

Retraction

Retracted: Multimode Intelligent Control Based on Multidata Fusion Filtering in High-Speed Train Traffic Signal and Control

Journal of Sensors

Received 31 October 2023; Accepted 31 October 2023; Published 1 November 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] B. Huang and Y. Huang, "Multimode Intelligent Control Based on Multidata Fusion Filtering in High-Speed Train Traffic Signal and Control," *Journal of Sensors*, vol. 2021, Article ID 6081999, 10 pages, 2021.

Research Article

Multimode Intelligent Control Based on Multidata Fusion Filtering in High-Speed Train Traffic Signal and Control

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Received 15 April 2021; Revised 26 April 2021; Accepted 6 May 2021; Published 1 June 2021

Academic Editor: Mu Zhou

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As the speed of high-speed trains continues to increase, the intelligent monitoring of high-speed trains has become a concern of people. This research mainly discusses the application of multimode intelligent control of multidata fusion filtering in high-speed train traffic signal and control. In multimodal intelligent control, BangBang, PI control, adaptive fuzzy PID control, and expert monitoring control under special circumstances can be used, respectively, according to the error and the rate of change of the error, which can achieve the best control effect under safe conditions. Take the allowable speed of ATP as the target speed of the control system, and combine the operation process, operation requirements, traction characteristics, braking characteristics of high-speed trains, and meet the two conditions for improving the operating efficiency of high-speed trains. According to the dynamic expected speed value of high-speed trains, dynamically adjust the switching threshold. This study uses a pulse signal generator to simulate the speed data of the vehicle speed sensor (all pulse data), and then read the speed (pulse) signal data through the pulse signal acquisition card, and display the simulated speed data under the Kingview software. The monitoring computer is used to collect train speed information, display speed information, manage speed information, and output speed information. Then, through OPC technology, the simulation speed data is transmitted to MATLAB software for multidata fusion filtering processing and multimodal control simulation. In the simulation process, the train adopts a multimodal intelligent control response scheme, with a total time of 2183.7 s, which is shortened by 214.5 s and improved by nearly 10%. The multimode intelligent control scheme of multidata fusion filtering proposed in this study can better meet the control of high-speed train traffic signals.

1. Introduction

The twenty-first century is an excellent period for the development of high-speed railways in the world. It is a new era characterized by high speed in the history of world transportation, especially in China. In recent years, the construction of high-speed railways has made brilliant achievements. At the same time, China also has its own train operation control system CTCS (Chinese Train Control System). In addition, ATO technology has been successfully applied in urban rail and intercity rail transit, but it is rarely used in high-speed railways.

In order to realize the full utilization and efficient transmission of multimodal data, this paper will study a fusion transmission scheme for multimodal data, that is, adopt the

method of fusing multimodal data first and then transmitting the fused information to effectively reduce network energy. At the same time, it is ensured that the fusion information can contain important expressions hidden in the original multimodal data, so that even if the amount of transmitted data is reduced, the key information contained in the original multimodal data will not be lost.

The fusion filtering algorithm increases the reliability of location information. F Caron simulates the algorithm by fusing GPS and IMU data from actual tests on land vehicles. Bad data transmitted by GPS sensors can be detected and rejected using contextual information, thereby improving reliability. In addition, the current GPS/INS correlation is not satisfactory [1]. Although the filter he developed makes it possible to easily add other sensors to achieve the desired

performance, the research lacks simulation data [2]. Zhu H believes that accurate measurement of dynamic displacement is very important for structural health monitoring and safety assessment of super high-rise structures. It is difficult for him to accurately measure the displacements of super high-rise structures using traditional methods because they are inaccurate or inconvenient to set in practice. His research provides an accurate and economical method to accurately measure the dynamic displacement of super high-rise structures by fusing acceleration and strain data, which are usually available in structural health monitoring systems. The dynamic displacement is first derived from the measured longitudinal strain based on the geometric deformation and does not require a modal shape. He uses an optimization technique to optimize the deployment of strain sensors to achieve more accurate strain-derived displacements. Although his research has been applied to numerical super high-rise structures and laboratory cantilever beams to verify the displacement of the high-frequency component and pseudostatic component of the method, the research lacks logic [3]. Amamra A proposed a new method; his method can accurately track the driving vehicle by using the multiview setting of the red-green-blue depth (RGBD) camera. He first proposed a correction method to eliminate the offset that occurs when the depth sensor is worn. Otherwise, using conventional calibration procedures cannot solve this problem. Next, he introduces a sensor-based filtering system to correct unknown vehicle movement. The data fusion algorithm is then used to best merge the estimated trajectories of the sensor orientation. He implemented most of the solution in the graphics processor. Although the accuracy obtained by his research and the robustness of the solution in overcoming the uncertainty of measurement and modeling, the research lacks contrast [4]. Balakrishnan S N proposed a modular method to solve the multisensor multitarget problem in space. His method combines clustering techniques developed in the field of pattern recognition with filtering techniques developed to estimate multiple target states in space. He introduced the results of cluster analysis and used two scenes with multiple targets and used an orbital platform as a sensor. Although his research gave the estimation error history of position and velocity, it did not describe their relevance to target recognition and data fusion [5].

This research mainly discusses the application of multimode intelligent control of multidata fusion filtering in high-speed train traffic signal and control. In multimodal intelligent control, BangBang, PI control, adaptive fuzzy PID control, and expert monitoring control under special circumstances can be used, respectively, according to the error and the rate of change of the error, which can achieve the best control effect under safe conditions. Take the allowable speed of ATP as the target speed of the control system and combine the operation process, operation requirements, traction characteristics, and braking characteristics of high-speed trains, and meet the two conditions for improving the operating efficiency of high-speed trains. According to the dynamic expected speed value of high-speed trains, dynamically adjust the switching threshold. This study uses a pulse signal generator to simulate the speed data of the vehicle speed sensor (all

pulse data), and then read the speed (pulse) signal data through the pulse signal acquisition card, and display the simulated speed data under the Kingview software. The monitoring computer is used to collect train speed information, display speed information, manage speed information, and output speed information. Then, through OPC technology, the simulation speed data is transmitted to MATLAB software for multidata fusion filtering processing and multimodal control simulation.

2. High-Speed Train Traffic Signal and Control

2.1. Traffic Signal Control. Using multimodal control based on feature identification, it follows the speed control target well. In addition, there are control methods such as two-level fuzzy neural network control, fuzzy PID control, adaptive fuzzy PID control, and fault-tolerant control. These control methods and algorithms include classic PID control and improved PID control. Some of these control methods theoretically verify the feasibility of the method, and some first conduct theoretical research and analysis and then apply the theoretical research results to actual train control. These studies have achieved good results to a large extent, solved certain practical problems, and obtained a series of research results [6, 7]. Most of the above research methods and control algorithms ignore an important issue, that is, assuming that the real-time detection value of the control system (strictly speaking, it should be the real-time speed detection value or the detection processing value) is very accurate, and the quality of the control method is measured. The control effect is to make the output value of the control system follow the expected value of the control system well and/or to improve the robustness, rapidity, and stability of the system. However, the real-time speed detection value of the actual running train is sometimes inaccurate. For a control system with inaccurate detection value itself, the control algorithm, control method, and control effect cannot fully reflect the true effect, and if the speed measurement error or speed processing error is too large, there may be a rear-end collision safety risk [8].

At present, the actual control of high-speed trains has not reached the level of theoretical research. Most high-speed train control only implements functions such as ATP, and the ATO function needs to be introduced into the high-speed train operation control system. In recent years, a small number of high-speed trains have realized the ATO function, but the control algorithm still adopts the traditional PID control, and the control system design does not consider the accuracy of the detection and processing. In the actual operation of high-speed trains, in order to avoid safety problems caused by speed measurement errors (or speed processing errors), the maximum speed of multiple speed sensors is often used when calculating speed, and the speed control setting value is lower than the allowable speed of ATP, resulting in speed of high-speed trains is reduced or the interval between train departures becomes longer, which affects the operating efficiency of high-speed trains, which in turn affects the utilization rate of the entire high-speed railway network, and cannot give full play to the transportation

capacity of the entire high-speed railway network, resulting in a waste of resources [9].

There is usually a certain delay in road network traffic [10].

$$\begin{cases} W_{ij} = \exp\left(\frac{\alpha_i D_{\text{HOL},i} - x}{1 + \sqrt{x}}\right) \times \frac{r_{ij}}{R_i}, \\ x = \frac{1}{N} \sum_1^N \alpha_i D_{\text{HOL},i}, \end{cases}$$

$$P_a(s, s') = P(s_{t+1} = s' | s_t = s, a_t = a) \begin{cases} 1 (s' = 0, a = a_1), \\ P(s, s') (a = a_2), \\ 0 (\text{else}). \end{cases} \quad (1)$$

W_{ij} represents the final delayed power. Certain information and data support is required in the loading and transmission of data [11, 12].

$$\Pr[E_2] = 1 - \frac{q_{\text{sc}}(q_{H_2} + q_{H_3})}{2^l}. \quad (2)$$

Among them, $\Pr[E_1]$ represents the intensity of data transmission. The wireless network driver can perform channel tuning, multichannel synchronization, and channel routing, and interact with the upper and lower data protocol $\Pr[E_2]$. In order to request data from above and move down, these are the implementation of the multichannel protocol mechanism $q_{\text{att}}/2$. This is the premise and basis of basic data transmission of signals [13, 14].

Information recognition carried by the Internet of vehicles requires the common realization of the same points of each model [15]

$$\begin{aligned} \Pr[C] &= \Pr[E_1 \cap E_2 \cap E_3] \geq \left(1 - \frac{q_{\text{ppk}}}{q_{H_1}}\right) \left(1 - \frac{q_{\text{att}}}{2^l}\right) \\ &\quad \cdot \left(1 - \frac{q_{\text{sc}}(q_{H_2} + q_{H_3})}{2^l}\right) \mathcal{E}, \quad (3) \\ \Pr[C] &\geq \left(1 - \frac{q_{\text{ppk}}}{q_{H_1}}\right) \left(1 - \frac{q_{\text{sc}}(q_{H_2} + q_{H_3})}{2^l}\right) \mathcal{E}. \end{aligned}$$

$P[C]$ represents the final analysis data [16].

2.2. Multimodal Data Fusion. Multimodal data fusion mainly refers to the comprehensive processing of multiple modal information using computers, proposing various theories and algorithms, and comprehensively processing different types of multimodal data to obtain a more accurate state of objective objects, and environmental information is the focus of multimodal data fusion research. The focus of the research is feature recognition methods and fusion algorithms. These

algorithms can complete the coordination and complementation of a variety of different sensor information and improve the decision-making process based on uncertain data. What we usually call multimodal data fusion is essentially an imitation of the ability of organisms to comprehensively process a variety of information. In a multimodal fusion system, the data measured by various sensors will have different characteristics and be expressed in different formats. The multimodal data fusion system will make full use of the resources provided by a variety of sensors, and through the reasonable analysis and utilization of various data, the data will be coordinated according to the pre-given optimization principles to obtain the final fusion result. Observe the state or activity law of the target to make judgments and interpretations. Compared with a single sensor system, a multimodal sensor system has the following advantages:

- (i) System stability is strong. When there are several sensors due to their own reasons or strong interference from the environment, there will always be several sensors that cannot work normally, and the range of target activities is often not covered by all sensors. Through the various sensors provided by various sensors. The analysis of redundant information in the form can ensure that the system works normally under any conditions
- (ii) Wide coverage. In a system composed of multiple sensors, the range of the area detected by each sensor is also different. It is possible for a certain sensor to detect places that other sensors cannot detect. Therefore, the coverage of the system is greatly improved
- (iii) Information is provided at all times. Due to the different working hours and detection cycles of various sensors, the synergy of multiple sensors can greatly improve the time coverage of the system and ensure the continuity of information supply
- (iv) High credibility. The redundant information provided by a variety of sensors can ensure that the system finds its own errors in time, which greatly improves the reliability of the system [17]

In order to accurately analyze the characteristics of the original data sequence, after the network training prediction is completed, we need to denormalize the predicted value. The calculation formulas are

$$\begin{aligned} X(i) &= X_{\text{gvh}}(\max(X) - \min(X)) + \min(X), \\ X(i) &= X_{\text{gvh}}(i)\sigma_x + \bar{X}. \end{aligned} \quad (4)$$

The denormalized data is in the same dimension as the original data, and analyzing it can more accurately extract the features and laws contained in the relevant data [18, 19].

2.3. Fusion Model. High-speed train operation automatic control systems such as ETCS and CTCS can realize functions such as the high-speed train operation automatic

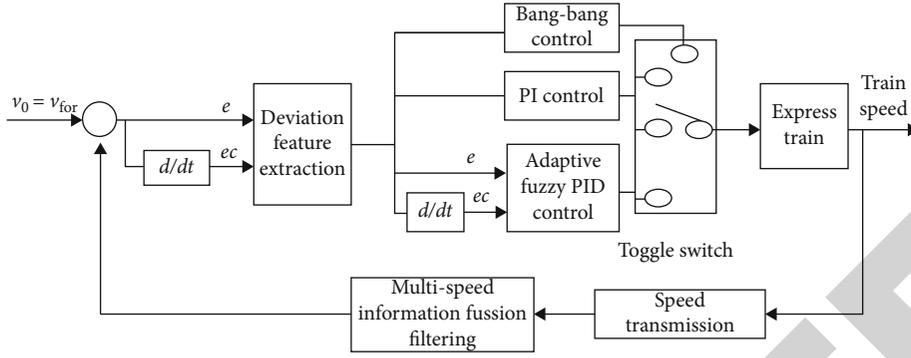


FIGURE 1: High-speed train speed control based on multi-information fusion filtering and multimodal intelligent control.

protection system ATP (Automatic Train Protection). As for the high-speed train automatic driving technology ATO (Automatic Train Operation) based on the high-speed train operation automatic protection system, it is still more theoretical studies and fewer practical applications. When designing the multimodal fusion method for ranging, this article considers the following application objectives and scenarios: a variety of ranging sensors are used to simultaneously measure a target to cope with the environment where noise factors such as climate and environment change rapidly, ground configuration, and synchronous sampling. The distance dynamic model of the target is

$$\begin{aligned} R_x E[X(t)X^H(t)] &= AE[SS^H]A^H + AE[SN^H] \\ &= E[NS^H]A^H + E[NN^H]. \end{aligned} \quad (5)$$

There are a variety of ranging sensors such as radar and infrared, and their measurement models are [19]

$$Z = Hx + v. \quad (6)$$

Among them, Z is the measured value and H is the state transition matrix. Assuming that the signal and noise are independent, and the noise is Gaussian white noise with zero mean and variance of σ^2 , namely,

$$E[NN^H] = \sigma^2 I. \quad (7)$$

Then, the above formula can be simplified to [20]

$$R_x = AR_s A^H + \sigma^2 I, \quad (8)$$

where R_s is the covariance matrix of the incident signal. TDOA is a technology derived from TOA. Its main advantage is to overcome the problem of electronic clock time synchronization, that is, it does not require a strictly synchronized electronic clock [21, 22]. Assuming there are two signals with different propagation speeds, the calculation formula of distance R is as follows:

$$R = |(T_4 - T_3) - (T_2 - T_1)| \times \frac{V_2 - V_1}{V_2 \times V_1}. \quad (9)$$

In the formula, V_1 and V_2 are the propagation speeds of the two signals, respectively. Data fusion can be expressed as

$$Y = \frac{C_{1j} \times Z_1 + C_{21j} \times Z_2 + C_{3j} \times Z_3 + \dots + C_{nj} \times Z_n}{N}. \quad (10)$$

2.4. Multimodal Intelligent Control of High-Speed Train Speed Signal.

The speed signal control of high-speed trains needs to consider many factors, such as line speed, train speed limit, ramps, curves, and target points. There have been many studies on the speed control of high-speed trains, but in practical applications, advanced control algorithms and control methods are still relatively few, and the control algorithm is mainly based on classic PID control [23]. Therefore, in this paper, a specific multimodal control method is designed in combination with the operation goals of high-speed train safety, efficiency, and comfort.

In the multimodal intelligent control in Figure 1, Bang-Bang, PI control, adaptive fuzzy PID control, and expert monitoring control under special circumstances can be used according to the error and the rate of change of the error, which can achieve the best under safe conditions. The multi-speed information fusion filtering module in the high-speed train speed control system mainly performs fusion filtering processing on the information of the four speed sensors to improve the detection processing accuracy [24, 25].

This design idea is not essentially different from the general multimodal control, but the given value of the high-speed train speed control system is optimized, that is, the allowable speed of the ATP is taken as the target speed of the control system, and combined with the operation process of the high-speed train, operation requirements, traction characteristics, braking characteristics, and satisfying the two conditions for improving the operating efficiency of high-speed trains, the switching threshold of the multimodal intelligent control algorithm is optimized [26]. The specific content of the optimization design is to dynamically adjust the switching threshold according to the dynamic expected speed value of the high-speed train [27, 28].

$$\begin{aligned} E_{\max} &= V_0 - 1, \\ E &= V_0 - V. \end{aligned} \quad (11)$$

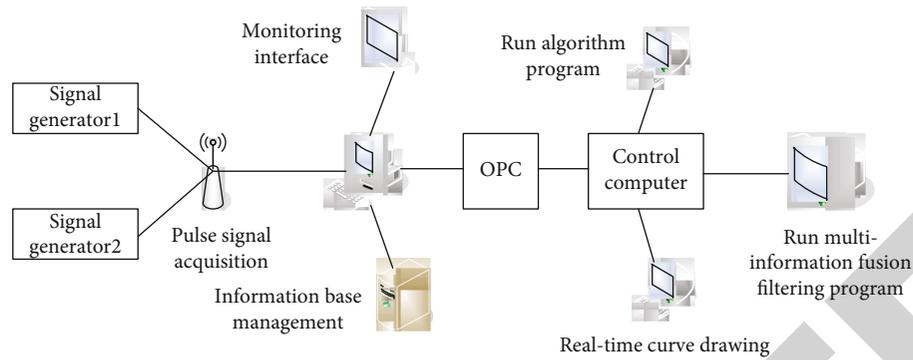


FIGURE 2: Real-time control of multimodal intelligent control system.

That is, when the expected speed is higher, the switching thresholds E_{\max} and E are set to be smaller to ensure that the maximum acceleration and deceleration time are longer, and the speed and efficiency are improved; when the expected speed is lower, the switching thresholds E_{\max} and E are set to be larger. One point is to improve the control accuracy without affecting the operating efficiency [29].

3. High-Speed Train Traffic Signal and Control Experiment

3.1. Simulation Test Platform. There are on-board speed and distance measurement unit SDU (Speed & Distance Unit) and SDP (Speed & Distance Processing Unit) in the on-board equipment of high-speed trains, which are used to provide real-time speed value and positioning information. However, the real-time speed data of the study cannot be obtained from actual high-speed trains, and it is inconvenient to use real test benches to simulate high-speed train speed measurement [30]. Therefore, this study uses a pulse signal generator to simulate the speed data of the on-board speed sensor (all pulse data). Then, read the speed (pulse) data through the pulse signal acquisition card, display, store, and manage the simulated speed data under the Kingview software, and then, transfer the simulated speed data to the MATLAB software for multidata fusion filtering processing through OPC technology control simulation with multimodal control. The advantage of this design method is to make full use of the advantages of configuration software to read hardware data and the advantages of MATLAB software data processing.

3.2. Overall Structure Principle of the Simulation Test Platform

(1) Signal detection

The signal detection part completes the detection and conditioning of the speed sensor information. The speed sensor is used to detect the real-time speed information of the train running process, and the signal conditioning circuit is to perform standardized processing such as filtering and pulse shaping on the detected speed sensor information.

(2) Monitoring computer

The monitoring computer is used to collect train speed information, display speed information, manage speed information, and output speed information.

(3) OPC technology

OPC (Object Linking and Embedding for Process Control) technology is a software interface standard for the transmission and exchange of train speed information, which realizes the communication between the monitoring computer and the control computer.

(4) Control computer

The control computer is used to receive the simulation speed information transmitted by OPC (Object Linking and Embedding for Process Control), realize multispeed information fusion filtering and simulation research, and use the fusion filtering result as the feedback value of the multimodal intelligent control system to realize the simulation real-time closed-loop control of the same speed of high-speed trains, complete the drawing, and display of related simulation curves. The real-time control of the multimodal intelligent control system is shown in Figure 2.

3.3. Hardware Design of Simulation Test Platform. The hardware design of the simulation test platform adopts pulse data acquisition card and related accessories to realize multichannel speed information detection. The pulse data acquisition card is a counter/timer and digital input/output card for IBM PC/AT. The card provides six 16-bit counter channels, and it also has 16 digital inputs and 16 digital outputs. The two 8254 chips on the card provide various counter/timer function modes, which can be used in experimental equipment and actual industrial products.

The pulse data acquisition card is equipped with a special digital filter, which can eliminate the noise in the input pulse signal, and its frequency can be adjusted to provide a more stable output reading during use. The main function of the pulse signal data acquisition card is six counters or timers. The board also has 16 switching output and 16 switching input functions. The output and input levels of the board are both standard TTL levels. In this research, the pulse

TABLE 1: RH3 model train size parameters.

Project	The main parameters
Chief of EMU	200.67 m
Length of head car	25.52 m
Maximum width of car body	3.265 m
Maximum height of car body	3.890 m
Gauge	1.435 m

TABLE 2: Traction and braking parameters of CRH3 EMU.

Project	The main parameters
Total traction power	8800 (kW)
Start acceleration	0.38 (m/s) (0-200 km/h)
Weight of empty car marshalling	479.36 (t)
Capacity of capacity	536 (t)
Speed class	300 (km/h)

TABLE 3: Braking distance requirements.

Braking speed	Distance requirement
Initial braking speed 300 km/h	≤3700 m
Initial braking speed 200 km/h	≤2000 m
Initial braking speed 160 km/h	≤1400 m

counting function is mainly used to realize the output pulse counting of analog speed sensors (wheel Hall speed sensor and Doppler radar speed sensor) to calculate the real-time running speed and running distance of high-speed trains.

3.4. Configuration Software Design

(1) Monitoring interface design

Use pulse signal generator, pulse signal acquisition card, and related accessories; connect to industrial control computer; and realize real-time simulation speed data acquisition and display through Kingview software.

The simulation test platform designed in this study uses OPC technology to connect KingView configuration software and MATLAB software and utilizes the advantages of MATLAB software's strong data processing ability and good simulation to realize multi-information fusion filtering and multimodal intelligent control algorithms. KingView configuration software realizes real-time simulation speed data acquisition and real-time monitoring of the main parameters of the system. Taking full advantage of the strong human-machine interface of KingView configuration software, it is easier to realize the collection of peripheral hardware data. At the same time, it showed the friendly man-machine interface of KingView configuration software, which well completed the real-time monitoring of simulation speed information.

To design real-time data variables, you must first define the data variables. Specifically, click the data dictionary in the menu bar on the left side of the configuration software

to create 4 sets of I/O integer data variables, namely, display, display 1, display 2, and display 3. The connected device is selected as the new I/O device, the register is selected as the RADOM type, and the data type is the SHORT type.

After completing the "data dictionary" design, you can start various other interface designs. The design content mainly includes simulation test system monitoring main interface, simulation speed information acquisition and display interface, and simulation real-time speed curve generation interface. The high-speed train analog signal detection interface is shown in Figure 2.

(2) OPCTOOL design under MATLAB software

The specific design process is to first open the MATLAB software, enter the OPCTOOL command at the MATLAB command window command prompt, and then, press the Enter key to open the OPCTOOL toolbox. After understanding the function of OPCTOOL, familiar with and mastering the connection method of OPCTOOL, you can design the OPC communication system. The OPCTOOL toolbox is mainly divided into three parts for the OPC communication connection: first, the computer DCOM setting, the second is the establishment and setting of the OPC server of the configuration software, and the third is the debugging of the MATLAB software, and the final communication of the OPC is successful. Computer DCOM settings, click the start menu, enter dcomcnfg in the run box, and click Enter; the configuration window will pop up and click Component Services, Computer, My Computer, DCOM Configuration in turn. Find OPCEnum in the DCOM configuration, right-click to enter the properties interface, click Security, select all three items as custom, and click OK, DCOM configuration is complete. To establish and set up the configuration software OPC server, click the OPC server in the project browser, double-click the new icon, enter \localhost in the network node name field, select KingView-View1 for the server, and click OK. Then, select the board and click new to use the default new IO device, make corresponding settings, and complete the configuration software configuration.

3.5. Simulation Platform Software Joint Debugging and Simulation. After completing the Kingview interface design, Kingview software OPC design, and MATLAB software OPCTOOL setting design, the system software will be debugged. After the system is running, the Kingview software detects the pulse generated by the pulse signal generator in real time through the pulse signal acquisition card information (i.e., simulated speed information), and then, realize the real-time display of the simulation speed, the storage of the simulation speed data, and the generation of the curve of the simulation real-time speed value in the configuration software environment. From these results, we can basically understand the real-time speed information of the external simulation. Later, Kingview software transfers the collected simulation real-time speed information to the OPC of MATLAB software through OPC technology. OPC receives the simulation speed information through OPCTOOL and then processes the simulation speed information. On the

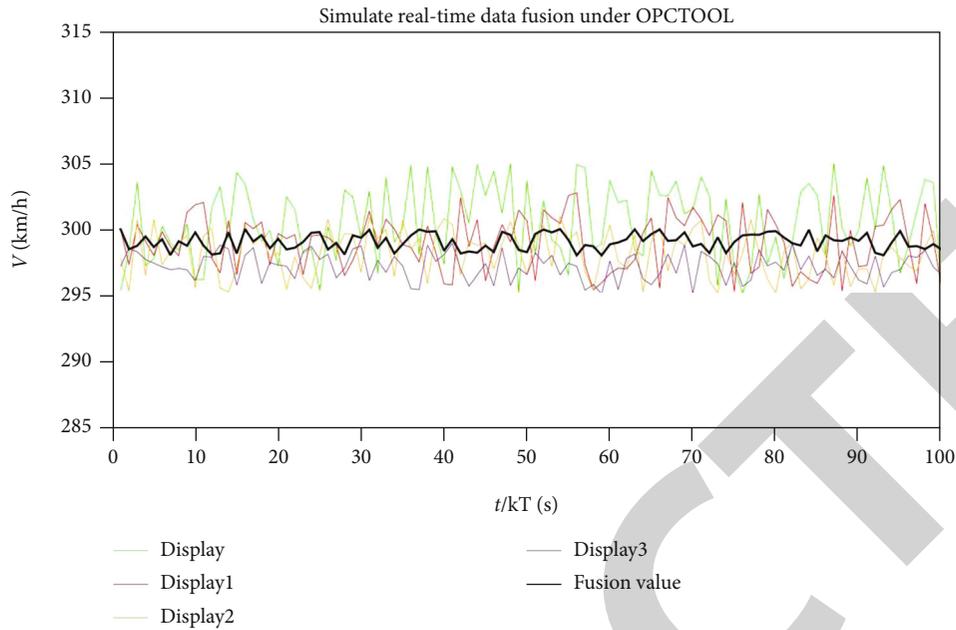


FIGURE 3: Multi-information fusion filtering processing of the simulated real-time speed value received by MATLAB.

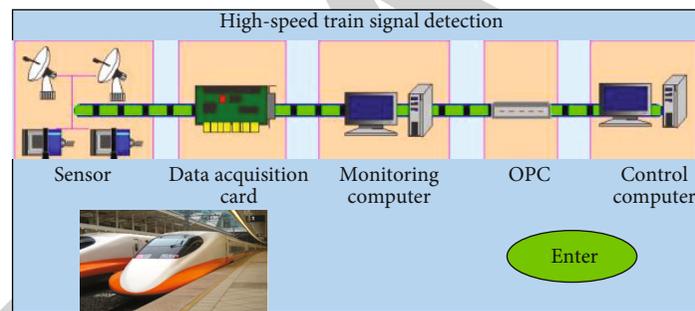


FIGURE 4: High-speed train analog signal detection interface.

one hand, it performs real-time display and storage. On the one hand, the received simulation real-time speed value is drawn into a curve. In this way, the consistency and synchronization of the simulation speed data under the Kingview software and the simulation speed data under the MATLAB software can be observed intuitively.

4. Results and Discussion

4.1. Joint Debugging of Software System. The CRH3 high-speed train was selected for the simulation. This model is a 4-motion +4 drag train, single-phase power supply, and the standard voltage is AC25kV, 50 Hz. The axle load is about 17 t when the capacity is fixed, and the number of people: 600 people, 72 people for the first-class seats, 528 people for the second-class seats, and the capacity $M = 536$ t. The minimum radius of train passing requirements: rotation quality coefficient $r = 0.08$, $R = 250$ m in continuous operation, and $R = 150$ m in single-vehicle shunting. CRH3 model train size parameters are shown in Table 1.

CRH3 EMU traction and braking parameters are shown in Table 2.

On a straight track, the braking distance for emergency braking of high-speed trains of EMUs needs to meet the requirements. The specific braking distance requirements are shown in Table 3.

Multi-information fusion filtering is performed on the simulated real-time speed value received by MATLAB, and the result after processing is shown in Figure 3. In Figure 4, the real-time curves of the 4 channels of speed information simulation values all have certain fluctuations (a random disturbance signal is added when reading the pulse of the pulse signal generator to simulate the actual speed error), so the use is based on the self. It adapts to the federated Kalman data fusion method for processing, and the processed speed value fluctuates little, which improves the accuracy of simulated speed measurement.

The previous research based on the simulation test platform verified the correctness and rationality of the multi-information fusion filtering method. Let us continue to use the simulation test platform to verify the multimodal intelligent control algorithm. The 4-channel simulation speed information has large errors and unevenness, and good results have been obtained after multi-information fusion

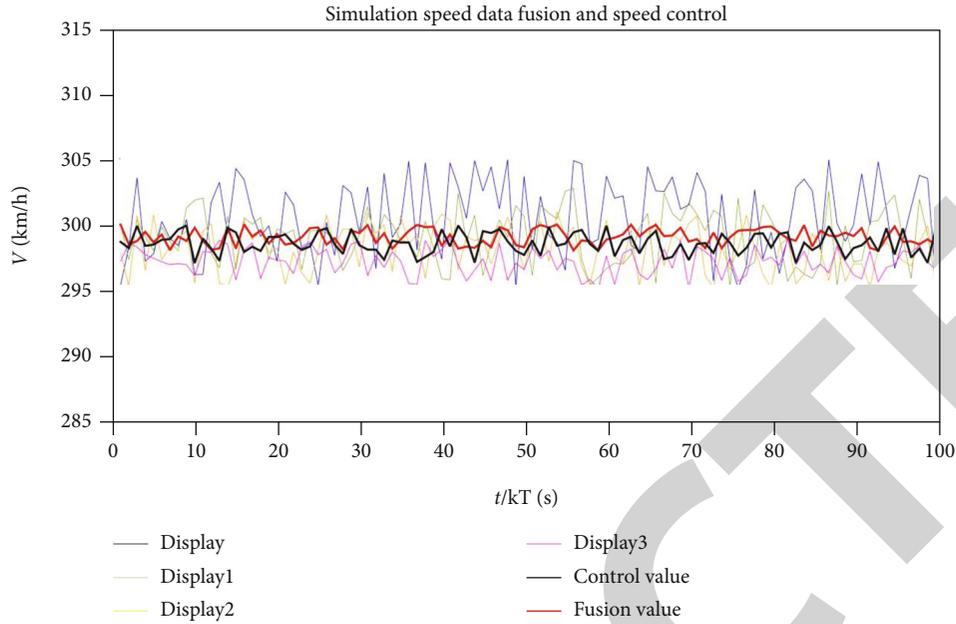


FIGURE 5: Simulation speed data fusion and speed control.

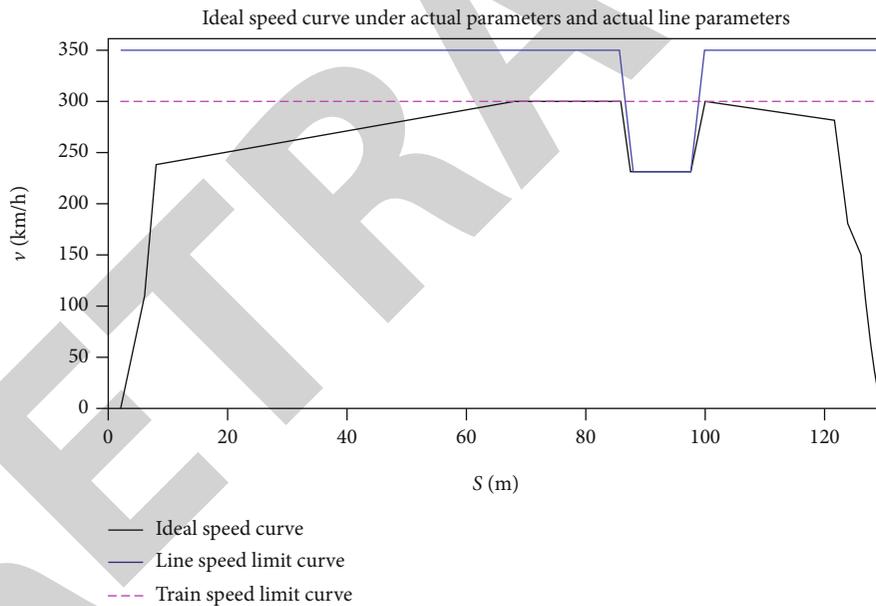


FIGURE 6: Specific ideal speed curve and speed limit curve.

filtering processing. At the same time, the multimodal intelligent control simulation using the result of multispeed information fusion filtering as the speed feedback value of speed control has also achieved good results. Simulation speed data fusion and speed control are shown in Figure 5.

4.2. Simulation Analysis of High-Speed Train Speed Signal. On the ideal speed curve, the line speed limit and the high-speed train speed limit are added to obtain the specific ideal speed curve and speed limit curve (as shown in Figure 6). In order to ensure the safety of train operation, the current

speed control of high-speed trains mostly adopts reduced speed operation, that is, the maximum positive error value is used for control. This result can ensure safety, but affects the efficiency of train operation. The ideal speed curve after speed reduction is simulated based on the average value of 3 km/h-5 km/h reduced by the ATP allowable speed curve of the CTCS-3 grade control system. In the actual programming process, the ideal value is also derived from theory according to the line parameters, high-speed train parameters, and control requirements. Figure 6 does not show a big difference. It can only reflect that the ideal speed value

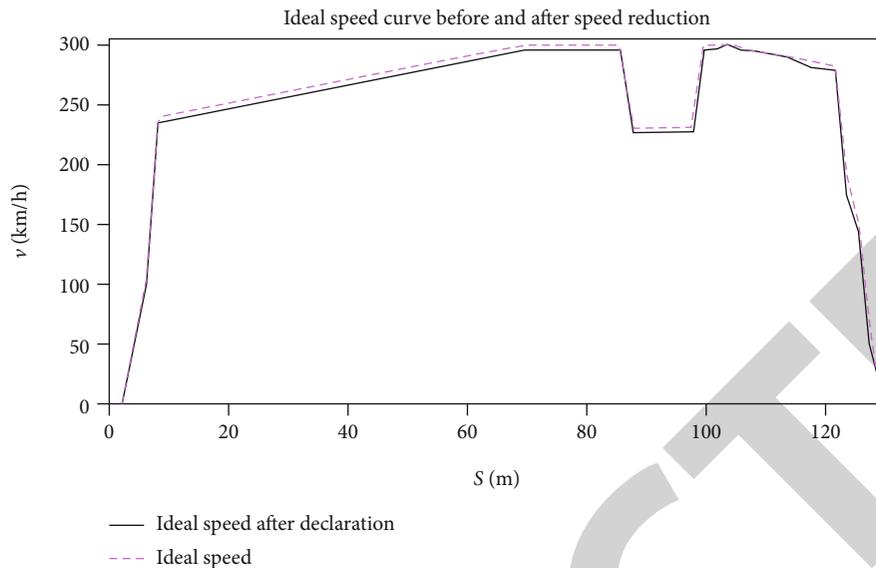


FIGURE 7: Multimodal intelligent control of multidata fusion filtering and ideal train speed.

of the high-speed train after speed reduction is always lower than the ideal speed value during the operation of the high-speed train in the simulation section.

The multimodal intelligent control of multidata fusion filtering and the ideal train speed are shown in Figure 7. It can be seen that the ideal speed curve before deceleration takes less time, the total time is 2183.7 s, which is shortened by 214.5 s, and the time is shortened by nearly 10%. That is to say, the use of tracking the ideal speed curve control can increase the efficiency by about 10%. The multimodal intelligent control response curve has small fluctuations and can better follow the ideal speed curve; although the PID control response curve can also better track the ideal speed curve after speed reduction, the curve fluctuations are large, which affects the high speed to a certain extent. The smoothness of the train running process affects comfort. Therefore, multimodal intelligent control can achieve better results when used for speed control of high-speed trains.

5. Conclusion

This research mainly discusses the application of multimode intelligent control of multidata fusion filtering in high-speed train traffic signal and control. In multimodal intelligent control, BangBang, PI control, adaptive fuzzy PID control, and expert monitoring control under special circumstances can be used, respectively, according to the error and the rate of change of the error, which can achieve the best control effect under safe conditions. Take the allowable speed of ATP as the target speed of the control system and combine the operation process, operation requirements, traction characteristics, and braking characteristics of high-speed trains, and meet the two conditions for improving the operating efficiency of high-speed trains. According to the dynamic expected speed value of high-speed trains, dynamically adjust the switching threshold. Then, through OPC technology, the simulation speed data is transmitted to MATLAB software for multidata

fusion filtering processing and multimodal control simulation. In future research, when there are many data modalities involved in the system, the complexity of the model will increase accordingly. How to save computing resources and time overhead to perform model training more efficiently will be a very critical issue. Further research can reduce the difficulty of multimodal data fusion, expand the scope of application of multimodal data fusion, and enhance its practical application value.

Data Availability

No data were used to support this study.

Conflicts of Interest

There are no potential competing interests in our paper.

Authors' Contributions

All authors have seen the manuscript and approved to submit to your journal.

Acknowledgments

This work was supported by the Guangxi University Innovation Team and Excellence Scholar Program. Also, the paper is supported by the Basic Research Ability Improvement Project of Young and Middle-aged Teachers in Guangxi Universities in 2021 (No. 2021KY1398).

References

- [1] M. Zhou, Y. Wang, Y. Liu, and Z. Tian, "An information-theoretic view of WLAN localization error bound in GPS-denied environment," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 4, pp. 4089–4093, 2019.

- [2] F. Caron, E. Duflos, D. Pomorski, and P. Vanheeghe, "GPS/IMU data fusion using multisensor Kalman filtering: introduction of contextual aspects," *Information Fusion*, vol. 7, no. 2, pp. 221–230, 2006.
- [3] H. Zhu, K. Gao, Y. Xia et al., "Multi-rate data fusion for dynamic displacement measurement of beam-like supertall structures using acceleration and strain sensors," *Structural Health Monitoring*, vol. 19, no. 2, pp. 520–536, 2020.
- [4] A. Amamra and N. Aouf, "Real-time multiview data fusion for object tracking with RGBD sensors," *Robotica*, vol. 34, no. 8, pp. 1855–1879, 2016.
- [5] S. N. Balakrishnan and B. D. Tapley, "Multitarget classification and estimation using clustering techniques," *Journal of Guidance, Control, and Dynamics*, vol. 13, no. 1, pp. 121–127, 1990.
- [6] Z. Xing and Y. Xia, "Comparison of centralised scaled unscented Kalman filter and extended Kalman filter for multi-sensor data fusion architectures," *IET Signal Processing*, vol. 10, no. 4, pp. 359–365, 2016.
- [7] X. Chi, X. Jia, F. Cheng, and M. Fan, "Networked H_{∞} filtering for Takagi-Sugeno fuzzy systems under multi-output multi-rate sampling," *Journal of the Franklin Institute*, vol. 356, no. 6, pp. 3661–3691, 2019.
- [8] X. H. Wu and S. M. Song, "Covariance intersection-based fusion algorithm for asynchronous multirate multisensor system with cross-correlation," *IET Science Measurement & Technology*, vol. 11, no. 7, pp. 878–885, 2017.
- [9] C. Stahlschmidt, A. Gavriilidis, J. Velten, and A. Kummert, "Applications for a people detection and tracking algorithm using a time-of-flight camera," *Multimedia Tools & Applications*, vol. 75, no. 17, pp. 10769–10786, 2016.
- [10] W. Jiang, Y. Li, and C. Rizos, "Improved decentralized multi-sensor navigation system for airborne applications," *GPS Solutions*, vol. 22, no. 3, pp. 1–13, 2018.
- [11] F. García-García, P. Benito, and M. Hernando, "Automatic identification of physical activity intensity and modality from the fusion of accelerometry and heart rate data," *Methods of Information in Medicine*, vol. 55, no. 6, pp. 533–544, 2016.
- [12] F. Kara and C. Vural, "Blind restoration and resolution enhancement of images based on complex filtering," *Signal Image and Video Processing*, vol. 10, no. 6, pp. 1159–1167, 2016.
- [13] D. Wang, Z. Li, L. Cao et al., "Image fusion incorporating parameter estimation optimized Gaussian mixture model and fuzzy weighted evaluation system: a case study in time-series plantar pressure data set," *IEEE Sensors Journal*, vol. 17, no. 5, pp. 1407–1420, 2017.
- [14] M. Zhou, X. Li, Y. Wang, S. Li, Y. Ding, and W. Nie, "6G multi-source information fusion based indoor positioning via Gaussian kernel density estimation," *IEEE Internet of Things Journal*, 2020.
- [15] K. K. Rai, A. Rai, K. Dhar, J. Senthilnath, S. N. Omkar, and K. N. Ramesh, "SIFT-FANN: an efficient framework for spatio-spectral fusion of satellite images," *Journal of the Indian Society of Remote Sensing*, vol. 45, no. 1, pp. 55–65, 2017.
- [16] S. Xiong, C. Chen, F. Wang, and Y. Xia, "Dynamic detection method for rail cants based on laser camera transducers," *Zhendong yu Chongji/Journal of Vibration and Shock*, vol. 37, no. 18, pp. 251–256, 2018.
- [17] P. Wild, P. Radu, L. Chen, and J. Ferryman, "Robust multimodal face and fingerprint fusion in the presence of spoofing attacks," *Pattern Recognition*, vol. 50, no. C, pp. 17–25, 2016.
- [18] A. Verger, F. Baret, and M. Weiss, "A multisensor fusion approach to improve LAI time series," *Remote Sensing of Environment*, vol. 115, no. 10, pp. 2460–2470, 2011.
- [19] Z. Hu, J. Zhang, and Z. Guo, "Multi-sensor Ensemble Kalman filtering algorithm based on observation fuzzy support degree fusion," *Optik*, vol. 127, no. 20, pp. 8520–8529, 2016.
- [20] M. Crosetto, O. Monserrat, M. Cuevas-González, N. Devanthery, and B. Crippa, "Persistent scatterer interferometry: a review," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 115, pp. 78–89, 2016.
- [21] M. S. Sigdel, M. Sigdel, S. Dinc, I. Dinc, M. L. Pusey, and R. S. Aygun, "FocusALL: focal stacking of microscopic images using modified Harris corner response measure," *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 13, no. 2, pp. 326–340, 2016.
- [22] Q. Ge, T. Shao, Q. Yang, X. Shen, and C. Wen, "Multisensor nonlinear fusion methods based on adaptive ensemble fifth-degree iterated cubature information filter for biomechatronics," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 46, no. 7, pp. 912–925, 2016.
- [23] Y. Wang, J. Yue, Y. Dong, and Z. Hu, "Review on kernel based target tracking for autonomous driving," *Journal of Information Processing*, vol. 24, no. 1, pp. 49–63, 2016.
- [24] M. Zarei-Jalalabadi and S. M.-B. Malaek, "Motion estimation of uncooperative space objects: a case of multi-platform fusion," *Advances in Space Research*, vol. 62, no. 9, pp. 2665–2678, 2018.
- [25] N. Younes, "Islet transplantation: the quest for an ideal source," *Annals of Saudi Medicine*, vol. 28, no. 5, pp. 325–333, 2020.
- [26] C. Xing, Z. Wang, Q. Ouyang, and C. Dong, "Method based on bitonic filtering decomposition and sparse representation for fusion of infrared and visible images," *IET Image Processing*, vol. 12, no. 12, pp. 2300–2310, 2018.
- [27] R. Caballero-Aguila, A. Hermoso-Carazo, and J. Linares-Perez, "Networked distributed fusion estimation under uncertain outputs with random transmission delays, packet losses and multi-packet processing," *Signal Processing*, vol. 156, pp. 71–83, 2019.
- [28] J. Liu, Z. Tang, A. Wang, and C. Shi, "Negative obstacle detection in unstructured environment based on multiple LiDARs and compositional features," *Jiqiren/Robot*, vol. 39, no. 5, pp. 638–651, 2017.
- [29] L. V. Santana, A. S. Brandão, and M. Sarcinelli-Filho, "Navigation and cooperative control using the ar. drone quadrotor," *Journal of Intelligent & Robotic Systems*, vol. 84, no. 1-4, pp. 327–350, 2016.
- [30] Y. Guan, X. Ge, and X. Jiang, "Cluster and local mode-dependent filtering for distributed Markovian jump systems in lossy multi-sensor networks," *IET Signal Processing*, vol. 11, no. 3, pp. 295–303, 2017.