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Optimal design of bus schedule timing based on PID system

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Abstract. With more and more attention paid to the concept of low-carbon travel, public transport has gradually become the mainstream mode of travel. Nowadays many people will choose bus as a means of transportation. But how to make a reasonable bus departure schedule is a very complicated problem. Sometimes the departure interval is long, which leads to passengers having to wait for a long time, and sometimes there are not many passengers or even empty cars, resulting in a waste of resources. The purpose of this paper is to create a Proportional Integral Derivative (PID) controlled automated control system, which can adjust the bus departure schedule by the number of passengers on the bus in real time, to make a more reasonable bus schedule. Shorten the departure interval when the number of people is large and extend the departure interval when the number of people is small. This can greatly reduce the waiting time for passengers and reduce the waste of public resources when there are fewer people.

Keywords: Bus schedule, Closed loop control loop, PID controller, MATLAB, People count.

1. Introduction

Today, the concept of low-carbon travel has been deeply rooted in people's minds, and public transportation system is an indispensable part of low-carbon travel. One of the main means of transportation for people to travel today is the bus, which is an important part of the public transport system today. But nowadays many buses have fixed schedules. This can lead to problems, such as empty cars when there are fewer people, leading to a waste of resources, and when there are more people, it can lead to too many cars or long waits for departure. Therefore, the control system in this paper aims to reasonably adjust the departure interval of the bus according to the change of the number of people.

The control system used in this paper is a continuous Proportional Integral Derivative (PID) control system [1]. The input is the expected departure interval, and then the function of departure interval and the number of passengers is constructed. When the number of passengers changes, the departure interval will also change accordingly, and the final stability is at the set expected departure interval. In this way, the bus departure interval can be intelligently adjusted, shortening the departure interval when there are more people and lengthening the departure interval when there are fewer people.

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2. The basic theory of the system

2.1. Control system theory

The meaning of automatic control system is that in the absence of human intervention, through the controller and the set program, some physical quantities in the controlled object automatically operate in accordance with the expected situation and finally reach a stable state. The system processes the input signal to generate the output signal, which is basically a causal relationship that resembles a function. The automatic control system can be divided into two forms: System without feedback and system with feedback. Figure 1 shows the flow chart of Control system without feedback [2].

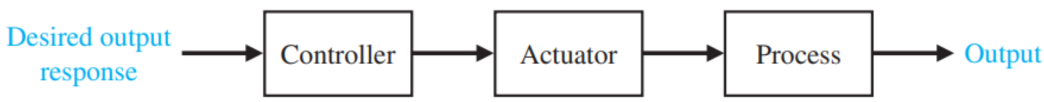

Figure 1. Control system without feedback (Photo/Picture credit: Original)

Figure 2 shows the flow chart of closed-loop control, which is different from open-loop control in that the measured amount of actual input signal is increased as feedback [3]. The use of a difference as a control mechanism and comparing the functions of the variables ensures a predetermined connection between the variables in a feedback control system.

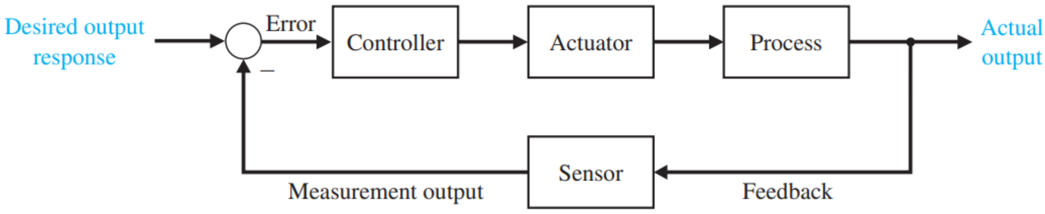

Figure 2. Control system with feedback (Photo/Picture credit: Original)

At the same time, the control system can also be divided into continuous control system and discrete control system due to the distinction between continuous and discrete signals in duration. Discrete control systems are also known as digital control systems [4]. And digital control systems can be used in many fields [5]. There are many advantages to using digital control, including increased measurement sensitivity, the utilization of signals that have been digitally coded, Sensors and transducers that are digital, and lowered the sensitivity of signal noise. The use of computers in control systems are connected to actuators and processes through signal converters. A digital-to-analog converter processes the computer's output. The approximate flow chart of the discrete system is shown in Figure 3.

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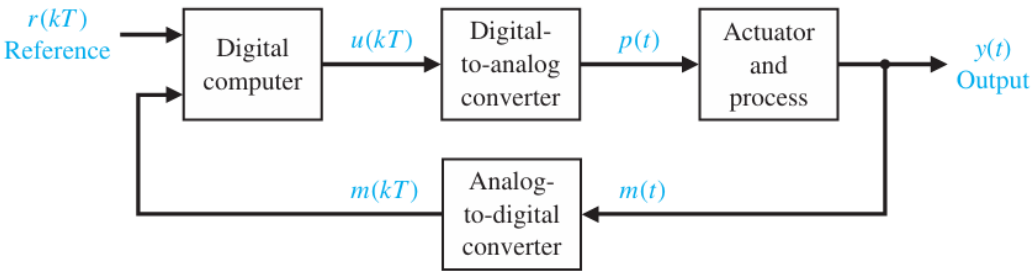

Figure 3. Digital control system (Photo/Picture credit: Original)

2.2. PID Control System

The control system relies heavily on PID controllers. This controller is also chosen in this paper. The letters P, I and D correspond to the proportion, integration, and differentiation of the controller respectively. Each of the three links has a role in the controller. When the proportional constants gradually increase, the response speed of the system will become faster, so that the system will approach the expected value faster, but relying on the proportional link alone will produce steady-state error, so that the system can never truly reach the expected value. This integral link needs to be introduced to get rid of the steady-state error. At the same time, the differential link can play a role in eliminating the oscillation phenomenon of the system [6]. The mathematical expression of PID controller can be written as follow:

$$u(t) = Kpe(t) + Ki\int_0^t e(\tau)\,d\tau + Kd\frac{de(t)}{dt} \tag{1}$$

Where e(t) represents the input signal after subtraction adjustment with the feedback signal, Kp, Ki, and Kd represent the coefficients of proportion, integration, and derivation, respectively, and u(t) represents the output signal of the controller. Figure 4 can represent a complete PID control system.

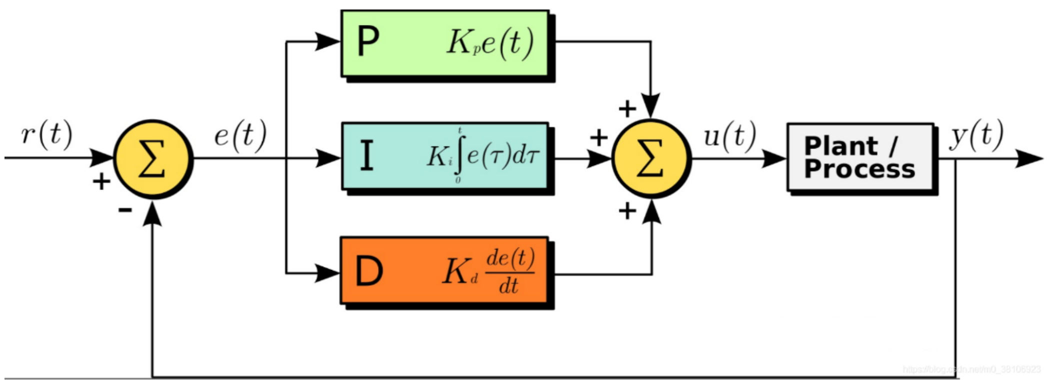

Figure 4. PID control system (Photo/Picture credit: Original)

The input signal is r(t), and the feedback signal y(t) is subtracted to obtain the error function e(t), which enters the subsequent controller and the controlled object, and finally makes the whole system reach the expected value and is in a stable state.

2.3. Bus internal construction

The purpose of using PID controller in this paper is to make a more reasonable departure schedule for buses according to the number of passengers on the bus. The specific operation of making a more reasonable departure schedule is to adjust the departure interval of buses. In this system, the number of passengers on the bus needs to be monitored. Because a function about the number of passengers on the bus in real time and the departure interval needs to be built.

To know the number of passengers in the car, two infrared cameras are planned to be placed inside the car [7]. The locations are on and off the bus. That way every passenger getting on and off the bus will be photographed and recorded. To know the number of passengers on the bus in real time, just two data points needed to be subtracted. After knowing the number of passengers on the train, the function of the number of people and the time between departures can be simulated. The relationship between the number of people and the time between departures will be known by this function. The departure interval time will be reasonably adjusted with the change of the number of passengers, to optimize the bus departure schedule.

3. Simulation and result analysis

3.1. Software advantage analysis

There are many simulations software to choose from, such as ANSYS, Autodesk, LTspice, Simulink and so on. In this paper, Simulink is selected. Because Simulink has a very rich module library, the modules commonly used in automatic control systems can basically be found. Secondly, simulation in Simulink does not need to write a lot of programs, the control system covered in this paper, only need to connect the module. Simulink offers capabilities for multi-process modeling, continuous and hybrid system modeling, discrete time, continuous and nonlinear systems, and a straightforward user interface. At the same time, the Scope function is also very convenient for subsequent image analysis [8].

3.2. Parameter setting and modeling

Because the function of the number of people and the departure interval is a more complicated function. Therefore, this function will be simplified to a certain extent in the subsequent simulation process. The simulation program is shown in Figure 5.

Figure 5. Simulation system (Picture credit: Original)

The expression of the function is y=1.8*u, and the input is a constant value 10, which is also the expected value of the entire system, and the physical meaning is a bus every 10 minutes. After the initial construction of the control system, the parameters of the controller and the subsequent transfer function need to be determined.

Since the second-order system is built, the form of the transfer function is preliminarily determined as follow:

$$G(s) = \frac{K}{(sT1+1)(sT2+1)} \tag{2}$$

where K Represents the overall scaling factor of the system, T1 and T2 respectively represent two-time constants, t1 is the time constant required by the system from the initial state to a stable state, T2 represents the response time when the system has oscillation in the later stage. Here they will be 5 and 10, respectively. When adjusting the controller parameters, the coefficient of the proportional link is the first to be adjusted, if the proportional coefficient is too small, it will lead to the system response time is too long, and the proportional coefficient is too large, it will cause the system to oscillate and be difficult to stabilize. After repeated adjustment, the ratio coefficient is determined to 8. Then the integral coefficient is adjusted to eliminate the steady-state error, and finally the differential coefficient

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is adjusted to eliminate the oscillation of the system. The simulation image obtained by the controller with scale coefficient of 8, integral coefficient of 0.2 and differential coefficient of 0.2 is shown in Figure 6.

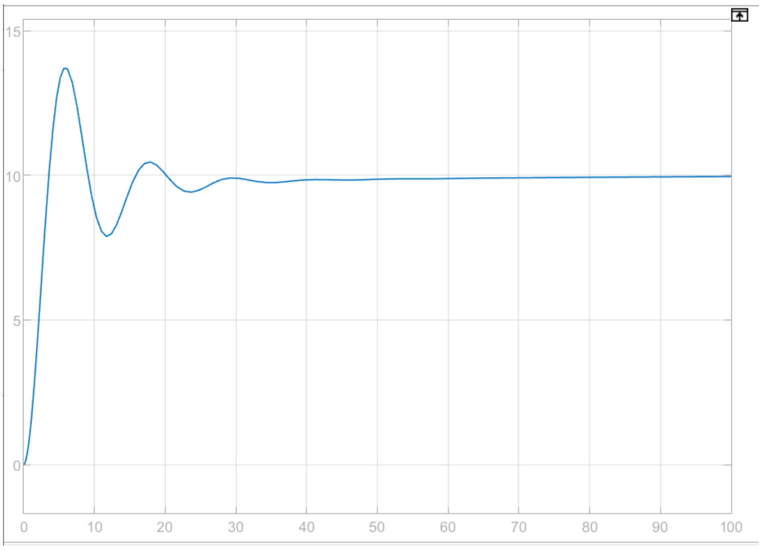

Figure 6. Simulation results (Picture credit: Original)

The final system can be stabilized at the initial set value of 10, and there is almost no steady-state error in the end because the system is relatively simple. Next, the system's dynamic performance must be examined. The system's rise time, peak time, overshoot, and correction times are the four components of its dynamic performance. The time it takes for the system response to increase from 10% to 90% is known as rise time. In the case of this control system, this is the time it takes to go from 1 to 9. The measurement method of rise time is shown in Figure 7.

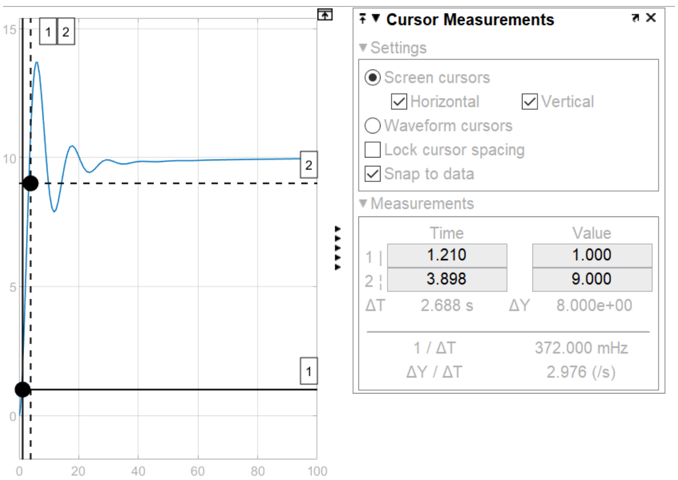

Figure 7. Rise time measurement (Picture credit: Original)

After Scope analysis, the rise time is about 2.688 seconds.

Peak time is the amount of time it takes for the system to respond to a crest. Figure 8 shows the measurement of peak time.

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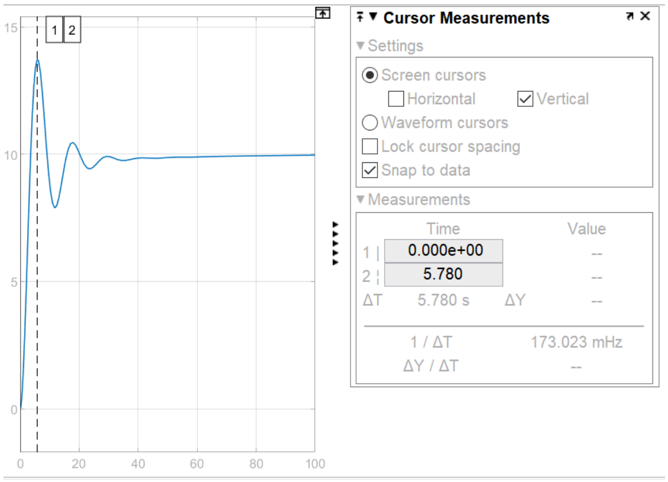

Figure 8. Peak time measurement (Picture credit: Original)

After Scope analysis, the peak time is about 5.7 seconds.

The peak overshoot is the difference between the first crest and the set value. Figure 9 shows how the peak overshoot is measured.

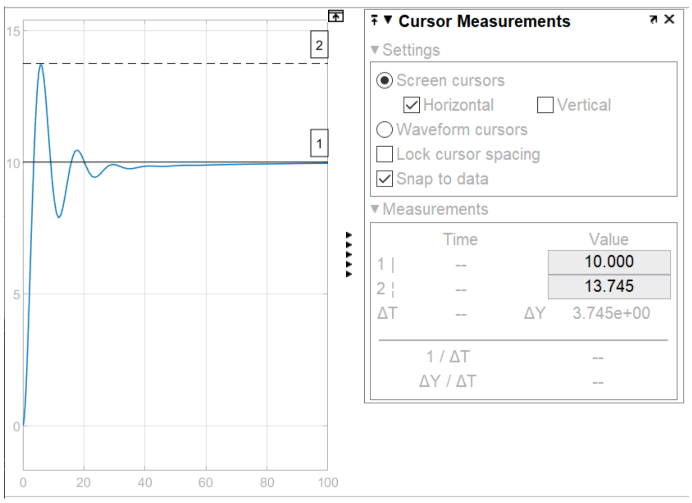

Figure 9. Overshoot measurement (Picture credit: Original)

After Scope analysis, it is found that the overshoot is about 3.7.

The time required for the system to reach and maintain a final value within 1% is called the settling time. In the control system described in this paper, it is within the range of 9 to 11. Figure 10 shows the measurement method of the settling time.

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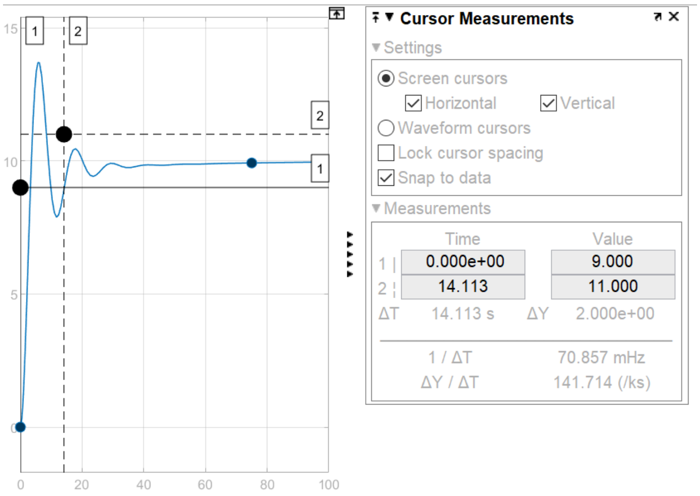

Figure 10. Settling time measurement (Picture credit: Original)

Through the analysis of Scope, it can be known that the settling time of this system is about 14 seconds.

Through the analysis of dynamic performance, the response speed, damping degree and other properties of the system can be analyzed, which are essential for the analysis of automatic control system.

4. Challenges and prospects

At present, there are still some problems and challenges when the control system covered in this paper is implemented in real life. The first problem is that it is bound to cost a lot of money to install infrared cameras that can identify the number of people on all the buses in the city, and it is necessary to optimize the program of counting the number of passengers on the bus from an economic point of view.

In addition, from a practical perspective., the change of crowd flow is very complex, if the crowd flow can be predicted, then it will be very helpful to planning the traffic system [9]. For example, most people go to and from work between eight and nine in the morning and five and six in the evening, so these two times are the most crowded times of the day for buses, and the road conditions are also the most crowded times. The 10-minute departure interval set by the control system before in this paper may no longer apply to the two time periods of morning and evening. Because these two periods need to have a greater tolerance for the number of passengers on the bus. For example, when there were more than 20 people on board, the departure interval needed to be shortened, and now the number may have to be increased to 30 people.

Finally, from the simulation system itself, this paper's control system needs to build the function between the passenger and the departure interval is a very key link. This paper uses a simple proportional function at present, which is obviously not accurate enough in real life. So, a lot of data from real life measurements, such as the number of passengers in a car in real time, is needed to simulate this function more accurately. However, in fact, this function is very complex, and at the same time the system will become more complex, at this time the selection of PID controller may not be accurate enough. The introduction of fuzzy PID controller may improve the accuracy of the system, and the fuzzy PID controller can modify the PID controller's parameters in real-time., which is more suitable for complex or difficult to accurately describe the system [10].

5. Conclusion

This paper utilizes a control system, which aims to adjust the bus departure interval according to the number of passengers on board, to make a more reasonable bus departure schedule. PID controller is

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selected as the controller in the control system of this paper. In addition, the function between the number of passengers on the train and the departure interval needs to be established. After setting up the system, by adjusting the parameters of PID controller and transfer function, the system is successfully stabilized at the initial set value 10.

However, there are still some problems to be solved when the system is implemented in practice, such as whether installing infrared cameras that can monitor the number of people on every bus will cause financial difficulties. Does the control strategy need to be adjusted in the morning and evening when there are many people and how to simulate the function more accurately between the number of passengers on the bus and the departure interval, and does the fuzzy PID control need to be used to enhance the precision of the system? These problems need to be considered during the actual implementation of the system.

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