristor trigger, inspiring him to create a visualization of the PID controller operation. GeoGebra, a dynamic mathematics software, offers an interesting solution to this need. Originally developed as a mathematics learning tool, GeoGebra has interactive visualization capabilities that can be utilized to design and study control systems. With a visual-based approach, GeoGebra allows users to model the system, visualize its response, and perform interactive PID parameter tuning.

Control system design is one of the important aspects in the field of control engineering that aims to ensure the stability, dynamic response, and optimal performance of a system. One method that is often used in control is Proportional-Integral-Derivative (PID) control. PID control is known for its simplicity, flexibility, and ability to be applied to various types of systems, from industry to academic applications.

However, the main challenge in designing PID control is the parameter tuning process involving proportional constant (Kp), integral (Ki), and derivative (Kd) values. This process requires a deep understanding of system dynamics and complex analytical or numerical approaches. To overcome this, a more intuitive and interactive method is needed to assist in designing and analyzing PID control systems, one of which is by using software-based visualization tools.

This study aims to analyze the application of the GeoGebra method in designing a PID control system visually. This approach is expected to provide convenience for practitioners and control engineering students in understanding system dynamics, while increasing the effectiveness and efficiency of the design process.

With this approach, it is expected to provide a significant contribution to the learning and practice of designing PID-based control systems more intuitively and interactively. In its implementation, PID control systems are often used in various applications, such as temperature control, motor speed, and actuator position. The manual PID parameter tuning process often takes a long time and requires sufficient experience, especially in complex systems or systems with nonlinear dynamics. The use of software-based tools such as GeoGebra is expected to simplify this process by providing a clear visual depiction of the effect of each parameter on system performance.

GeoGebra was originally designed for educational purposes in mathematics, such as geometry, algebra, and calculus. However, its flexibility allows users to create interactive models for various applications, including control systems. With features such as graphical representation, dynamic animation, and real-time parameter editing, GeoGebra provides an intuitive approach that can help users understand and analyze complex concepts in PID control.

This research is significant because it offers a new approach that integrates educational tools with control engineering applications. By using GeoGebra, the PID control design process can be accessed by a wider audience, including students and practitioners with varying levels of expertise. In addition, the visualization provided by GeoGebra can facilitate the understanding of concepts that are often difficult to understand through traditional analytical methods.

This research focuses on the design and simulation of a PID control system using GeoGebra, with a case study of a simple linear system such as actuator position control. The analysis will include a comparison of system responses, such as rise time, peak time, and steady-state error, between the GeoGebra method and conventional approaches. Through this research, it is expected to contribute to the development of more effective and efficient

SEAN INSTITUTE
SCIENCE ANALYTIC
Jurnal Scientia
Volume 13, Number 04, 2024, DOI 10.58471/ scientia.v13i04
ESSN 2723-7486 (Online)
https://infor.seaninstitute.org/index.php/pendidikan

control design tools, as well as encourage the use of educational software such as GeoGebra for wider engineering applications.

METHODS

The block diagram of PID control is generally shown in Figure 2 following:

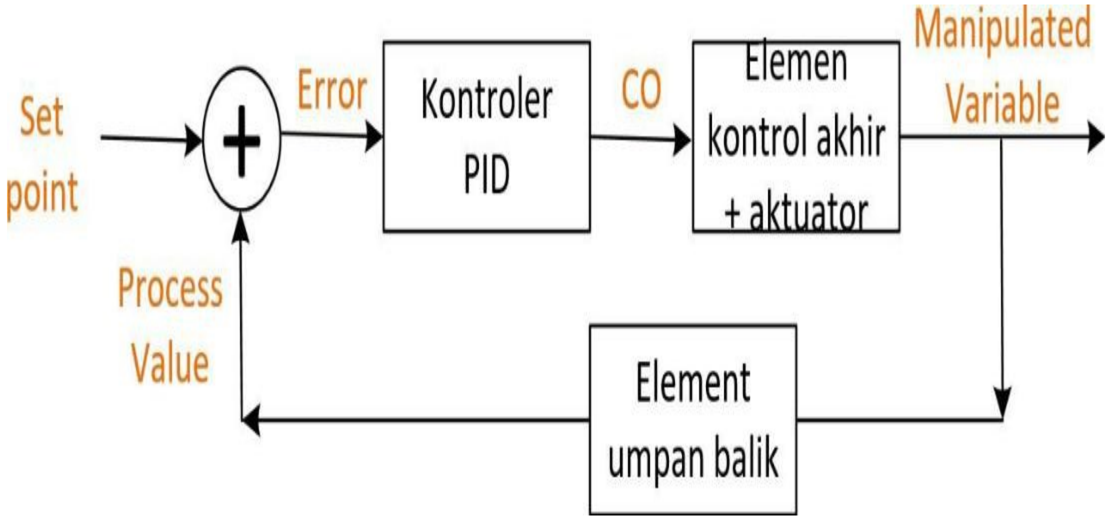

Figure 1. Block diagram of PID Controller

From the block diagram consists of signals and blocks. Signals include Set Point (SP), Process Value (PV), Error signals, Controller Output (CO) signals and Maniputated Variable (MV). Blocks include adders (or subtractors) for SP and PV, PID Controller blocks, Final Control Element blocks and actuators and Feedback elements.

Each block will be visualized using GeoGebra, namely the calculation of error signals in the form of direct acting and reverse acting. The process of changing (mapping) in the Final Control Element block and actuators. The PID controller block will be visualized in the proportional controller section, namely the influence of gain and proportional band. In the Integral controller section, the integral error signal will be visualized with a certain integral gain and a certain integral time. In the derivative controller section, changes to SP and changes to PV will be visualized.

RESULT

Proportional Controller

SP is a reference value, while PV is an input for the controller to calculate errors. The SP and PV units must be the same, usually in the form of %. There are minimum and maximum values. The SP and PV values in the form of percentages can make it easier for operators to provide values so as not to exceed the limit. The PV value can peak (overshoot) or valley (undershoot). The peak is not allowed to exceed the upper limit of the system, and the valley is not allowed to be less than the lower limit.

Jurnal Scientia
Volume 13, Number 04, 2024, DOI 10.58471/ scientia.v13i04
ESSN 2723-7486 (Online)
https://infor.seaninstitute.org/index.php/pendidikan

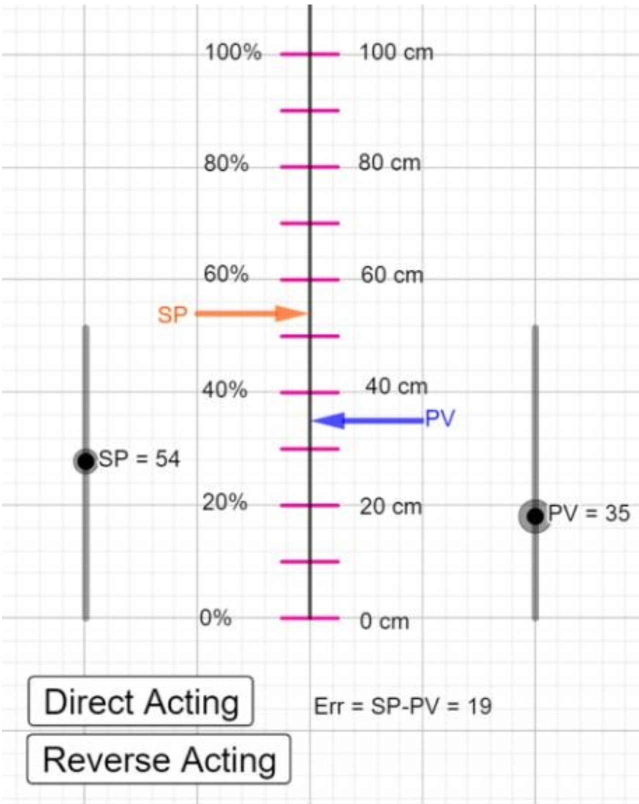

Figure 2. Control panel for SP and PV

The Final Control Element is related to the actuator to be controlled. The actuator setting unit is also in percent. The mapping of the controller output signal to the manipulated Variable is shown in Figure 3.

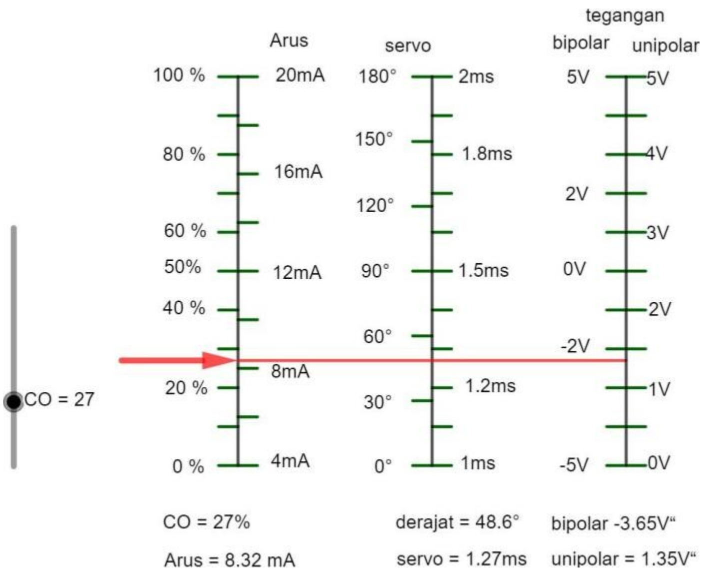

Figure 3. Mapping for CO to desired outputs

Jurnal Scientia
Volume 13, Number 04, 2024, DOI 10.58471/ scientia.v13i04
ESSN 2723-7486 (Online)
https://infor.seaninstitute.org/index.php/pendidikan

A narrow PB indicates a large gain, a small change in error results in a largecontroller output, the system is said to be sensitive to changes in input.

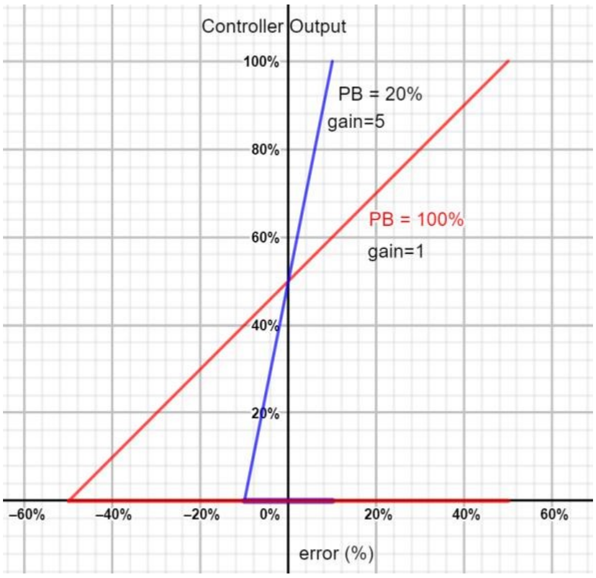

Figure 4. Proportional Band, Error and Controller Output

Integral Controller Section

The relationship between integral gain, integral time and controller output

$$CO = \int_0^t K_i E(t)dt$$

With integral time as follows

Ki= 1/ Ti

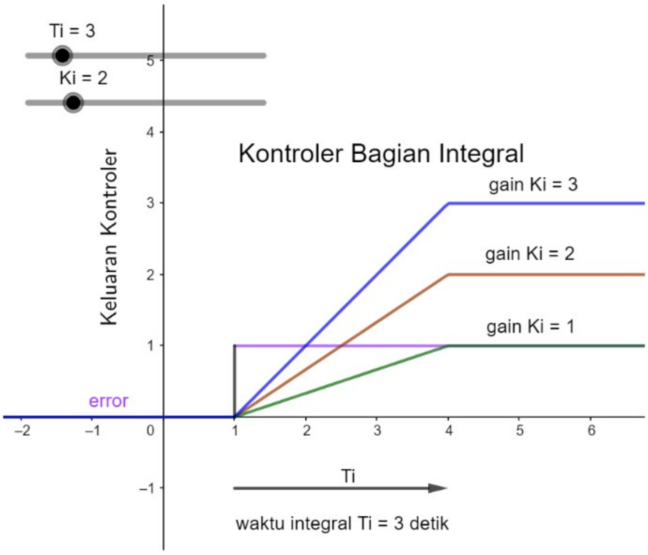

Figure 5. Effect of Integral Part Controller

The greater the integral gain constant, the greater the error that is still accumulated. The length of the integral time is determined by Ti, for large Ti, the integral factor has less

Jurnal Scientia
Volume 13, Number 04, 2024, DOI 10.58471/ scientia.v13i04
ESSN 2723-7486 (Online)
https://infor.seaninstitute.org/index.php/pendidikan

and less influence. To eliminate the integral factor, it is done by giving a value Ti= ∞. A large integral gain value means the system is fast, while a small integral gain value means the system is slow. The integral time value has a repeat unit/time unit. An example of a system with an integral time setting of 1 minute per repeat means the system output is one time the input within one minute. At figure 5 The integral time value Ti = 3 seconds and for Ki = 1 then within 3 seconds the controller output value will be the same as the controller input. For Ki = 3 then it can be said 3 repeats per second.

The integral part if not limited will cause the controller output to quickly become saturated. The output is said to be saturated if the addition of input does not change the output. For SP in the form of a step function, dSP/dt will produce an impulse function. shown on figure 6.

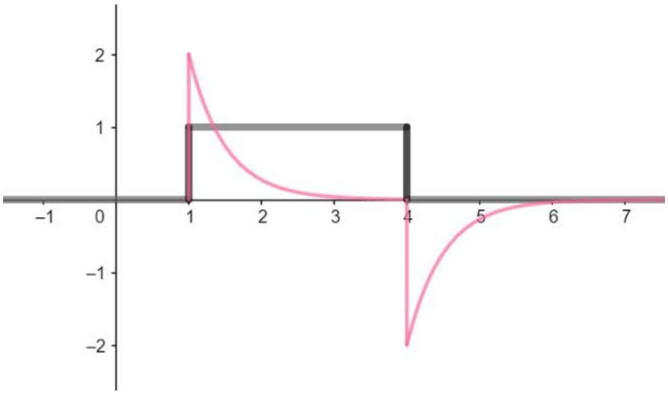

Figure 6. Shock (impulse function) on error change

To overcome the existence of surprises (called derivative kickoff), the error calculation process is carried out by changing the error in the PV for the derivative controller calculation, while in the Proportional controller and Integral controller the error calculation still uses e(t) as shown in figure 1.

The presence of an offset addition factor is used to adjust the manipulated variable for the actuator. The steps in GeoGebra are called Construction protocols which are the sequences for forming a graph. Here is an example of a Construction protocol for figure 6 shown in figure 7.

⋮	Name	Description	Value
1	Function f		f(t) = If(1 ≤ t ≤ 4, 1, 0)
2	Function g		g(t) = If(1 < t < 4, 2e^(-2 (t - 1))
3	Function h		h(t) = If(4 < t, -2 e^(-2 (t - 4)))
4	Segment i	Segment (1, 0), (1, 1)	i = 1
5	Segment j	Segment (4, 0), (4, 1)	j = 1
6	Segment k	Segment (1, 0), (1, 2)	k = 2
7	Segment l	Segment (4, 0), (4, -2)	l = 2

Figure 7. GeoGebra Construction Protocol

The limitation in this paper is that the implementation in script form for the PID controller is not discussed. The script for the PID controller is packaged in library form [8] so that users cannot easily observe the process that occurs. Visualization has not been implemented for changing input so that the display is not real time. The construction protocol in GeoGebra can have its parameters changed so that the effect of the parameters on certain blocks can be seen.

CONCLUSION

Based on the findings, the GeoGebra method has proven effective for visual design of PID control systems. GeoGebra facilitates system modeling, system response visualization, and interactive PID parameter tuning. This visual approach enables users to better understand system dynamics and the effects of each PID parameter on system performance. The main advantages of GeoGebra lie in its intuitive interface, flexibility in simulations, and real-time parameter adjustment capabilities. These features not only accelerate the design process but also enhance the quality of analysis and decision-making when selecting optimal control parameters. However, the study also identified some limitations of GeoGebra, such as its lack of support for complex nonlinear systems and limited features compared to specialized control software. Therefore, GeoGebra is more suitable for linear systems and for basic education or training purposes in control engineering. Overall, GeoGebra can be an effective and efficient tool for the design and learning of PID control systems, especially for students and practitioners who require an intuitive approach to understanding control concepts. Further development, such as integrating GeoGebra with other control software, could be a future step to enhance its capabilities for more complex applications.

REFERENCE

[1] Ogata, Katsuhiko. Modern control engineering. Prentice hall, 2010. Seborg, Dale E., et al. Process dynamics and control. John Wiley & Sons, 2017.
[2] Nise, NS Control Systems Engineering, 6th edition. New Jersey: John Wiley and Son. 2010
[3] Pedro Albertos, IM Feedback and Control for Everyone. Berlin: Springer, 2010
[4] Siagian, P., & Fahreza, F. (2020, February). Rekayasa Penanggulangan Fluktuasi Daya Pembangkit Listrik Tenaga Angin Dengan Vehicle To Grid (V2G). In *Seminar Nasional Teknologi Komputer & Sains (SAINTEKS)* (Vol. 1, No. 1, pp. 356-361).
[5] Siagian, P. (2022). Wind Resource for Electrical Energy of Tourism and Micro Small and Medium Enterprises (MSMEs) in Coastal Areas After the COVID-19 Pandemic. *Adpebi International Journal of Multidisciplinary Sciences*, *1*(1), 175-186.
[6] Setiawan, Iwan. PID control for industrial processes. Elex Media Komputindo, 2013.
[7] S. Aryza, & Lubis, Z. (2023). Enhanced of Electric Power Consumption Monitoring System in Household Based on Sensorless. *Jurnal Scientia*, *12*(04), 2107-2113.
[8] S. Aryza, S., Lubis, Z., & Putra, K. (2024). Sosialisasi Sistem Proteksi Over Voltage Kantor Lurah Kelambir Lima Berbasiskan IOT. *Jurnal Hasil Pengabdian Masyarakat (JURIBMAS)*, *3*(1), 306-314.

[9] Rosada, Kevin. Water Pump Control System Using Raspberry Pi Based PID Controller. Diss. Sepuluh Nopember Institute of Technology, 2017.
[10] Ali, Muhamad. "Learning the Design of PID Control System with MATLAB Software." Jurnal Edukasi@ Elektro 1.1 2004.
[11] Visioli, Antonio. Practical PID control. Springer Science & Business Media, 2006.
[12] Bista, Dinesh. "Understanding and Design of an Arduino-based PID Controller." 2016
[13] Suwarno, Djoko Untoro. "Visualization of Rectified Sine Waves and Triggering Angles on Thyristor Using GeoGebra." Proceedings of the International Conference on Mathematics and Learning Research. 2021
[14] Tharo, Z., & Hamdani, H. (2020). Analisis biaya pembangkit listrik tenaga surya (PLTS) atap skala rumah tangga. *Journal of Electrical and System Control Engineering*, *3*(2), 65-71.
[15] Tharo, Z., Syahputra, E., & Mulyadi, R. (2022). Analysis of Saving Electrical Load Costs With a Hybrid Source of PLN-PLTS 500 Wp. *Journal of Applied Engineering and Technological Science (JAETS)*, *4*(1), 235-243.