[Control, Communication and Emerging Technologies in Smart Rail Systems]

Rail transport networks are now reaching an important development stage worldwide. High-speed rail transport systems have achieved significant development in Europe and Asia and are beginning to become popular in many countries. Metropolitan transport will have an increasing importance in the coming years to reduce pollution and congestion in cities. Both metropolitan and high speed railways require the use of advanced signaling and control systems to guarantee and optimize their operation. For these reasons it is necessary to use modern communication and signaling systems for the intelligent control of these railways. In addition, the railway infrastructures use many supplementary systems such as remote control, video surveillance, obstacle detection and operating aids that require the intensive use of information and communication technologies. In all cases the electrical and electronics equipment must have a high quality of service, reliability and availability to fulfill railway requirements.

The aim of this special issue is to present a collection of high-quality research papers on recent developments, current research challenges and future directions in the use of control, communications, and emerging technologies to realize smart rail systems that are safer, and more efficient. We are soliciting original contributions that have not been published and are not currently under consideration by any other journals. The topics of interest include, but are not limited to:

• Energy efficiency and sustainability of public transportation

• Rail system modeling and optimization

• Architectures, algorithms and protocols for data dissemination, processing, and aggregation for smart rail systems

• Networked information processing, decision making, and intelligent control

• Railway communications and networking

• Wireless technologies for smart rail systems

• Applications and services for smart rail systems

• Security, privacy, and dependability in smart rail systems

• Results from experimental systems, testbeds, and pilot studies

• Intelligent transportation, rail traffic modeling, decentralized congestion control

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Title: Partial Game Based Offloading Scheme for Edge Computing-Enabled Automatic Train Operation Systems

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Abstract: An automatic train operation (ATO) system is a crucial part of CBTC systems. It enables the calculation and adjustment of trains operation curve, which guarantees the efficient operation of urban rail transits. With the limited computation resources, the present on-board ATO equipment cannot meet the latency-critical requirements of train travel curve calculation. Edge computing is considered as a promising approach to improve calculation capabilities for computation resource-constrained devices. This paper proposes a game-theoretic method for achieving efficient computation offloading for edge computing. We formulate the offloading decision of multiple trains as a multi-user partial offloading game. An optimal computation offloading scheme is obtained when multiple trains achieve a Nash equilibrium as game players. The simulation results demonstrate the effectiveness of our proposed method.

Title: An Edge Computing-Enabled Train Obstacle Detection Method Based on Adjusted YOLO Model

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Abstract: Rail transit is developing towards intelligence, but physical devices do not have sufficient computing power to perform deep learning tasks. At present, this problem is mainly solved through cloud computing, but the traditional cloud computing architecture cannot solve the problem of high transmission delay and heavy bandwidth usage, and thus failed to complete massive computing intensive tasks. Edge computing(EC) as an extension of cloud computing, it can reduce the pressure of cloud by offloading workloads to edge nodes. In our hierarchical architecture, edge is responsible for training model, and the devices on fast moving train are in charge of inference to detect the obstacles beside the track. In the usage of model, we have designed a fine-tuned YOLO model, and it can trade off better between real-time and accuracy on object detection than two-stage model, like R-CNN、Fast R-CNN、Faster R-CNN. To adapt to the edge collaboration scenario and emergency interruptions events, this paper proposes a method of cutting model. Each sub-model after cutting can inherit task progress by inputting with feature map of previous sub-model.

Title: A Bert Based Deep Learning Method for Data Communication System Failure Classification

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Abstract: Communication-based train control(CBTC) systems are automated train control systems based on continuous and bidirectional train-ground communications. Data Communication

System(DCS) is one of the key subsystems in CBTC. As one of the key subsystems in CBTC, DCS is also a valuable part of CBTC, since it is physically exposed to the environment. Certain DCS failures can have a severe negative impact on the operation of CBTC system, and may even cause catastrophic loss of lives or assets in urban rail transit system. Therefore, it is quite desirable to identify the DCS failures and take effective maintenance measures to fix it. Most existing works related to system failure classification are based on regular machine learning techniques, such as Decision Tree, Bayesian Network, etc. Substantial feature information is lost using these models when we extract features from the system logs manually. In is paper, we take a pre-trained Chinese Bidirectional Encoder Representation from Transformers (BERT) deep learning model to classify the DCS failure. The original Chinese pre-trained Bert model can capture the Chinese character-level representation by Masked Language Model (MLM), which contains significant system features for failure classification. To further improve the classification accuracy, we fine-tuned the original Chinese pre-trained Bert model using the raw DCS Chinese system logs. We compare the vocab list made for this task with the original vocab list, and choose the correct value for significant parameters. Simulation results illustrates that the fine-tuned training model achieve substantial accuracy improvement compared with the traditional machine learning techniques. Our study highlights the importance of the deep-learning models in DCS failure classification tasks, and proves it to be possible to open up new ideas for future DCS failure prediction tasks.

Title: Metro train scheduling optimization for virtual coupling based train control
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Abstract: With the development of China's economy and the increasing trend of urbanization, the pressure of urban rail transit is also increasing, and the capacity of the existing CBTC system has become saturated. In this paper, passenger flow forecasts are made for tidal and unexpected passenger flows, and the results are used to optimize the virtual formation of multiple trains and the shift change of trains. A mixed integer linear programming model (MILP) is proposed in order to achieve a balance between train utilization, train dwell time and passenger waiting time. The model is then solved using the CPLEX solver, and a good train schedule is generated based on the optimal solution. Finally, the validity of the model is verified based on numerical experiments of actual operation.

Title: Deep Reinforcement Learning Based Cloud Computing Resource Allocation for Rail Transit Business
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Abstract: Cloud computing allows customers to dynamically adjust resource usage based on their own needs, which has been widely used in most industries. In the urban rail transit industry, transplanting the rail transit business to the cloud can effectively solve the problem of data sharing and excessive loads among various subsystems. Yet, how to allocate computing resources to each urban rail transit business reasonably to guarantee Quality of Service (QoS) is a critical problem that needs to be studied. Traditional computing resource allocation methods are mostly manual policies, such as the most direct on-demand allocation method and the threshold-based allocation method. The former one is proved tricky to fully consider the limit of the total number of resources. And setting an appropriate resource threshold for each business is hard for the latter method. As an automated

decision-making method, reinforcement learning (RL) has been applied to solve the problem of resource allocation. However, a complete cloud resource allocation scene usually has high dimensions in the state spaces and action spaces. In this case, deep reinforcement learning (DRL), which interacts with the environment, explores and exploits the feedback from the environment to learn a maximum reward is a more suitable choice. In this paper, we use the Deep Q-Network to solve the cloud computing resource allocation problem in the rail transit business. Several business scenarios in the Communication-Based Train Control (CBTC) system and have been selected to simulate the cloud environment. And some rail transit businesses scene that may be placed in the cloud in the future have also been considered. Finally, we simulated both the manual policies-based and the DQN-based resource allocation methods. The simulation results show that the DQN-based resource allocation method can better satisfy the punctuality and safety of rail transit business to guarantee QoS.

Title: Evaluating Regional Rail Transit Safety: A Data-driven Approach*

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Abstract: Regional rail transit managers must have accurate and comprehensive assessments of regional rail transit system safety status, to grasp the change of safety status in the operation process of multi-system rail transit, and reasonably allocate transport capacity and operation and maintenance resources. A data-driven model for regional rail transit system safety evaluation is proposed in this study. The deep autoencoder networks were used to reduce the dimensions of evaluation index system constructed from the perspective of "human-machine-environment-management." The set of all possible safety status of the regional rail transit system was obtained using the hybrid hierarchical k-means clustering method. The tree-augmented naïve Bayes algorithm was employed to obtain the safety status index (SSI) and evaluate overall safety of the regional rail transit system. This method can be used to evaluate objects at different levels, such as a regional rail network, lines, sections, etc. With an evaluation of the whole system or a single index, risk control measures can be enacted appropriately. Using actual operations data from a regional urban metropolis in China, the validity and practicality of the model were verified. The comparison with the actual situation verifies that the proposed model can evaluate the safety status of the network effectively and comprehensively.

Title: Deep Spatio-Temporal Network Modeling and Forecasting of Passenger Volume for Regional Rail Transit

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Abstract: Passenger volume forecasting is an important basis for the planning, rescheduling, and dispatching of rail transit. In this study, we proposed and derived a sparse spatio-temporal residual network (OD-SparseSTnet) to forecast the origin-destination (OD) passenger volume of a region-wide rail transit network. In OD-SparseSTnet, the OD-ResUnit, Simp-SeqUnit, and non-zero attention mechanism were designed to improve the ability of the model to describe the complex spatio-temporal dependency and sparse distribution characteristics of OD passenger volume. Using a case study of the Chongqing Rail Transit, China, the proposed OD-SparseSTnet model shows a good prediction accuracy, reducing the forecast error by 14% at least compared with the traditional spatial model (CNN3), time series model (ARIMA, RNN, and LSTM), and spatio-temporal model (DeepST and ST-ResNet) types.

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