RESEARCH ON PORT AGV TRAJECTORY TRACKING CONTROL BASED ON IMPROVED FUZZY SLIDING MODE CONTROL

Qiu JIANDONG[1], Tang MINAN[2], Yu FAN[3], Ran JIAJIA[4], Lin DINGQIANG[5]

[1,3,4,5] *School of Mechanical and Engineering, Lanzhou Jiaotong University, Lanzhou, China*

[2] *School of Automation and Electrical Engineering, Lanzhou Jiaotong University, Lanzhou, China*

Abstract:

The operating environment of the port AGV is outdoors in the coastal area. There are complex and changeable environmental impacts such as rainfall, wind erosion, and salt erosion, which cause more disturbances to the port AGV. Aiming at the problem of the influence of environmental disturbance on trajectory tracking accuracy during the operation of port AGV, this paper proposes a control method based on fuzzy control theory and sliding mode variable structure control theory. Firstly, a two-degree-of-freedom dynamic model of AGV in port environment is established on the premise of accurately describing the dynamic characteristics of the vehicle and reducing the requirements for hardware and software. Secondly, for the tire model, the tire model formula constructed by the magic formula proposed by Pacejka with high fitting accuracy and simple modeling is used to establish the tire model. Thirdly, aiming at the chattering problem in sliding mode control, sliding mode variable structure control is designed, and fuzzy controller is added to control the change of switching gain coefficient. Finally, for the actual operating environment of the port, the Gaussian disturbance is used to simulate the external disturbance, and the controller model designed in various ways is built and simulated by Matlab / Simulink software. The experimental results show that the proposed algorithm is superior to the control group in response speed, anti-interference ability and reducing chattering. Compared with the traditional control method, the steady-state time of the position tracking method is increased by 73.41 %, and the error generated in the disturbance stage is 1.8 % of the initial error. The speed tracking enters the Gaussian disturbance stage after the steady state, and the error is less than 1 % of the initial error, which achieves the purpose of reducing chattering, realizes the optimization of the traditional sliding mode variable structure control, and verifies the feasibility of the algorithm in the future practical application.

Keywords: port AGV, dynamics, magic tire formulation, sliding mode control, fuzzy control

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Contact:
1) 379507225@qq.com [https://orcid.org/0000-0001-9972-898X]; 2) tangminan@mail.lzjtu.cn [https://orcid.org/0000-0003-1424-2708]—corresponding author; 3) 1286113952@qq.com [https://orcid.org/0000-0002-7834-7755]; 4) 1782285671@qq.com [https://orcid.org/0000-0001-9674-4079]; 5) 2252809520@qq.com [https://orcid.org/0000-0002-3232-9519];

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1. Introduction

With the rapid development of information technology and the arrival of the industrial 4.0 era, the port industry is also constantly transforming and upgrading. Traditional manual operations have been unable to meet the growing logistics needs of modern ports, and automated container ports have become the future development trend (Hui ,2023). In this process, AGV is increasingly widely used because of its advantages of high automation, large load capacity and stable control.

The main problems of port AGV compared to ordinary AGV: due to their own large load capacity, they need to overcome a large obstruction response control when driving; the larger body size leads to poorer operating accuracy; the operating environment is outdoors in coastal areas, with more rainfall, wind erosion, salt erosion and other complex and variable environmental influences, which cause more disturbances to the port AGV (You et al.,2022).

In this paper, with the main purpose of improving AGV path tracking control effect, the Improved Fuzzy Sliding Mode Control (IFSMC) is proposed by studying the control method of sliding mode control theory on the trajectory tracking problem. For the chattering problem in the traditional sliding mode process, the fuzzy control idea is used to establish the fuzzy controller with the change of switching gain coefficient to ensure the response speed and anti-interference capability of the whole control system. In the experimental simulation stage, Fuzzy Sliding Mode Control (FSMC) with constant switching gain and Global Sliding Mode Control (GSMC) are selected as the control group, and the three controller designs are used to compare the position deviation and velocity deviation of the research object. The comparison of the simulation results and the addition of external disturbances to simulate the external disturbances during the real operation, as well as the comparison of the output of the controller, with the experimental comparison of FSMC and GSMC, confirms the superiority of the proposed IFSMC. The paper consists of five main parts:

– Literature review -this section describes an overview of the current research status on the research problem by researchers worldwide, including a listing of control methods and improvement strategies for various traditional

approaches, with a particular focus on providing detailed explanations of the algorithmic source methods employed in text analysis.

– Port AGV dynamics modeling – this section describes the specific building methods and steps of port AGV model and tire model

– Fuzzy sliding mode controller design based on switching gain – this section describes the implementation steps and improvement strategies for the proposed algorithm.

– Simulation results−this section describes the process of constructing the Simulink model for the validation phase and the simulation results under different initial conditions.

– Conclusion−this section describes the research findings and highlights the current limitations in the study.

2. Literature review

Scholars at home and abroad have conducted a lot of research and proposed a variety of effective control methods. Among the existing researches, control algorithms such as model predictive control (Manikandan et al.,2019), PID control (Moshayedi et al.,2022), robust control (Chen et al.,2022), sliding mode control and the combination control methods of the above algorithms are widely used in the design of AGV path following controller, whose main purpose is to overcome the disturbance of AGV during operation, improve the trajectory tracking control accuracy more precisely, and increase the reliability, safety and accuracy of trajectory tracking.

A deep learning-based nonlinear model predictive control (NMPC) method is proposed to improve the path tracking performance of a robot for factors such as light changes and obstacles in outdoor environments. This is implemented by using a convolutional neural network (CNN) to learn the visual features of the robot, and then combining these features with the NMPC controller to achieve control of the robot path tracking. In addition to improve the robustness of the controller, the NMPC method based on robust control is introduced to handle uncertainties and perturbations in the environment (Ostafew et al.,2022). Liu et al.(2019) proposes an approach that utilizes worst-case scenario scenarios, and employs optimal control strategies to design the obstacle avoidance algorithm in response to the challenge of improving the robustness of model predictive control (MPC)-based obstacle avoidance algorithms in the presence

of parametric uncertainty. The objective is to ensure that the system can safely avoid obstacles even in the worst-case scenarios, thereby achieving a more reliable obstacle avoidance performance in the presence of parameter uncertainty. Weng et al.(2021) proposes a control method based on state classification model and smooth transition strategy. Firstly, the motion model of AGV is established and the state classification model is used to describe the motion characteristics under different working conditions, and then the controller is designed by MPC. In order to solve the problem of tracking performance differences under different working conditions, a smooth transition strategy is proposed to achieve smooth switching of the controller and optimize the tracking performance. Wang et al.(2021) designs a path tracking controller with compound nonlinear feedback control and a speed controller with PID control. Finally, the path tracking and speed control are realized by combining their output quantities.

Among the control methods, sliding mode control is a common method. The sliding mode motion of the system is independent of the parameter changes of the control object and the external disturbances of the system, so the robustness of the control system of the sliding mode variable structure is stronger than that of the general conventional continuous system. The discontinuous switching characteristics in the nature of the sliding-mode variational structure will cause chattering in the system (Liu ,2019). For the anti-chattering problem, many scholars have proposed solutions from different perspectives. Wang.(2020) uses an adaptive sliding mode robust control algorithm and adaptive adjustment of the control switch gain for the chattering problem in the sliding mode process. Wu et al.(2019) uses a non-singular terminal sliding mode control method to control AGV and adopts active interference suppression control to reduce the chattering caused by external disturbances. Hung et al.(2010) proposes a sliding mode controller for autonomous guided vehicles, considering the vehicle's dynamics characteristics and the requirements for robustness and stability of the controller. This design allows the autonomous guided vehicles to better achieve the desired trajectory tracking and dynamic attitude control. In the case of control problems for autonomous ground vehicles. Yin et al.(2019) adopts the adaptive sliding mode control trajectory tracking method, and adopts robustness gain and fuzzy logic to improve the

robustness of the controller and reduce the occurrence of chattering. Taghavifar et al.(2023) proposes a combined approach of adaptive robust control and terminal sliding mode control, aiming to maintain stable control of the vehicles in the presence of uncertainties and disturbances. Soysal (2014) adopts a tracking control method based on continuous modal sliding mode control to achieve the trajectory tracking and stability control of the vehicle, and adopts a continuous switching function in the sliding surface neighborhood to eliminate the chattering problem, so as to further improve the control accuracy and stability of the vehicle.

3. Port AGV dynamics modeling
3.1. AGV two-degree-of-freedom monorail model

First of all, the model of the port AGV needs to be built, and the accuracy of the model is directly related to whether it can reflect the actual operation of the port AGV (Zhang and Liu,2020). In order to reduce the complexity of the calculation, it is assumed that the running surface of the port AGV is a flat surface, i.e., there is no suspension motion of the object of study, and there is no vertical motion of the vehicle, and the load deflection of the vehicle under heavy load is not considered (Song et al.,2004). Before establishing the dynamics model of the research object, the coordinate system should be established. Define the vehicle coordinate system as $oxyz$, and the center of mass of AGV is located at the origin of the coordinate system, x axis is in the same direction as the longitudinal motion of AGV and the forward direction is the positive direction,y axis is to the left of the forward direction of AGV as the positive direction, z axis is perpendicular to the running road and upward as the positive direction. The monorail vehicle model of AGV is shown in Fig. 1, where m is the mass of the vehicle; u is the velocity component of the vehicle V in theox axis;v is the velocity component of the vehicle V in the oy axis; r is the vehicle l_f and l_r are the distances from the center of front and rear axles to the center of mass respectively; δ_f is the angle of rotation of front wheels; F_{yf} and F_{yr} are the lateral forces on front and rear tires; I_{zz} is the rotational inertia through the center of mass of the body about z axis. The dynamics model is shown in Fig. 1.

The following relationship is obtained from the analysis of Fig. 1:

$$\begin{cases} \beta = tan^{-1}\left(\frac{v}{u}\right) \\ V = \sqrt{u^2 + v^2} \\ \beta = \frac{1}{V^2}(\dot{v}u - \dot{u}v) \end{cases} \quad (1)$$

The force analysis of AGV, according to its force balance and moment balance to obtain the following relationship equation:

$$\begin{cases} m(\dot{u} - vr) = -2F_{yf}\sin\delta_f \\ m(\dot{v} + ur) = 2F_{yf}\cos\delta_f + 2F_{yr} \\ I_{zz}\dot{r} = 2l_fF_{yf}\cos\delta_f - 2l_rF_{yr} \end{cases} \quad (2)$$

Combining the above equations yields the following relationship equation:

$$\dot{\beta} = -r + 2\frac{F_{yf}}{mV}\cos(\beta - \delta) + 2\frac{F_{yr}}{mV}\cos\beta$$
$$\pi \qquad \qquad \qquad \qquad \qquad \qquad \qquad (3)$$
$$\dot{r} = 2\frac{l_f}{I_{zz}}F_{yf}\cos\delta - 2\frac{l_r}{I_{zz}}F_{yr}$$

The AGV two-degree-of-freedom model is established by Equation (3), and the input parameters of the tire model are center-of-mass lateral eccentricity β , transverse pendulum angular velocity r, steering wheel angle θ, front wheel lateral force F_{yf}, rear wheel lateral force F_{yr}, and vehicle speed V. The first-order differentiation of the lateral deflection angle of the center of mass β and the angular velocity of the transverse pendulum r are used as output variables to build the Simulink model as shown in Fig. 2.
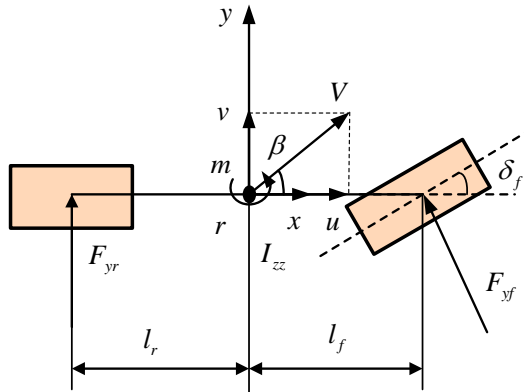

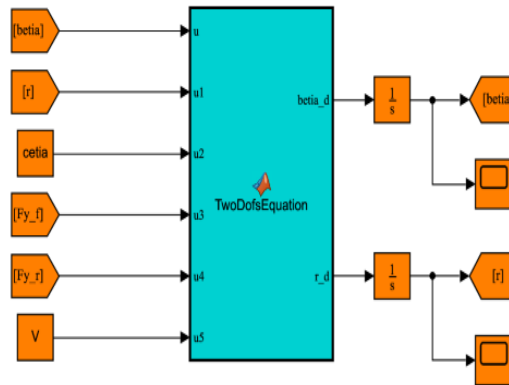Fig. 1. Two-degree-of-freedom dynamics model

Fig. 2. Simulink simulation model of port AGV

3.2. Tire model based on magic formula

During the operation of an AGV, the forces on the tires are critical to its maneuvering stability and safety. Due to the complex structure and nonlinear dynamics of tires, the selection of a suitable and easy-to-use tire model is the key to establish a vehicle dynamics model (Li et al.,2020). In this paper, a semi-empirical tire model based on the Magie Formula (MF) proposed by Pacejka is used (Zhou et al.,2019). The general expression of the magic formula is:

$$Y(x) = D \sin\{C \arctan[Bx - E(Bx - \arctan(Bx))]\} \quad (4)$$

The coefficients B are the stiffness factor, C is the shape factor, D is the peak factor, E is the curvature factor, which is determined by the vertical load and camber of the tire; $Y(x)$ is the output variable; x is the input variable, which indicates the lateral deflection angle or longitudinal slip rate of the tire in different cases, respectively. In this paper, the lateral force of the tire, i.e., the front wheel lateral force F_{yf} and the rear wheel lateral force F_{yr}, are used as output variables, and the lateral deflection angle of the center of mass β, the angular velocity of the transverse sway r, the steering wheel rotation angle θ, and the vehicle speed V are used as input variables. The Simulink model is shown in Fig. 3.

4. Fuzzy sliding mode controller design based on switching gain

Port AGV actual operation process with time-varying and nonlinear characteristics, for the establishment of complex coupled mathematical model of the problem, the traditional control research in the study of most of the simplified model, the study of the linearization of the object, to facilitate the simplification of the computing process, highlighting the improvement effect (Yang et al.,2020). In the controller design, in order to be closer to the actual, more intelligent algorithms are used for processing, which include expert control, fuzzy control (Shao et al.,2022), sliding mode control, neural network control (Xu et al.,2019), etc., which have better adaptability and optimization ability for nonlinear and complex research objects.

4.1. Design of fuzzy sliding mode controller

The fuzzy sliding-mode control system, with the sliding-mode controller as the main core, first considers nth-order nonlinear systems:

$$x^{(n)} = f(x,t) + g(x,t)u + E(t) \quad (5)$$

Where $x \in R^n$ is the state vector, $x = [r, v_r, k]^T$, where r is the position reference trajectory, v_r is the velocity reference trajectory, and k is the switching gain factor. u are the system inputs. $f(x,t)$ and $g(x,t)$ denote the influence of nonlinear factors inside the system and the system input u on the system state change, respectively, both are unknown functions, so the fuzzy idea is used to replace $f(x,t)$ and $g(x,t)$ in the above equation with $\hat{f}(x,t)$ and $\hat{g}(x,t)$. E(t) denotes the influence of external perturbations on the system state. The final replacement of the above equation is as follows

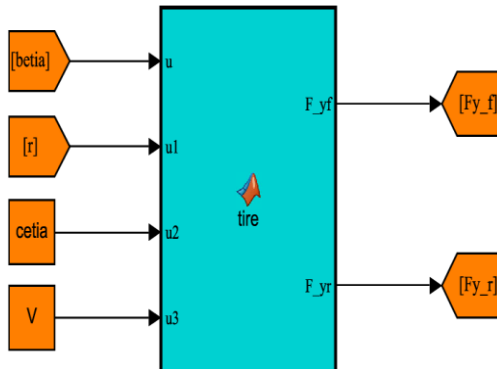$$x^{(n)} = \hat{f}(x,t) + \hat{g}(x,t)u + E(t) \quad (6)$$

Fig. 3. Simulink simulation model of magic tire

Also, define the system tracking error and the sliding mode function, i.e., the slip film surface, as follows:

$$e = x_d - x \tag{7}$$

$$s(x,t) = \dot{e} + ce \tag{8}$$

Also by using Lyapunov function to determine the stability of the system (Chih et al.,2017;Hiraoka et al.,2009),the function is:

$$V = \frac{1}{2}s^2 \tag{9}$$

Rule:

$$\dot{V} = s\dot{s} = s(\ddot{e} + c\dot{e}) = s(\ddot{\theta}_d - \ddot{\theta} + c\dot{e})$$
$$= s(\ddot{\theta}_d - f(\theta) - bu - E(t) + c\dot{e}) \tag{10}$$

Also substituting the control law in sliding mode control yields

$$\dot{V} = s(-K(t)sgn(s) - E(t)) = -K(t) \mid s$$
$$\mid -E(t)s \leqslant -\eta \mid s \mid \tag{11}$$

Since the external disturbance $E(t)$ to which the system is subjected is time-varying, while the switching gain $K(t)$ is needed to compensate for the uncertainty term $E(t)$ and also to reduce the chattering condition, it is also necessary to vary in real time (Guo et al.,2021). Therefore, this paper adopts fuzzy rules to achieve the variation of $K(t)$ empirically. The system structure diagram of its fuzzy sliding mode control is shown in Fig. 4.

4.2. Selection of switching gain coefficients

For the chattering problem of traditional sliding mode control, fuzzy rules are used to effectively estimate the switching gain according to the sliding mode arrival condition and use the switching gain to eliminate the disturbance term, thus weakening its chattering problem to a certain extent.

According to the law summarized by previous research, the language control rules of the controller are as follows: when $s\dot{s} > 0$, i.e., the system state changes faster, it is necessary to use a larger switching gain coefficient to quickly respond to the system state change. Conversely, when $s\dot{s} < 0$, i.e., the system state changes slowly, a smaller switching gain coefficient can better maintain the stability of the

system. The above linguistic rules are converted into fuzzy control rules, and the control rules are as follows: when $s\dot{s} > 0$, $K(t)$ increases; conversely, when $s\dot{s} < 0$, $K(t)$ decreases.

The relevant parameters are classified according to two kinds of large and small, while using the idea of symmetry, the set of fuzzy variables is divided into five grades of negative large (NB), negative small (NS), zero value (ZO), positive small (PS) and positive large (PB) (Liu and Duan,2019). With $s\dot{s}$ as the input variable and the change in switching gain $\Delta K(t)$ as the output, the language variables in this paper are set to 5 levels to reduce the amount of calculation while ensuring a finer control performance (Yang and Zhu,2008). The fuzzy set of its system input/output is defined as follows:

$$\begin{cases} s\dot{s} = \{NB \quad NM \quad ZO \quad PM \quad PB\} \\ \Delta K(t) = \{NB \quad NM \quad ZO \quad PM \quad PB\} \end{cases} \tag{12}$$

The design schematic of its fuzzy control is shown in Fig. 5.

Both the triangular affiliation function and the affiliation function of Gaussian distribution are used to represent the affiliation of fuzzy sets, and the expressions are as follows

$$A_1(x) = \begin{cases} 0 & x \leq a \\ \dfrac{x-a}{x-b} & a < x \leq b \\ \dfrac{c-x}{c-b} & b < x \leq c \\ 0 & x > c \end{cases} \tag{13}$$

$$A_2(x) = e^{-\frac{(x-c)^2}{2\sigma^2}} \tag{14}$$

A plot of the affiliation function for the inputs and outputs is shown in Fig. 6.

Fuzzy rules are usually determined in two ways, one is the Mamdani fuzzy model (Yang et al.,2022) and the other is the Takagi-Sugeno fuzzy model (Lee et al.,2022). In this paper, the Mamdani fuzzy model is used for the establishment of fuzzy rules, and its fuzzy rule table is as follows (Table 1).

Table 1. Fuzzy rule table

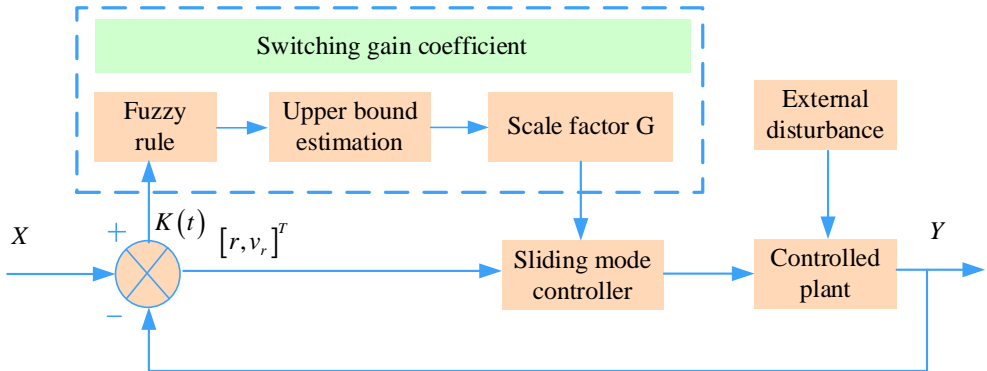|	$s\dot{s}$				
	PB	**PM**	**ZO**	**NM**	**NB**
$\Delta K(t)$	PB	PM	ZO	NM	NB

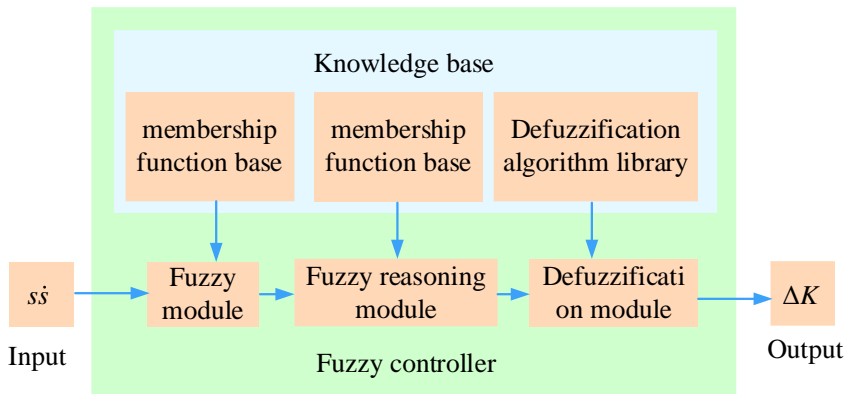Fig. 4. Control system structure diagram

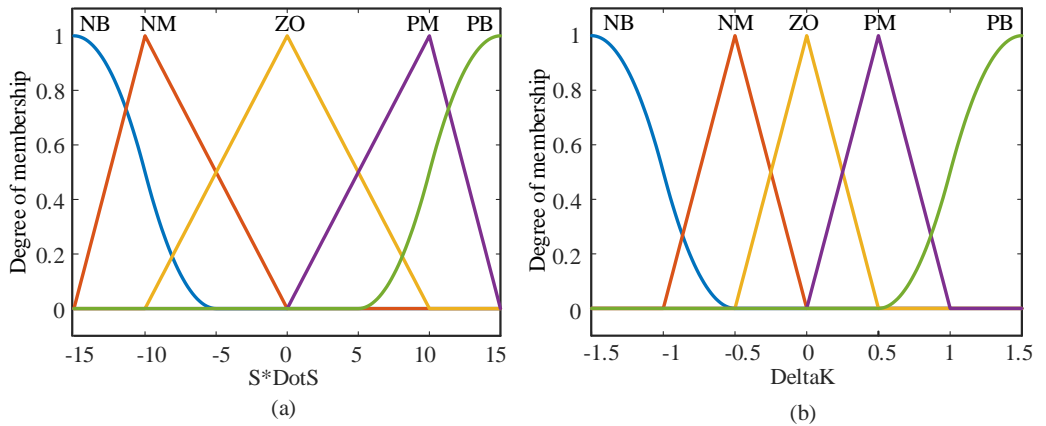Fig. 5. Fuzzy control schematic

Fig. 6. Fuzzy input/output affiliation function: (a) Input (b) Output

At the same time, to ensure the stability and robustness of the system, the upper bound of the switching gain is estimated to optimize the action range of the switching gain to ensure that the system can maintain stability and performance under different operating conditions. The specific implementation of the upper bound estimation is shown below:

$$\widehat{K}(t) = K_u \int_0^t \Delta K dt \qquad (15)$$

Where, $\widehat{K}(t)$ is the estimation of the upper bound of the switching gain and G is the scaling factor, which is used to change the range of the controller output and also to improve the robustness of the system so that it can maintain stability and control performance even under different operating environments. The final control law is confirmed as:

$$u = \frac{1}{b}\left(-f(\theta) + \ddot{\theta}_d + c\dot{e} + \widehat{K}(t)sgn(s)\right) \qquad (16)$$

5. Simulation results

For the above theory, Matlab/Simulink is used to build the simulation, while the Fuzzy Logic Toolbox is used to build the fuzzy controller for switching gain, and Simulink is combined with Simulink to build the simulation of the relevant model.

5.1. Establishment of simulation conditions

In order to compare the advantages and disadvantages of different control schemes, FSMC with constant switching gain and GSMC are selected as the control group in this paper. These two methods have certain control accuracy and control performance (Hou et al.,2020), so the simulation results of position deviation and velocity deviation of the research object are compared by using both methods.

In order to simulate the external disturbance of the actual application environment of the port AGV, Gaussian type noise is added to simulate the disturbance and influence of the port AGV in a complex environment, which is expressed as shown below, as shown in Fig. 7.

$$E(t) = 200exp\left(-\frac{(t - c_i)^2}{2b_i^2}\right) \qquad (17)$$

Where $E(t)$ is the external disturbance and $b_i =$

$0.50, c_i = 5.0$. The main impact interval of Gaussian perturbation is within 4-6 s and the upper bound estimate mentioned above $\widehat{K}(t) = 201$.

After determining the experimental control group and external perturbations, the simulation model is built as shown in Fig. 7.

5.2. Experimental Simulation

For the position and velocity tracking problems, the controllers designed by the three methods are used with the same signal as the controller input, while the performance and robustness of their control systems are tested by adding Gaussian noise in the operation stabilization phase. The reference trajectory of position tracking is $Q_d = sin(2\pi t)$ and that of velocity tracking is $\dot{Q}_d = 2\pi cos(2\pi t)$. The errors of the output curves of the three controllers compared with the reference trajectory are also analyzed, and the specific effects are shown in Fig. 8.

In terms of position tracking, the IFSMC exhibited the ability to achieve the desired trajectory in a relatively short time and was able to move stably along the desired trajectory. When the system is disturbed, the FSMC shows a certain degree of error and cannot be adaptively adjusted, and needs to wait until the external disturbance is removed to eliminate the error. However, IFSMC has the ability of adaptive adjustment and can automatically increase the switching gain coefficient to improve the response speed and stability of the system. After adding external perturbations, IFSMC did not show too obvious errors and still kept moving with the desired trajectory, and showed the stability of IFSMC in position tracking.

Meanwhile, in the speed tracking, the controlled object speed is increased from zero to the desired speed and runs with the desired speed trajectory. During the disturbance phase of the system, the FSMC showed a more obvious chattering and could not be weakened in the process of external disturbance, which caused the instability of the control system. In contrast, the GSMC also generates a certain degree of chattering during the disturbance phase, and the speed tracking curve is corrected to a smoother curve within a short period of time, and the error is gradually eliminated over a period of time so that the system can return to the normal trajectory, and its robustness is improved to a certain extent compared with the FSMC. The IFSMC can adjust the switching gain coefficient adaptively at the initial stage

when the system is disturbed by external disturbances, so that the system can maintain a more stable state, and at the same time, it can reduce the switching gain coefficient in time when the influence of external disturbances on the system decreases to prevent the system from being too sensitive and generating chattering. In a comprehensive view, the controller system designed by IFSMC has better system response, robustness and stability in speed tracking compared with the other two control groups. A comparison of the different tracking algorithms of the three methods is given in Table 2, and their quantified pairs are shown in the following figures.

In terms of position tracking, in the initial stage of operation, the steady-state time of IFSMC was increased by 73.41% compared to FSMC, while the steady-state time of GSMC was increased by 79.26% compared to FSMC instead. Meanwhile, the system was stabilized after the third second and Gaussian

perturbation was added. Due to the addition of Gaussian perturbation, the system produced a certain amount of error, and FSMC produced a larger error than the initial error, while the maximum error produced by FSMC was 1.8% of the initial error, which had less impact on the system stability, proving that the improved algorithm has improved the system stability. In terms of speed tracking, the response speed of IFSMC is slow in the initial stage of operation, but the error has been slowly decreasing after entering the steady-state stage, and its maximum error does not exceed 1% of the initial error in Gaussian perturbation stage after the 3rd second, and the system stability is significant, which achieves the purpose of the improved method.

During the operation, the change of switching gain coefficient of the algorithm in this paper is shown in Fig. 9.
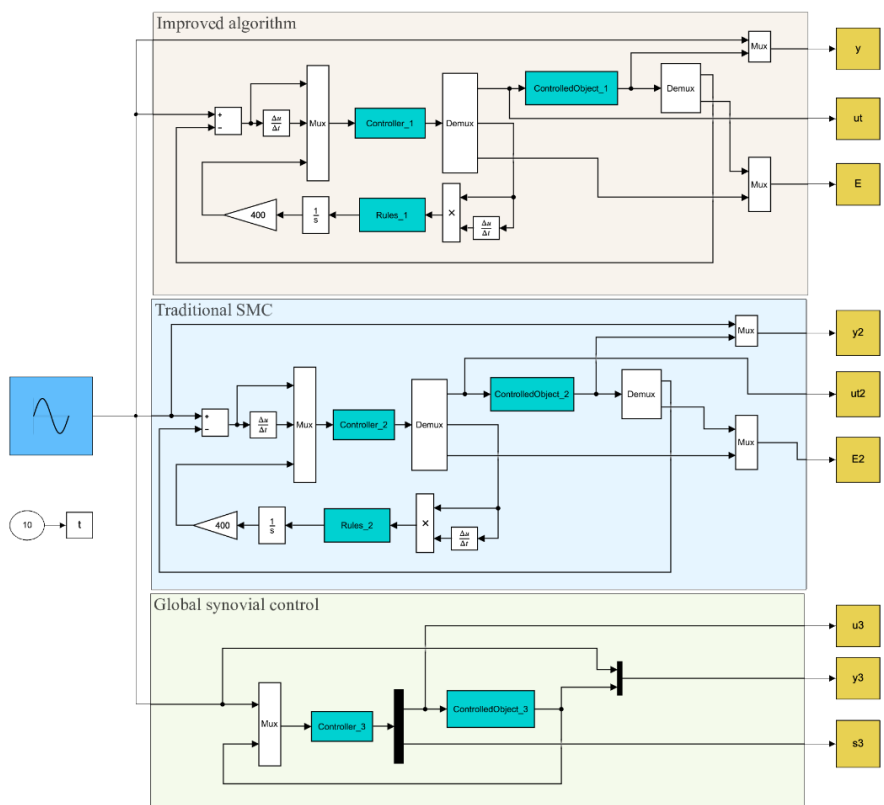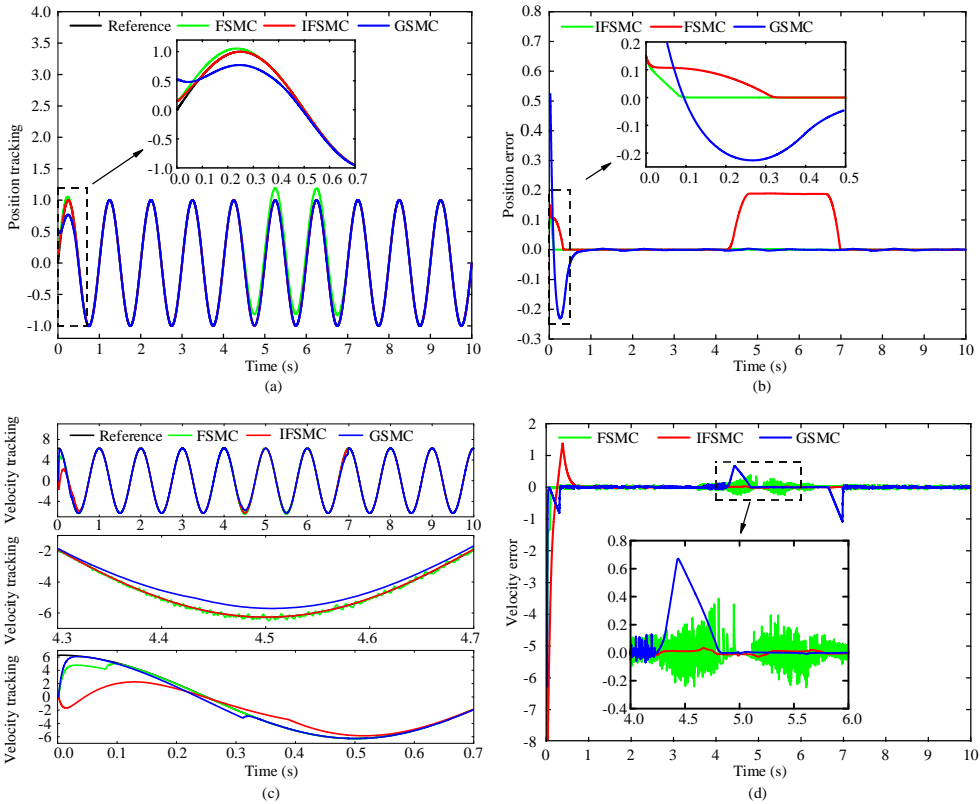

Fig. 7. Schematic diagram of the simulation system

Fig. 8. Path following performance of different control methods: (a) Position tracking diagram (b) Position tracking error diagram (c) Velocity tracking diagram (d) Velocity tracking error diagram

Table 2 Comparison results of path trajectory tracking

Control algorithm		Initial error	Settling time	Maximum error after 3s
Position tracking	IFSMC	0.1500	0.0823	0.0028
	FSMC	0.1500	0.3096	0.1890
	GSMC	0.5236	0.5554	-0.02613
Velocity tracking	IFSMC	-6.2832	0.5366	0.0032
	FSMC	-6.2832	0.0914	0.3871
	GSMC	-6.2832	0.3185	-1.0173

In the first stage of the operating state, that is, the converging mode stage, because the system state has not reached the equilibrium, in order to speed up the response speed, the switching gain coefficient should be increased to speed up the system state to reach the designed slip film surface; after running for a period of time, when the system state reaches the slip film surface for the first time, the operation proceeds to the second stage, that is, the sliding mode stage, because the system itself has chattering vibration, so in order to minimize the chattering vibration brought about by the As the system itself has chattering, so in order to minimize the unstable influence of the system, the gain coefficient of the switching with the chattering system is also adjusted with a weak chattering.

To fit the actual situation, the operation process of adding Gaussian perturbation is called the third stage, namely, the anti-interference stage, as can be seen from the FSMC of Fig. 8(d), the system state at this stage will be aggravated by external interference if it is not corrected, so the switching gain coefficient will be increased proportionally according to the degree of influence of external interference on the system state to make the system state resist the chattering brought by interference and ensure the stability of the whole system, for the convenience of comparison, for the output of the controller, the switching gain coefficient of 201, 100.5, 30 output as a comparison chart, as shown in Fig. 10a. and 10b.
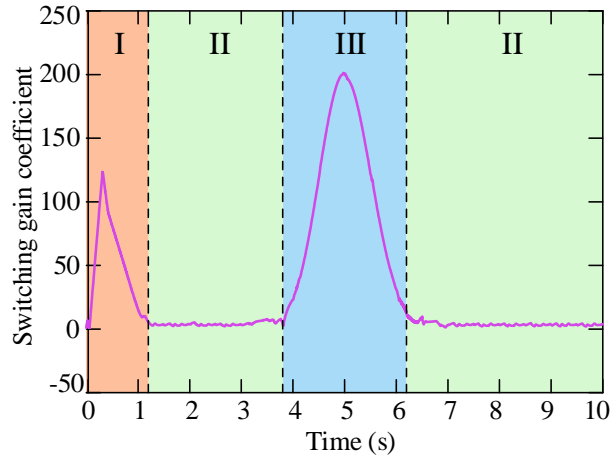

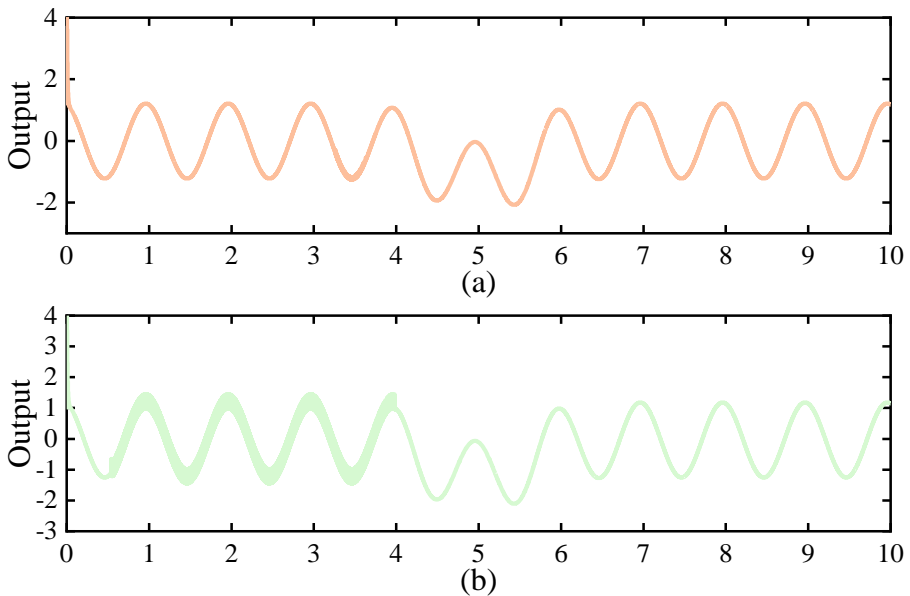Fig. 9 Change of switching gain coefficient

Fig. 10a Controller output with different switching gain coefficients (a) Controller output of the algorithm in this paper (b) k=30
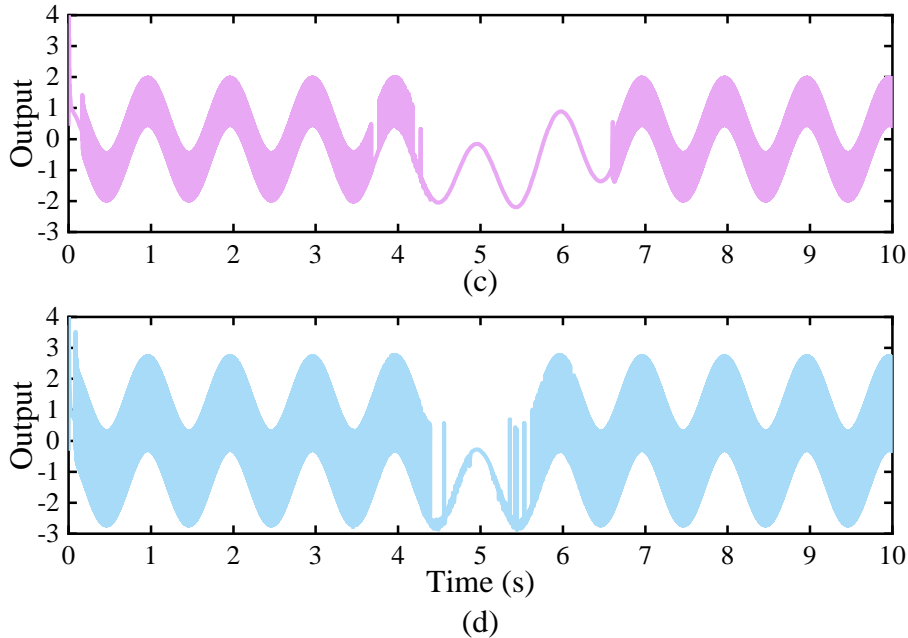
Fig. 10b Controller output with different switching gain coefficients (c) k=100.5 (d) k=20

As can be seen from Fig. 10, the system state appears in different degrees of chattering when the switching gain is a constant of different values, while the switching gain used in this paper uses the fuzzy idea of adaptive adjustment of the controller output according to real-time changes in system momentum has significantly improved, verifying the feasibility and effectiveness of the algorithm in this paper.

6. Conclusion

Aiming at the problem of environmental disturbance on trajectory tracking accuracy during the operation of port AGV, this paper proposes a control method based on the combination of fuzzy control theory and sliding mode control theory to study the trajectory tracking problem of AGV. Firstly, a two-degree-of-freedom monorail model is established based on the vehicle dynamics theory, while the magic formula is used to establish the tire model. Then the sliding mode control is used as an improved traditional method, and the change of switching gain coefficient is controlled by designing a fuzzy controller for the chattering problem generated by this control method. Finally, Matlab/Simulink software is used to simulate and analyze the

control algorithm, including the trajectory tracking and speed tracking of AGV operation process, as well as the change of switching gain coefficient and the comparison of controller output during the process with Gaussian disturbance. The experimental results show that compared with the traditional fuzzy sliding mode control and global sliding mode control, the algorithm proposed in this paper outperforms the two control groups in terms of response speed, anti-disturbance ability and chattering reduction, achieves the purpose of chattering reduction, optimizes the traditional sliding film variable structure control, and verifies the feasibility of the algorithm in future practical applications.

However, the algorithm in this paper has not been effectively experimented in the actual application, and no relevant comparison has been made for the no-load/load situation of the port AGV. At the same time for the actual application environment of the complex and changing external disturbances can not make a good simulation, such as: the real road vibration, bumps, slope conditions, coastal areas of wind, rain and snow environmental conditions, etc., the practical feasibility of the algorithm is still to be studied and discussed.

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