Brilliance
Research of Artificial Intelligence

Volume 1, **Number** 2, November 2021
https://doi.org/10.47709/brilliance.v1i2.1705

Evaluation and Modeling of the Car Speed Control Process using a PID Controller

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open access

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Article History:
Submitted: 03-12-2021
Accepted: 04-12-2021
Published: 05-12-2021

Keywords:
Car speed; Speed control; PID controller.

ABSTRACT

Car speed is an essential attribute for analysing the utility of a transport mode. The speed relationship between multiple modes of transport is of interest to traffic planners and operators. Nowadays, the cruise control system has become a common feature of modern cars. A car control system helps in providing comfortability to the driver while driving long-distance travel. Using a car control system, travelling on the highways has become easier than before because it reduces the mental and physical stress caused by regularly monitoring the speed of the car and frequently pressing the gas pedal to maintain the speed. This paper is aimed at modelling a car control system and examining its characteristics based on the PID control strategy. Proportional-Integral-Derivative (PID) controller provides a great way to stabilize systems. It has the ability to change the response of the system to be stable and reliable when it is used for controlling systems. This system is actualized with the help of MATLAB for simulation and control purposes. The paper showed that without the use of the PID controller, the speed was stable after 100 seconds, and when the controller was used and self-turned, the speed was approximately stable at 20 seconds, and this shows the effectiveness of using the PID controller.

INTRODUCTION

The human driver typically performs three primary activities when driving. He regulates the car's speed, applies the brakes when necessary, and operates the steering wheel. The driving System accomplishes these essential responsibilities of a human driver and controls the car entirely. The driving system includes the Brake control system, the Steering control system, and the Speed control system. Obtaining a model for a traditional method system that performs these activities is typically difficult and time-consuming, making such a system typically quite complex [1].
The car control system has become a standard feature on modern vehicles [2]. Long-distance travel is made more comfortable for the driver by the use of a car control system. By reducing the mental and physical strain caused by constantly checking the car's speed and tapping the gas pedal repeatedly to maintain the speed, the use of a car control system has made traveling on the roads easier than ever before [3]. The primary function of the cruise control system is to maintain the vehicle's speed at a previously determined set point. A button on the car control system enables the driver to choose a desired speed.

The Proportional-Integral-Derivative (PID) controller is an excellent method for stabilizing systems. When utilized for controlling systems, it has the ability to make the system's reaction stable and dependable. Three parameters comprise the PID controller: proportional (K_P), integral (Ki), and derivative (K_d) (K_d). These three parameters are adjusted to stabilize the system according to predetermined criteria. Moreover, the majority of feedback systems are controlled by PID controllers. PID controllers can also be implemented as PI or PD. Therefore, it provides researchers with numerous options for working with it [4].

Due to its efficacy and ease of use, the Proportional Integral Derivative Controller (PID) has been widely adopted for controlling the majority of industrial processes [5]. This sort of controller is often employed in level, flow, temperature, vehicular, and electric motor systems [6]. In addition, the design of the PID controller is thought to be simple to implement, as only three parameters,,, and, must be tuned and tuning procedures can be accomplished automatically [7]. In control engineering literature, Ziegler and Nichols, Cohen and Conn, the Relay technique, and the Relatus Apparatus are some of the most popular PID tuning approaches. Although several of these strategies are also

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relevant to multivariable systems, they are efficient and yield great results when regulating unconstrained single-variable systems.

Numerous studies [8] have focused on the modeling of cruise control systems for automobiles. Some of the researchers created controllers to improve the performance of the car control system. A PID controller is utilized for this [9]. State space, fuzzy logic, and genetic algorithm were utilized by the researchers to fine-tune the PID controller's parameters (GA). The output response of the state space and fuzzy logic-based PID controller was satisfactory.

This work offers a PID controller that stabilizes an unstable car control system in order to achieve rapid speed stability.

LITERATURE REVIEW

Car model

An outstanding example of a feedback control system seen in many current automobiles is automatic car control. The objective of the vehicle control system is to maintain a consistent vehicle speed regardless of environmental disturbances, such as wind or road grade variations. This is performed by measuring the vehicle's speed, comparing it to the desired or reference speed, and adjusting the throttle automatically according to the control law.

Figure 1 represents the free-body diagram (FBD) which depicts a simplified model of the car's dynamics, which we will examine in this paper. The car with mass M is acted upon by a controlled force F. The force u represents the force generated at the interface between the road and tire. For this simple model, we shall assume direct control over this force and ignore the dynamics of the powertrain, tires, etc. that contribute to its generation. The rolling resistance and wind drag resistive forces, Bv, are supposed to fluctuate linearly with the vehicle's velocity, v, and operate in the opposite direction of the vehicle's motion.

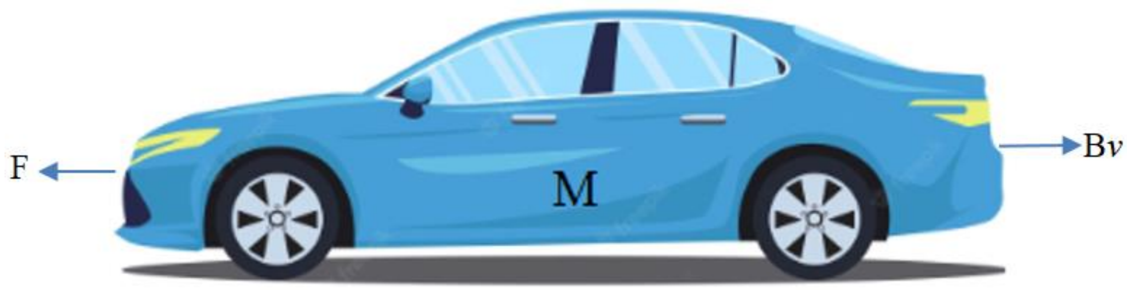

Figure 1. Car model.

Mathematical equations

According to Newton's law of motion [10], the car's longitudinal dynamics can be expressed as:

$$M\dot{v} + Bv = F$$

Since we are interested in controlling the car's speed, the following output equation is chosen:

$$y = v$$

Where M is the car mass in Kg and B is the damping coefficient in N.s/m, while v is the car speed in m/s.

Using the previous two equations that were derived from Newton's second law, we can build the model of the car system using MATLAB/Simulink as shown in figure 2.

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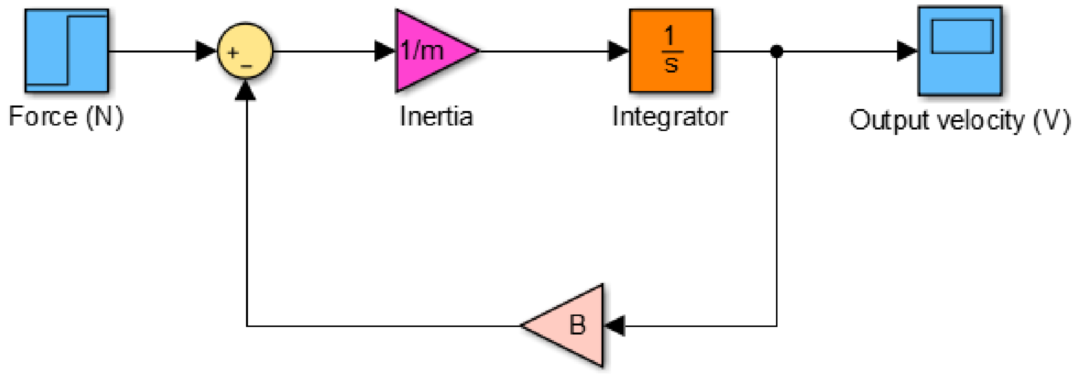

Figure 2. The car Simulink model.

The physical parameters of the model are selected as shown in table 1, and by run the simulation in Simulink window in Matlab. When the simulation is finished, we should see the car speed as shown in figure 3. By Observing figure 3, we would like to improve the response of the car control system, Because the car's speed took a long time to stabilize, after about ten seconds from the start of its movement, this time must be reduced using a suitable car speed control system.

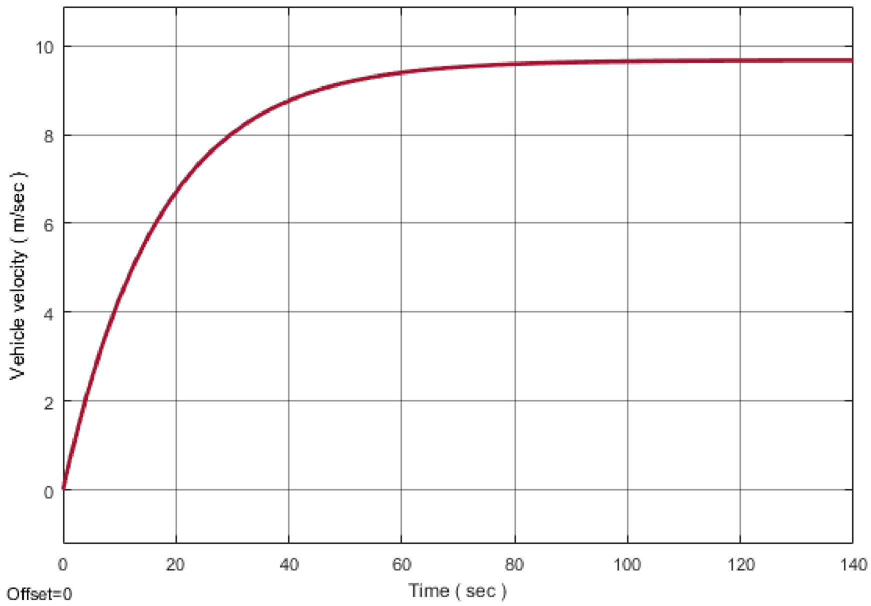

Figure 3. The car speed in a non-control state.

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METHODS

Control strategy

A control system is the entirety of the mechanical, physical, or digital machinery, including its operating environment (the plant) and the device used to govern it (the controller). A controller modifies the externally determined target input to create the desired output in a real-world control system, such as when setting a temperature with a thermostat or a speed with a car's speed control. Incorporating the plant's characteristics into the controller allows for the optimization of the time required to accomplish the desired goal. Additionally, the plant's response to various rates of change of the intended target value can be evaluated and managed. In this paper, the most well-known and sustainable control methods were used, which is the PID control method.

PID is one type of device used to regulate process variables such as pressure, flow, temperature, and speed in industrial applications. PID is an acronym for proportional integral derivative. In this controller, all process variables are regulated

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by a control loop feedback device.

This sort of control is used to steer an otherwise level system in the direction of an objective location. It is utilized nearly everywhere for temperature control and in numerous scientific, automation, car speed control, and chemical processes. In this controller, closed-loop feedback is utilized to keep the actual output of a method as close to the target as possible, if not produced at a fixed point. In this paper, the design of PID controllers and its control modes P, I, and D are explained and used.

A feedback control system is a component of a closed-loop system, such as a PID controller. This system uses a fixed-point evaluation of the feedback variable to generate an error signal. In response, it modifies the system output. This method will continue until the error reaches zero; otherwise, the feedback variable's value will become fixed.

This controller is superior to the ON/OFF controller in terms of performance. In a controller of the ON/OFF kind, only two conditions are available to regulate the system. Once the process value falls below the predetermined point, the device will switch on. Similarly, it will turn OFF when the value exceeds a predetermined threshold. In this type of controller, the output is not stable and will oscillate often around the fixed point. Nonetheless, this controller is more stable and accurate than the ON/OFF type controller.

With a low-cost simple ON-OFF controller, only two control states, such as fully ON or fully OFF, are possible. It is employed for limited control applications in which these two control states are sufficient to achieve the control aim. However, the oscillating nature of this control limits its application, and PID controllers are gradually replacing it.
Through closed-loop actions, a PID controller maintains the output so that there is no difference between the process variable and the set point or desired output.
Figure 4. shows the block diagram and the working principles of the PID controller.

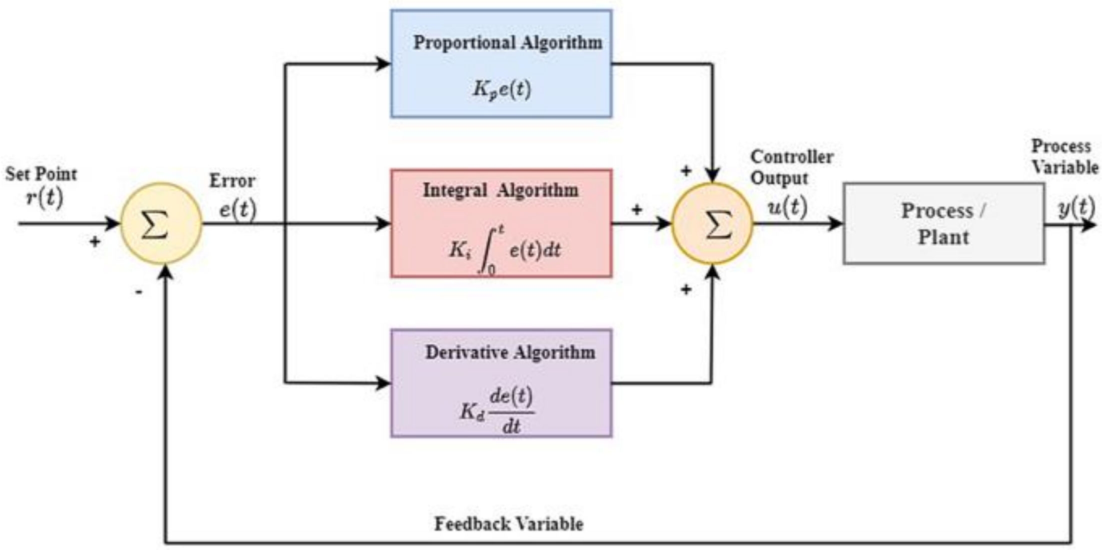

Figure 4. PID controller block diagram.

Using the two mathematical equations mentioned earlier and the Simulink model in figure 2, in addition to the PID controller obtained in figure 4, we can build the car speed system of the as shown in the following figure:

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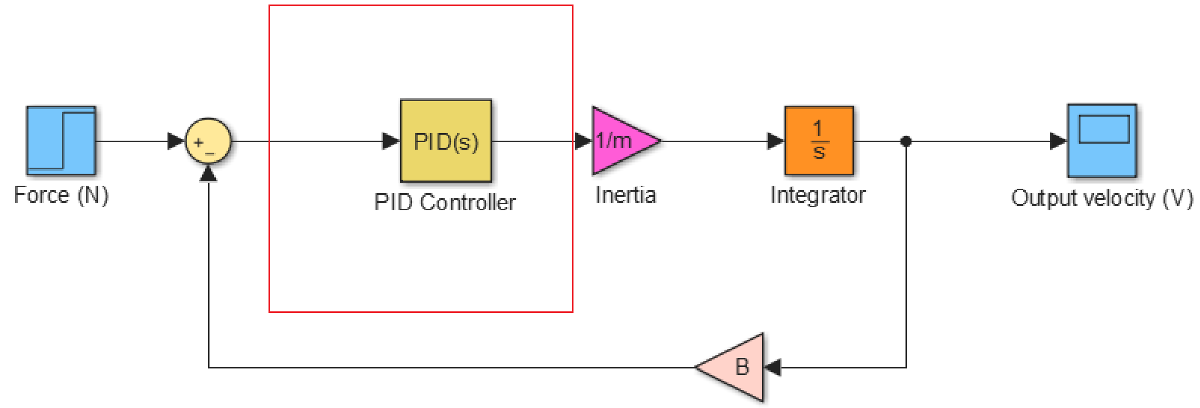

Figure 5. PID controller block diagram.

The PID controller used in this paper is an auto tuning" or "self-tuning" PID controllers which are designed to simplify matters by choosing their own tuning parameters based on some sort of automated analysis of the controlled process's behavior. These automatic procedures often involve a mathematical model of the process's input/output relationship derived from process data augmented by information provided by an experienced operator.

In the case of the self-tuning" PID controllers, the three parameters P, I, and D of the controller are automatically generated, as shown in Figure 6.

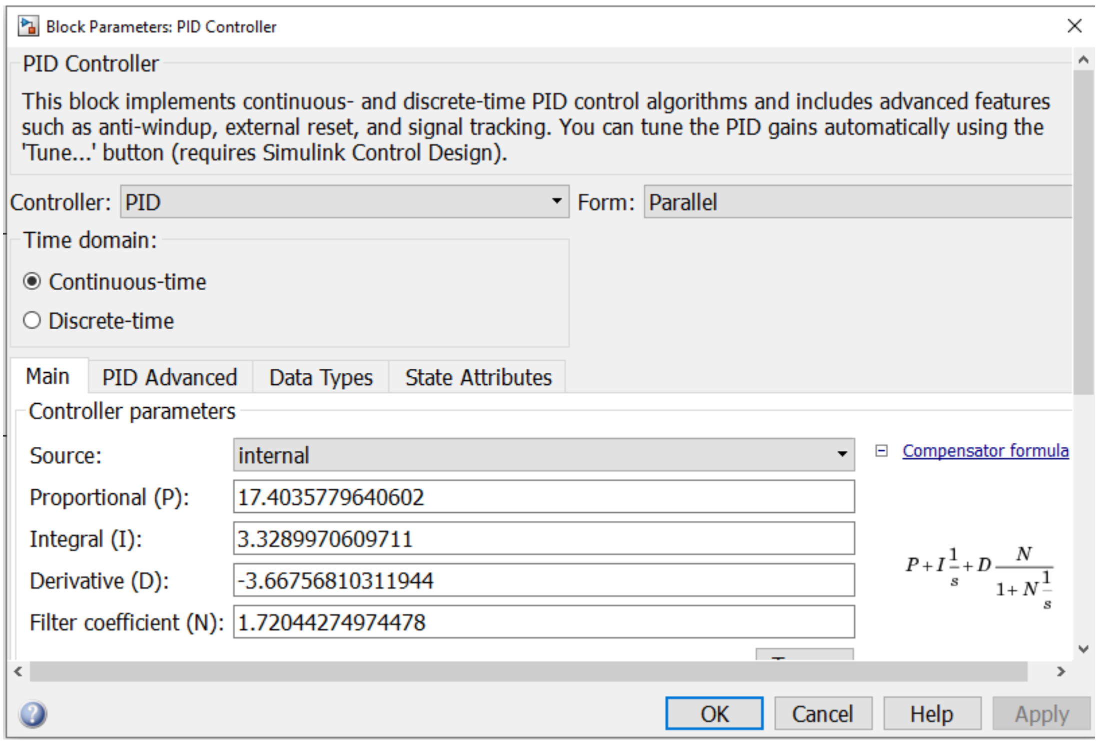

Figure 6. The PID controller parameters (P, I, and D).

The shape of the velocity curve that we obtained after using the PID controller is shown in Figure 7, which will be explained in the next part of the paper.

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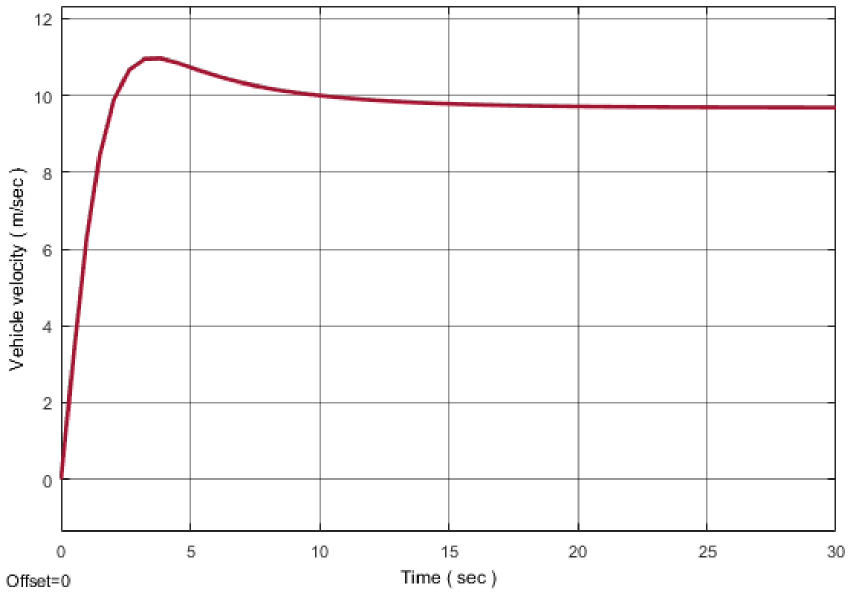

Figure 7. The car speed in a control state.

RESULT

Simulation results

Table 1. shows the car physical parameters that were used in this work, in addition to the three controller variables (P, I, and D) which are illustrated in the figure 6.

Table 1. The physical parameters of the car and controller.

Parameter	Value
Car mass, M	1050 Kg
Damping coefficient, B	62 N.s/m
Proportional parameter, K_p	17.4035779640602
Integral parameter, K_i	3.3289970609711
Derivative parameter, K_d	-3.66756810311944

In figure 3, which shows the curve or behavior of the car's speed, where the stability of the car's speed was at the second 120, and after that a control system was established for the car by adding the PID controller, The result was better, as it was found that the speed reached the stability limit at 20 seconds approximately, and this shows and confirms the success of using the PID controller in this the work.

DISCUSSION AND CONCLUSION

The car speed control system is presented in this paper. A mathematical equation of a car model is obtained, then the system performance and the car speed is examined using PID controller. The Simulink model of the control system have implemented using MATLAB software. The results showed that using the PID control method provides good performance of the car and car speed, where the stability of the car's speed was reached in a short time estimated at ten seconds. As a future work, it is better to test the car's speed using other nontraditional control methods, while comparing the car's performance and speed in several control methods, and thus we get the best control method that gives us the best performance of the car.

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