An Intelligent Vehicle Based on an Improved PID Speed Control Algorithm for Driving Trend Graphs

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***Abstract* — In order to improve the accuracy and stability of the intelligent vehicle speed control. The control method is based on the traditional PID control algorithm; the error of setting speed and actual speed from driving trend graphs are used as the input of PID controller. In this paper, we proposed an improved PID speed control algorithm for driving trend graphs in intelligent vehicle. First, built the driving trend graphs, driving trend graphs is the vehicle road environment perception systems with Log-Polar transform, it is in accordance with characteristics of human perception, and it is established according to collection of camera, radar, navigation, other on-board sensors data and the vehicle status parameters. Second, according to the driving trend graph set the acceleration and deceleration distance, obtain the corresponding acceleration.Last,Establish the mathematical model of the acceleration between throttle increment and brake grade, through the throttle actuator and the brake actuator to control the speed of the engine, and the output is vehicle's actual speed.**

Key words - PID control; intelligent vehicle; speed control; driving trend graphs

I. INTRODUCTION

Intelligent automotive is the product of the development of computer science, pattern recognition and intelligent control technology, which Integrated vehicle technology, sensor technology, artificial intelligence, automatic control technology, In recent years, the research of intelligent vehicle technology has attracted the attention of a large number of universities, enterprises and related scientists in the world [1,2].

Speed control system is one of the most basic control systems of unmanned intelligent vehicle, which is the most important part of the realization of unmanned intelligent vehicle stability and safety. An unmanned intelligent vehicle can collect the current road traffic information with on-board sensors, according to the traffic information and the road environment to control throttle actuator and brake actuator, adjust the speed of the vehicle to ensure the stability and safety of the autonomous driving, So the improved PID speed control algorithm for driving trend graphs was designed ,and the results show that through the real vehicle on the fully open road of "Zhengzhou To Kaifeng" test, the 32.6km real road test analysis that the speed control algorithm of our research based on driving trend graphs is better than traditional PID speed control, which can be met the requirements of intelligent vehicle speed control.

II. RELATED WORK

At present, there are many algorithms for intelligent vehicle speed control system, such as PID control algorithm, fuzzy control theory, model predictive control (MPC) algorithm, and so on. Traditional PID control technology is mature in motor speed control; it is difficult to keep its ideal performance as designed affected by nonlinear factors of motor load in practice. It is inconvenient to debug in operation as the index parameters need a strictly controlled outer environmental as well [3, 4, 5]. The fuzzy control method proposed by Tsai et al , has been proved to meet the requirements of vehicle safety and comfort, and it has been proposed that the fuzzy PID control algorithm is applied to the vehicle speed control system [6,7]. MPC control algorithm has three basic features of model prediction, rolling optimization and feedback correction. It can be used to control on-line rolling optimization in advance. It has good control effect, and it is suitable for the control system that is not easy to build accurate digital models and more complex system [8, 9, 10, 11]. The MPC control algorithm is applied to the speed control system of intelligent vehicle, which is used to control the vehicle's driving speed smoothly and effectively, and to meet the safety and comfort requirements of passengers. A multi-objective adaptive cruise controller (ACC) is developed for intelligent hybrid electric vehicles (I-HEV).The controller integrates the advantages of both intelligent transportation systems (ITS) and HEV to improve traffic safety, fuel efficiency and ride comfort. The system has a hierarchical control structure with steady-state optimization and dynamic coordination in a nonlinear predictive control algorithm [12].

IMC (Internal Model Control) is a new control method which can be used in controller design based on Process Mathematical Model proposed by Garcia & Morrari. Compared with traditional PID, IMC has one setting parameter only that makes is clear when debugging the parameter, good dynamical performance and clear robustness [13, 14]. Easy framework, good performance in follow-up control, powerful robustness, high-denoise quality in immeasurable disturbance are the main advantages of IMC. By controlling different traits based on IMC, the results indicate that controller is easily designed and wide-used as parameters are easy to set and the designer may consider several parameters at the same time. The corresponding relationship between IMC and PID makes it possible to shift PID design to IMC [15]. IMC a is reliable model for sources apportionment and outcomes in accord with what it is. Can make the requirements of fuzzy PID control with reduced complexity and randomness in parameter design. In order to solve the problem of PMSM speed control, a novel control method is put forward in this article, which is based on fuzzy self-tuning PI. The simulation on an inverter based on MATLAB was implemented [16]. The result shows that the new control algorithm compared with the traditional PI, It has strong adaptability, robustness and ant interference. And it can track speed quickly; it can also be quickly restored to the rated condition when the load is change.

The traditional PID control algorithm is simple in structure and has low hardware requirements, But its proportion, integral and differential parameters are preset and fixed, and as the change of traffic environment , the response of the traditional PID control algorithm to the intelligent vehicle system deviation is poor, and it is easier to appear overshoot and oscillation phenomenon [17]. In this paper, an improved PID control algorithm is applied to the speed control of the intelligent vehicle, and it can improve the stability and comfort of the intelligent vehicle speed control.

III. BUILD MATHEMATICAL MODEL OF THE VEHICLE

The mathematical model of the vehicle can be divided into kinematic model and dynamic model. The kinematics is from the point of view of geometry to study the motion of the object. And the study of dynamics involves the relationship between motion and force, quality, etc. Vehicle dynamics in the strict sense should include the vehicle's power performance, fuel economy, braking comfortable, smoothness, stability, etc.

A. Establishment Of Vehicle Dynamics Model

Vehicle kinematics is mainly refers to the transmission of power from the transmission to the Motor Sports, and it is made up mainly by the universal transmission device, the speed reducer, differential, half shaft, tire, vehicle inertia part and braking device, etc. This paper only considers longitudinal motion of the vehicle; the lateral motion and the vertical motion are not considered.

Vehicle traveling equation:

$$F_t = \sum F \tag{1}$$

$$\sum F = F_w + F_f + F_j \tag{2}$$

Where F_t is driving force; $\sum F$ all of running resistance ; F_f the rolling resistance ; F_w the air resistance ; F_j the acceleration resistance; m the quality of the vehicle ; g the acceleration of gravity; θ the Pavement slope.

The torque of vehicle engine is transmitted to the driving wheel through the transmission system. This time the torque (T_t) of driving wheel will produce a pair of road surface Circumferential force F_0 , the road to driving wheel will produce a reaction force that is driving force (F_t).

Then the driving force:

$$F_t = \frac{T_e i_g i_0 \eta_T}{r} \tag{3}$$

where T_e is the engine torque; i_g the transmission ratio of gearbox; i_0 the main reducer transmission ratio; η_T the transmission System of mechanical efficiency; r the radius of wheel.

Because the general road of the slope angle is small, $\cos\theta \approx 1$, $\sin\theta \approx \tan\theta$, through the above analysis can get the vehicle traveling equation:

$$\begin{cases} \dfrac{T_e i_g i_0 \eta_T}{r} = mgf + \dfrac{C_D A}{21.15} v + \delta m a & \cos\theta \approx 1, \sin\theta \approx \tan\theta \\ \dfrac{T_e i_g i_0 \eta_T}{r} = mgf + \dfrac{C_D A}{21.15} v + \delta m a & \cos\theta \neq 1 \end{cases} \tag{4}$$

where f is the rolling resistance coefficient; C_D the air drag coefficient; A the wind area; δ the conversion of the vehicle's rotational mass; a the driving acceleration.

B. Establishment Of Vehicle Brake Model

Majority vehicles is used Electro-Hydraulic Brake System. It combines the traditional hydraulic brake system and electronic control technology. Hydraulic control unit is composed mainly by the electric hydraulic pump, high pressure accumulator, and the four groups Solenoid valve are used to adjust four pressure of wheel braking cylinder. The braking force of EHB system is not controlled by hydraulic or pneumatic control device, but controlled by electronic controllable motor. The electronic controller sends out control signals to control the brake drive motor, and the motor drives the hydraulic to pump the high pressure oil to energy accumulator to achieve braking force. In this system, each wheel can be independently controlled, which can ensure the stability for vehicle's braking process.

When the brake pedal is pressed, unit the brake pedal receives the signal of foot, pressure increasing valve open, pressure reducing valve close. At this point the two isolation valve is closed, high pressure energy accumulator provides high pressure oil, flow through the pressure increasing valve into wheel braking cylinder, and the pressure of wheel cylinder increases rapidly, this process is pressurization of EHB system; When the wheel cylinder pressure reaches a certain value, it needs to keep the pressure constant, At this point, both pressure increasing valve and pressure reducing valve are closed, the high pressure oil is enclosed in wheel cylinder, thus keeping the pressure of wheel cylinder constant, this process is Packing Process of EHB system; When the brake pedal is released, the electronic control unit receives the displacement signal of brake pedal, pressure increasing valve close, pressure reducing valve open, the hydraulic oil flow back to liquid-storage tank through oil return pipe, and the brake wheel cylinder pressure will be dropped, this process is decompression progress of EHB system [18].

Control signals and currents are transmitted through CAN bus to brake, the control signal and current are inputted to valve actuator and electro hydraulic brake valve, valve actuator generates control current and input to the electro-hydraulic brake valve according to the larger values of the two input signals. Electro hydraulic brake valve adjust brake pressure according to the input current [19].

In this paper, the relationship between the control signal of different brake level and the corresponding deceleration is obtained by real vehicle test. When the vehicle is driving at a constant speed, then receives a constant braking level, the speed of the vehicle can be seen as a constant deceleration.

In the process of automobile braking , the wheel will be suffer brake actuator friction moment and the road friction moment at the same time, where the former moment can be called input moment and the later can be called output moment. In the brake system, we introduced the brake efficiency factor φ .

Be defined as

$$\varphi = \frac{outputmoment}{inputmoment} = \frac{B \times R_t}{\frac{\pi}{4} D^2 \times (P - P_s) \times R_b} \tag{5}$$

where B is brake force from the road, R_t is wheel radius, D is wheel cylinder diameter, P is wheel cylinder brake pressure, P_S is the loss of wheel cylinder pressure, R_b is brake effective radius.

According to (5) can be drawn front and back wheel brake pressure calculation expression:

$$\begin{cases} P_f = \dfrac{R_{tf}}{2\varphi \frac{\pi}{4} D_f^2 N_f R_{bf}} B_f + P_{Sf} \\ P_r = \dfrac{R_{tf}}{2\varphi \frac{\pi}{4} D_r^2 N_r R_{br}} B_r + P_{Sr} \end{cases} \tag{6}$$

Where N_r is the front wheel cylinder number, N_f is the back wheel cylinder number.

Order:

$$\begin{cases} K_f = \dfrac{R_{tf}}{2\varphi \frac{\pi}{4} D_f^2 N_f R_{bf}} \\ K_r = \dfrac{R_{tf}}{2\varphi \frac{\pi}{4} D_r^2 N_r R_{br}} \end{cases} \tag{7}$$

Then (6) can be expressed:

$$\begin{cases} P_f = K_f B_f + P_{Sf} \\ P_r = K_r B_r + P_{Sr} \end{cases} \tag{8}$$

Brake pressure and brake force is linear relationship.

According to (8) we can get the brake force:

$$\begin{cases} B_f = \dfrac{1}{K_f}(P_f - P_{sf}) \\ B_r = \dfrac{1}{K_r}(P_r - P_{sr}) \end{cases} \tag{9}$$

IV. INTELLIGENT VEHICLE SPEED CONTROL METHOD

The speed of the intelligent vehicle depends on the speed of its engine，and the engine speed depends on the fuel delivery of Electronic throttle . When the vehicle wants to slow down or stop, the brake pedal through hydraulic brake device to reduce vehicle's speed. When the intelligent vehicle is autonomous driving, it will go through different road sections (straight, bend, turning, etc.). So the speed of intelligent vehicle needs to change with different road sections to reach the expected speed. Turn namely straight, high speed, big arc corner deceleration, etc.

A. The Traditional PID Speed Control Algorithm

PID is proportion (Kp), integral (Ki) and differential (Kd) closed-loop control algorithm, and the proportion part of the system are used to control response speed and accuracy of the system, the integral part mainly to ensure the system steady-state process output and input Consistent, the differential part mainly to improve the stability of the closed-loop system, and each parameter need to be set and adjusted in the practical engineering [20]. PID speed control system structure is shown in figure 1.

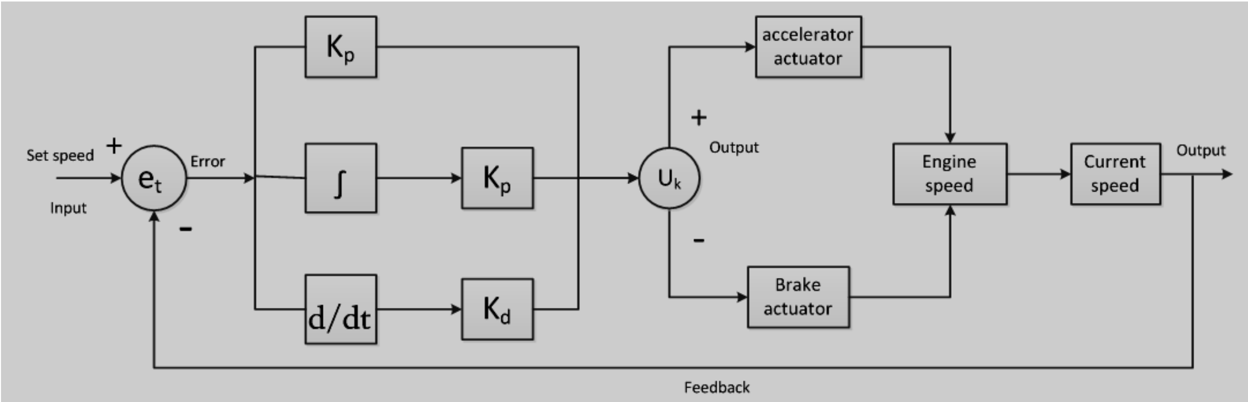

Fig.1 PID speed control system structure

The general mathematical equations:

$$U_k(t) = k_p(e(t) + \frac{1}{T_i}\int e(t)d_t + T_d\frac{d_{e(t)}}{d_t}) \tag{10}$$

Here, k_p represents as proportional coefficient, T_i and T_d **Error! Reference source not found.** represent Integral and differential time constant, $e(t)$ **Error! Reference source not found.** represents as Control Error, $U_k(t)$ represents as output control variable, which Corresponding to the car's accelerator and brake controller[21].

According to the parameters of the vehicle itself, the throttle incremental (40 ~ 200) and brake level (1 ~ 25) mathematical expression:

$$\begin{cases} Accelerator = U_k(t) \times p_a + 40(U_k(t) > 0) \\ BrakeLevel = U_k(t) \times p_b(U_k(t) < 0) \end{cases} \tag{11}$$

Here, p_a and p_b represent throttle incremental and brake level coefficient.

Traditional PID speed control algorithm has simple structure, fast response and parameter adjustment is simpler, but for the high accuracy of speed control system, traditional PID control accuracy is lower, overshoot is larger, will occur severe brake and catching up, and greatly reduce the vehicle's safety, stability and comfort.

B. The Speed Control Algorithm of Our Research

The speed control algorithm of our research lead up distance strategy based on the traditional PID control, preset the distance of current speed reach to expect speed, ensure the vehicle to reach the expect speed within the preset distance, and keep the expected speed driving, entering no range of traditional PID speed control. The speed control system structure of our research is shown in figure 2.

The acceleration:

$$a = \frac{v_t^2 - v_0^2}{2S} \tag{12}$$

Here, S represents as preset distance, v_t represents as expect speed , v_0 represents as current speed. According to the acceleration, the throttle incremental (40 ~ 200) and brake level (1 ~ 25) mathematical expression:

$$\begin{cases} Accelerator = a \times p_c + 40(a > 0) \\ BrakeLevel = a \times p_d(a < 0) \end{cases} \tag{13}$$

Here, p_c and p_d represent throttle incremental and brake level coefficient. So we can be obtain by formula (12), (13):

$$\begin{cases} \begin{cases} Accelerator = a \times p_c + 40(a > 0) \\ BrakeLevel = a \times p_d(a < 0) \end{cases} (S > 0) \\ \begin{cases} Accelerator = U_k(t) \times p_a + 40(U_k(t) > 0) \\ BrakeLevel = U_k(t) \times p_b(U_k(t) < 0) \end{cases} (S = 0, a = 0) \end{cases} \tag{14}$$

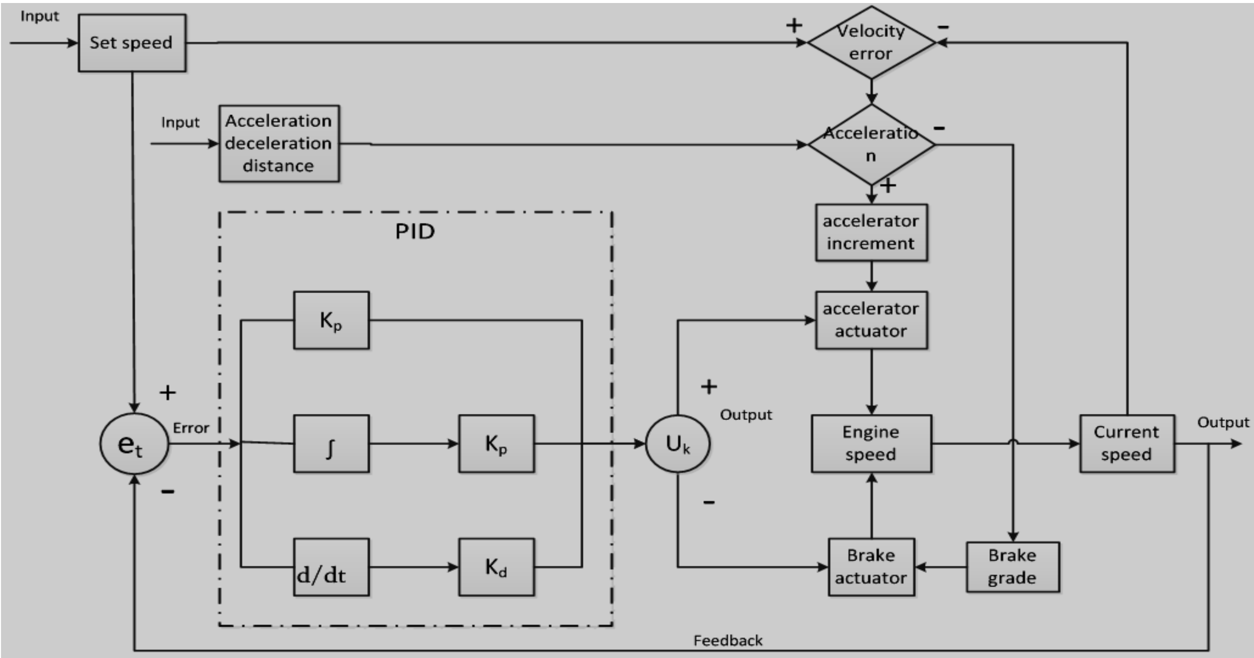

Fig.2 The speed control system structure of our research

V. THE RESULTS AND ANALYSIS OF TWO KINDS OF SPEED CONTROL ALGORITHM

In this paper, the experimental platform is C70 intelligent vehicle modified by ourselves; Brake controller and throttle controller are electronically hydraulic brake system and electronic throttle system. Road environment is real suburban driveway with Pedestrians and vehicles; the top speed is 60km/h, C70 intelligent vehicle done a large number of experiments on traditional PID speed control system and the speed control system of our research in the same real driveway environment, including acceleration, deceleration, stop and ACC driving, etc. C70 had taken part in the first completely open road “Zheng Zhou TO Kai Feng”, the whole journey is 32.6km.The traditional PID speed control algorithm was implementation of the control algorithm of literature [5] .The follow figures are the results of two different speed control systems.

A. Traditional PID Speed Variation Analysis

1. The Traditional PID speed variation analysis

(1) From 0km/h accelerate to 40km/h

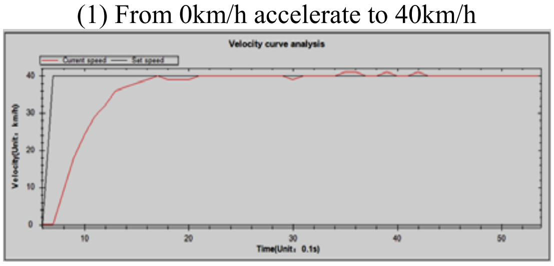

Fig.3 Traditional PID algorithm from 0 km/h accelerate up to 40 km/h

(2) From 9km/h accelerate to 35km/h

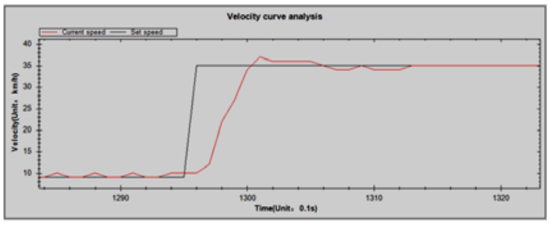

Fig.4 Traditional PID algorithm from 10 km/h accelerate up to 35 km/h

(3) From 40km/h Slow down to 20km/h

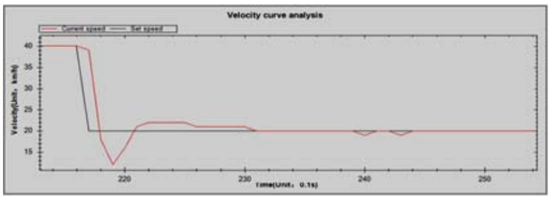

Fig.5 Traditional PID algorithm from 40 km/h slow down to 20 km/h

(4) The ACC of traditional PID control algorithm

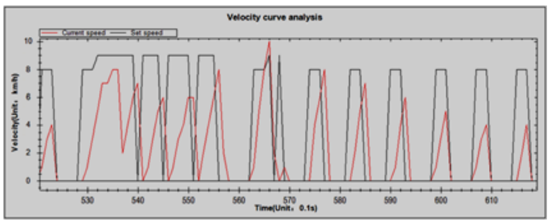

Fig.6 The ACC of traditional PID control algorithm

2. The speed variation analysis of control algorithm of our research

(1) From 0km/h accelerate to 50km/h

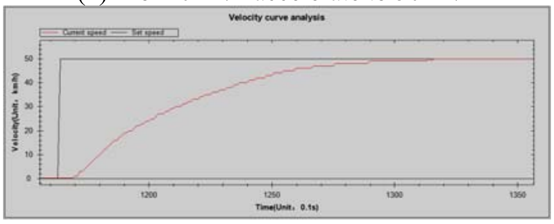

Fig.7 The control algorithm of our research from 0 km/h accelerate up to 50 km/h

(2) From 10km/h accelerate to 40km/h

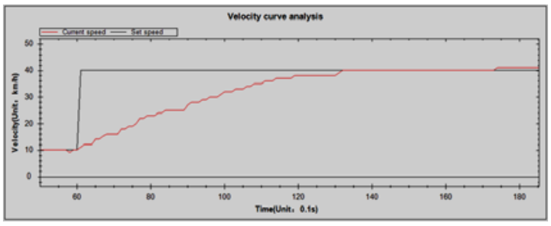

Fig.8 The control algorithm of our research from 10 km/h accelerate up to 40 km/h

(3) From 50km/h slow down to 15km/h

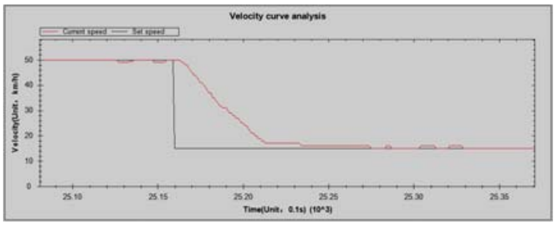

Fig.9 The control algorithm of our research from 50 km/h slow down to 15 km/h

(4) From 50km/h slow down to 30km/h, and then stop.

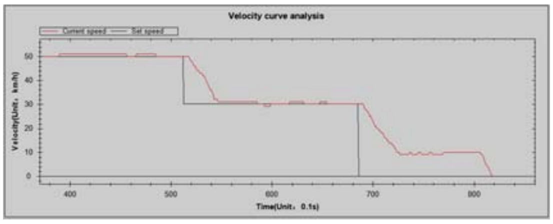

Fig.10 The control algorithm of our research from 50 km/h down to 30km/h, and then stop

(5) The ACC of improved PID control algorithm

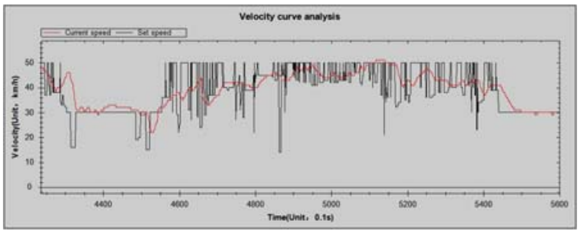

Fig.11. The ACC of control algorithm of our research

Figures 3 to Fig 11 are the velocity curves of two kinds of control algorithm in the same road environment and with the same experiment platform.

B. The Data Comparisons of Traditional PID Algorithm And The Algorithm of Our Research

From Fig 3～Fig 11 ,we can get the data comparisons of two kinds of control algorithm (Table Ⅰ).

From the figures above and Table Ⅰ, it is obviously that the speed control algorithm of our research is better than traditional PID algorithm in acceleration, deceleration, stop and ACC driving.

TABLE I. THE DATA COMPARISONS OF TWO KINDS OF CONTROL ALGORITHM

control algorithm	velocity change（km/h）	time（s）	overshoot	vehicle riding comfort ability
Traditional PID algorithm	0 ～ 40	11	1	uncomfortable
	9 ～ 35	5	2	
	40 ～ 20	5	8	
	ACC		Frequency	
Our method	0 ～ 50	15	-1	Smooth and steady
	10 ～ 40	7	1	
	50 ～ 15	6	-1	
	ACC		Unapparent	

VI. CONCLUSION

The intelligent control strategy proposed in this paper is used improved PID speed control algorithm based on driving trend graph to realize the closed-loop control of vehicle speed. The speed control algorithm of our research is obviously better than the traditional PID control system; Specific performance in the following aspects: firstly, the speed overshoot volume is small, and the speed control algorithm of our research won't appear a large overshoot; secondly, The deceleration and acceleration of the intelligent vehicle are more smoothly, would not occur severe brake and catching up; what is more, the ACC is more smooth and steady; and the last, the vehicle riding comfortability is better. In a word, this method can make the driving performance of intelligent vehicles more identical to conventional vehicles, greatly improved the vehicle's safety, stability and comfort.

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