Intelligent Application of Big Data in Rail Transit

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Abstract: With the rapid development of technology, especially the widespread application of big data, cloud computing, and the Internet of Things, the rail transit industry is undergoing unprecedented transformation. It is gradually shifting from a traditional management model heavily reliant on manual operations towards a direction of intelligence and automation. This article delves into the intelligent operation system of rail transit from two aspects: train operation situation and passenger flow, analysing its significant role in enhancing operational efficiency, optimizing resource allocation, and improving service quality.

Keywords: Big Data; Rail Transit; Intelligent Operation

1. Intelligent Train Operation

Train operation control system

Modern rail transit systems universally adopt advanced Automatic Train Control (ATC) systems, comprising three subsystems: Automatic Train Protection (ATP), Automatic Train Operation (ATO), and Automatic Train Supervision (ATS). These systems include digital sensors, wireless communication networks, and other technological means to collect key parameters such as train position, speed, traction force, and braking force in real-time, ensuring safe and efficient train operation.[1]

Automatic Train Protection (ATP)

ATP is the foundation of the ATC system. Both ATO and ATS rely on the work of the ATP subsystem. The Automatic Train Protection (ATP) system, also known as the Train Overspeed Protection System, automatically brakes the train when it exceeds the specified speed. When the onboard equipment receives ground speed limit information, it compares the processed information with the actual speed. If the actual speed exceeds the speed limit, the braking system will control the train braking system to brake.

ATP automatically detects the actual running position of the train, automatically determines the maximum safe running speed of the train, continuously and uninterruptedly implements speed supervision, realizes overspeed protection, and automatically monitors the running interval of the train to ensure the realization of the specified running interval.

Automatic Train Operation (ATO)

Automatic Train Operation (ATO) is a complete closed-loop automatic control system. On the one hand, the train detects its actual running speed, and on the other hand, it continuously obtains the maximum allowable speed provided by the ground. After computation by a computer and based on other factors related to driving, such as locomotive traction characteristics, section gradients, curves, etc., the optimal driving speed is obtained, and the train is controlled to accelerate, decelerate, or even brake.

In the ATO system, the driver plays a supervisory role, so it is required that the channels for obtaining the maximum allowable speed and the locomotive computer for solving the optimal speed have higher reliability and practicability.

Automatic Train Supervision (ATS)

Automatic Train Supervision (ATS) is a complete train command system that organizes and controls train operations through computers. ATS transmits on-site train operation information to the train operation command center in a timely manner. After synthesizing the train operation information, the center issues train operation instructions to the site in a timely and accurate manner to ensure accuracy, speed, safety, and reliability.[2]

In the field of rail transit, the intelligent management of train operations is becoming crucial for enhancing operational efficiency and safety. The application of key technologies such as digital sensors, wireless communication networks, and algorithm optimization has played an important role in the intelligent operation of rail transit. By applying these key technologies, the rail transit system has undergone a transformation from manual operation to automatic control, significantly boosting operational efficiency. The departure and arrival times of trains are now more precisely controlled, leading to a notable improvement in passengers' travel experience. Furthermore, intelligent monitoring and prediction mechanisms have effectively reduced accident risks, safeguarding the lives and property of passengers.

Dynamic Scheduling Optimization

Real-time data analysis serves as the corn of the intelligent operations system, providing precise data support for the rail transit network through high-speed processing of massive amounts of real-time passenger flow data and train status information. This data encompasses critical parameters such as the precise location, speed, traction, and braking force of trains, as well as valuable insights into passenger travel habits and station passenger flow distributions, offering operators a multi-faceted decision-making foundation.

The intelligent operations system dynamically adjusts train diagrams based on real-time passenger flow data, train status, and route conditions, achieving refined scheduling of train operations. Algorithm optimization ensures that during peak hours, trains are dispatched more frequently to meet heavy passenger demand. Conversely, during off-peak periods, the frequency is reduced to conserve energy and reduce costs. During peak hours, the system effectively alleviates passenger congestion by increasing service frequencies and optimizing headways, guaranteeing a smooth travel experience for commuters. Furthermore, it ensures that trains operate along optimal routes and at the most reasonable speeds, significantly enhancing operational efficiency.

The intelligent operations system also plays an important role in emergency response such as equipment failures or weather changes. The intelligent system can swiftly activate pre-defined emergency response processes, adjusting train schedules to minimize the impact on operations and safeguard passenger safety and comfort.

2. Intelligent Management of Passenger Flow

Passenger flow forecast and analyse

The key to passenger flow forecasting lies in utilizing diversified data resources.[3] Using big data prediction to optimize scheduling decisions mainly involves adjusting train schedules and improving headways. Based on predicted passenger flow data, train schedule adjustment strategies can be employed to increase or decrease the number of trains during specific time periods, particularly during peak hours and holidays, in order to accommodate changes in passenger flow, alleviate congestion, and shorten waiting times. The optimization of headways relies on real-time passenger flow information to adjust the running time between trains, thereby meeting passenger demand while enhancing vehicle utilization. Predictive maintenance based on big data enables rail transit operators to plan the maintenance of vehicles and facilities in advance, reducing unexpected disruptions caused by failures and ensuring smooth operation. Implementing these strategies necessitates efficient data analysis capabilities and an agile scheduling system to promptly respond to and process vast amounts of real-time data.[4]

Passenger Information Service

The intelligent operation system provides passengers with information services such as real-time train arrival information, carriage congestion levels, and transfer suggestions through various channels like electronic display screens, mobile apps, and social media. This information helps passengers plan their travel routes reasonably, reduce waiting time, and enhance their travel experience. At the same time, the system can continuously optimize service content and improve service quality based on passenger feedback and behaviours.

Real-time Train Arrival Information

The passenger information service system can display real-time train arrival times, departure intervals, and other critical information, helping passengers plan their travel time reasonably and reduce waiting anxiety. Through electronic display screens, mobile apps, and other terminals, passengers can access this information anytime, anywhere, thereby improving travel efficiency.

Carriage Congestion Indication

Utilizing cameras installed in carriages and image processing technology, the system can monitor the congestion level of carriages in real-time and display this information to passengers through information distribution terminals. This feature helps passengers in making more informed decisions when selecting carriages, avoiding entering overly crowded ones, and enhancing the comfort of their ride.

Transfer Suggestions and Navigation

For passengers requiring transfers, the system can provide optimal transfer suggestions based on real-time passenger flow data and train operation status. Additionally, by integrating rail transit route maps and in-station navigation functions, the system offers detailed transfer routes and walking navigation to ensure passengers arrive at their destinations smoothly.

Passenger Feedback and Complaint Handling

The passenger information service system typically includes a passenger feedback and complaint handling module. Passengers can submit feedback or complaint information to the system through mobile apps, social media, and other channels. The system automatically records and forwards these to relevant departments for processing. This feature not only helps improve service quality but also enhances passenger engagement and satisfaction.

Weather Warnings and Special Event Notifications

The system is also capable of connecting to external data sources such as weather forecasts and special event notifications, promptly disseminating relevant information to passengers. For instance, during extreme weather or emergency situations, the system can issue early warning messages and countermeasures through various channels including announcements, electronic display screens, and mobile apps, ensuring the safety of passengers' travel.

Passenger Flow Safety Monitoring

In the rail transit system, the application of big data technology provides robust support for passenger flow safety monitoring. By collecting and analysing massive historical passenger flow data, combined with intelligent technologies such as real-time video surveillance and face recognition, the system can accurately predict and monitor passenger flow dynamics. When detecting excessively high pedestrian density in a specific area, the system can automatically trigger an early warning mechanism, promptly pushing warning information to management personnel and passengers, effectively preventing safety incidents such as overcrowding and stampedes. Furthermore, big data analysis can help operators in identifying potential safety hazards, including malicious and abnormal behaviours, providing strong support for safety management efforts. Through the in-depth application of big data technology, the efficiency and accuracy of rail transit passenger flow safety monitoring have been significantly improved, offering robust safeguards for passengers' travel safety.

3. Conclusion

Comprehensive upgrades and optimizations to the rail transit system have been achieved through intelligent management of both train operations and passenger flow. This system not only enhances operational efficiency and service quality but also promotes efficient resource allocation, energy conservation, and emission reduction. In the future, with continuous advancements in technology and the expansion of application scenarios, intelligent rail transit operations will showcase even broader development prospects and limitless possibilities.

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