Research Article

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Automatic control of computer application data processing system based on artificial intelligence

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Abstract: To shorten the travel time and improve comfort, the automatic train driving system is considered to replace manual driving. In this article, an automatic control method of computer application dataprocessing system based on artificial intelligence is proposed. An automatic train operation (ATO) introduced the structure and function of an autopilot system (train), optimized the train running on the target curve, introduced the basic principle of fuzzy generalized predictive control (PC) algorithm, and combined with the characteristics of ATO system design the speed controller based on optimization algorithm, the target curve to make use of the designed controller to track and simulation validation. The experimental outcomes demonstrate that when the train runs to 90 s, the displacement difference reaches about 40 m, which proves that the fuzzy PC has better displacement tracking, punctual arrival, and higher stopping accuracy.

Keywords: automatic train driving, fuzzy predictive control, computer application

1 Introduction

Computer automatic control technology is widely used in agricultural production, industrial production and daily life and other fields, in the computer automatic control of network technology, to improve the production environment, improve production efficiency to apply logic way of thinking and logic operation management, resolved to make the defects existing in the control technology, improve flexible management in computer automatic control technology, and improve data processing in automatic control [1]. With the continuous improvement of train speed and transportation density, the traditional manual driving mode is difficult to meet the increasingly developing demand of rail transit. Automatic driving can improve the safety and reliability of train operation, improve train transportation efficiency, reduce train energy consumption, transportation cost, and driver labor intensity, etc. [2]. Urban rail transit has a high possibility to realize the level of automatic train driving because of its simple lines, less interference conditions, and advanced onboard and ground system equipment. Therefore, urban rail transit automatic train operation

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(ATO) is more rapid development through earlier study [3]. At present, the subway basically adopts the automatic train driving system with certain intelligent control.

As we know, the automatic train driving system uses different control algorithms, and its control effects are also different, so it is necessary to study the optimal automatic train control (ATC) algorithm to make the train run in the best state [4]. The control strategy of urban rail train in operation is adaptive proportional integral derivative (PID) or conventional PID, so it is of great significance to the simulation research of urban rail train speed controller based on fuzzy predictive control (FPC). Due to the complexity of railway lines and the uneven degree of advanced equipment, the research degree of automatic train driving is far behind that of urban rail transit, but some research achievements have been made. The control of train running on ordinary railway is a very complicated process. The characteristics of trains under different operating conditions are completely different, and the corresponding control strategies and control objectives are also different [5]. Because the mathematical description of train running process is a multiobjective and complex nonlinear system, an accurate mathematical model and an optimal solution are difficult to obtain. To realize the high quality control of ordinary railway train operation, this study adopts the control mode combining fuzzy logic and predictive control (PC) and determines the control indexes, automatic driving strategies, and principles in the process of train operation according to the existing driving experience and expert knowledge. The running process is modeled in real time using a PC approach based on fuzzy strategy, and a reasonable and optimum automatic driving scheme is obtained. Chen et al. offered two strategies for improving the stability of strategic model training while using the least amount of manual data possible. The first method uses a modest amount of manual data to train the characteristic network with parameter initialization using reinforcement learning and imitation learning. In the second technique, auxiliary networks are added to the reinforcement learning framework, allowing it to use real-time measurement data to enhance awareness of the environment without the need for demonstrators' assistance. The end-toend autonomous drive system of image information and information of light detection and ranging is simulated to verify the effectiveness of the two approaches. We built a three-dimensional (3D) world based on the Ranger XP900 platform, the real obstacle 3D model of real models, and inertia characteristics of real motion constraints to ensure that the trained end-to-end autonomous driving model is more suitable for the real world. Experimental results reveal that the virtual game world's performance is improved by 45%, and that it can be promptly and consistently converged in the pavilion, where the earlier method failed [6].

To sum up, this article proposes a research on automatic control of computer application data processing system based on AI and applies fuzzy logic and PC algorithm to train automatic driving system. By studying traction calculation model, train automatic driving theory and train operation model in detail, data processing method of train operation line, operation principle, and operation strategy of train automatic driving optimization are given. The simulation results are very close to the actual results of excellent driver operating the train. It is proved that the FPC technology can ensure the high quality of train operation in the automatic train driving system.

The following is a breakdown of the structure of this research article. Section 2 illustrates the background of ATO system and FPC technique and related studies on ATO control algorithms. Section 3 describes the proposed design of ATO. Section 4 contains the experimental results. Section 5 describes the conclusion.

2 Background

2.1 ATO system

ATO system is a component of the ATC system. The function of ATO is performed with the collaboration of each ATC subsystem. As a result, before introducing ATO, it is vital to first comprehend the composition of ATC. ATC is a collection of automatic equipment of control that may change the interval of train's running

for efficiency reasons and safety. The control system, which includes a control center, a station, ground equipment, and onboard equipment, completes the process control. The system is split into four parts: automatic train monitoring (ATM) system, automatic train protection (ATP) system, and the ATO system. The ATC loop control system aboard the train is composed of the ATM, ATP, and ATO subsystems and the equivalent ground supporting systems. Figure 1 depicts the system control structure. Door control, over speed protection, and speed detection are all features of the ATP system, which is the heart of the ATC system [7]. The ATO system may intelligently replace the driver and efficiently drive the train by allowing the train to smoothly accelerate to the desired speed. It can also automatically change the train's speed and bring the train to a smooth stop at the precise station location. The applicant tracking system (ATS) system can track and direct the train to ensure that it stays on track and the system remains stable. By switching turnouts, the ATS system defines the departure path and supplies monitoring commands that are given through the train arriving control room. Metro trains are becoming more densely packed, and safety standards have become increasingly stringent.



Figure 1: Diagram of system control structure.

As a result, the train must have an ATM system. The train follows the planned schedule in a precise and organized manner. The ATM system can keep track of the train's status and make intelligent scheduling decisions. ATS is normally found in the subway line's biggest stop. The remote control system completes the connection between each station's interlocking equipment and control center. The data delivered from ATS to ATO is sent via the cable to the wayside ATP transmitting device, which is then collected and processed by the onboard ATP equipment before being sent to the onboard ATO equipment. ATO determines the running speed based on the speed of maximum permissible and actual running of ATP after gathering essential data. The quantity of control is acquired, and the command to control is issued. ATO delivers data to ATS via the position train identification subsystem, which sends information to the station's ground loop and then transmits it to ATS to determine the train's position. ATS determines the train's new task based on the train information and then passes the track circuit to the ATO. ATS regulates the train's new mission based on the train's information and then sends it to ATO via track circuit. During the interval operation, ATO achieved a critical track segment and obtains new pavement details for speed adjustments. The automatic driving procedure in the ATO system is a closed-loop feedback method. The ATP takes position and speed information from the ranging device, running task information and speed measurement from the ATS, and positioning detail from the system of positioning, transmits it, and processes it to the ATO with its own information of overspeed protection. Based on this data, the ATO provides the cruising, best control, idling, traction, and braking. Simultaneously, ATO seems to have a two-way communication structure that lets the train to communicate directly with the ATS inside the station via the ground ATO loop and vehicle antenna and transmits train-relevant data to the ATS to determine the train's position, and ATS defines the new running instruction of the train based on data. Figure 2 depicts the basic relationship block diagram [7].



Figure 2: Block diagram of ATO relationship.

2.2 Generalized FPC technique

Fuzzy control technique is driven by human experience and intuition, which means that the operator's comprehension of the controlled system is based on the operator's extensive practical experience and intuitive feeling rather than quantitative expression. This method can be thought of as a collection of experimental guidelines. The control action is inconsistent and subjective because human decision making is intrinsically ambiguous. The operator's control strategy can, however, be articulated in language to develop a set of qualitative decision rules represented in language by monitoring and conversing with the operator in the design of fuzzy control.

This article compiles and formalizes the knowledge and practical experience of specialists in a particular topic. Language is utilized to create a set of qualitatively conditional assertions and imprecise rules of decision, which is subsequently quantified using the fuzzy set. A controller is created that mimics human control strategies by using formal human experience rules. The controller can control complex industrial processes by driving equipment. The following components make up a fuzzy control system: a controlled object, an input/output interface, a fuzzy controller, a detecting device, and an actuator. Fuzzy and PC are two types of current control methods that control an uncertain system and are created independently. Nonlinear system based on the FPC technique is basically an organic blend of PC and fuzzy decision making, which is more in accordance with human control philosophy. People's natural concepts in dealing with complex industrial process control challenges are system prediction and fuzzy reasoning. The rationality of FPC can be explained by the following points. Both strategies are good for controlling an uncertain system, and combining prediction and fuzzy control will boost the control effect even more. The fuzzy control trend is shifting from rule to model. PC is a common model-based control method, and the object model may serve as a communication link between the two. PC is an optimal control strategy that is based on a mathematical model of an object. The precision of the analytic system, however, limits the system's complexity. PC research in a fuzzy environment is critical for expanding the PC application range.

2.3 Literature review on ATO control algorithms

Various types of control algorithms have emerged during the development of ATO. As indicated in Table 1, we give a review of the earlier 47 researches that used control algorithms in ATO settings, extending from 1983 to 2021.

To address the aforementioned issues, a number of researchers have developed several ATC technologies in recent years. Different forms of train-control objectives and models, as well as different types of algorithms, are used in these studies, depending on the applications. Table 1 shows a high-level overview of these investigations. In general, these studies, can be split into two types. To synthesize or portray these experiences, one of these strategies uses empirical knowledge and professional expertise. These methods,

Author	Algorithm	Benefits
Yasunobu et al.,	Rules of linguistical control using fuzzy control	Ensured that train stops are controlled in a
1983 [8]		comfortable and precise manner
Yasunobu and	Predictive fuzzy (PF) control	Improved energy savings, accuracy of station
Miyamoto, 1985 [9]		stopping, and comfort of riding
Sekine et al.,	Neural network fuzzy control (NNFC)	Minimized fuzzy train operation rules of
1995 [10]		Miyamoto's study (1985)
Yang and Sun,	Mixed H_2/H_{∞} controller	Developed speed-tracking technique with high
2001 [11]		accuracy with resistance and coupler forces
Chou and Xia,	Closed-loop cruise controller	Improved energy usage, management of in-train
2007 [12]		force, and accuracy of speed tracking
Meulen, 2008 [13]	Expert knowledge	Get control factics from professional drivers and
7huan and Via	Output regulation foodback measurement	engineers to boost driving performance
	Output regulation reedback measurement	incremented a technique that is accessible due to
2008 [14]		execution
Song et al 2010 [15]	Adaptive position and speed control	Minimized the impact of the train's resistance and
5011g et al., 2010 [15]	Adaptive position and speed control	obtained control of speed tracking and high-
		precision position
Dong et al., 2010 [16]	Fuzzy PID control	Ensured exact parking and smooth comfort during
	· ·····	the operations of train, solved the problem of the
		PID algorithm's such as rapidity and stability not
		being considered at the same time, as well as the
		problem of the fuzzy control algorithm's control
		precision being low
De-Wang et al.,	Intelligent control based on online learning	Resolved the issues of precise parking of trains
2010 [17]	and offline data mining	based on urban trail
Du et al., 2011 [18]	Parameter adaptive (PA) control for braking model	Attained the better accuracy of parking
Ke et al., 2011 [19]	Fuzzy PID control	Minimized energy consumption
Song et al., 2011 [20]	Robust adaptive (RA) control based on optimal	Achieved good robustness with unknown
	distribution	parameters, external disturbances, and resistances
Hou et al., 2011 [21]	Iterative learning (IL) control	Proposed an iterative learning control-based train
		and ansures tracking afficacy and asymptotic
Ren-Shi et al	PA control	Effectively resolve the parking control
2012 [22]		misalignment induced by train brake model
2012 [22]		parameter uncertainty
Dong et al., 2013 [23]	Fuzzy logic control	Enhanced comfort of riding and tracking accuracy
Gao et al., 2013 [24]	RA control based on radial basis function	Emphasized the nonlinearity of actuator saturation
, , , ,	neural network	through unknown parameters in the train models
		with high speed
Heng-Yu and Hong-	PA control	Precisely track the target curve of train braking
Ze, 2013 [25]		structure
Wang et al.,	IL control	Resolved the issues of precise parking of trains
2013 [26]		based on urban trail
Wu et al., 2013 [27]	Multitarget and multiobjective predictive	Achieved the highest accuracy of parking and
	intelligent control	guarantee the parking comfort
Yin et al., 2014 [28]	Reinforcement learning and expert system	Improved energy savings, riding comfort, and
		punctuality by implementing two intelligent
Ealoghi and Islali	PA cruica control	operations of train algorithms
raiegiii and Jalall,	KA LIUISE COIILIOL	Attained disturbance rejection and asymptotic
2014 [27] Song et al 2013 [20]	Back-stenning adaptive control	Obtained highest accuracy of tracking control with
Joing et al., 2013 [30]	Back-stepping adaptive control	hraking failures/traction of time-varving with
		unknown parameters of systems

Table 1: Continued

Author	Algorithm	Benefits
Yang et al., 2014 [31]	PC based on adaptive neuro-fuzzy inference model (ANFIM)	Improved the accuracy of tracking through dynamics modeling of high-speed train utilizing ANFIM
Li et al., 2014 [32]	Robust cruise control based on sampled data	Ensured accuracy of speed tracking with in presence of unknown disturbances and stability of
Yang et al., 2014 [33]	Adaptive and robust control	relative spring displacement Improved existing PID algorithm, allowing trains to follow a perfect target curve, perform interstation procedures, and come to a precise halt
Hui et al., 2015 [34]	Integrated intelligent (II) control using improved multiobjective particle swarm optimization (PSO)	Improved the energy saving, punctuality, safety, and achieved the operation comfortability of electric multiple unit (EMU) tracking
Wang et al., 2015 [35]	II control using multimass operation and nonlinear resistance	Improved the safety constraints, algorithm practicability, and reduced the complexity of computational
Zhong-Qi et al., 2015 [36]	Adaptive neuro-fuzzy control	Resolved the parameters of time-varying characteristics using nonlinear unmolded dynamic componention and linear adaptive models
Yin et al., 2016 [37]	Ensemble classification and regression trees and expert system	Improved energy savings, riding comfort, and punctuality by utilizing data mining technique
Kaviarasan et al., 2016 [38]	Reliable dissipative control	Developed a necessary condition to ensure the stability of probabilistic delays of time-varying
Wang et al.,	Train parking adaptive parameter control	Obtained highest speed-tracking precision, good
2016 [39]	based on sliding mode	adaptability, better robustness, and minimize the effect of parking under the principle of rare switching input
Yang et al., 2016 [40]	PF control based on neural network	Achieved the precise control on speed tracking of high-speed EMU train
Sheng-Ping, 2017 [41]	PID control based on fuzzy and neural network	Improved the accuracy of ATC
Yang-Dong et al., 2017 [42]	Optimal predictive tracking control	Ensured the comfort of train operation by applying appropriate control amounts in advance to achieve exact parking and accurate speed monitoring
Kai et al., 2017 [43]	II control based on hybrid improved cuckoo search and PSO	Optimized the train's running curve to come up with the best choice method for controlling the
Xiao-Na et al., 2018 [44]	Gray PF PID control	Obtained better effect of ATO control and resolve the nonlinear issues and large lag of the running train procedure
Wang et al., 2018 [45]	Robust PF control	Reduced the delays induced by uncertain disturbance and ensured that the practical train timetable follows the nominal one for a certain level of disturbance attenuation
Cao et al., 2019 [46]	PF control	Improved the performance of other indicators, accuracy of parking, comfort, and train safety
Felez et al., 2019 [47]	PC using virtual coupling	Minimized train distance and headway while ensuring safe separation between two successive trains at all times
Gao et al., 2019 [48]	Nonlinear gain control based on feedback	Ensured the satisfactory performance of tracking
Zhang et al.,	PC, traffic control, and nonlinear optimal	Reduced headway deviations and timetable for
2019 [49]	control	metro lines and improved the energy-saving efficiency
Wang et al., 2020 [50]	PC with event-triggered method	Improved the comfort of riding, operation efficiency, and ensured the train schedule

(Continued)

Table 1: Co	ntinued
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Author	Algorithm	Benefits
Wang et al., 2020 [51]	PC based on fusion velocity and softness factor	Improved the precision of tracking, ensured that the procedure is basic and straightforward, and guaranteed that computational activities are completed in real time
Moaveni et al., 2020 [52]	Fuzzy supervisory PC	Calculated the velocity of train's longitudinal and the coefficient of adhesion between rail surface and wheels
Chu et al., 2020 [53]	Fuzzy immune PID control based on nondominated sorting genetic algorithm-II- parameter and fuzzy gray immune PID control based on gray technique	Obtained better performance on the level of comfort and traceability indicators
Xiao et al., 2021 [54]	Level-wise driving fuzzy rule-based knowledge induction control	Improved the accuracy of energy consumption reduction

which are referred to as intelligent and II control methods in this study, are mostly based on expert systems, data mining, or fuzzy logic algorithms to improve numerous objectives for ATO. Meanwhile, the second class of methods, referred to as PA control methods in the following discussion, uses train model information to develop an efficient speed controller to ensure trajectory tracking accuracy. In conclusion, fuzzy control shows a high level of flexibility to parameter changes, although the partition of linguistic terms and membership functions shape in control are highly dependent on expert expertise and difficult to update online. In the realm of simulation experts, the expert system is an issue. Manual transplantation is used to acquire knowledge. It is limited to solving professional difficulties in a specific field and has poor reasoning abilities. Neural network control is a nonlinear adaptive dynamic system in which neurons are interconnected. The benefit is that the challenge can be handled parallel in large scale, and the personalized learning is great; however, the process of reasoning cannot be described, and the speed of network convergence must be increased. The II algorithm avoids the flaws of the intelligent algorithms while maintaining their respective benefits, resulting in improved results [54].

The railway sciences of China academy have integrated the fuzzy logic, artificial intelligence (AI), and knowledge engineering technologies with the ATO system to achieved some results. Yet, the applications on the ATC system are not providing good performance. Therefore, in this study, the algorithm based on fuzzy and PC is integrated and used on the ATO.

3 ATC design

In this section, the design of the ATC is explained as follows:

3.1 Train dynamics model and its control objectives

3.1.1 Train dynamics model

The train operates like a snake, relying on the sticky traction of locomotives on tracks with curves and ramps. The train is treated as a particle, and its motion equation is demonstrated as follows:

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$$\frac{dv}{dt} = \frac{g}{10^{3}(1+\gamma)}c$$

$$\frac{ds}{dt} = v$$

$$J = \int_{0}^{T} p(t)dt$$
(1)

where v – the train speed, m; t – time, m/s; s – distance, s; g – acceleration of gravity; y – mass coefficient of rotation, generally 0.6; J – train energy consumption; kW/h; p(t) – energy consumption per unit time of the train, kW; c – unit resultant force on the train, n/kN; and t – train running time. Equation (1) takes time as an independent variable. To be more suitable for fuzzy PC, distance is taken as a variable in actual operation, so the equation of motion is changed into a function with distance as an independent variable, as shown in equation (2):

$$\frac{dv}{ds} = \frac{g}{10^{3}(1+\gamma)} \frac{c}{v} \\
\frac{ds}{dt} = \frac{1}{v} \\
J = \int_{0}^{s} \frac{p(s)}{v} ds$$
(2)

The resultant force of the train is mainly divided into three parts: train output force, basic resistance, and additional resistance, as shown in equation (3):

$$c = f(v) - w_0(v) - g(s), \tag{3}$$

where f(v) – unit traction or braking force on the train; g(s) – additional ramp resistance of the train, consisting of converted slopes of ramps, curves, tunnels, etc.; and $w_0(v)$ – basic unit running resistance of the train, and its value is shown in equation (4):

$$w_0(v) = A + Bv + Cv^2,$$
 (4)

where A – operating resistance coefficient; B – rolling resistance coefficient; and C – air resistance coefficient. In the process of train operation, the operating conditions at different stages are different, and the resultant force on the train is also different, as shown in equation (5):

$$f(v) = \begin{cases} q(v), \text{ Traction condition,} \\ 0, \text{ Inert working conditions,} \\ b_d(v), \text{ Power brake condition,} \\ b_e(v), \text{ Emergency braking condition,} \\ b_s(v), \text{ Common brake conditions,} \end{cases}$$
(5)

where q(v) – unit traction force of the train; $b_s(v)$ – air brake unit force; $b_e(v)$ – maximum unit force of air braking; and $b_d(v)$ – dynamic braking unit force, $b_s(v)$ and $b_e(v)$ of which are determined by the train traction and braking characteristic curves. In simplified equations (2)–(5), the general form of the train motion equation is shown in equation (6):

$$v\frac{dv}{ds} = F(v,s) = \zeta(f(v) - w_0(v) - g(s)).$$
(6)

As the train is long, it is simplified to a train with each carriage as the particle and no relative movement between particles. Then the additional ramp resistance is shown in equation (7):

$$g(s) = \sum_{i=1}^{N} g_i(s),$$
 (7)

where N – total number of train cars and $g_i(s)$ – additional drag per car. To sum up, the kinematics equation of the train can be expressed as equation (8):

$$v\frac{dv}{ds} = F(v, s) = \zeta \left(f(v) - w_0(v) - \sum_{i=1}^N g_i(s) \right).$$
(8)

3.2 ATO system structure and function

The main purpose of automatic train speed control is to regulate the train's braking/traction system in accordance with the ATP's goal speed. According to the system's state transition sequence, first, the ATO determines the current state of operational. Automatic speed regulation is a negative feedback closed-loop method for acceleration control and speed. The braking/traction command is output by ATO to assess the train's braking/traction condition, and the output current defines the magnitude of the traction/braking. The comfort, energy saving, efficiency, and punctuality of the entire system are all influenced by the execution of the ATO algorithm. The main concept behind the ATO FPC is as follows: First, the predictive model is used to obtain the future system's prediction output. Second, the fuzzy controller takes the prediction output value and variation rate of the prediction error between the set output value and prediction error as input. To obtain control output, the controller uses fuzzy rule logic. Further, model self-tuning, fuzzy control, and model prediction are the three fundamental components of an FPC system [55].

ATO system features include automatic driving mode, train speed control, train target braking, door control, and energy-saving speed curve generation based on schedule. In autopilot mode, the ATO system completely simulates an experienced driver controlling the train from one station to the next. For train speed control, the ATO system controls and supervises the train to operate at speeds below the maximum allowable speed provided by ATP. The function of train target braking is to calculate the initial position of train braking in advance to make the train stop at the specified target position. The train door opening and closing control refers to the operation of the driver opening or closing the door after the ATO system receives the allowed opening or closing order after the train arrives and stops steadily, or automatically triggers the completion of the stop time [56]. The function of generating energy-saving speed curve according to schedule is also optional. If the train running between two stations has sufficient travel time, this function can be selected, so that the train can obtain a more economical speed to run at a uniform speed, thus saving energy.

3.3 Generation of train operation target curve

The function of the speed controller is to ensure that the train can follow the target curve well. When the target curve supplied by the speed controller is poor, no matter how good the performance of the designed speed controller is, the ATO system cannot achieve good performance. The advantages and disadvantages of ATO system, such as safety punctuality, comfort and energy saving, and accurate parking, are reflected in the target curve. This requires that the target curve to be tracked by the speed controller is an optimized curve, and only in this way can the actual running curve of the train be better. In this article, part of the data of eight marshaled CRH3 EMUs put into operation by a certain rail Bus Co, Ltd. are used as train model parameters, as shown in Table 2.

In this study, the running speed of the train in and out of the station is set as 120 km/h, the platform distance is set as 1,500 m, and the maximum running speed under the interval speed limit should be slightly lower than the speed limit given by the ATP system. In this study, 305 km/h is taken, and the target speed of the train is 300 km/h. When the train target speed is 300 km/h, there is no ramp over 13.06% on the secondary line, so the maximum speed of the train during cruise operation is 305 km/h, and the minimum speed is 295 km/h. When the target speed of a train running on a straight line is 120 km/h, the maximum speed is 125 km/h, and the minimum speed is 115 km/h. After leaving the station, the train adopts the appropriate traction gear (the traction force does not exceed the adhesive traction force and can accelerate

Table 2: Main parameters and characteristics of CRH3 EMU

The project name	CRH3 EMU	
Total train weight (t)	536 (seating capacity 601 persons)	
Maximum operating speed (km/h)	350	
Marshaling length (m)	200	
Traction characteristics (kN)	$F = -0.285 v + 300 (0 < v \le 119 \text{ km/h})$	
Weekly power 8,000 kW	<i>F</i> = 31,500/ <i>v</i> (<i>v</i> > 119 km/h)	
Coefficient of mass of rotation	0.08	
Wheel diameter new/old (mm)	920/830	
Braking characteristics (M/S2)	$1 (0 < v \le 160 \text{ km/h})$	
(Grade 8 common brake)	-0.0136 <i>v</i> + 3.176 (160 < <i>v</i> ≤ 160 km/h)	
Braking characteristics (M/S2)	$0.86 \ (0 < v \le 160 \ km/h)$	
(Grade 7 common brake)	−0.0095 <i>ν</i> + 1.1788 (182 < <i>ν</i> ≤ 210 km/h)	

the train with the maximum acceleration as soon as possible while considering the comfort) to accelerate the speed up to 300 km/h; before arriving at the station, the train takes 120 km/h as its initial speed and calculates it with the reverse iteration algorithm (the iteration step is 0.1 s). The target speed (i.e., the initial braking speed) of the train needs to make a speedy trial and match with the terminal speed in cruising operation within the speed range of 295–305 km/h at the end of iteration. When the difference between the two final speeds is less than a given value, the speed is the target speed, and its corresponding position is the initial position of braking. When the train runs to the starting position of the breaking point, it uses the appropriate braking gear to slow down the train. The braking distance, including the blank walking braking distance, is 1.5 s. The calculation method of the starting position point of train braking stop is the same as that of deceleration braking. The initial speed only needs to be 0 km/h, so the basic resistance of train needs to be converted into the corresponding deceleration. The target curve of train operation can be obtained from the above train model parameters, line parameters, and software flow chart, as shown in Figure 3.



Figure 3: Running curve on the line.

3.4 Fuzzy generalized PC

Fuzzy generalized prediction (FGPC) algorithm is a new algorithm, which combines fuzzy logic with PC. It compensates the error of generalized prediction (GPC) by fuzzy reasoning. A basic model is established

offline using priori information to describe the main dynamics of the prediction process. To make up for the deficiency of GPC algorithm in system information processing, the error between the actual measured and predicted information is regarded as the information of uncertainty, and the possible error in the process of PC is compensated appropriately at the high level.

Based on GPC algorithm, FGPC algorithm directly compensates system deviation according to fuzzy reasoning. In this way, the integrated control quantity acting on the controlled object is shown in equation (9):

$$u(t) = u_1(t) + u_2(t),$$
(9)

where $u_1(t)$ is the generalized PC quantity, and $u_2(t)$ is the control quantity for compensating system error by fuzzy reasoning. In this algorithm, the basic rule of the system is reflected by GPC control, and the output deviation caused by other interference factors or model mismatch is compensated by fuzzy reasoning. Suppose e(t) is the process output deviation at t sampling time, ec(t) is the rate of deviation change, and the process has d step pure delay, and then the fuzzy compensation control quantity is determined by e(t + d) and ec(t + d). Define e(t + d) and ec(t + d) as equations (10) and (11):

$$e(t+d) = r(t+d) - y(t+d),$$
(10)

$$ec(t + d) = e(t + d) - e(t + d - 1).$$
 (11)

First, fuzzy control compensation comes from process output deviation and deviation variation. Second, the process input control quantity is the sum of generalized PC quantity and fuzzy control compensation quantity. Finally, to achieve a better control effect, process input control quantity is used to control the whole system. It should be emphasized that because the optimization goal of GPC algorithm is over time, fuzzy reasoning compensation function needs to be updated online repeatedly rather than offline once [57]. Due to the use of fuzzy reasoning compensation method, it does not only retains the excellent performance of GPC algorithm but also compensates for many shortcomings of GPC algorithm such as random factors that cannot be estimated and the inaccuracy caused by the length of prediction domain is too short. The static accuracy and dynamic tracking performance of the controlled system are improved [58]. Moreover, FGPC can improve the robustness of the controlled system in the presence of strong external disturbances or time-varying parameters [59].



Figure 4: Tracking curve and ideal target curve based on PID control.



Figure 5: Speed tracking curve and ideal target curve based on FPC.

4 Result analysis

The generation of ideal target curve is calculated according to the line situation and train model. In this article, a subway B-type car is selected to calculate the acceleration, time, and displacement of each speed interval.

4.1 Tracking curve and ideal target curve

Figures 4 and 5 show that the tracking curve of PID control has more fluctuations, and its steady-state error is also large, whereas the tracking curve of FPC basically coincides with the target curve, indicating that FPC has a more stable and excellent train control.

4.2 Acceleration simulation curve

According to Figure 6, the acceleration fluctuation based on PID control is highly common and has a wide range, resulting in train instability and reduced passenger comfort. Based on the FPC algorithm, the speed fluctuation caused by line problems can be solved in a short time and the train runs more smoothly.

4.3 Target displacement curve and displacement simulation curve

Figure 7 shows that there are many displacement differences between PID control's displacement tracking curve and ideal target curve. For example, when the train runs to 90 s, the displacement difference reaches about 40 m, indicating that FPC has a better displacement tracking performance, punctuality of train arrival, and higher stopping accuracy.



Figure 6: Ideal target curve and displacement tracking curve based on PID control.



Figure 7: Ideal target curve and displacement tracking curve based on FPC.

5 Conclusion

The simulation formulation of train's operation, the concept of ATO, the operation strategy, and FPC algorithm application in train automatic driving are all investigated in depth in this study. The goal is to create an FPC that can control the train speed. After comparing the system to classical PID control, the system simulation is used to verify the controller's robustness and adaptability. The controller is capable of meeting the basic requirements of train operation while also making significant measures for the real line's application of the fuzzy prediction concept. The development status and functioning system of ATO are thoroughly understood due to practical research and extensive theoretical. The evolution of the ATO control algorithm is described and examined, as well as the benefits and drawbacks of other control algorithms.

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The use of FPC in ATO is proposed, as well as use of an II control techniques in ATO is considered. Further, predictive and fuzzy control essential principles are also investigated. The dynamic matrix and fuzzy control are coupled to overcome ineffective anti-interference effectiveness issue in the optimization of receding horizon procedure produced through extended sampling cycle and excessive computation. The fuzzy controller achieves the best PC calculation. For a sophisticated train autonomous operation system, an FPC is utilized to manage train speed to ensure accurate parking, comfort, timeliness, and energy savings. This study proposes a research on automatic control of computer application data processing system based on AI design and ATO system based on FPC is designed. The fuzzy control approach can achieve a high-level regulation and has a superior train speed controller's control function based on changing error rate and prediction error. The simulation's relevant flow chart is achieved. The simulation results are compared to the methods of PID control that has been used in the past. The findings of the simulation suggest that the FPC has a superior control effect and can increase train safety. The FPC significantly increases passenger comfort and precision of train stopping, offering a favorable on a trial basis for its implementation. The simulation results reached the expected goals and proved that the FPC can realize high quality control, the train operation process is presented in this article using the AI, computer data processing system for the automatic control method is reasonable.

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