1st Japan-China Symposium on Railway Technology

8-9 August 2024

Surugadai campus, College of Science and Technology, Nihon University
Tower Scola / Room S101

Proceedings

1st Japan-China Symposium on Railway Technology

8-9 August 2024, Tokyo, Japan

8 AUG (Tower Scola / Room S101)

09:30 - 09:40	Opening Remarks	Professor Hitoshi TSUNASHIMA (Nihon University) Professor Tomoyuki TODOROKI (Nihon University)
09:45 - 10:45	Keynote Speech 1 Chair: H. TSUNASHIMA	Professor Mingli WU (Beijing Jiaotong University) Resent research development of traction power supply of electric railway in China
10:45 - 11:00	Short Break	
11:00 - 11:20	Electrical System 1 Chairs: K. KONDO M. WU	Recent Trends in Automatic Train Operation Technology in Japan Takafumi KOSEKI (The University of Tokyo)
11:20 - 11:40		Study on the Application of Wayside Supercapacitor Energy Recovery Systems in Urban Rail Transit Zhongping YANG (Beijing Jiaotong University)
11:40 - 12:00		Research Trends on Energy-efficient Operation Technologies for Electric Railways in Japan Masafumi MIYATAKE (Sophia University)
12:00 - 13:00	Lunch	
13:00 - 13:20	Invited Speech Chairs: A. MATSUMOTO J. XU	Evolution of Railway Development and Operation Schemes in Japan Yoichi KANAYAMA (University of Toyama)
13:20 - 13:40	Civil Engineering	Drone-based Observation and Monitoring of Railway Infrastructure Threats Zhipeng WANG (Beijing Jiaotong University)
13:40 - 14:00		Study on the Market Demand and Development Trend of High-speed Railway Express Logistics in China Ke QIAO (Beijing Jiaotong University)
14:00 - 14:15	Short Break	
14:15 - 14:35	Electrical System 2 Chairs: T. KOSEKI J. KANG	Intelligent Health Management of Railway Point Machines Yuan CAO (Beijing Jiaotong University)
14:35 - 14:55		Recent Trends in Vehicle Traction System and Energy Storage Application Technologies Hiroyasu KOBAYASHI (Chiba University)
14:55 - 15:15		Analysis and Suppression Strategies of Thrust Fluctuations in High-Speed Maglev Linear Synchronous Motor Jinsong KANG (Tongji University)
15:15 - 15:35		Fault diagnosis of traction power supply system based on artificial intelligence Fulin ZHOU (Southwest Jiaotong University)
15:35 - 15:50	Short Break	
15:50 - 17:20	Shotgun Session	(Tower Scola / Room S204)
17:20 - 17:30	Closing Remarks	Photo session
17:30 - 18:00	Short Break	
18:00 - 19:30	Reception	(Building 1 / 2F Cafeteria)

9 AUG (Tower Scola / Room S101)

09:30 - 09:40	Opening Remarks	Professor Sei TAKAHASHI (Nihon University)
09:45 - 10:45	Keynote Speech 2 Chair: Z. YANG	Professor Hitoshi TSUNASHIMA (Nihon University) Current Status of Research and Education on Railway-related Technology at Japanese Universities of Science and Technology Professor Akira MATSUMOTO (Nihon University) Japanese Approach to Railway Accident Investigation and Past Experience
10:45 - 11:00	Short Break	
11:00 - 11:20	Operation and Signaling 1 Chairs: N. TOMII B. CAI	Dependable Train Positioning by Fusing Multiple Sensors Information Baigen CAI (Beijing Jiaotong University)
11:20 - 11:40		Transition of Fail-safe technology - From Fail-safe circuits to Fail-safe technology on Complex Systems - Hideo NAKAMURA (Nihon University)
11:40 - 12:00		Research and Applications of Rail Transit Safety Assurance and Intelligence Xinhong HEI (Xi'an University of Technology)
12:00 - 13:00	Lunch	
13:00 - 13:20	Operation and Signaling 2 Chairs: H. NAKAMURA X. WANG	Impact of COVID-19 on Train Operation in Japan Norio TOMII (Tokyo Tech / Nihon University)
13:20 - 13:40		Communication and signal processing technologies for advanced railway signaling systems Hiroshi MOCHIZUKI (Nihon University)
13:40 - 14:00	Mechanical System 1 Chairs: H. NAKAMURA X. WANG	Construction and Development of a Safety Assessment Center: From the Perspective of AI Safety Assurance Wei ZHENG (Beijing Jiaotong University)
14:00 - 14:20		Recent Technology on Steering Bogie in Japan Yohei MICHITSUJI (Ibaraki University)
14:20 - 14:35	Short Break	
14:35 - 14:55	Mechanical System 2 Chairs: Y. MICHITSUJI W. ZHENG	Rolling contact performance testing techniques for forward design and maintenance of roller bearings Xi WANG (Beijing Jiaotong University)
14:55 - 15:15		Wheel Profile Optimization Considering Rail Wear on Curved Sections Masahiko AKI (Nihon University)
15:15 - 15:35		Research on the dynamic theory, methods, and applications of the wheel-rail system in high-speed railway turnout Jingmang XU (Southwest Jiaotong University)
15:35 - 15:50	Short Break	
15:50 - 17:20	Shotgun Session	(Tower Scola / Room S204)
17:20 - 17:30	Closing Remarks	Professor Zhongping YANG (Beijing Jiaotong University)

Shotgun Session (Tower Scola / Room S204)

8 AUG (15:50 - 17:20) Chair: M. AKI

ST-1	Origin-Destination Estimation Method for Regional Trains Using Bluetooth Observation Data Masato NISHIWAKI (Nihon University)
ST-2	Establishment and application of load spectrum for high-speed train bogie frame Chengxiang JI (Beijing Jiaotong University)
ST-3	Railroad Level Crossing Using Mobile Phone Lines and Level Crossing Passage Assistance System for Road Vehicles Koki NAKAYAMA (Institute of Industrial Science, the University of Tokyo)
ST-4	Exploration of regenerative braking energy utilisation within the electrified railways Liran WU (Beijing Jiaotong University)
ST-5	Basic Proposal for Predicting Train Delay Time Using LSTM Keiji KATO (Nihon University)
ST-6	A Combined Experimental and Analytical Method to Determine the EHL Friction Force Distribution between Rollers and Outer Raceway in a Cylindrical Roller Bearing Yu HOU (Beijing Jiaotong University)
ST-7	Optimization of energy-saving operation of urban railway considering the use of regenerative braking energy Xuanlang MENG (The University of Tokyo)
ST-8	AI Safety Validation via Diverse Testing and Uncertainty Quantification Rui WANG (Beijing Jiaotong University)
ST-9	Fast and Scalable Optimization of Energy-Efficient Train Trajectory by Parallel Dynamic Programming Keisuke SAKAI(The University of Tokyo)
ST-10	Research on the Recognition Method of Internal Rail Defects in Heavy-Haul Railways Based on Deep Learning Yongkui SUN (Beijing Jiaotong University)
ST-11	Study on the mechanism of wheelset angular velocity change on curved tracks Yuzuki ENDO (Ibaraki University)
ST-12	Efficient dual-stream fusion network for real-time railway scene understanding Zhiwei CAO (Beijing Jiaotong University)
ST-13	Measurement experiment with scale model wheel and rail for longitudinal and lateral creep force Tomoyuki SUZUKI (Meisei University)
ST-14	Energy Management Strategy Based on Train Status Perception Yan LI (Beijing Jiaotong University)
ST-15	Impact Analysis of Equivalent Electrical Models for Supercapacitor Energy Storage Systems in Urban Rail Transit Hailiang ZHANG (Beijing Jiaotong University)
ST-16	Integrated Optimization Approach for Train Timetable Rescheduling and Passenger Reassignment under Disruptions in China's High-Speed Railway Pengcheng WEN (Beijing Jiaotong University)

9 AUG (15:50 - 17:20) Chair: T. MATSUMURA

SF-1	Proposal of onboard train localization method based on surrounding structure identification Kensuke NAGAI(The University of Tokyo)
SF-2	Study on Chinese High-speed Railway Rolling Stock Planning Jiaxin NIU (Beijing Jiaotong University)
SF-3	Optimization of the Tilt Control Pattern Considering the Air Insufficiency on Many Curves in Air Spring Car-Body Tilting Control System Hiroya FUJII (Nihon University)
SF-4	Black-box Adversarial Test Generation and Prioritization for Deep Neural Networks Tao HUANG (Beijing Jiaotong University)
SF-5	Improvement methods of transmission characteristics for railway signaling systems using FFT and development of a FPGA-based processing unit Takuto SUZUKI (Nihon University)
SF-6	Model Predictive Thrust Force Control for 3L-NPC Fed Linear Synchronous Motor of Maglev Train Hao DING (Tongji University)
SF-7	Proposal of train control system on commercial cloud services Koudai FUKUDA (Nihon University)
SF-8	Energy Management Strategy Based on Reinforcement Learning and Frequency Decoupling for Fuel Cell Hybrid Powertrain Hongzhe LI (Tongji University)
SF-9	Smart level crossing controller with train moving direction detection function and hardware development using embedded devices Haruki ARAIE (Nihon University)
SF-10	An Intelligent BIM Approach to Foster Rail Bridge Design Zhaoxi MA (Xi'an University of Technology)
SF-11	Track condition management based on in-service vehicle vibration Takuya NAKANO (Nihon University)
SF-12	A Fault Diagnosis Method for Railway Turnout Systems Based on Improved Autoencoder and Data Augmentation Mengyang LI (Xi'an University of Technology)
SF-13	Analysis of Braking Patterns Considering Delays in Moving Block Systems Using Simulation Shunichi SATO (Nihon University)
SF-14	A robust multi-objective optimization framework for rail profiles considering uncertainty Jun LAI (Southwest Jiaotong University)
SF-15	Faults and Disturbances Identification in Co-Phase Power Supply System Bingxu ZHU (Southwest Jiaotong University)
SF-16	Analysis of Low Frequency Oscillation in Co-phase Power S0upply Systems Feifan LIU (Southwest Jiaotong University)
SF-17	Study on the mechanism of fatigue crack initiation in rail steels considering crystalline plasticity at micro-nano scale Kai WANG (Southwest Jiaotong University)

Keynote Speech

Resent Research Development of Traction Power Supply of Electric Railway in China

Mingli Wu
Beijing Jiaotong University

With the operating kilometrage of electric railway up to 110,000km, on the Chinese mainland, many researches on traction power supply have been conducted resent years. These researches, on the whole, can be classified into two categories. (1) Intelligent power supply: such as the smart traction substation, simplification and unification of OCS, 6C systems for OCS monitoring, automatic passing phase insulator based on power electronic devices. (2) Green power supply: such as transformers with wound core, co-phase traction power supply, storage utilization of regenerative energy, renewable energy for traction usage. This speech will give a brief introduction to these researches.

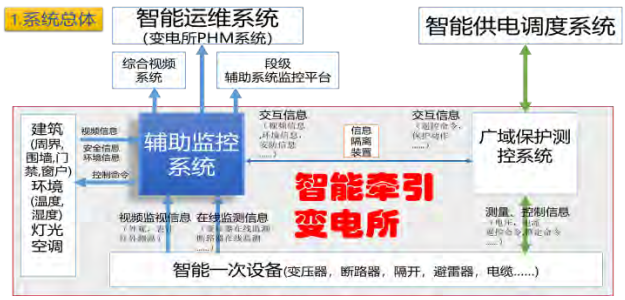


Fig.1 Structure of Intelligent power supply

Fig.2 PV connected into traction power supply

Current Status of Research and Education on Railway-related Technology at Japanese Universities of Science and Technology

Hitoshi Tsunashima [1]

[1] Center for Railway Research, College of Industrial Technology, Nihon University

Research and education on railway technology in Japanese universities is conducted mainly in the departments of civil, electrical, and mechanical engineering. Major activities at universities include the University of Tokyo, Institute of Industrial Science, which has a railway test line at Kashiwa campus, and Kogakuin University, which continues to offer off-campus lectures on railways as an open college. Nihon University, College of Industrial Technology, established the Center for Railway Research in 2017 and is promoting joint research with other universities and the private sector. The table 1 shows major universities that conduct research and other activities related to railways and their research fields.

NU-Rail was first held in 2008 under the leadership of the College of Science and Engineering and the College of Industrial Engineering of Nihon University, and has since been joined by many universities, including Niigata University, the University of Tokyo, Chiba University, Chiba Institute of Technology, and Kogakuin University. The event has been held annually as a forum for inter-university research exchange under the name NU: Network of Universities.

Table 1. Major universities and their main research fields.

University	Mechanical	Electorical	Civil	Main Research Fields
Nihon University, CIT	○			Center for Railway Research, condition monitoring of track, wheels, and rails, automatic generation of train schedules
Nihon University, CST	○	○		Signaling, train control, vehicle dynamics
The University of Tokyo	○			Experimental field, bogie, vehicle, automatic operation, monitoring
The University of Tokyo		○		Vehicles, operation, linear motors
Sophia University	○	○		Vehicle dynamics, wheels and rails, energy management
Ibaraki University	○			Vehicle dynamics, wheels and rails
Niigata University			○	Railway track mechanics
Kogakuin University		○		Railway lectures, electric drive, train control
Chiba Institute of Technology	○			Wheels and rails
Waseda University		○		Electric mobility, power electronics
Meijo University	○			Vehicle motion, derailment, vehicle shape, aerodynamics
Osaka Sangyo University	○			Vehicle dynamics, vibration
National Defense Academy of Japan	○			Vehicle dynamics
Shibaura Institute of Technology			○	Transportation planning
Toyama University			○	Railway development system, financial resources, and train schedules
Kyoto University			○	Transportation planning, train scheduling
Tokai University	○			Vehicle dynamics, railway materials, welding technology, vibration and noise

Japanese Approach to Railway Accident Investigation and Past Experience

Akira Matsumoto
Center for Railway Research, College of Industrial Technology, Nihon University

The first national agency for accident investigation of transportation systems in Japan was established in 1974 as a national agency for aviation in accordance with the ICAO convention. The agency of railway accidents was established 27 years later, in 2001, following serious accidents on Shigaraki and Hibiya lines. Then, in 2008, the Japanese Transportation Safety Board (JTSB) was established, integrating the maritime sector, in response to the Fukuchiyama Line accident and the frequent occurrence of aviation incidents (Fig.1).

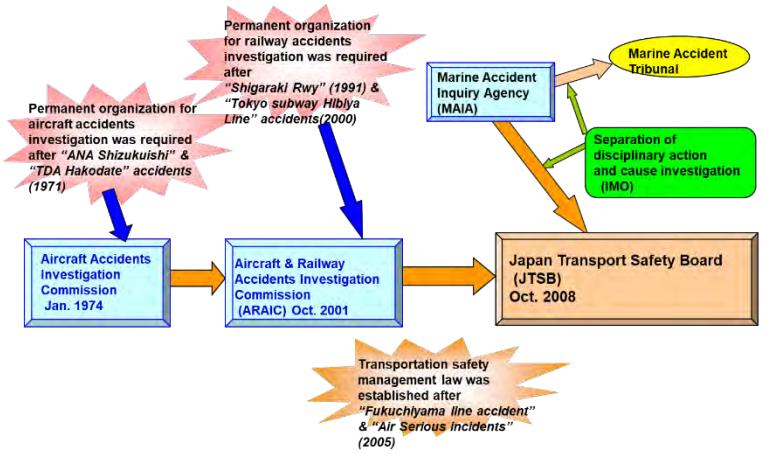


Fig.1. History of accident investigation organizations in Japan and the accidents that lead to these establishment. -from "aircraft only" to JTB for land, sea and air-

The JTSB is empowered by the national law to conduct independently accident investigations, including the right of entry.

Of course, even before the establishment of the Accident Investigation Agency, people involved in Japanese railways had been making efforts improve safety measures and enhance safety by learning from accidents.

Figure 2 shows a 60-year genealogical chart of major serious accidents on Japanese railway and advances in safety technologies in various fields that have been learned from these accidents. The starting point for R&D of signals, i.e. ATS, was mikawashima (1962), and for running system, Tsurumi (1963).

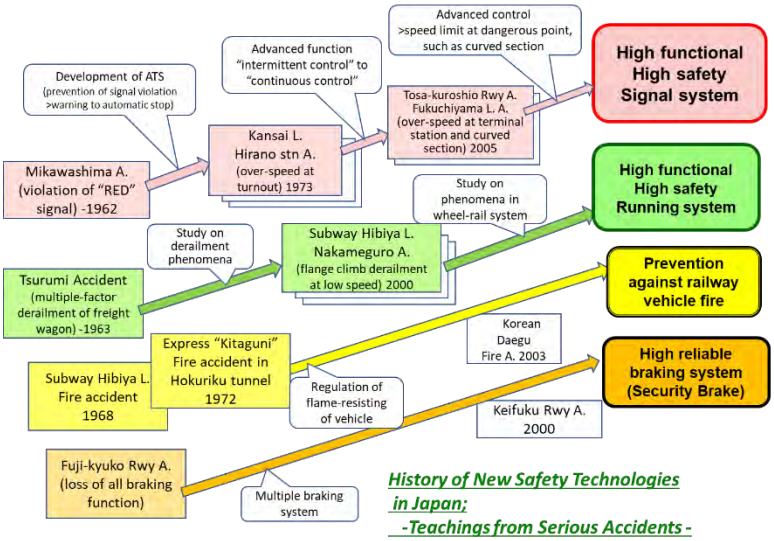


Fig.2. History of new safety technologies in Japanese railways; teaching from serious accidents; signaling system, vehicle running system, fire suppression and braking system.

General Lecture
Invited Speech

Recent Trends in Automatic Train Operation Technology in Japan

Takafumi Koseki
Dept. EEIS, School of Engineering, The University of Tokyo, Japan

The implementation of automatic train operation in Japan has been significantly slower than in other countries, including China. In September 2022, the Study Group on Automatic Train Operation Technology for Railways, established by the Ministry of Land, Infrastructure, Transport and Tourism of Japan, published a report that provides guidance for railway operators on the development of automatic train operation technology and the practical implementation of automated train operation in the medium to long term. Moreover, in March 2024, the Railway Bureau of the Ministry of Land, Infrastructure, Transport and Tourism formally amended the technical standards for the implementation of driverless operation.

The following ideas represent the fundamental approach to ensuring safety on conventional railways with drivers, which represents the principle of "non-worse than status quo."

(1) The safety of trains is ensured by ground- and on-board equipment, including automatic train protection. (2) External disturbances are responded to by physical protection, such as protective fences and platform fences. (3) Entry to the railroad by people and other objects is prevented by legal prohibitive measures. (4) Furthermore, abnormal events, such as natural disasters, are addressed in advance and systematically through measures such as advance notification to the driver, driving restrictions, speed limits, and planned service cancellations. And (5) facilities and equipment such as vehicles have been strictly managed in accordance with legal regulations on structure and maintenance.

Although train drivers are undoubtedly an essential component of the safety system, it is notable that the legal obligation of drivers to detect obstacles on the tracks and avoid danger is not explicitly outlined in present railway regulations. It is evident that the on-board sensor system is not the optimal solution for ensuring safety by monitoring obstacles in front of the train and avoiding the risk of collision. In other words, the comprehensive measures outlined above (1)-(5) can ensure safety, even in driverless automatic operation. This will avoid extreme increases in vehicle and ground equipment investment costs.

It is evident that the technological studies conducted in Japan appear to be relatively conservative in comparison to those undertaken in China and other countries. However, the introduction of automatic train operation has been challenging for Japanese railways, which are required to provide affordable and sustainable services as a mass passenger public transport system operated by private companies that are subject to stringent safety requirements and significant social responsibility.

Study on the Application of Wayside Supercapacitor Energy Recovery Systems in Urban Rail Transit

Zhongping Yang
Beijing Jiaotong University

With the rapid development of energy storage component technologies such as supercapacitors, lithium-ion batteries, and flywheels, energy storage technology is increasingly widely used in China's urban rail transit. Regarding the wayside storage systems, this speech first introduces the development history and application status of energy storage technology in urban rail transit in China. Secondly, summarize the research results on the system design and evaluation methods, energy management strategies, and energy storage device design of wayside supercapacitor regenerative braking energy absorption and utilization systems in China in recent years. Based on these research results, the 1.5MW supercapacitor energy storage system developed by the speaker's research team has been successfully applied in 9 substations along the Beijing Subway Batong Line. Finally, introduce the application effect of energy storage systems in the Batong Line and future research topics.

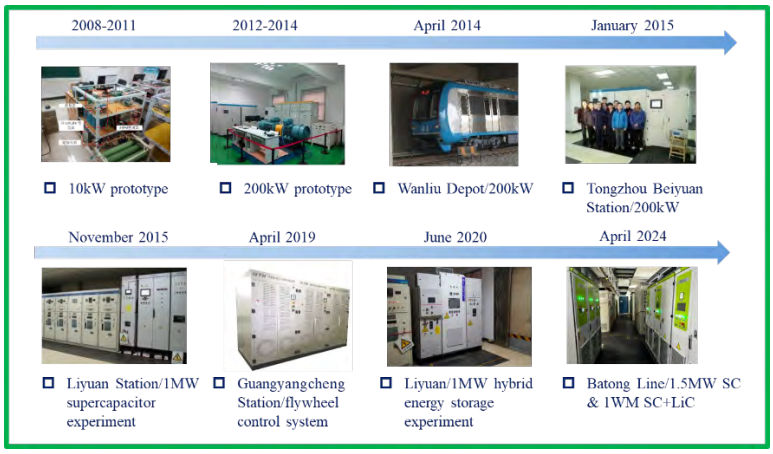


Fig.1. The R&D process of the WESS in Yang Laboratory.

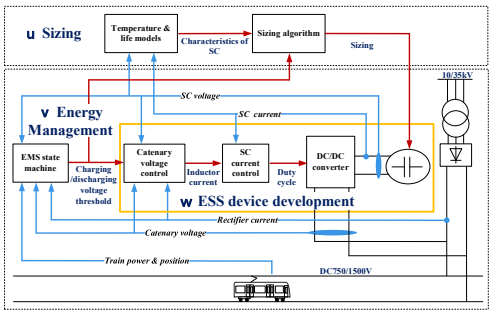


Fig.2. The main research topics of WESS.

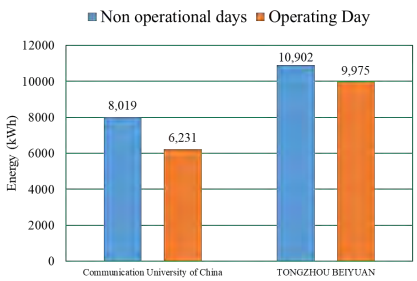


Fig.3. Energy saving effect of WESS on Batong Line.

Research Trends on Energy-efficient Operation Technologies for Electric Railways in Japan

Masafumi Miyatake[1]
[1]Sophia University

Time as well as energy must be managed properly in order to achieve high energy efficiency in railway operations. The running time at each interstation has a supplement for delay recovery. The utilization of the running time supplement (RTS) enables saving energy as the energy consumption can be formulated as a function of the running time as $W_k(T)$ illustrated in Fig. 1. We introduce some methodologies for EE railway operation by RTS.

EE driving shifts the curve of $W_k(T)$ downwards as in Fig. 1. We developed the method of train trajectory optimization based on dynamic programming under the scheduled running time[1]. Recently, we have applied it to various tracks with long distances and complicated profiles under signaling systems and characteristics of DC/AC electrification.

EE timetabling involves optimal assigning RTSs to each interstation. For an energy-optimal timetable, we proposed the law of identical incremental energy consumption[2] as depicted in Fig. 2. We have considered regenerative energy utilization and passenger services. We have also applied it to timetables for battery-powered trains with optimal charging facility locations.

References

[1] M. Miyatake, H. Ko, Optimization of Train Speed Profile for Minimum Energy Consumption, IEEJ Transactions on Electrical and Electronic Engineering, Vol. 5, No. 3, pp.263-269, 2010.
[2] M. Miyatake, A Simple Mathematical Model for Energy-saving Train Scheduling, IEEJ Transactions on Industry Applications, Vol. 131, No.6, pp.860-861, 2011. (in Japanese)

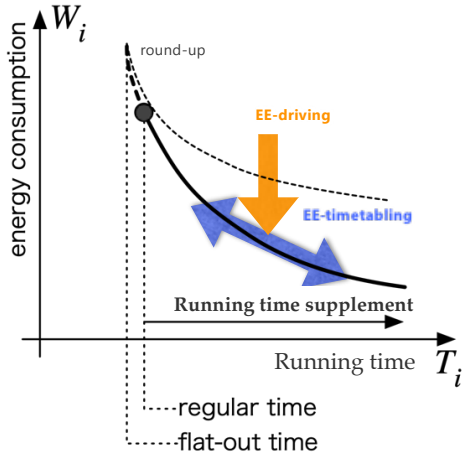


Fig.1. More energy-efficient train operation.

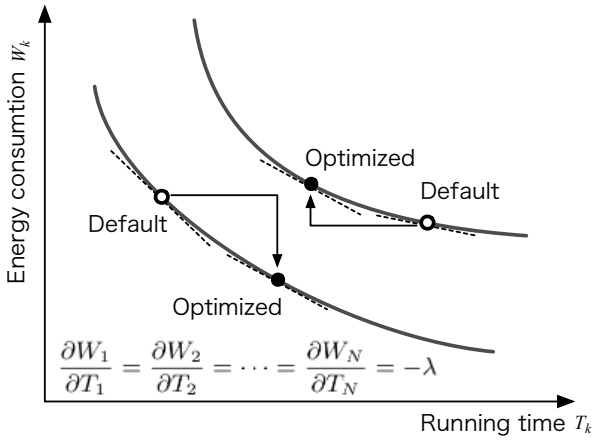


Fig.2. Law of identical incremental energy consumption.

Evolution of railway development and operation schemes in Japan

Yoichi Kanayama[1]
[1]University of Toyama, JTTRI

1. Japan's railways began with the government's construction on October 14, 1872, when the Shinbashi-Yokohama section opened.
2. Railway construction by the government and JNR (1949-). Since 1964, railway construction has also been carried out by the Japan Railway Construction Public Corporation.
3. In 1987, the Japan National Railways was divided and privatized. The Japan Railway Construction Public Corporation was retained, leading to the introduction of vertical separation in the construction of the Shinkansen.

(Private railways)

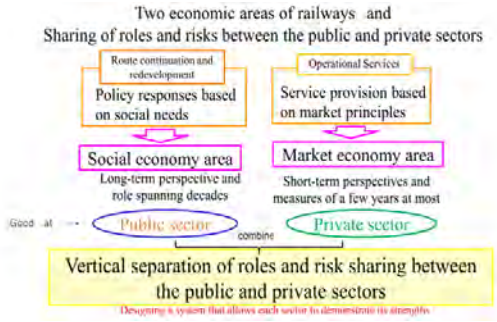
4. The birth of private railways (1881).
   Railway construction and urban development by railway operators in cities.
   The success of the Kobayashi Ichizo model since the early 1990s.
5. Around 1970, the interest subsidy system for construction by private railways (private railway line method) and the introduction of a railway construction method by the third sector funded by local governments were introduced.
6. Railway development through interest-free loans and urban development under the Special Measures Law (1989).

(Introduction of a versatile railway development scheme (common to JR and private railways)

7. Introduction of vertical separation (Act on Promotion of Urban Railway Convenience, etc. enacted in 2005)

（Overall summary）

8. Japan's railway development and operation scheme has evolved from a private or public approach to a public-private mixed partnership, and then to a public-private role sharing partnership. In other words, it has evolved with the development of PPP (public private partnership). Urban development along railway lines has been mainly carried out by the private and public sectors (urban municipalities) that are the players in the development or operation.



Drone-based Observation and Monitoring of Railway Infrastructure Threats

Zhipeng Wang
State Key Laboratory of Advanced Rail Autonomous Operation, Beijing Jiaotong University

This report introduces a railway infrastructure unmanned aerial vehicle intelligent inspection and analysis system.

This system covers four major specialties: railway engineering, power supply, electrical services, and environment. It realizes the analysis of railway lines and surrounding environmental scenarios at the airborne end, and can independently and parallelly inspect multiple specialties of power supply and engineering. And it can provide comprehensive flight management, route management, intelligent analysis, defect review, and statistical reporting functions.

Based on the intelligent detection of unmanned aerial vehicles, various image detection models have been studied for different inspection targets in different professions, achieving the detection of infrastructure defects in various railway specialties. And combined with LiDAR, a semantic segmentation method for railway infrastructure point cloud was studied, which can achieve high-precision static geometric parameter measurement of contact lines and fine-grained segmentation of railway key infrastructure during operation.

The intelligent inspection and analysis system for railway infrastructure unmanned aerial vehicles has rich application cases in China, which can solve industry pain points with all-weather, high-precision, wide field of view, and efficient mobility, and provide support for the rail transit system.

Study on the Market Demand and Development Trend of High-speed Railway Express Logistics in China

Ke QIAO[1], Jiaxin NIU[1]
[1]School of traffic and transportation, Beijing Jiaotong University, Beijing, China

With the growth of e-commerce and the demand for express delivery, high-speed rail express is developing rapidly in China. The principal objective of this study is to forecast the potential market demand for high-speed rail express, to demonstrate the feasibility of large-scale development of high-speed rail express, and to propose key technological solutions for freight EMU trains under conditions of large-scale development. Firstly, an exhaustive analysis of the present state of China's express delivery market was presented and the operation mode of high-speed rail express was analyzed. Subsequently, the timeliness and category positioning of high-speed rail express in the express market were proposed. A three-stage prediction method has been constructed for the OD flow of high-speed rail express based on the relevant theory of demand forecasting, and the demand for express freight between major city nodes has been calculated. The results indicate that the utilization of a dedicated high-speed freight train on the main corridor is a viable proposition. Finally, the technical requirements of the freight EMUs in terms of loading and unloading, fixing, handling and in-transit management were discussed, based on the characteristics of express cargo and the process of high-speed rail express. In accordance with the stipulated requirements, the principal technical solutions pertaining to the freight EMUs were devised, encompassing the standard container equipment programme, the virtual stowage overall programme, the convenient loading and unloading system overall programme, the cargo data management system, and so forth. The rationality and feasibility of the aforementioned programme were then subjected to a verification process. The results demonstrate that there is a substantial market potential for high-time-sensitive transport demand, which can satisfy the demand for mainline transport between major node cities. By enhancing the technical capabilities of freight EMUs, it can facilitate the promotion and expansion of high-speed rail express operations.

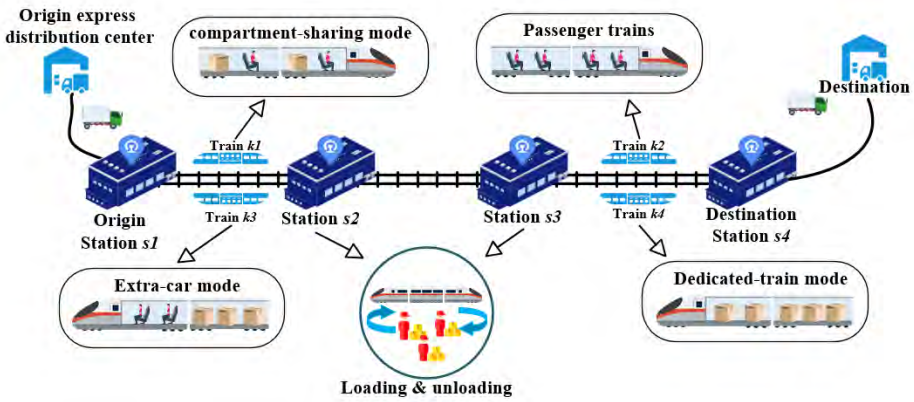


Fig.1. Operation mode of high-speed rail express.

Intelligent Health Management of Railway Point Machines

Yuan Cao
Beijing Jiaotong University

Railway point machines are the key equipment that controls the train route and affects the safety of train operation. Complex and harsh working environments lead to frequent failures, accounting for 40% of the total failures of the railway signaling system. Thus, it is an urgent task to present an intelligent fault diagnosis approach

This topic mainly contains the following parts:

- Introduction of Turnout;
- Common fault types of railway point machines;
- Investigation of existing condition monitoring systems of turnout;
- Some state of art research on health management algorithms;
- Some related research results of our team on health management of railway point machines: mainly including a) the application of new sensors, such as audio sensor, acceleration sensor; b) fault diagnosis under small samples; c) Application of the third generation neural network – spiking neural network in fault diagnosis; d) Application of digital twin in fault diagnosis; e) Remaining useful life prediction; f) Fault diagnosis and health management platform for railway point machine.

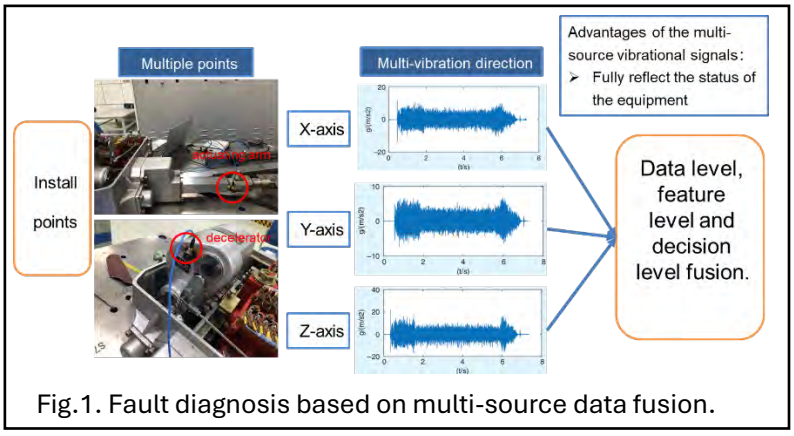


Fig.1. Fault diagnosis based on multi-source data fusion.

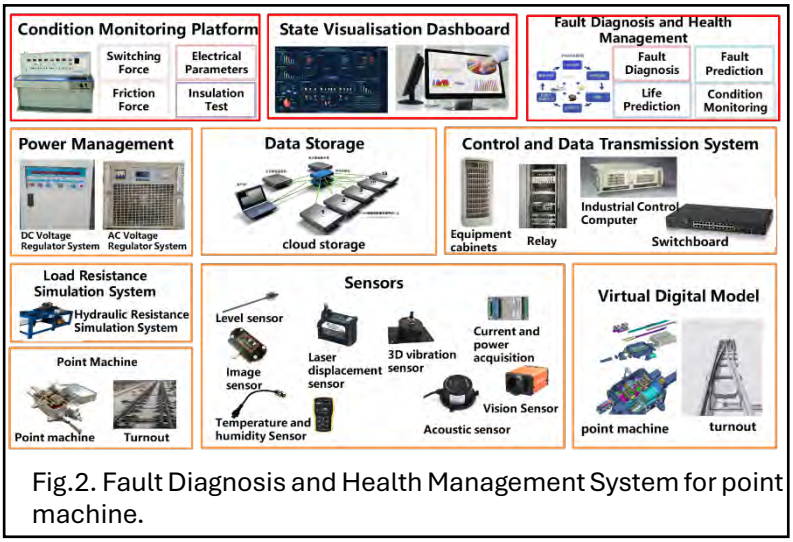


Fig.2. Fault Diagnosis and Health Management System for point machine.

Recent Trends in Vehicle Traction System and Energy Storage Application Technologies

Hiroyasu Kobayashi[1]
[1]Chiba University

For the realization of energy-saving railways, it is important to develop rail vehicle traction systems and effectively utilize Energy Storage Devices (ESDs). In DC-electrified railways, regenerative brake control is one of the crucial traction technologies for energy saving. Fig. 1 shows the traction circuit of railway vehicle and typical configuration of regenerative brake control system. The regenerative brake power must be consumed by the other powering train because the diode rectifier is generally utilized in substations. Therefore, motor torque control according to input voltage of traction inverter is commonly applied to railway vehicle for the purpose of control of regenerative power corresponding to load power. It is effective to keep higher Filter Capacitor (FC) voltage v_{creg} for the increase of regenerative power considering voltage drop of feeder resistance between regenerating train and powering train. However, ACR of the motor current, which is assumed as an one-order delay, is placed in the inner loop of the regenerative brake controller. Therefore, excessive k_p makes the control system unstable since k_p equals to the feedback gain of the control system. In recent year, a novel control, which utilizes feed-forward control, is also developed.

ESD application is spreading as a measure for energy saving in DC railways. Fig. 2 shows one of the typical control strategies of wayside ESDs. As shown in Fig. 2, Charge/Discharge current i_{ess} is controlled according to v_p, which is the voltage at the connecting point to feeder system, and the state of charge (SOC). If v_p stays the middle section, charge or discharge is determined according to SOC level. Recently, new control strategies utilizing AI technology or real-time information in feeder system have been proposed.

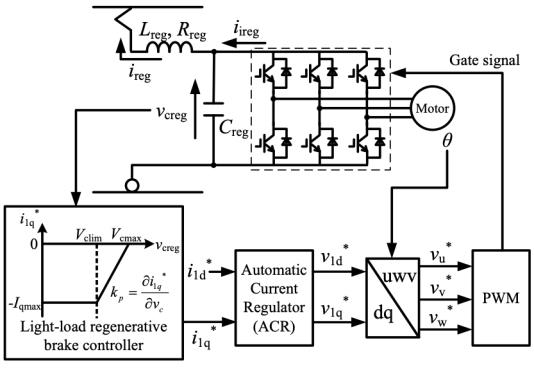


Fig.1. Traction circuit of railway vehicle and typical configuration of regenerative brake control system.

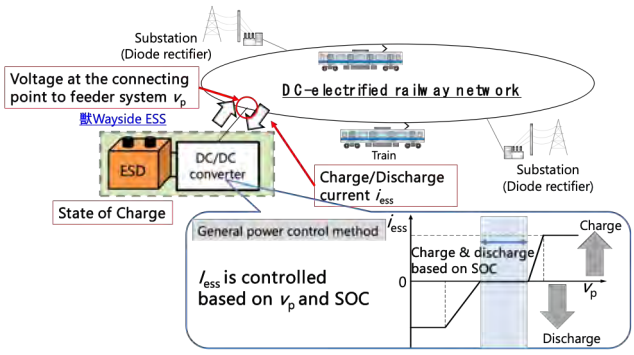


Fig.2. Typical power control strategy of wayside

Analysis and Suppression Strategies of Thrust Force Fluctuation in High-Speed Maglev Linear Synchronous Motor

Jinsong Kang[1]
[1]Tongji University

This report begins with an introduction to Tongji University, the Key Laboratory of Maglev Technology in Railway Industry, and the SPEED research team.

Following this, it provides a detailed description of magnetic suspension technology, including principles and characteristics of maglev trains. The presentation then analyzes the advantages of maglev trains, encompassing noise reduction, smooth and comfortable travel, safety and reliability, low energy consumption, minimal maintenance, strong climbing ability with a small footprint, high speed for time-saving travel, and environmental friendliness. Additionally, the classification of maglev trains is examined, with detailed introductions to both EMS and EDS trains. Current research on maglev trains in China is also highlighted (refer to Fig. 1).

The third section of the presentation focuses on traction systems in high-speed maglev, covering the composition of TR high-speed maglev, the high-speed maglev traction system, analysis and suppression strategies for thrust force fluctuation, and modeling of high-speed maglev LSM. Model predictive control (see Fig. 2) and sliding mode control have been successfully integrated into high-speed maglev traction control, with detailed discussion provided in this section. Furthermore, we introduce several high-speed maglev experimental platforms developed by our team and recent publications.

Finally, the presentation concludes with a summary and outlines future research directions in high-speed maglev.

Fig.1. Some maglev trains currently under research in China.

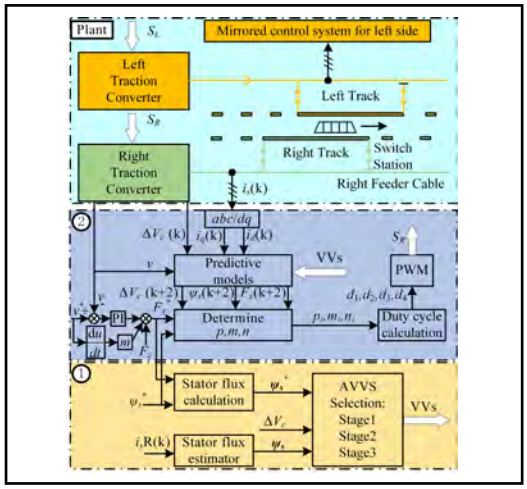


Fig.2. Model Predictive Thrust Force Control for High-speed maglev LSM.

Fault Diagnosis of Traction Power Supply System Based on AI

Fulin Zhou[1]

[1] Southwest Jiaotong University

An artificial intelligence framework for train-grid system fault diagnosis is proposed.The framework includes feature extraction, pre-classification and re-identification as shown in Fig. 1. First, the Hilbert transform (HT) is used for initial feature extraction of the train-grid electrical signals. Second, a one-dimensional convolutional neural network (1-D CNN) is designed to extract deep features and perform pre-classification. In the CNN model, arcface is used instead of softmax to enhance the recognition performance. In order to reduce the complexity of the CNN model, the global average pooling layer is used instead of the fully connected layers. The feature library of each known electrical signal can be obtained based on the well-trained CNN model. Finally, the final result is determined by feature similarity calculation in the re-identification session. The experimental results show that the framework can both detect typical electrical fault and unknown electrical fault accurately and efficiently

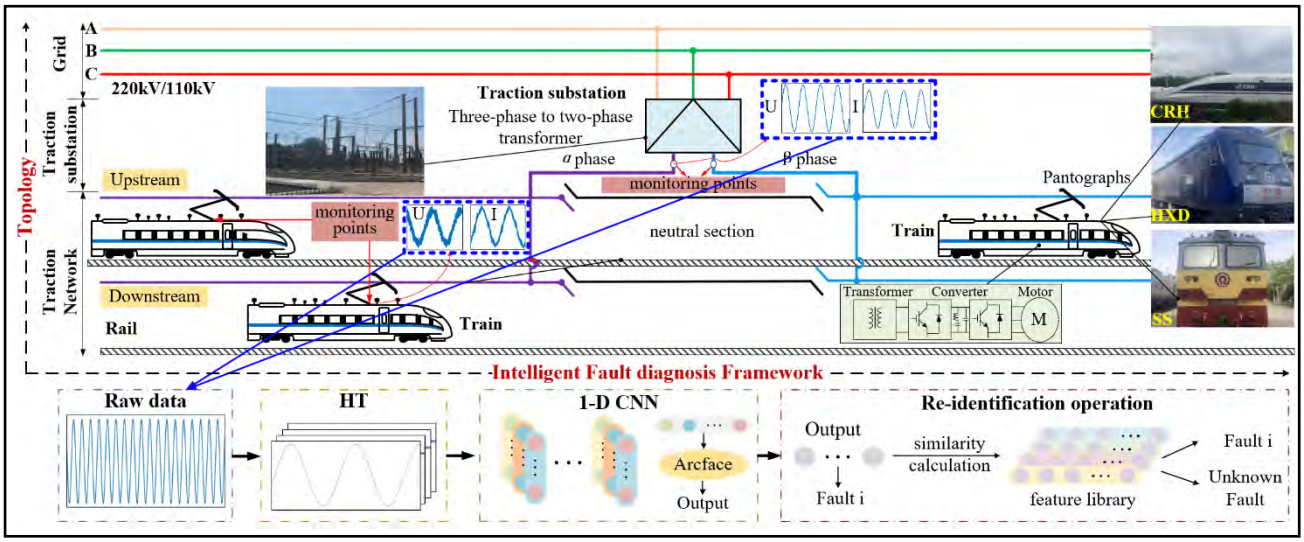


Fig.1. The intelligent fault diagnosis framework.

Dependable Train Positioning by Fusing Multiple Sensors Information

Bai-gen Cai, Jian Wang, Jiang Liu
School of Automation and Intelligence, Beijing Jiaotong University, Beijing 100044, China

The advanced next-generation train control systems, both in Europe and China, are designed to take advantages of new technologies and practices, where satellite-based positioning by GPS, Galileo and BeiDou Navigation Satellite System (BDS) has been highly investigated. Dependable train positioning using BDS and assistance sensors is of great necessity to realize “fail-safe” determination of the train’s running state and enable different location-based applications. In this presentation, architecture of an advanced dependable train positioning system based on information fusion of BDS with other assistant sensors is proposed, which enables the holographic perception of the train’s operational status over ordinary running state variables. Key technologies and applications based on multi-sensor-fusion-enabled dependable train positioning are introduced as follows.

1) Under a redundant Location Determination System (LDS) architecture that is compatible to the on-board train control system, the state estimation solution for multi-sensor integrated positioning is investigated using the Bayesian filtering and specific fault tolerant strategies.

2) An automatic trackmap generation solution is presented considering the multi-resolution characteristics of the railway tracks. The design and development of a specific map-tool-chain is introduced with field tests and implementations in Qinghai-Tibet Railway.

3) The train integrity monitoring technique based on the real-time evaluation of the train length is investigated. With the integration of BDS, inertial navigation sensors and the trackmap database, the novel safe End-of-Train (EoT) system architecture is designed and realized.

By utilizing the key technologies, a novel train control system was developed. Simulation tests were carried out in a laboratory environment, and the practical equipment was demonstrated in Hargai-Muli Railway. Field test results illustrate the capability and advantages of the presented dependable train positioning solution in enabling the BDS-based novel train control system, which indicate great potentials in many other related applications in future intelligent railway systems.

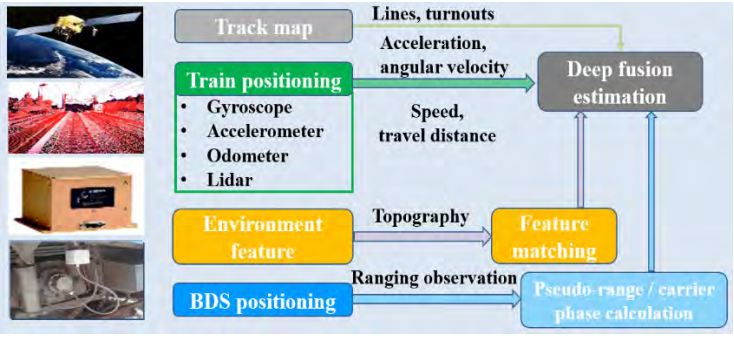


Fig.1. Architecture of multi-sensor information fusion-based dependable train positioning.

Fig.2. Whole-set system field installation and deployment in HMR.

Transition of Fail-safe Technology.
~ From Fail-safe Circuit to Fail-safe Technology on Complex System ~

Hideo Nakamura[1]
[1]Nihon University

Devices that require a high level of safety, such as railway signals, are required to be fail-safe, so that the output of the safe side is taken in the event of a failure. Fail-safe control circuits have been achieved by using logic elements with asymmetric error characteristics, such as signal relays.

In the 1980s, research on the use of computers was developed, and a number of fail-safe computers were developed and introduced into control devices. There are various methods for fail-safe computers, but a method of adopting some kind of redundancy configuration and diagnosing whether the data match during the process is also adopted.

Advances in network and communication technologies are leading to large-scale bloated systems. In addition, systems that incorporate sensors and devices that are not fail-safe are emerging. The question is how to manage safety in such a complex system. In this lecture, I propose the idea of ensuring safety by checking the erroneity of information.

Fig.1. Illustrates the transition of fail-safe technologies.

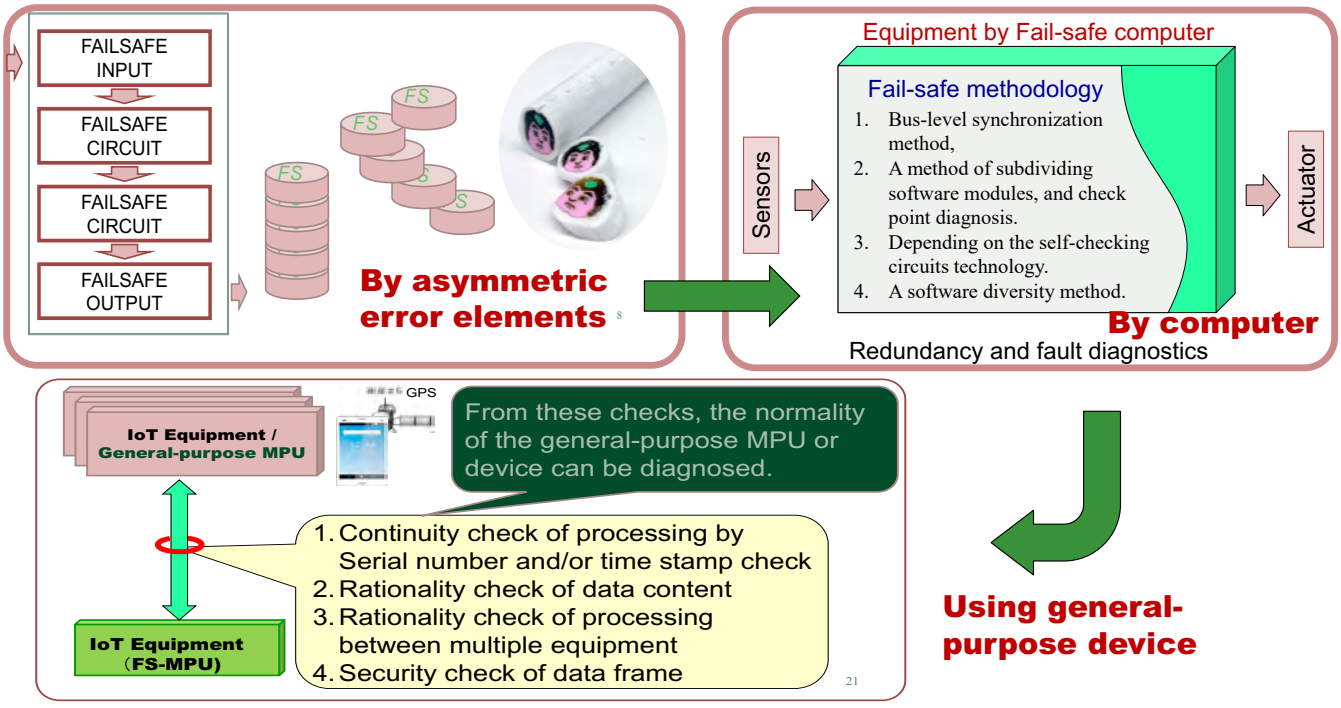


Fig.1. Transition of Fail-safety technology.

Research and Applications of Rail Transit Safety Assurance and Intelligentization

Xinhong Hei[1], Wenjiang Ji[1], Anqi Shangguan[1] and Mingsong Yang[1]
[1]School of Computer Science and Engineering, Xi'an University of Technology

With the great progress of technological innovation characterized by internet of things, big data, and artificial intelligence, rail transit industry is coming into the era in which digital design, intelligent construction, and information-based services become new tasks. In this talk, we mainly introduce our research progress of three works:

(1) Automatic compliance checking of rail transit engineering design using knowledge graphs. To address the issues of inefficiency and high rates of missed and false detections in current manual inspection methods, we researched information description and knowledge reconstruction methods for design specifications. We developed a new representation model based on knowledge graphs (KG). This model enables the automatic compliance checking of rail transit design outcomes.

(2) Risk assessment of system operation under small sample conditions. We proposed small sample expansion techniques, established an accurate sample generation models. These can address the issues such as imbalanced monitoring samples or insufficient sample characteristics, thereby enhancing the accuracy of system risk assessment.

(3) Intelligent fault diagnosis of key rail transit equipment using machine learning. we propose data preprocessing techniques such as intelligent curve segmentation and establish an adaptive fault diagnosis model based on machine learning. This model addresses the limitations of traditional fault diagnosis methods that rely on fixed thresholds and manual intervention.

These efforts aim to provide theoretical foundations for improving the design quality, operation reliability and safety of rail transit.

Impact of COVID-19 on Train Operation in Japan

Norio Tomii
Tokyo Institute of Technology / Nihon University

1. Introduction

Since February 2020, there has been a significant change in the volume of rail passengers due to the outbreak of COVID-19. Not only did the number of passengers decrease significantly, but there were changes in their behavior. This also had an impact on train operations, as delays during the morning rush hours, which had been frequent until then, were drastically reduced.

2. Passengers Behavior Patterns

On 7th April 2020, Japan was placed under a state of emergency. The government strongly urged people to stay home. The number of railway users dropped to more than 20% of the previous level. It then recovered, but remained at 60% of the normal level for a long period. It showed a slight recovery trend, but dropped again with the outbreak. Fig.1 shows daily volume of passengers late in the evening in December 2020. From this analysis, we can know many people went out on Friday night despite the number of infected people was increasing rapidly.

3. Volume of Passengers and Delays

On commuter routes in Tokyo, before the spread of COVID-19, small delays were a chronic occurrence during the morning rush hour. However, as a result of the sharp decline in the number of passengers, delays have almost disappeared. Fig. 2 shows the relationship between the number of passengers and delays in the metropolitan area. From Fig. 2, it can be seen that when the number of users exceeds a certain threshold, delay increases rapidly. It also shows that when the number of passengers is high, train operations become unstable (meaning some days have small delays, while other days have very large delays).

4. Conclusion

The impact of COVID-19 on railways was analyzed on the basis of actual data. From these data, we have succeeded to get new findings. We hope that this approach will lead to realize more convenient railways.

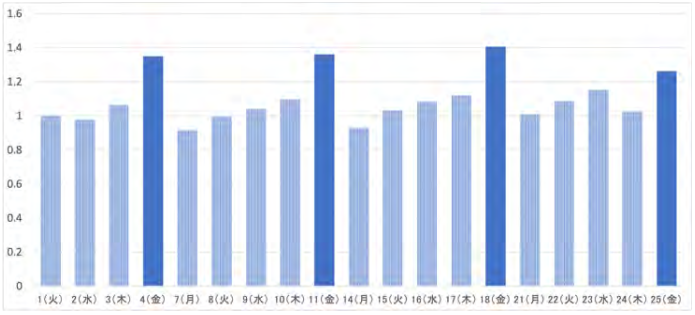


Fig.1. Volume of Passengers on each Day (Dec.2020).

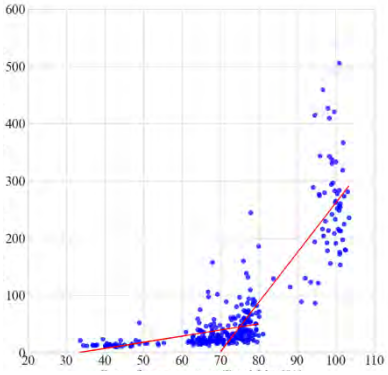


Fig.2. Passenger Volume vs Delays.

Communication and signal processing technologies for advanced railway signaling systems

Hiroshi Mochizuki[1]
[1] Nihon University

At present, railway signaling systems in which control information is transmitted via track circuits (rails) have been deployed in many applications, such as automatic train control (ATC) systems in Japan. These systems have some problems, however, such as the strong influence of unique railway noise to trains and the difficulty of increasing the transmission speed due to the use of the audible frequency band. To overcome these problems, we have proposed new transmission methods for advanced railway signaling systems.

At first, we have proposed a novel railway signaling system using mixed digital and analog signals. Although the installation of digital ATC system has been attempted instead of analog ATC system, it is difficult to ensure a new channel for installing digital ATC system because the transmission band is so narrow at the audible frequency band. Therefore, we proposed the scheme for generating a so-called digital-analog signal shown in Fig.1. In this figure, the AM-based analog transmitter is employed as the carrier of the PSK-based digital transmitter, it is possible to transmit both digital and analog signals simultaneously at the same frequency band.

On the other hand, we have also proposed the transmission method for increasing the transmission speed of digital ATC system. Specifically, we have been looking at introducing orthogonal frequency division multiplexing (OFDM) transmission into the orbital circuit. In OFDM, it is possible to overlap many carriers within a limited frequency by narrowing the spacing between subcarriers. However, since this transmission received the influence of unique railway noise shown in Fig.2, we have attempted to avoid this influence using FFT analysis.

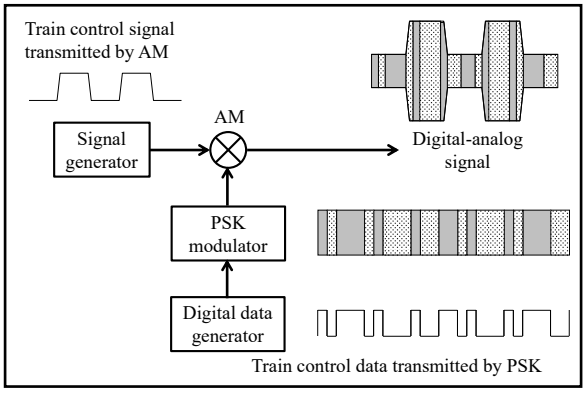


Fig.1. Generation of digital-analog signal for mixed digital and analog ATC system.

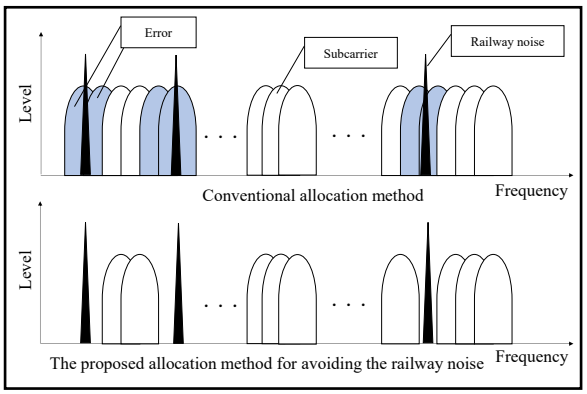


Fig.2. The influence of unique railway noise and the proposed allocation method for avoidance.

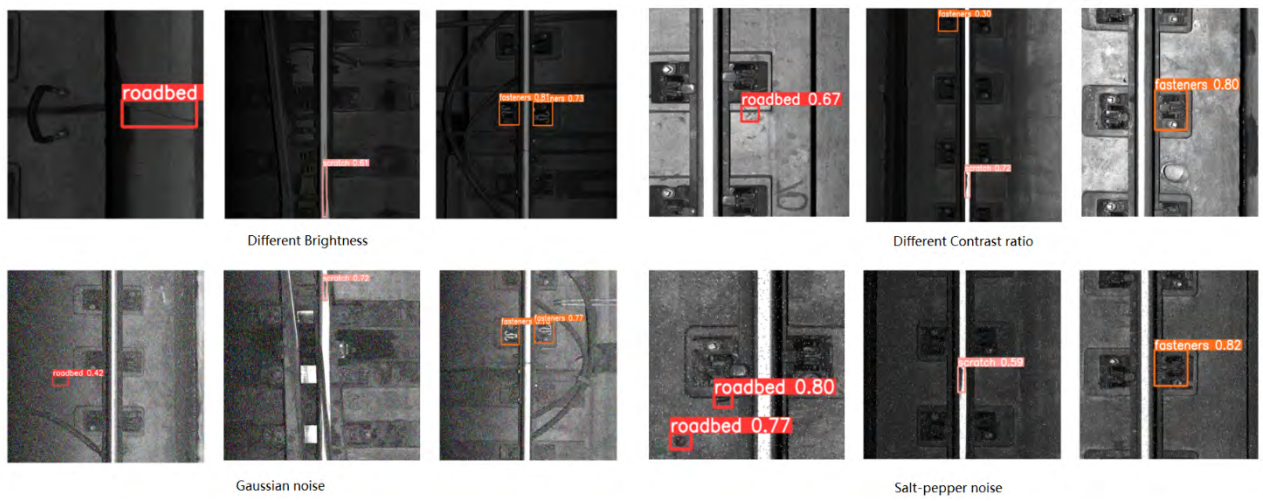
Construction and Development of a Safety Assessment Center: From the Perspective of AI Safety Assurance

Wei Zheng[1], Rui Wang[2], Tao Huang[2]
[1]School of Automation and Intelligence, Beijing Jiaotong University,
[2] School of computer science and technology, Beijing Jiaotong University

The railway infrastructure will produce many problems due to long-term exposure to the external environment, and there exist great potential safety hazards to the train operation. Railway infrastructure mainly relied on traditional manual inspection, which required a lot of manpower and material resources. The detection of rail surface based on machine vision is realized in a non-intrusive way, and the detection method based on deep learning learns the rules from a large amount of data through algorithms, and its generalization ability, robustness and detection performance are better than those of traditional processing detection methods.

In order to solve the uncertainty problem of decision-making caused by the decrease of robustness of the track defect detection system under the interference of actual natural environmental factors，a method is proposed to improve the robustness of the detection system. Firstly, the mutation algorithm is proposed to generate more diverse robust training samples so that the model can learn to adapt to various environmental disturbances and changes. Then, the target detection model based on YOLOv5 is selected as the track defect detector, and the model can not only meet the high requirements of track defect detection for detection accuracy and real-time performance, but also achieve good detection results with its excellent generalization ability even if the number of training samples is limited.

AI model robustness test and safety assurance are key issues before the model is used in the railway domain and the national research center of railway safety assessment is established in BJTU to conduct comprehensive AI relative systems research on testing and certification.



Recent Technology on Steering Bogie in Japan

Yohei Michitsuji
Ibaraki University

The conventional railway wheelset has the advantage of being self-steering and self-centering. Due to the simple structure and favorable dynamics of the wheelset, railway bogies with wheelsets have been widely used from the dawn of the railway history. In the design of a railway bogie, the compatibility between cornering ability and hunting stability has been studied by many researchers for many years. Based on past research, the vehicle design with conventional wheelsets has been well summarized. However, there is room for improvement in steering performance with conventional bogies, and steering bogies are still attracting attention from this perspective.

Link type forced steering bogies are used in the world because the cornering performance is effectively improved by the link mechanism, which is simpler and more reliable than using forced steering with active control devices. The aim of the steering mechanism is to achieve radial steering of each wheelset along the curved track. Until now, radial steering of single-axle bogies has been achieved by hydraulic steering systems using the bending angle between the bogies frame and the car body as an input signal, or by steering linkages between the bogies and the wheels. Although the link type forced steering bogie is effective, the vehicle is introduced in a limited area because the bogie structure becomes more complex compared to conventional bogies without a steering mechanism. A more practical problem is the alignment of the traction and braking devices, since the wheelset steers dynamically, especially in sharp curves. To achieve compatibility between the steering capability and the implementation of a simpler mechanism, the asymmetric bogie with single-axle steering bogie is now gradually being used in the Japanese metro as a successful example. This presentation will give a brief history of the research and development of steering bogies with asymmetric structures originated from Japan.

Rolling contact performance testing techniques for forward design and maintenance of roller bearings

Xi Wang
Beijing Jiaotong University

Roller bearing is a key component in various high-end engineering fields to carry load and support a rotating shaft. It is required to maintain high performance like longer life or higher reliability under very tough service conditions. There are mainly three challenges for forward design and maintenance of roller bearings. Firstly, the accurate bearing service conditions are needed as the inputs for design, testing loading and life prediction. Secondly, the existing performance testing only focuses on temperature rise under standard load and more abnormal loading conditions and more performance indexes are needed to be considered. Thirdly, it is necessary to establish a clear quantitative mapping from the external signal to internal failure for fault diagnosis of roller bearing, especially at the early stage of the fault. The bearing performance is closely related to contact mechanics at roller-raceway interface. The mechanics parameters can be divided into two categories: force and motion. Normal force and tangential force are the interaction forces between the roller and raceway, which are driving force leading to rolling contact fatigue and wear. The friction moment represents the power loss of the bearing, and is a mechanical quantity characterizing the lubrication condition and heat generation. The motion of the roller includes the rolling and sliding of the roller, as well as the skew and tilt angle of the roller deviating from its own axis in space. Tilting the roller can cause stress concentration, leading to early failure of the bearing raceway. Our task is to study how to measure these contact mechanics parameters, especially to develop in situ measurement methods and relate them with bearing service performance.

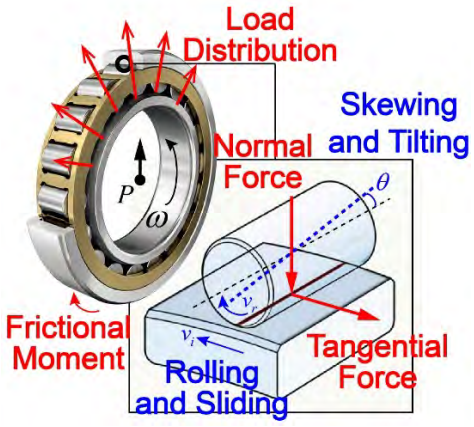
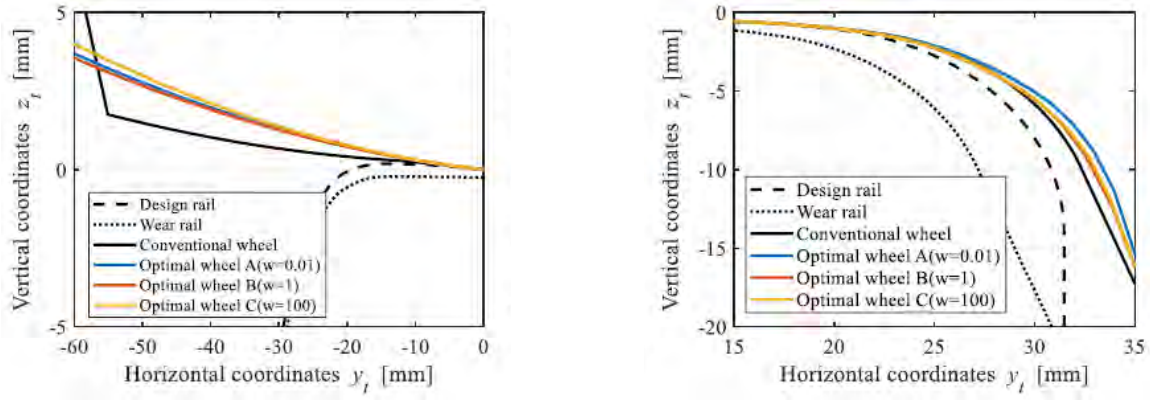


Fig.1 Contact mechanics parameters at roller-raceway interface

Wheel Profile Optimization Considering Rail Wear on Curved Sections

Masahiko Aki[1], Masahiko Simbayashi[1]
[1]Dept. of Mechanical Engineering, College of Science and Technology, Nihon University

This paper deals with an optimization of a wheel profile for improvement curving performance on design rails and wear rails for railway vehicles. An objective function was calculated based on time-history responses of a lateral force of a railway vehicle model running on a curve using multibody dynamics software Simpack. By setting parameters defining a wheel profile as design variables, an optimal wheel profile was generated using a Genetic Algorithm based on the objective function. The results show that the profile of the wheel flange root and wheel tread was generated to improve the contact condition with the design rail and the wear rail (Fig.1). Also, the optimal wheel profile reduced the lateral force on the design rail and the wear rail when travelling on the curve compared to the conventional wheel profile (Fig.2). Therefore, effectiveness of the wheel profile optimization for improvement curving performance on the design rail and the wear rail was demonstrated.



(a) Tread profile (b) Flange profile

Fig.1. Optimal wheel profile.

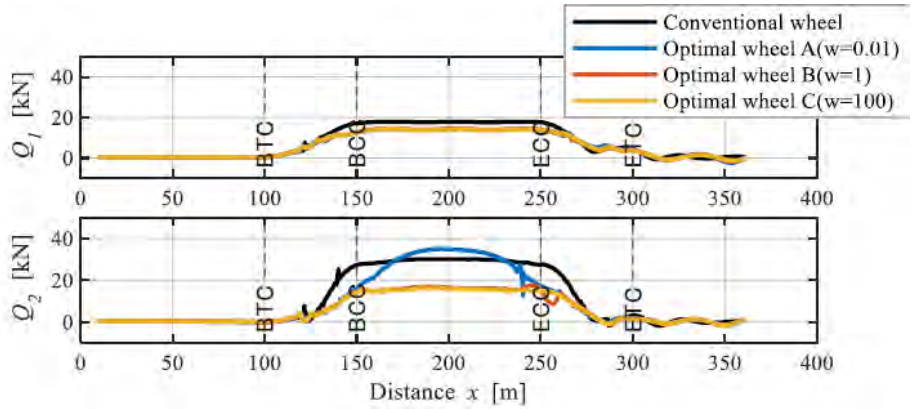


Fig.2. Relationship between the distance of wheels on 1st axis and the lateral force.

Research on the dynamic theory, methods, and applications of the wheel-rail system in high-speed railway turnout

Jingmang Xu[1], Kai Wang[1], Jun Lai[1]
[1]Southwest Jiaotong University, Chengdu, 610031, China

The high-frequency vibrations in high-speed railway turnouts significantly impact the evolution of wheel-rail relationships and structural integrity. Traditional dynamic models analyze low frequencies but lack systematic research on high-frequency responses, hindering the understanding of wide-band vibrations. This paper addresses the dynamic theoretical methods and applications for high-speed railway turnout areas:

Dynamic Theoretical Methods:

Developed a rigid-flexible coupling dynamic model of the wheelset in the Euler coordinate system, established a dynamic model of high-speed vehicles considering nonlinear damping of suspension components, and created a dynamic model for the high-speed turnout rail-pad-turnout plate-base plate system. Utilized Bezier curve fitting for the 3D profile of the turnout and developed a multi-point contact geometry algorithm for the wheel-rail system. Selected a normal contact damping model for the wheel-rail system and derived the wheel-rail creep rate algorithm. Developed a variable step size implicit numerical integration algorithm, constructing a rigid-flexible coupling dynamic model of the high-speed vehicle-turnout system. Incorporated the SDITT dynamic calculation program into the international S&C Benchmark for vehicle-turnout wheel-rail multi-body system dynamics.

Dynamic Response Characteristics:

Analyzed vibration characteristics of high-speed turnout rails and proposed a method for identifying dynamic parameters. Investigated lateral and vertical dynamic response characteristics of the wheel-rail system in the turnout area. Introduced a frequency domain calculation model for wheel-rail dynamic interaction and proposed a quasi-static structural irregularity iterative algorithm considering dynamic reconstruction of multi-rail profiles.

Applications:

Developed a horizontal concealed tip structure for the nose rail to ensure train safety at 350 km/h. Constructed a low disturbance wheel load transition technology for guiding stability in high-speed turnouts. Studied the impact of track stiffness on train running quality and proposed a uniformity design method for turnout stiffness. Proposed a dynamic load coefficient design to maintain long-term turnout performance and durability.

This report presents an efficient simulation dynamics theory for the wheel-rail system in the 2 kHz frequency range of turnouts, exploring complex constraints, vibration characteristics, dynamic responses, and frequency occurrence mechanisms, establishing design theory and maintenance technology for high-speed turnouts.

Shotgun Session

Origin-Destination Estimation Method for Regional Trains Using Bluetooth Observation Data

Masato Nishiwaki[1], Tomoyuki Todoroki[2], Satoshi Hyodo[3], Keisuke Yoshioka[2], Koichi Furutake[4]
[1]Graduate School of Nihon University, [2]Nihon University,
[3]Tokushima University, [4]Isumi Railway

Grasping daily passenger origin-destination (OD) patterns is crucial for planning and implementing measures to maintain and revitalize public transportation. While automatic faregate passage data is utilized in urban railways, OD estimation remains challenging in regional railways due to cost-prohibitive infrastructure investments. Leveraging Bluetooth Low Energy on smartphones holds promise for acquiring user OD data conveniently and at low cost.

However, the widespread adoption of Bluetooth MAC address randomization for privacy protection necessitates the development of OD estimation methods for such data.

In this study, we propose an origin-destination (OD) traffic estimation system for regional railways, as illustrated in Figure 1. The system utilizes Bluetooth to measure on-board passenger occupancy and accounts for the impact of MAC address randomization, as demonstrated in Figure 2 for the Isumi Railway.

The proposed system was validated against data from a concurrent passenger survey. The results, as presented in Figure 3, indicate the feasibility of estimating user OD even under randomized MAC addresses.

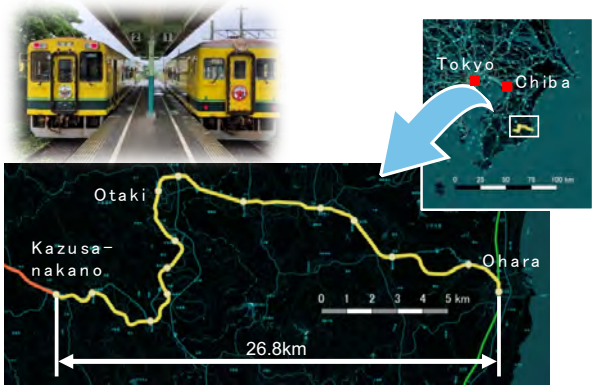


Fig.1. Overview of Isumi Railway

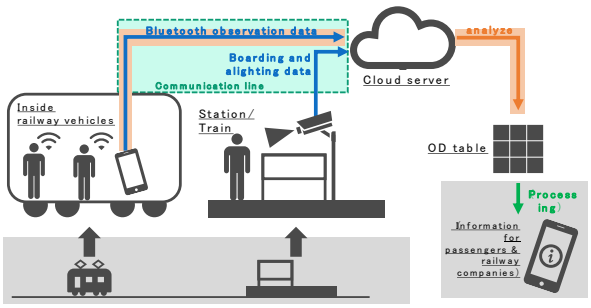


Fig.2. Proposed System

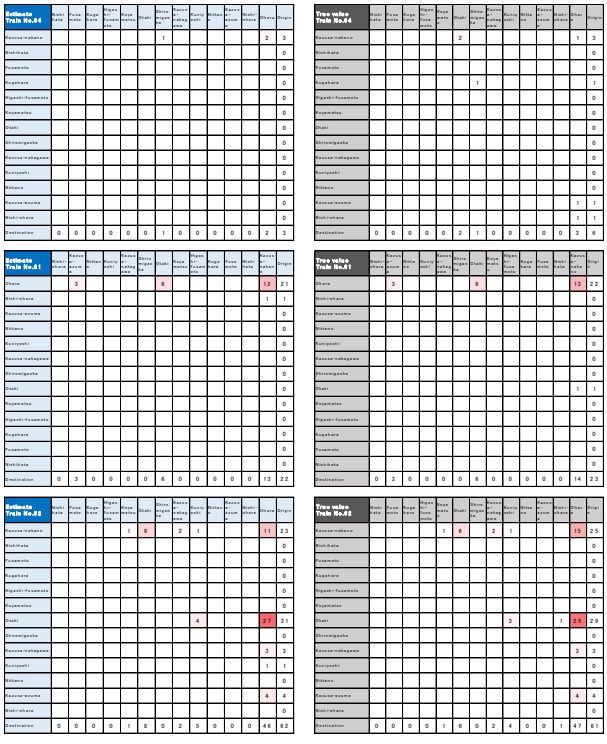


Fig.3. Estimation Result of Origin-Destination Table

Establishment and application of load spectrum for high-speed train bogie frame

Chengxiang Ji, Shouguang Sun, Qiang Li, Zhiming Liu, Guangxue Yang
School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University

The bogie frame of high-speed train is a large welded structure that bears complex multi-source coupled loads, and its structural reliability is crucial for the safety of train operation. The load spectrum, which refers to the distribution of amplitude (or range) and frequency of service loads, is a crucial foundation for structural reliability design and assessment. In this paper, we propose a novel method for establishing load spectrum considering the coupling effect between multi-source loads of bogie frame. First, the strain gauged bogie frame is used to synchronously obtained 16 load-time histories and stress-time histories of fatigue key points (FKPs) under actual service conditions. Then, the load spectrum is established considering the four core elements of load type, load phase, load cycle and load amplitude. Finally, the load spectrum is applied to predicted stress response at the FKPs of the bogie frame. The equivalent stress amplitude ratios between the predicted stress of load spectrum and the measured stress are mostly between 0.9 and 1.1, with a minimum value of 0.81 and a maximum value of 1.21. This shows that the load spectrum can accurately reproduce the damage of the bogie frame in service and can be used for the quantitative assessment of the fatigue life of the bogie frame.

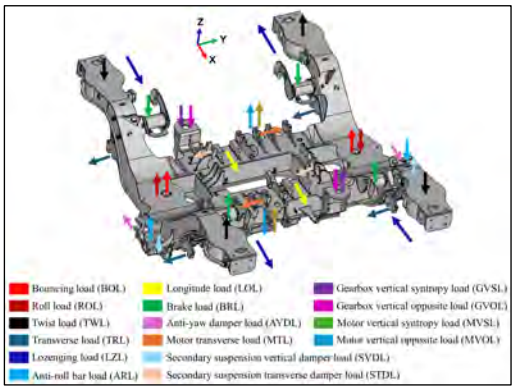


Fig .1 Load series of powered bogie frame of high-speed train.

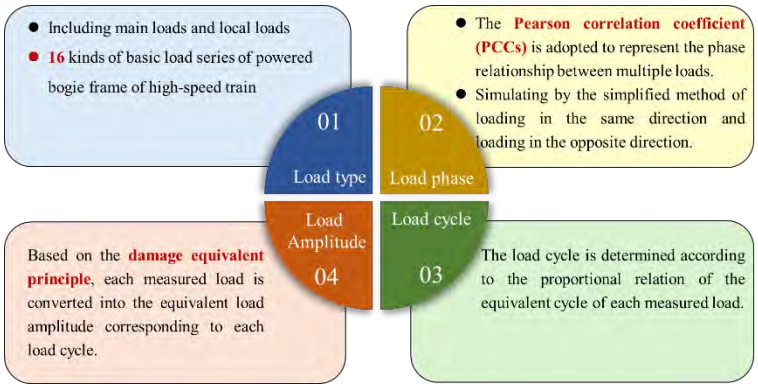


Fig .2 Four core elements for establishing load spectrum.

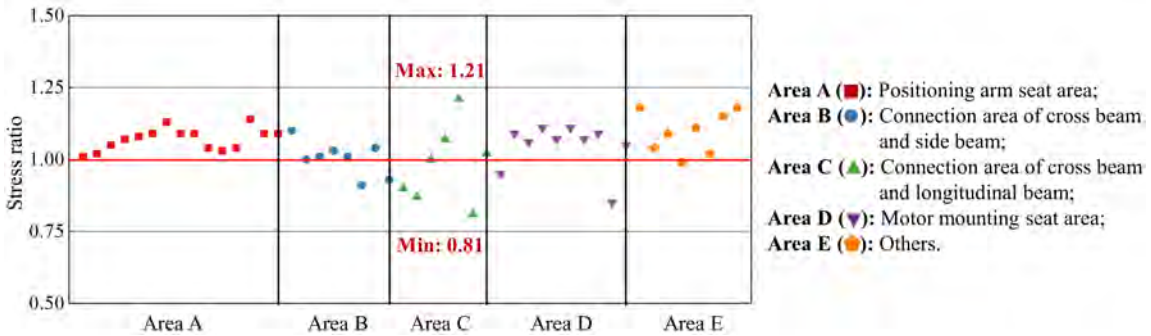


Fig .3 The equivalent stress amplitude ratios at the FKPs between the predicted stress of load spectrum and the measured stress.

Railroad Level Crossing Using Mobile Phone Lines and Level Crossing Passage Assistance System for Road Vehicles

Koki Nakayama[1], Kimihiko Nakano[1], Nijiro Fukushima[1],
Tetsuya Takata[2], Hiroyuki Nagasawa[2]
[1]The University of Tokyo Institute of Industrial Science,
[2]Kyosan Electric Manufacturing, Co., Ltd.

The authors have developed a railway level crossing control system that ensures safety using a general system, as shown in Fig. 1. Each train uses GNSS to identify its position and transmits this data to a central processor via mobile phone lines. The central processor calculates the fastest time to reach the crossing and sends the alarm start time to the crossing controller, which activates the alarm accordingly. Regular position updates ensure the alarm start time is adjusted for the earliest possible arrival. The system is designed with a fail-safe concept, and information is also transmitted to automobiles and traffic signals for integrated traffic control, enhancing safety and traffic flow.

The authors propose a system that uses an onboard camera and radar to detect stopping positions before passing the level crossing and vacant space after, estimating the time needed to pass by detecting the position and speed of other vehicles and pedestrians. This system supports drivers in deciding when to cross by comparing the central processor's alert time with the estimated passing time. The system's performance in detecting the distance to the front and back warning signs of the level crossing with an onboard camera was evaluated through experiments using a test crossing and test vehicles on a university campus, as well as by analyzing footage recorded by a driving recorder while passing through an actual level crossing. Results showed the system could accurately detect positions unless warning signs were outside the camera's field of vision. Additionally, tests on estimating passing time also yielded reasonable results, demonstrating the system's feasibility.

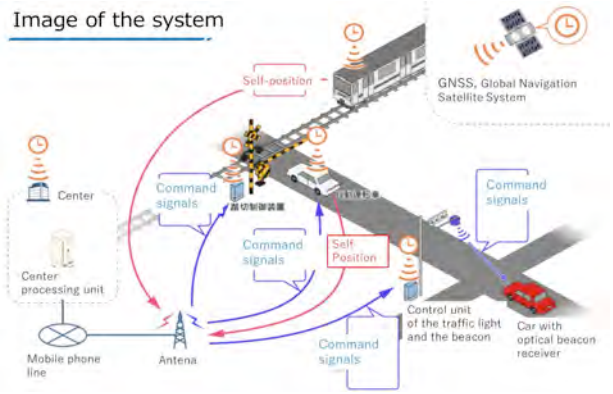


Fig.1. The unified traffic control system using mobile phone line.

Fig.2. Detected distance to the waring signs.

Exploration of regenerative braking energy utilisation in the electrified railways

Wu Liran
Beijing Jiaotong University

The reuse of regenerative braking energy on electrified railways is a hot topic. This report describes the exploration of regenerative braking energy reuse with the railway power conditioner (RPC) in China, which can also been called a railway regenerative braking power conditioner (RBPC). The RBPC is located at the end of the power sections between adjacent TSSs. First, the RB characteristics are studied based on a large amount of measured data, and the load power states are classified according to the load powers of adjacent power sections. Then a RB energy utilization scheme, transferring the RB power to adjacent power section where traction power exists, has been studied. Moreover, a dual closed-loop control strategy for a back-to-back converter is adopted to achieve the RB energy utilization. Finally, a case study and an engineering application are carried out. The results have verified the feasibility of this method, which can illustrate that more than half of the RB energy can be mutually utilized in adjacent power sections.

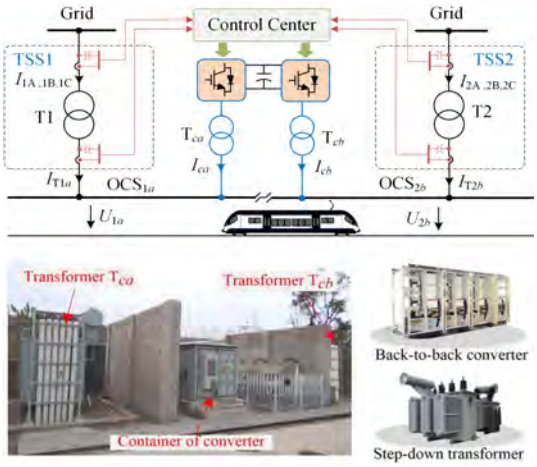


Fig.1. Proposed RBPC system.

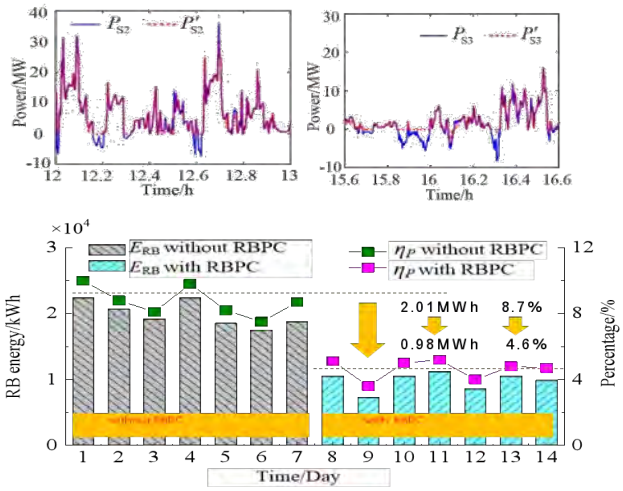


Fig.2. Experimental results.

Basic Proposal for Predicting Train Delay Time Using LSTM

Keiji Kato[1], Takashi Ono[1], Taiyo Matsumura[1]
[1]Nihon University

Since most railway delay trends are gradual, it is expected that economic losses can be reduced if the delay time or recovery of such delays can be predicted. However, most of the existing methods for predicting departure time are simple methods that add the latest delay time to the timetable, and they have a large margin of error. Therefore, the purpose of this study is to predict the delay time of departure time based on the operation records, and to provide the users with an outlook of the delay trend. This paper proposes a delay prediction method using Long Short Term Memory (LSTM). LSTM is trained on 22 days of actual train operations and predicts the delay time at departure time for each station.

The LSTM consisted of an input layer, an LSTM layer, and an output layer, where the input and output were the delay times at each station, the input was 10 preceding trains, and the output was one train to be predicted. LSTM was trained 10 times with the number of neurons in the LSTM layer set to 16 or 32. As a result, the losses were minimized when the number of neurons was 32 and the number of training epochs was 10, which was used as the trained LSTM.

Fig.1. shows the predicted departure times for each station for one train. The root mean squared error between the prediction results and the results of timetable was 10.8 [s], and the prediction error was less than one minute, which is the smallest unit of the schedule.

Fig.2. compares the actual and predicted delay times at departure times for each train and station for one day. Fig.1. and Fig.2. show that predictions are relatively correct for short departure time delays. However, in the longer case, the predicted delay is shorter.

These results indicate that this method is expected to be able to predict the delay time of departure time, although the accuracy of prediction needs to be improved.

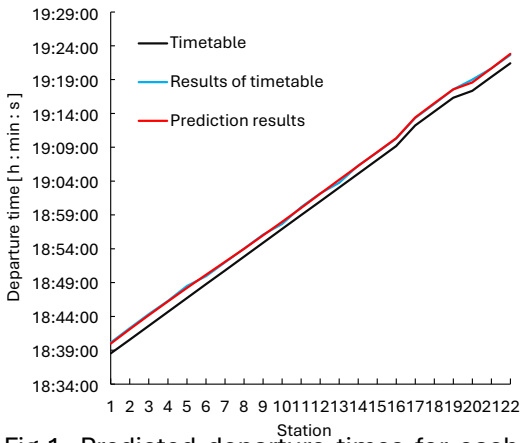


Fig.1. Predicted departure times for each station for one train.

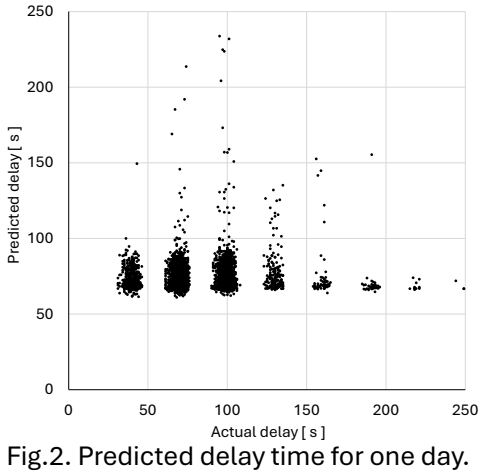


Fig.2. Predicted delay time for one day.

A Combined Experimental and Analytical Method to Determine the EHL Friction Force Distribution between Rollers and Outer Raceway in a Cylindrical Roller Bearing

Yu Hou[1], Xi Wang[1,2], Di Yang[2]
[1]Frontiers Science Center for Smart High-speed Railway System, Beijing Jiaotong University,
[2]School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University

The rolling element bearing plays a critical role in the safety and reliability of the drivetrain in high-speed trains. Friction from the roller-raceway contact with in a rolling element bearing is one of the direct causes of wear and fatigue damage of the raceways and rollers. In order to accurately assess the heat generation rate and fatigue life of bearings, a method is proposed for measuring the friction torque between rollers and raceways of radial roller bearings under radial heavy load conditions. A bearing-shaft system with one test bearing and two other bearings is specially designed and two steps are required in this method. Firstly, under given heavy load conditions, the total friction torque of the bearing-shaft system is measured from its free deceleration based on the energy conservation principle. Then, the friction torque between rollers and raceways of the test bearing is decoupled from the total torque of the bearing-shaft system by using a linear superposition approach combined with the quantitative adjustment of counterweights on the shaft. The effectiveness of the method was validated by building a test rig.

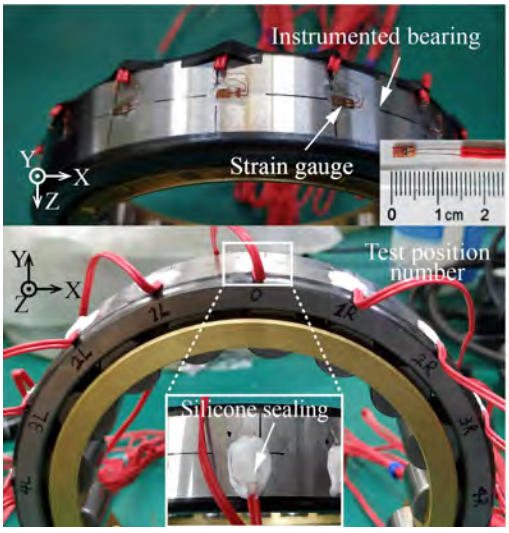


Fig.1. Instrumented bearing for measuring the frictional force distribution between rollers-raceway contact.

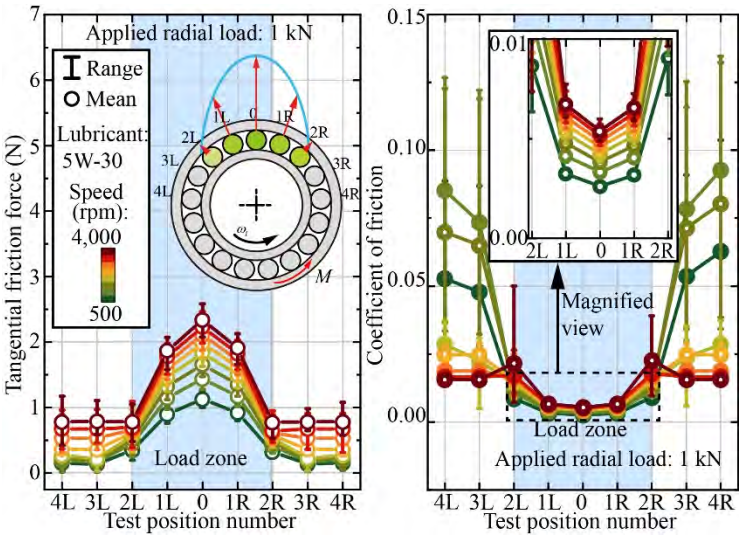


Fig.2. Measured frictional force and coefficient distribution based on combined data-model driven method.

Optimization of energy-saving operation of urban railway considering the use of regenerative braking energy

Xuanlang Meng[1], Tianyue Sun[1], Wataru Ohnishi[1], Takafumi Koseki[1]
[1]The University of Tokyo

Designing energy-efficient train operation strategies presents a significant computational challenge due to the inherent nonlinearity introduced by factors such as friction forces, motor efficiency variations, and power supply network fluctuations. Furthermore, when considering the utilization of regenerative braking energy (RBE) between trains, the complexity of collaborative train operation increases.

To address this challenge while avoiding excessive computational costs, a neighborhood-search based optimization method is proposed. The solution space is explored focusing on the neighborhood of an empirically good initial solution, and potential solutions are assessed using multi-fidelity simulators, including a numerical simulator considering the power supply network and an analytical simulator.

In addition, the proposed methodology has been applied to a two-train case study and a periodic multi-train case study where RBE exchange is feasible. The results show that collaborative optimization, including can reduce energy consumption. However, based on the analysis of the causal law, the collaborative adjustment of two or multiple trains leads to an increase in the amount of traction energy, which makes this operation weak in the face of delays and may even lead to a waste of energy when original schedule is disturbed. To address this problem, a new strategy of local optimization of train operations and its extension are proposed.

The algorithm is applied to a model with periodically operated trains, and repeatedly optimizes the train curve one by one in temporal order. A stable solution for all train operations is acquired within several cycles, yielding the reliability and applicability of the proposed method. Also, numerical case studies with delay are carried out, and the proposed method is proved to be effective in reducing the effect of disturbance on energy consumption. Adjusting only the operation of the receiver train, instead of both trains in a pair, can still significantly reduce net energy consumption.

Besides the operation optimization, energy storage system can absorb RBE and save energy consumption. However, its economic cost, the extra energy consumption caused by its weight, and the low utilization rate during peak hour are still problems. We discuss cases under different departure intervals to determine the feasible capacity range of the storage, and then more detailed optimization is carried out according to this capacity range.

AI Safety Validation via Diverse Testing and Uncertainty Quantification

Rui Wang[1,2,3,4], Zhouxian Jiang[2,4], Ci Liang[5], Mengying Wang[2,4], Honghui Li[2,3,4]
[1]Beijing Key Lab of Traffic Data Analysis and Mining, [2]School of Computer Science and Technology, [3]Collaborative Innovation Center of Railway Traffic Safety, [4]Beijing Jiaotong University, [5]Harbin Institute of Technology

Traditional software relies on deterministic logic, characterizing a predictable and consistent behavior, whereas deep learning-based software operates on probabilistic outputs. Hence, the safety validation of AI systems necessitates a paradigm shift towards diverse testing strategies and uncertainty quantification to ensure the reliability and robustness of these probabilistic models. Such approaches help in identifying potential errors and vulnerabilities of deep learning-based software, thereby enhancing the robustness and reliability of AI systems. By examining valid test inputs generation, predictive uncertainty metrics, and uncertainty quantification methods, our recent studies have demonstrated their effectiveness in improving the safety and robustness of deep neural networks (DNNs). AugTest introduces a novel approach to generating valid and diverse test inputs for deep neural networks by leveraging stochastic optimization. This method not only increases the efficiency of DNN testing but also ensures the generalizability of the test inputs across different model structures, thereby enhancing the safety validation process. EviSeg highlights the significance of uncertainty quantification that applies Dempster-Shafer theory to semantic segmentation models. By estimating the predictive uncertainty without altering the model's architecture, EviSeg provides a critical tool for safety-critical applications, such as autonomous driving, where the reliability of AI decisions can have profound implications.

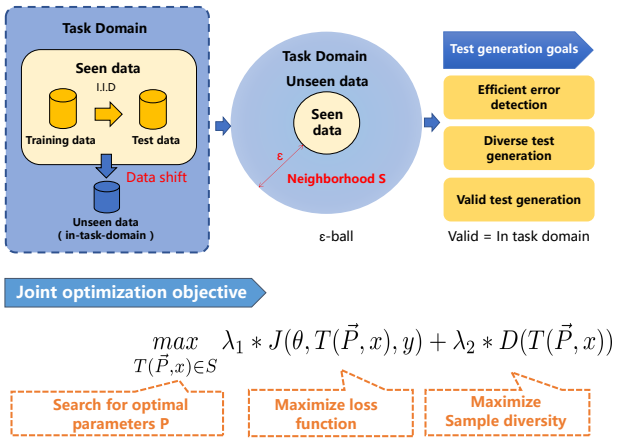


Fig.1. AugTest：valid and diverse test input generation method for neural network.

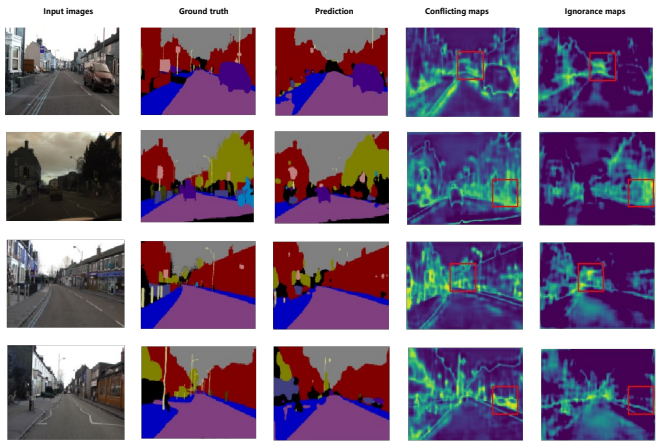


Fig.2. EviSeg: Visualization of prediction and uncertainty maps.

Fast and Scalable Optimization of Energy-Efficient Train Trajectory by Parallel Dynamic Programming

Keisuke Sakai[1], Wataru Ohnishi[1], Takafumi Koseki[1]
[1]Department of Electrical Engineering and Information Systems,
Graduate School of Engineering, The University of Tokyo

Carbon neutrality is also a major issue for railway operators. That is because most of the carbon dioxide emission by railway operators is for train driving energy. It is crucial to reduce the train driving energy of urban railways with high traffic volume and high-speed railways with large running resistance.

Previous studies have proposed various mathematical optimization methods for train trajectories. Dynamic programming is one of the most effective methods. It supports nonlinear complex models, including speed limits. However, there is a problem: huge calculation costs are necessary to improve the quality of the solution.

In this study, we focus on dynamic programming and parallel computing. We propose an optimization method for the train trajectories by dynamic programming applying thread and process parallelism. We also propose omitting storing the optimal control input to reduce computer memory consumption.

First, we numerically verified the acceleration effect of parallel computing. The result shows that increasing the number of threads improves the speed-up ratio of calculation time. A numerical experiment comparing commercial PCs and supercomputers found that supercomputers have an advantage in that the speed-up ratio of commercial PCs is saturated, but that of supercomputers is not. This difference is derived from computer memory bandwidth.

Next, we applied parallel computing to large-scale problems. The results show that the extension of the calculation time is suppressed against the expansion of the problem size. In a case study with the jerk limit, we verified that an energy-efficient train trajectory can be obtained while reducing the number of accelerations. We can conclude that the parallel dynamic programming for train trajectory optimization shows strong and weak scaling laws.

Research on the Recognition Method of Internal Rail Defects in Heavy-Haul Railways Based on Deep Learning

Yongkui Sun[1]

[1]Beijing Jiaotong University

The rapid detection of internal rail defects is critical to maintaining railway safety, but this task faces a significant challenge due to the limited computational resources of onboard detection systems. This paper presents YOLOv8n-LiteCBAM, an advanced network designed to enhance the efficiency of rail defect detection. The network designs a lightweight DepthStackNet backbone to replace the existing CSPDarkNet backbone. Further optimization is achieved through model pruning techniques and the incorporation of a Bidirectional Convolutional Block Attention Module (BiCBAM). Additionally, inference acceleration is realized via ONNX Runtime. Experimental results on the rail defect dataset demonstrate that our model achieves 92.9% mAP with inference speeds of 136.79 FPS on the GPU and 38.36 FPS on the CPU. The model's inference speed outperforms that of other lightweight models and ensures that it meets the real-time detection requirements of Rail Flaw Detection (RFD) vehicles traveling at 80 km/h. Consequently, the YOLOv8n-LiteCBAM network is with some potential for industrial application in the fast detection of internal rail defects.

Defect types	Railhead flaw	Rail jaw flaw	Screw hole crack	Bottom flaw	Weld joint	Rail joint
Defect images						
Number of defects	1406	1377	2160	710	886	1082

Tab.1. Internal rail defect data set

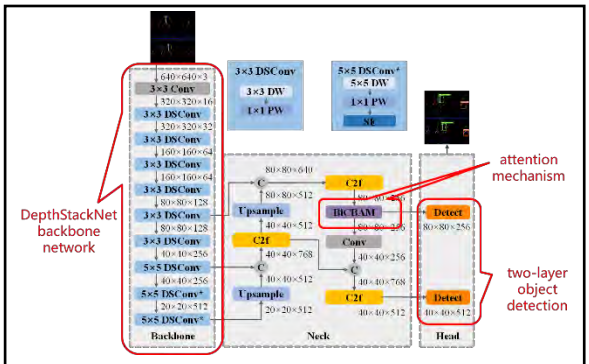


Fig.1. Structure of YOLOv8n-LiteCBAM model

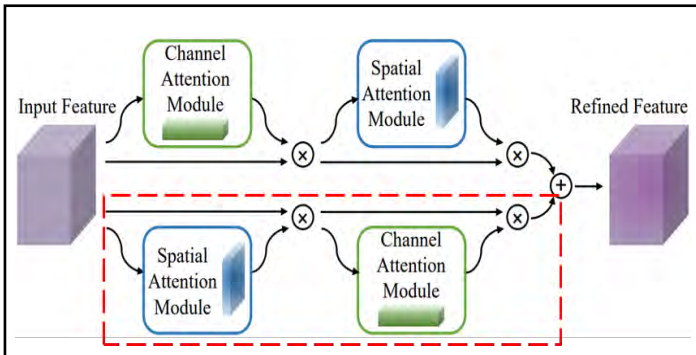


Fig.2. Structure of BiCBAM block.

Algorithm	FLOPs (10^9)	Parameters (10^6)	Model size (MB)	P (%)	R (%)	mAP50 (%)	FPS^{GPU}	FPS^{CPU}
YOLOv3-tiny	19.0	12.16	24.4	93.1	85.1	91.4	120.48	11.29
YOLOv5n	7.7	2.64	5.5	92.2	92.4	94.9	89.53	9.71
YOLOv5s	24.0	9.14	18.6	93.9	91.0	95.5	87.18	5.12
YOLOv8n	8.7	3.15	6.2	94.2	91.2	95.2	99.40	9.48
YOLOv8s	28.6	11.15	22.6	96.0	93.0	96.2	86.73	4.81
Faster RCNN-Resnet50-FPN	134.4	41.76	315.0	93.6	86.5	93.0	11.37	0.74
RT-DETR	222.5	65.48	135.3	94.6	94.6	95.9	29.85	0.82
YOLOv8n-LiteCBAM (ONNX Runtime)	1.4	0.22	0.6	87.8	89.9	92.9	136.79	38.36

Tab.2. Results of comparative experiments.

Study on the mechanism of wheelset angular velocity change on curved tracks

Yuzuki ENDO[1], Yohei MICHITSUJI[1]
[1]Ibaraki University

In recent years, the moving block system provided by CBTC is gaining attention for its ability to increase train operation frequency and improve facilities management efficiency compared to the fixed block system. Trains controlled by CBTC need to have onboard functions to estimate their locations. One method for location estimation involves integrating the measured translational velocity of the trains based on the angular velocity of the wheelset. However, this method may introduce errors in distance measurement due to changes in the wheelset's angular velocity on curved tracks, caused by mechanical factors such as variations in wheel/rail contact conditions. In this study, experiments and simulations were conducted to observe angular velocity changes on curved tracks (FIg.1). Both experiments (Fig.2) and simulations (Fig.3) yielded similar results, indicating that the angular velocity of wheelsets varies on curved tracks, with differing relative changes observed between the front and rear axles of the bogie. The mechanisms behind these angular velocity changes were clarified, identifying three factors: differences in arc length between the high and low rails, changes in rolling radius of the wheels, and longitudinal creepages. Additionally, the differences in angular velocity changes between the front and rear axles of the bogie observed in the experiments are discussed from the perspective of vehicle dynamics, along with a visualization method to illustrate the effects of these three factors.

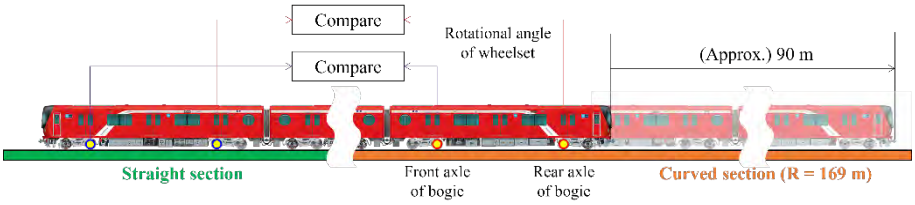


Fig.1. Condition of experiment and simulation.

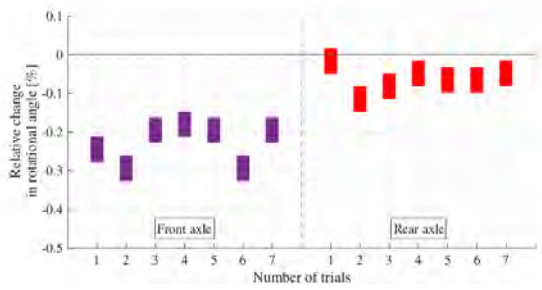


Fig.2. Experimental results.

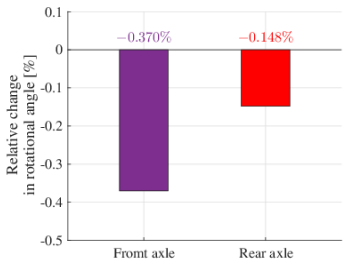


Fig.3. Simulation result.

Efficient dual-stream fusion network for real-time railway scene understanding

Zhiwei Cao [1], Yang Gao [1], Jie Bai [1], Yong Qin [1], Yuanjin Zheng [2], Limin Jia [1]
[1] Beijing Jiaotong University, [2] Nanyang Technological University

Railway scene understanding is key to autonomous train operation and important in active train perception. However, most railway scene understanding methods focus on track extraction and ignore other components of railway scenes. Although several semantic segmentation algorithms are used to identify railway scenes, they are computationally expensive and slow with limits applications in railways. To solve these problems, we propose efficient dual-stream fusion network (EDFNet), a lightweight semantic segmentation algorithm, for understanding railway scenes. First, a dual-stream backbone network based on mobile inverted residual blocks is proposed to extract and fuse detailed features and semantic features. Next, a bi-directional feature pyramid pooling module is proposed to obtain multi-scale features and deep semantic features. Finally, a multi-task aggregate loss is designed to learn semantic and boundary information, thus improving the accuracy without increasing the computational complexity. Extensive experimental results demonstrate that EDFNet outperforms the lightweight state-of-the-art algorithms with high accuracy and fast speed on two railway datasets.

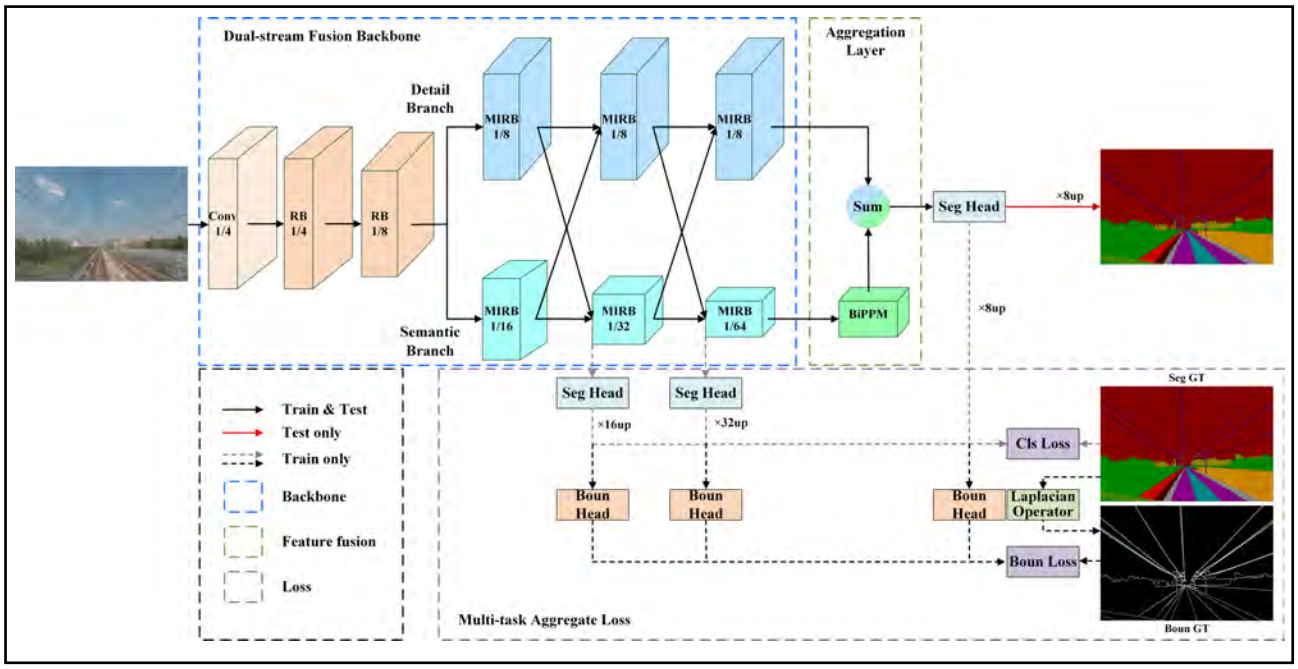


Fig.1. The overall framework of EDFNet including dual-stream fusion backbone, aggregation layer and multi-task aggregate loss. Dual-stream fusion backbone is based on the proposed MIRB. Aggregation layer proposes a novel BiPPM. Multi-task aggregate loss simultaneously combines semantic prediction and edge prediction.

Measurement experiment with scale model wheel and rail for longitudinal and lateral creep force

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[1] Mechanical Engineering Major, Grad. Sch. of Science and Engineering, Meisei Univ.
[2] Mechanical Engineering Course, Sch. of Science and Engineering, Meisei Univ.

When a railway vehicle runs, a tangential force acts between the wheels and the rails. This force, called the creep force, consists of a longitudinal creep force acting in the direction of travel and a lateral creep force acting in the horizontal direction. The creep force is necessary for acceleration and deceleration, but it also influences the motion of railway vehicles, such as wheel climb derailment. Therefore, it is important to accurately grasp and evaluate the creep force between wheels and rails to ensure the movement and safety performance of railway vehicles.

In model experiments of railway vehicles, extreme conditions, such as reproducing accident scenarios, can be set, and the cost of experiments can be reduced. As a result, running experiments of model vehicles for various purposes are conducted in various places. In our laboratory, we are working on research using model wheels and rails to achieve mechanically similar creep forces. The apparatus used in our research is shown in Figure 1. A model wheel is run on a model rail, and the creep force is measured. The results of creep force experiments with two types of materials (steel and aluminum) differed depending on the model. In addition, it was found that the experimental results of the longitudinal creep force were smaller than the linear theoretical values. This paper reports the analysis results of these experimental data.

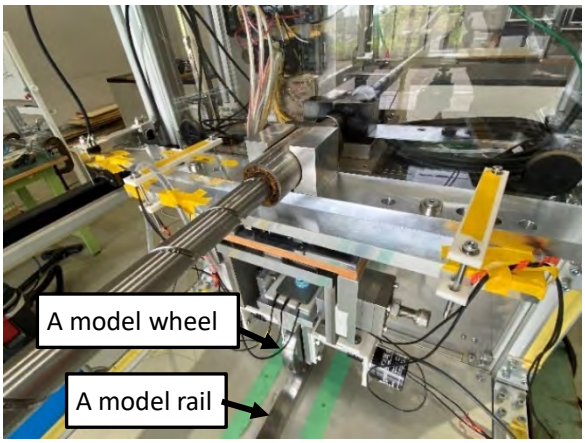


Fig.1. The apparatus uses in our research

Energy Management Strategy Based on Train Status Perception

Yan Li[1], Zhongping Yang[1], Fei Lin[1]
[1]School of Electrical Engineering, Beijing Jiaotong University, Beijing, China

The wayside energy storage system (WESS) can effectively recovery the regenerative braking energy in the traction power supply system (TPSS) of urban rail, thus achieving energy saving and emission reduction. Energy management strategy (EMS), as the top-level control of WESS, is crucially influenced by the train status in its optimal control. In the past, the method based on indirect state such as traction network voltage is difficult to achieve accurate identification of train status. Moreover, the method of directly obtaining train status requires high-performance communication between the train and WESS. This paper proposes a train status perception method based on K-means-DNN through deep learning, which only needs to collect some ground information to achieve online identification of the overall status of trains in the power supply section. On this basis, this paper proposes an energy management strategy based on train status perception, which realizes the adaptive charging and discharging control of the ESS according to the perception results. The simulation results show that the proposed method can identify the sum power of the trains in the power supply section accurately and adjust the EMS adaptively, thus improving the energy saving performance of the system.

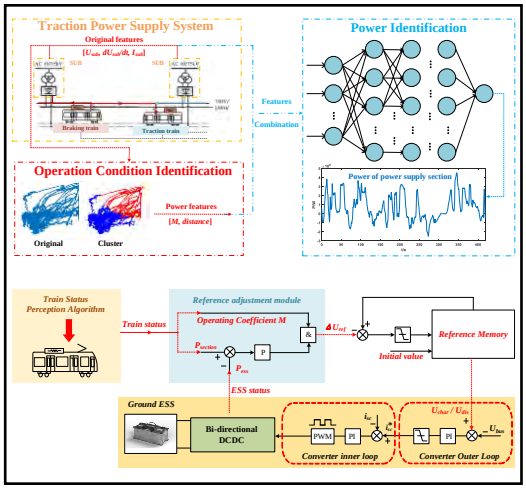
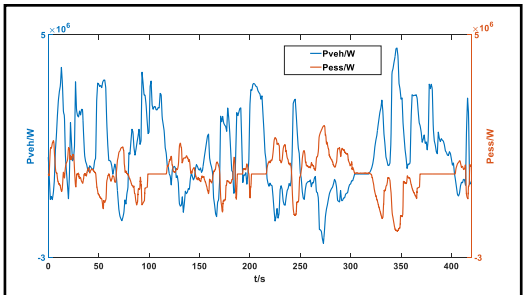


Fig.1. Energy Management Strategy Based on Train Status Perception.



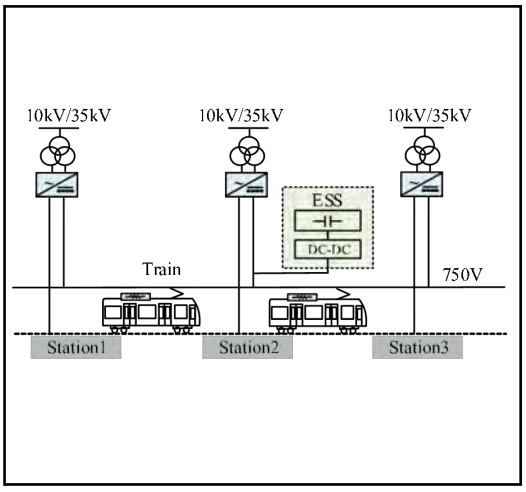
EMS	Ebr(kWh)	Esub(kWh)	Energy saving rate(SUB)
Without ESS	30.8	123.1	/
Based on no-load voltage	13.3	117.2	4.8%
Based on offline power curve	6.9	102.2	17.0%
This article	6.9	100.6	18.3%

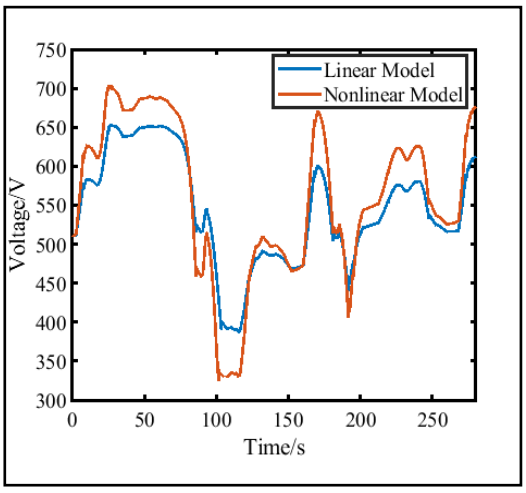
Fig.2. Simulation results of energy management.

Impact Analysis of Equivalent Electrical Models for Supercapacitor Energy Storage Systems in Urban Rail Transit

Hailiang Zhang, Zhongping Yang, Fei Lin
Beijing Jiaotong University

The widespread adoption of supercapacitor regenerative braking energy recovery systems in urban rail transit has given a significant attention regarding on the evaluation of energy savings and voltage stabilization effects of traction power supply networks. This study analysis the impact of supercapacitor electrical models and parameter selection on these effects. Initially, a comparative analysis is conducted between the linear model and the nonlinear branch model of supercapacitor, with parameter identification performed using Arbin test rig. Subsequently, typical operating conditions from a Beijing subway line are used to simulate and analyze the energy-saving rate and voltage stabilization rate of various electrical models, leading to the selection of the most suitable model for evaluation. Finally, the energy-saving rate and voltage stabilization rate under different series-parallel configurations of individual cells are compared under a fixed supercapacitor system capacity configuration.





Integrated Optimization Approach for Train Rescheduling and Passenger Reassignment under Disruptions in High-Speed Railway

Pengcheng Wen, Peng Zhao, Ke Qiao
Beijing Jiaotong University, Beijing, China

In railway operations, unexpected events can cause disruptions, preventing trains from adhering to their original timetable, increasing operating costs, and degrading the quality of passenger transport services. This study addresses the issue of train timetable rescheduling and passenger reassignment in a railway system utilizing a seat-reservation mechanism during disruptions. For train scheduling, strategies such as retiming, reordering, rerouting, and adding extra stops are considered. For passenger reassignment, measures such as interchange and refund are considered, with compensation provided to affected passengers to uphold the quality of passenger transport services. A mixed-integer linear programming (MILP) model is developed to minimize the weighted total cost of train delays and passenger compensation, thus offering cost savings for operating companies. The constraints primarily include section track capacity, station track capacity, and passenger transfer rules. Numerical experiments based on a real-world case of China's high-speed railway are conducted to verify the effectiveness of the proposed optimization approach. Parameter values and the impact of various compensation policies on scheduling effectiveness are also analyzed, resulting in a practical approach that balances operating costs and the quality of passenger transport services during disruptions.

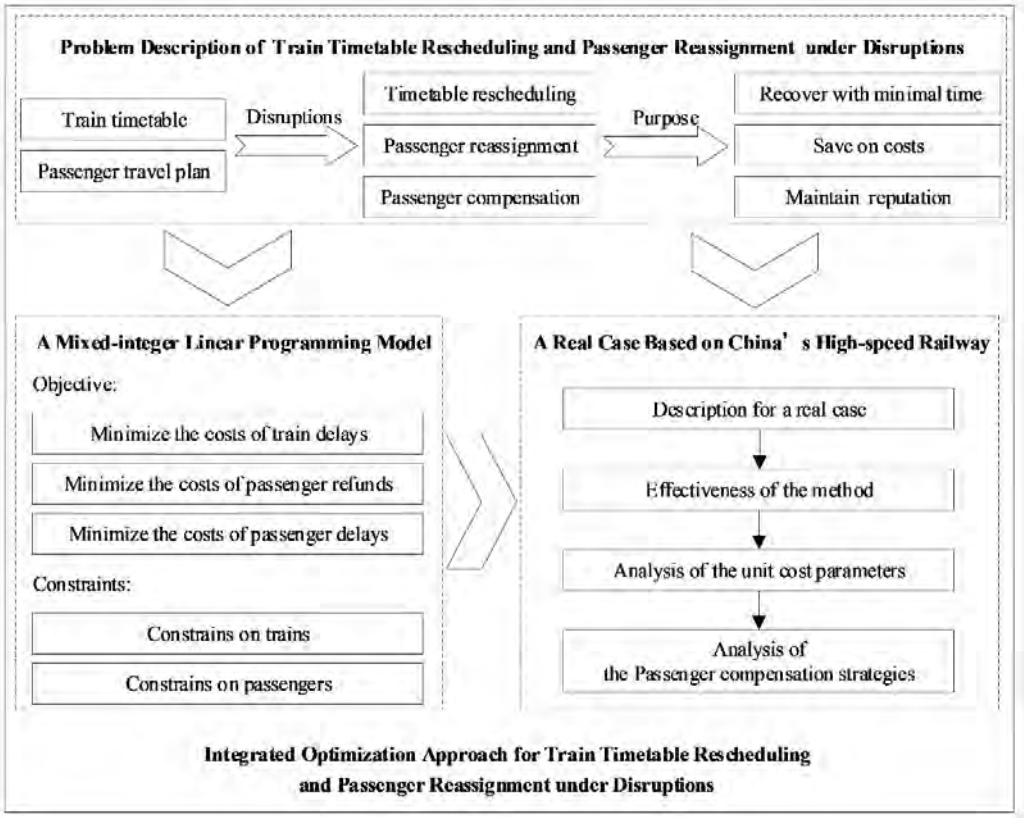


Fig.1. The architecture of this study.

Proposal of onboard train localization method based on surrounding structure identification

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Graduate School of Engineering, The University of Tokyo

Train localization technology has been playing an important role in railway signaling systems. Currently, Train localization is achieved using ground equipment such as track circuits and balises. However, maintaining these ground sensors is expensive and requires many workers.

Recognizing the limitations of ground-based methods, researchers have turned to onboard sensors as a potential solution for train localization. The Global Navigation Satellite System (GNSS), Inertial Measurement Unit (IMU), and Tachometer Generator (TG) are among the promising onboard sensors being explored.

Therefore, we propose adding structure identification using a one-dimensional Light Detection And Ranging sensor (1D LiDAR sensor) to GNSS / IMU / TG measurements like Fig. 1. When a train runs under / side of surrounding structures such as tunnels, bridges, and stations, the LiDAR sensor measures the distance between train vehicles and them. Measurement data is matched to reference data of structures, and we can detect the measured structure location. This method has mainly two advantages compared to conventional methods;

1. Getting the absolute location of the train: No need for balises,
2. High-speed measurement of 1D LiDAR: Feasible in high-speed railways such as Shinkansen.

In the point of view of safety, misidentification of structures is dangerous. We also propose testing methods for eliminating structure matching failure.

We conducted experiments using car environments, which are similar to railway environments. In Table 1, The experimental results show that our method achieves higher than 90% success rate of localization. In addition, combining testing methods, misidentification rate went down as small as 2%. These results indicate that Proposed method can replace conventional ground-based localization method.

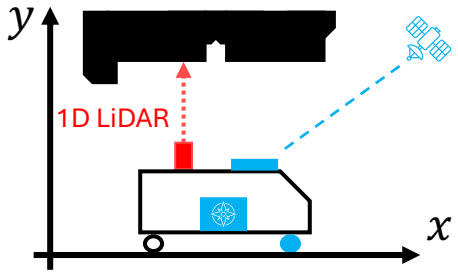

Fig.1. Concept of addition of 1D LiDAR sensor.

Table 1. Success rate of structure identification using proposed method.[1]

	ID. success	MisID.	ID. failure	Cal. time
ICP	0.83	0.17	-	1.86s
NDT	0.82	0.18	-	3.45s
ICP w/ RF	0.90	0.10	-	1.85s
NDT w/ RF	0.89	0.11	-	3.42s
ICP w/ RF・RR	0.95	0.05	-	0.48s
NDT w/ RF・RR	0.95	0.05	-	0.83s
ICP w/ RF・RR・Test (5%)	0.80	0.00	0.20	0.48s
NDT w/ RF・RR・Test (5%)	0.80	0.00	0.20	0.83s
ICP w/ RF・RR・Test (10%)	0.88	0.01	0.11	0.48s
NDT w/ RF・RR・Test (10%)	0.89	0.02	0.09	0.83s

※ ID. = Identification
※ This table shows the average rate of ID. success/MisID./ID. failure
※ RF = Raindrops Filter, RR = Range Restriction
※ Cal. time means the time that was used for scan matching. It is the average time per structure.

References

[1] K. Nagai, W. Ohnishi, and T. Koseki, “Absolute Train Localization Based on the Identification of Surrounding Structures using 1D-LiDAR Sensor,” IEEJ Transactions on Industry Applications, 144, 6, 442-451, 2024 (in Japanese).

Study on Chinese High-speed Railway Rolling Stock Planning

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Rolling stock planning is a core problem in high-speed railway transport production planning. A space–time–state network is established to describe the operation of rolling stocks considering accumulated mileage and running time constraints for maintenance.

A new multiobjective mixed-integer nonlinear programming (MIP) model is established according to a space–time–state network for robust rolling stock planning. A state dimension is introduced to describe the maintenance constraints. An alternating direction method of multipliers (ADMM)-based dual decomposition approach is used to solve this formulation. The augmented LR, which includes an additional quadratic penalty term in the objective, can improve the computational performance of the standard LR by optimising the solution symmetry in subproblems. However, the quadratic penalty term is difficult to decompose. In this paper, we develop an ADMM approach with a rolling update mechanism to handle the quadratic penalty term. Because of the properties of the 0-1 decision variables in the established model, it can be effectively linearised and thus possesses decomposable properties. The original MIP model is decomposed into a set of independent rolling stock route selection subproblems. A shortest path algorithm with resource constraints is designed to effectively solve the subproblems. That is, a route is arranged for each rolling stock that meets maintenance requirements and has a better absorption capacity for trip delays.

The results show that the ADMM considerably outperforms the traditional Lagrangian relaxation (LR) method. On a set of larger-scale cases, the proposed ADMM with enhancements obtains an optimality gap of 2.42% on average. This result is substantially better than LR, which provides optimality gaps of 32.55% on average.

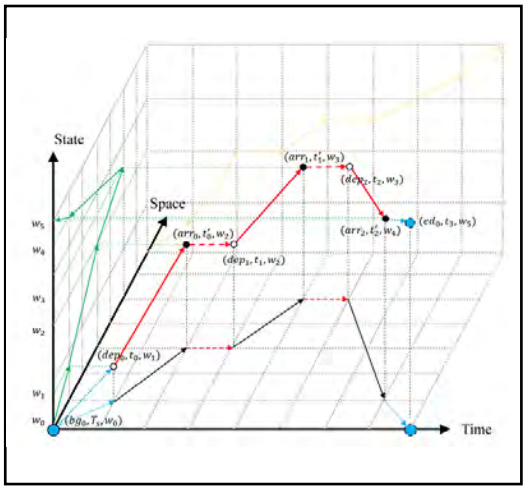

Fig.1. Illustration of the rolling stock route in the space–time–state network.

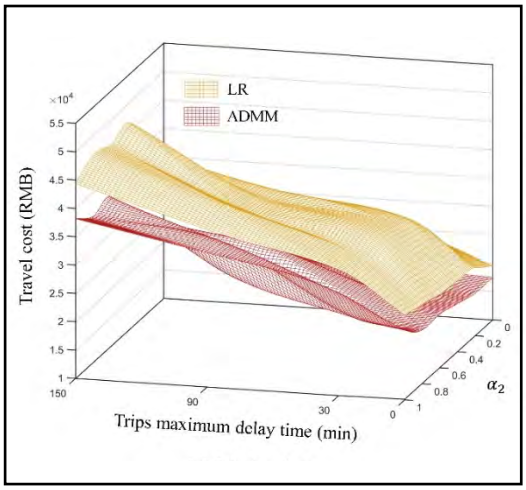

Fig.2. Results obtained by ADMM and LR with different parameter combinations.

Optimization of the Tilt Control Pattern Considering the Air Insufficiency on Many Curves in Air Spring Car-Body Tilting Control System

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Air spring car-body tilting control system uses compressed air to tilts car body when approaching a curve. On routes with continuous curves, there is concern about insufficiency of compressed air.

In this background, the research objective is to generate tilt control pattern that avoids any Insufficiency of compressed air during travel. This objective is accomplished by suppressing tilt angle of some curves. The amount of suppress and which curves are affected determined based on the air reservoir pressure and curve profile data. Fig. 1, is a vehicle model used to generate the tilt control pattern.

Fig. 2, depicts the results. It is calculated by dynamic programming(1). Fig. 2(a), illustrates the tilt control pattern, while Fig. 2(b), shows the air reservoir internal pressure. Based on generated tilt control patterns, the tilting of the first and fourth curves is prioritized. The reason for this is that the lengths of the second and third curves are shorter than those of the first and fourth curves. Therefore, it is thought that the tilting at the second and third curves was reduced in order to prioritize the tilting at the longer curves, thereby saving on the use of compressed air.

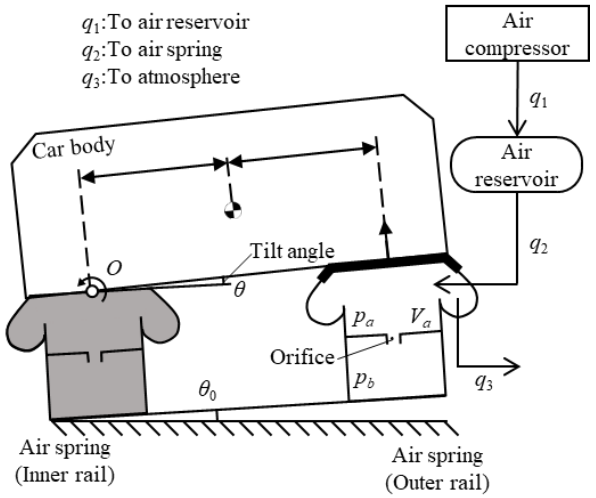

Fig.1. Vehicle model

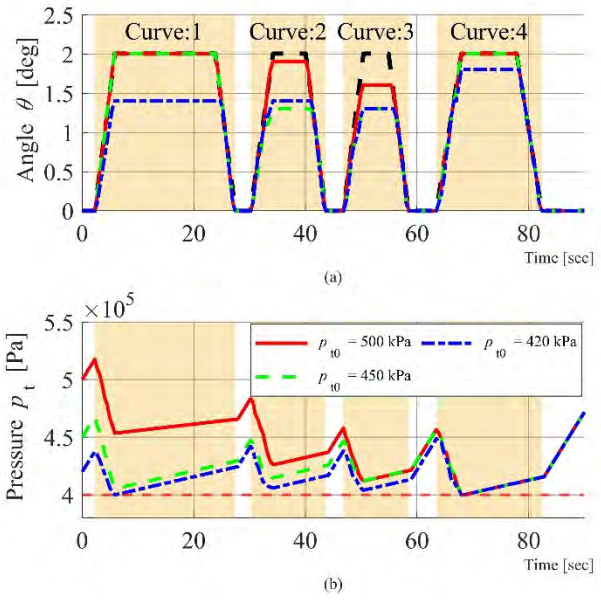

Fig.2. Calculation results. (a) is the tilt angle, and (b) is the air reservoir internal pressure.

(1) Ko, H., Koseki, T. and Miyatake, M., Numerical study on dynamic programming applied to optimization of running profile of a train, TEEJ (D), Vol.125, No.12 (2005), pp.1084-1092.

Black-box Adversarial Test Generation and Prioritization for Deep Neural Networks

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Computer vision techniques have demonstrated exceptional performance in image classification, object segmentation, and detection tasks. However, their reliability in high-security domains, such as facial recognition and autonomous driving, remains a concern, particularly under adversarial attacks. Recent research suggests a link between model generalization and the transferability of adversarial examples, the connection is crucial for understanding how adversarial robustness can be achieved.

Building on this insight, we propose the Asymptotically Normal Distribution Attack (ANDA), an innovative approach for generating adversarial examples that capitalize on the asymptotic normality of Stochastic Gradient Descent (SGD) to estimate the posterior distribution of perturbations at each step. Additionally, we introduce the Flat Adversarial Subspace Attack (FASA), a method designed to learn a flat subspace, thereby enhancing the smoothness of the loss landscape that underpins adversarial example generation. To strengthen the robustness of models against adversarial threats, we have developed the Uncertainty-Driven Test Input Prioritization (UTIP) method, which leverages uncertainty in example selection to refine the transferability of adversarial examples. This innovative strategy, complementing our existing approaches, a series of experimental results has proven effective against both undefended and defended models, showcasing the versatility and comprehensiveness of our approach.

We are hopeful that our research will contribute to the development of more robust models, enhancing the security and reliability of AI systems in critical domains.

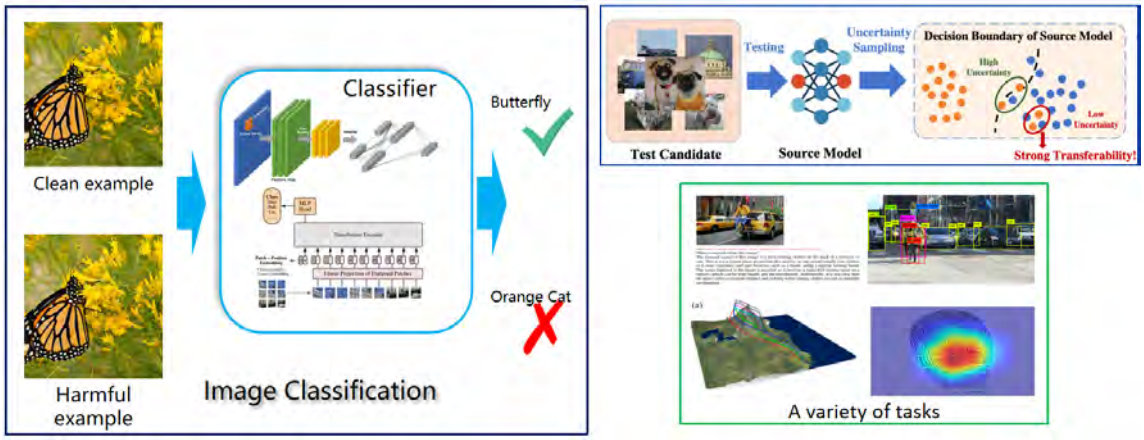

Fig1. Adversarial Testing in Deep Learning: Black-box Attacks and Prioritization

Improvement methods of transmission characteristics for railway signaling systems using FFT and development of a FPGA-based processing unit

Takuto Suzuki[1], Hiroshi Mochizuki[1]
[1] Nihon University

In Japan, there are railway signaling systems such as automatic train control (ATC) system via track circuits (rails). Here, it is necessary to consider the return current noise that occurs when trains move in the transmission characteristics over track circuits. To overcome this noise, it is effective to use digital signal processing technologies. In particular, we have focused on applications of Fast Fourier Transform (FFT) to improve the transmission characteristics.

In this study, we proposed a method for improving transmission characteristics by estimating the frequency of return current noise based on FFT analysis and performing inverse FFT (IFFT) after removing this frequency component. We verified the effectiveness of our proposed method in a computer simulation result as shown in Fig. 1. In addition, we attempted to develop a processing unit using FPGA. FPGA has an advantage for parallel processing capability, it is suitable for implementing FFT. This time, we constructed the butterfly computation which is the basic computation in FFT by the hardware descript language (HDL). And we evaluated the basic performance by observing the output signals of the developed processing unit as shown in Fig. 2.

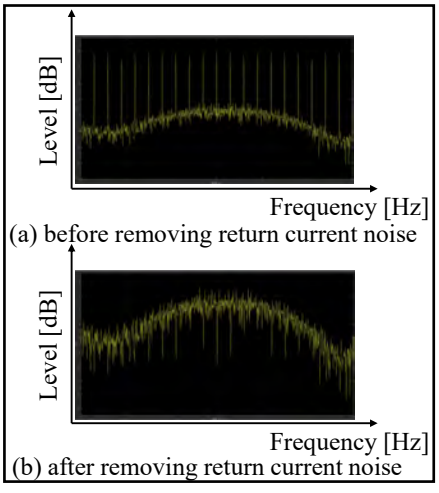

Fig.1. Spectral distribution before or after removing return current noise.

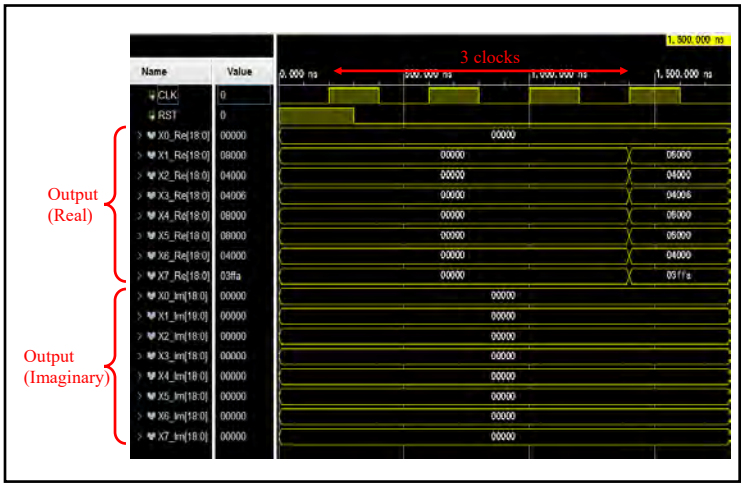

Fig.2. Output signals of developed processing unit using FPGA.

Model Predictive Thrust Force Control for three-level neutral point clamped inverter Fed Linear Synchronous Motor of Maglev Train

Jinsong Kang[1], Yuanzhe Zhao[1], Hao Ding[1]
[1]Tongji University

The thrust force ripple of High-speed maglev linear synchronous motor (LSM) would reduce comfort and even cause resonance. Moreover, the neutral point voltage of the three-level neutral point clamped inverter will also affect the safety. In order to reduce the thrust force and neutral point voltage ripple, a traction control scheme based on model predictive thrust force control (MPTC) method for maglev is proposed in this article. First, the control of thrust force and stator flux is transformed into the control of flux vector, eliminating weighting factor of flux in the cost function. Then, a three-stage selection scheme is applied to determine four effective voltage vectors (VVs). Additionally, the concept of deadbeat control is introduced to allocate the durations of each vector in every control period, which is based on thrust force, stator flux, and neutral point voltage difference parameters. Finally, the experimental results are validated based on a hardware-in-the-loop (HIL) system. The comparative experimental results show that compared with the traditional control methods, the proposed MPTC could significantly reduce the thrust force and neutral point voltage ripple under matched parameters. In cases of parameters mismatch, the suppressive capability of neutral point voltage remains superior to other methods.

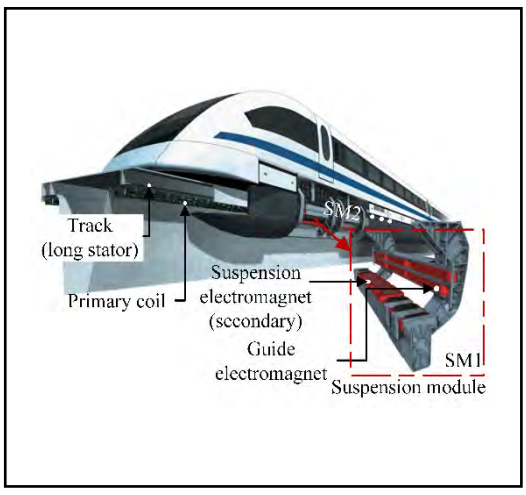

Fig.1. The illustration of the TR type high-speed maglev system.

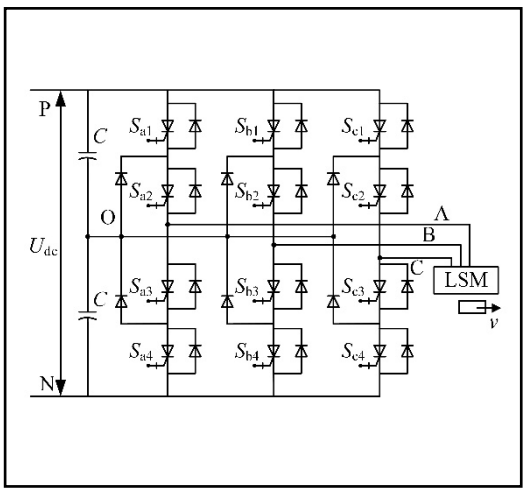

Fig.2. Simplified circuit topology of a 3L-NPC Fed LSM system.

Proposal of train control system on commercial cloud services

Koudai Fukuda[1], Hiroshi Mochizuki[1]
[1] Nihon University

At present, railway signaling systems in which control information is transmitted via track circuits (rails) have been deployed in many applications, such as automatic train control (ATC) systems in Japan. Although they can provide a high level of safety for train control, it is necessary to consider the ease of maintenance of the signaling equipment. Therefore, there have been many studies train control systems using general-purpose equipment such as mobile communications, GNSS and so on.

Based on these ideas, we focused on cloud computing technologies. Existing systems have been secured by specially designed equipment. However, cloud computing has the potential to change the way systems are installed and the way their functions are realized. If the cloud could handle the signalers, it would reduce the costs. This study discussed the system configuration, safety method, and experiments using cloud services to realize a train control system with commercial cloud services. In the experiments, a simple train control system was implemented in two cloud services for safety as shown in Fig. 1, and a model was evaluated for comparison of results between the two services. For each cloud, we found that processing times varied by about a factor ten between minimum and maximum, and by about a factor six between average and peak as shown in Fig. 2.

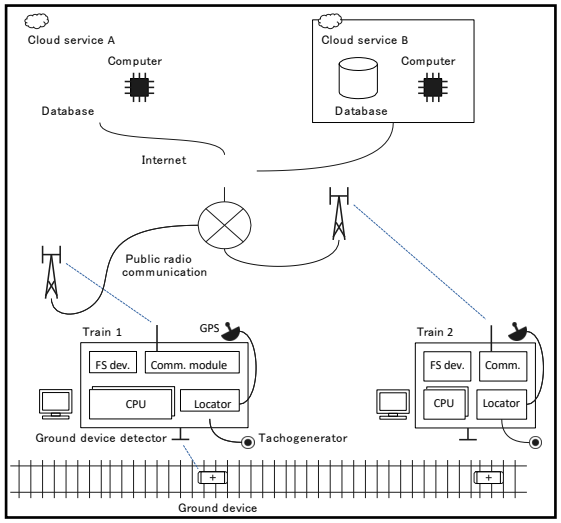

Fig.1. Configuration of train control system on commercial cloud services.

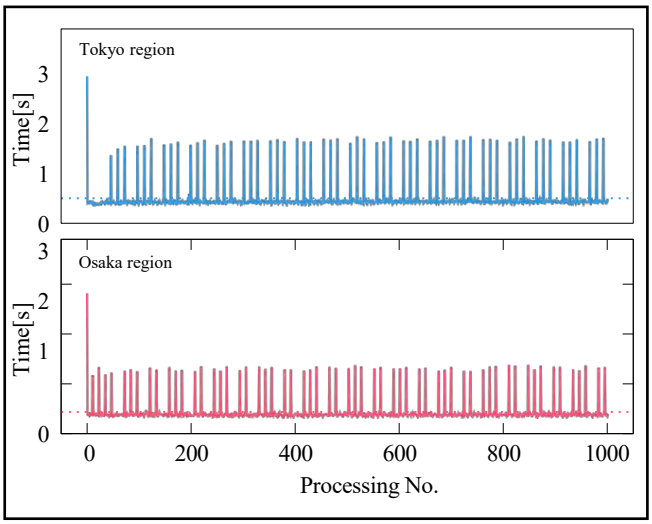

Fig.2. Time variance in overall processing time on commercial cloud.

Energy Management Strategy Based on Reinforcement Learning and Frequency Decoupling for Fuel Cell Hybrid Powertrain

Hongzhe Li[1], Jinsong Kang[2],MinLiu[1]
[1]College of Electronic and Information Engineering, Tongji University
[2]Institute of Rail Transit, Tongji University

Energy Management Strategy (EMS) is a pivotal research area within the realm of hybrid power systems. Reinforcement Learning (RL) has become a focal point for optimizing the energy management of rail transit vehicles equipped with hybrid power systems, featuring hydrogen fuel cells and lithium-ion batteries. However, challenges arise during RL training, where the accuracy and convergence speed of algorithms hinge heavily on initial values. Furthermore, RL algorithms encounter limitations in optimizing variables observable only at a single time step, posing difficulties in considering variables requiring a comprehensive understanding of system operations. In response to these challenges, this study presents a Two-Layer Deep Deterministic Policy Gradient (TL-DDPG) energy management strategy. Augmenting the optimization capabilities of the inner layer, a frequency decoupling algorithm integrates into the outer layer, furnishing a fitting initial value for strategy optimization. This addition aims to bolster the stability of fuel cell output, thereby enhancing the overall efficiency of the hybrid power system. In comparison with the traditional reinforcement learning algorithm, the proposed approach demonstrates not able improvements: a reduction in hydrogen consumption per 100 km by 16.3 kg, a 9.7% increase in the output power stability of the fuel cell, and a 1.8% enhancement in its efficiency.

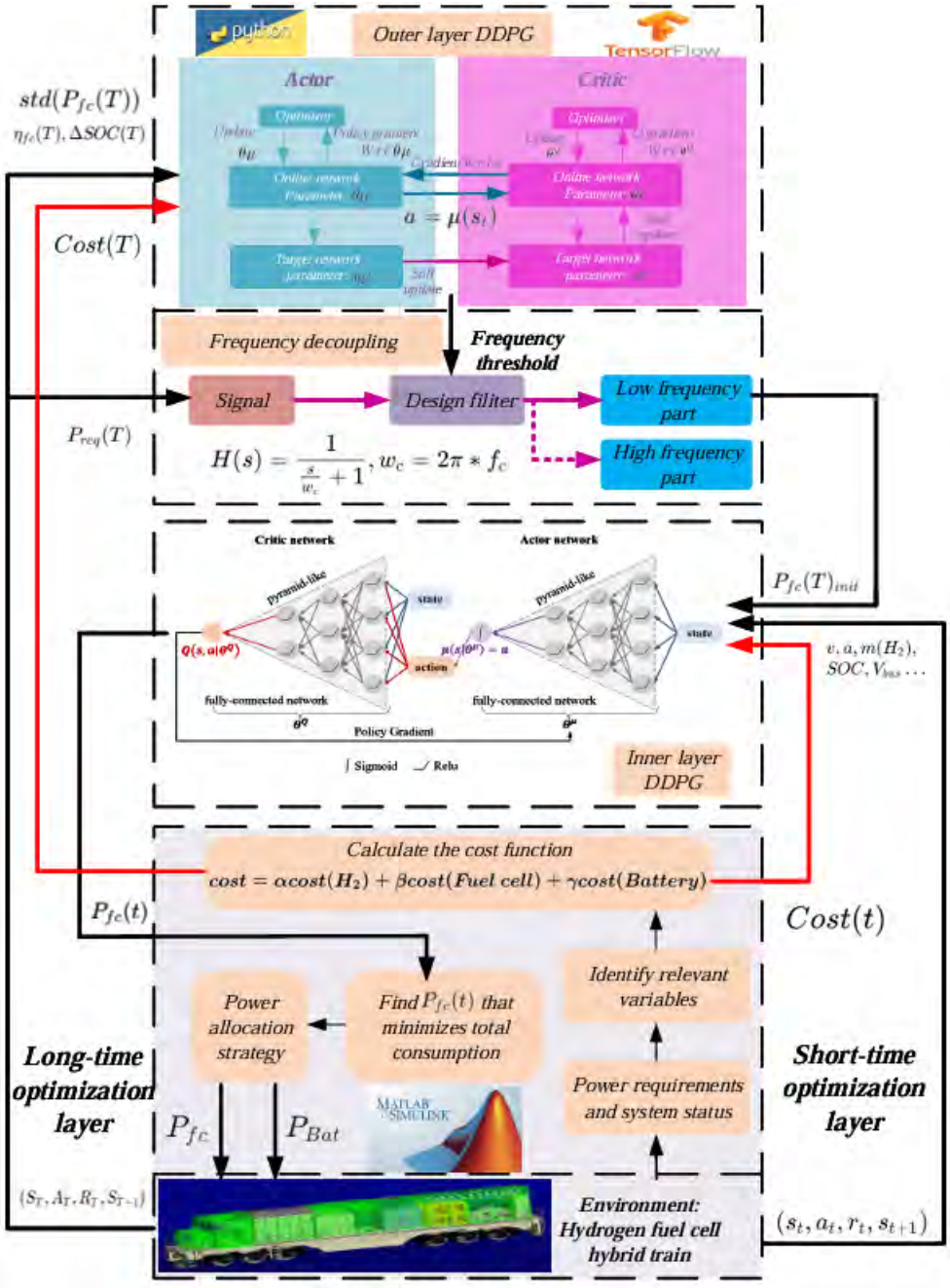

Fig.1.Adaptive hierarchical EMS combining frequency decoupling and two-layer DDPG.

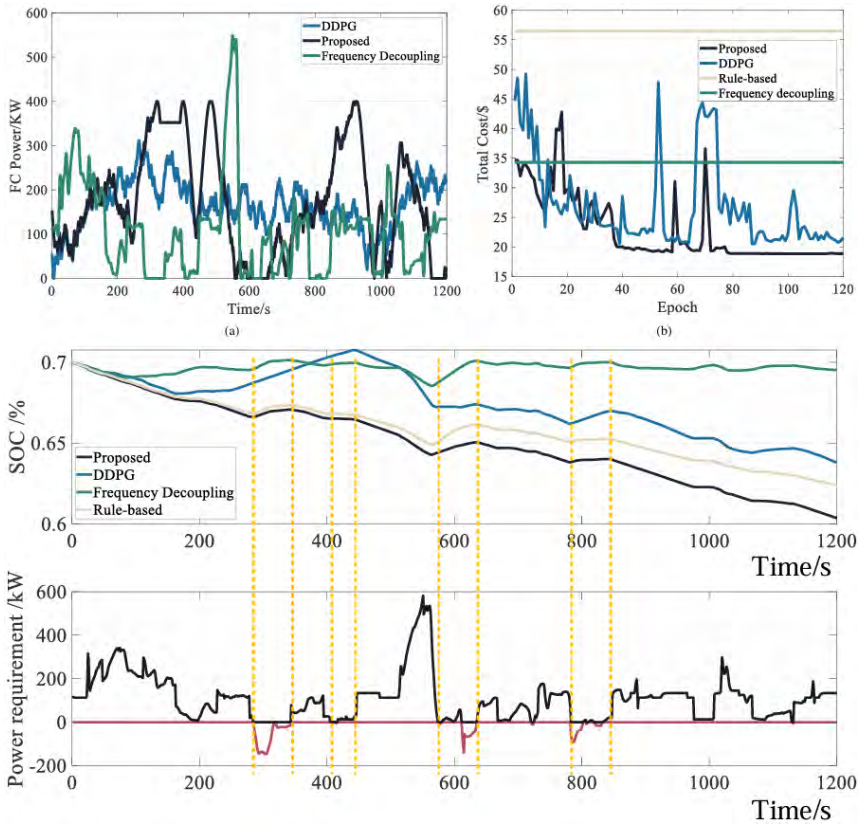

Fig.2. Comparison of each index of the algorithm. (a) Fuel cell power of different algorithms at the first epoch. (b) the total cost of one complete run. (c) SOC trajectory and energy recovery.

Algorithm	Fuel Consumption (kg)	Terminal SOC(%)	Average Efficiency of Fuel Cell(%)	Total Cost($)	Training Time(s)
Rule-based	2.78	62.40	54.78	56.49	40.12
DDPG	3.84	63.8	53.38	21.45	123.56+33.54
Frequency Decoupling	5.02	69.52	51.49	34.29	66.38
Proposed	2.21	60.36	55.20	18.90	206.71+45.40

Table.1. Comparison of different EMSs

Smart level crossing controller with train moving direction detection function and hardware development using embedded devices

Haruki Araie[1], Hiroshi Mochizuki[1]
[1] Nihon University

Level crossing controllers employed in a railway signaling system detect trains using the principle of track circuits. However, this requires detecting both the presence and moving directions of trains in a single-track section, and conventional level crossing controllers have complex configurations including cables that carry this information.

To overcome this restriction, we propose a novel method for detecting a train moving direction by observing the transmit and receive signals of a level crossing controller as shown in Fig. 1. After we verified the effectiveness of the proposed method by conducting computer simulations including actual signals of level crossing controllers, we developed a processing device equipped with a train moving direction detection function using an embedded device. Fig. 2 shows a comparison of the output characteristics between the up and down trains in the developed processing device. The differential signal in this figure was masked on the processing device side so that it was output only near the approach section of the level crossing controller. We confirmed that each differential signal between the up and down trains was different and verified that it is possible to apply this to train moving direction detection.

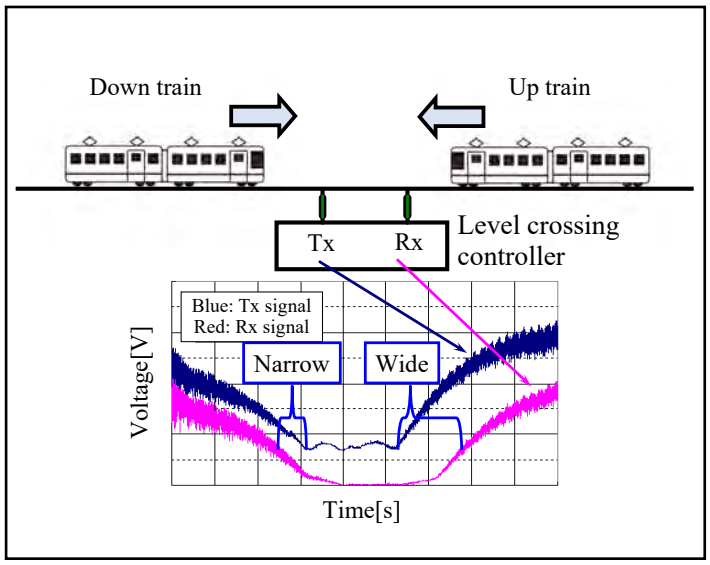

Fig.1. An example of output characteristics after processing the actual level crossing controller signal.

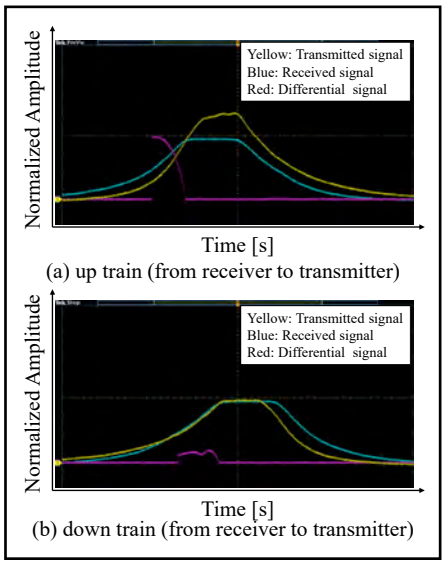

Fig.2. Comparison of output characteristics between up and down trains.

An Intelligent BIM Approach to Foster Rail Bridge Design

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[2] School of Computer Science and Engineering, Xi'an University of Technology

As integral structures within transportation infrastructure, bridges serve as vital connections in railway systems. Traditional railway bridge design primarily relies on the experience of designers for component selection and repetitive parameter calculations. This approach lacks effective integration of information management, leading to challenges in design quality and efficiency. Building Information Modeling (BIM) provides a comprehensive digital representation of physical and functional characteristics, offering a promising solution to these challenges. This study proposes an intelligent design method for railway bridges using a knowledge-driven BIM model. Initially, using the railway bridge design codes and related materials as knowledge sources, we investigate the extraction of design knowledge and categorize bridge-related terms, and further create an ontology of concepts and properties, as shown in Fig.1. Then the definition of conceptual-level relationships, such as attribute definition domain, value domain, and constraint relationship, is carried out according to the semantic logic of bridge design knowledge.[1] Subsequently, this design knowledge is utilized to reconstruct design rules. We establish semantic element mapping patterns and rule transformation templates to formulate Semantic Web Rule Language (SWRL) reasoning rules, and use the reconstructed design rule to infer design parameters for the bridge model. Finally, a parametric component adaptive generation algorithm, based on the knowledge ontology model and reasoning rules, is proposed to achieve the intelligent generation of the railway bridge BIM model, as shown in Fig.2. Validation shows that the generated bridge model meets geometric expression requirements according to design codes and can be imported into structural analysis software for further processing. Our method effectively supports intelligent railway bridge design, enhancing design efficiency.

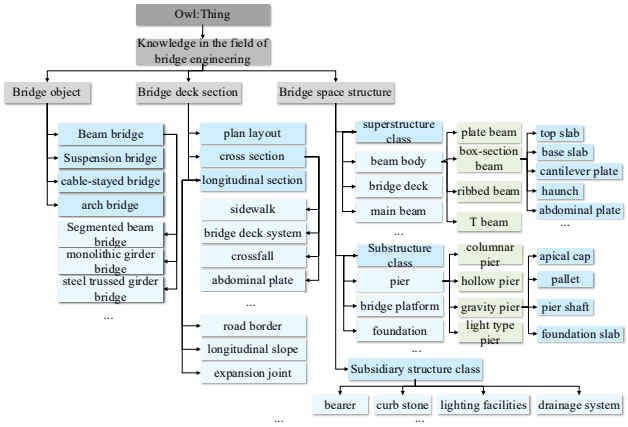

Fig.1. Knowledge Ontology Class Structure Diagram

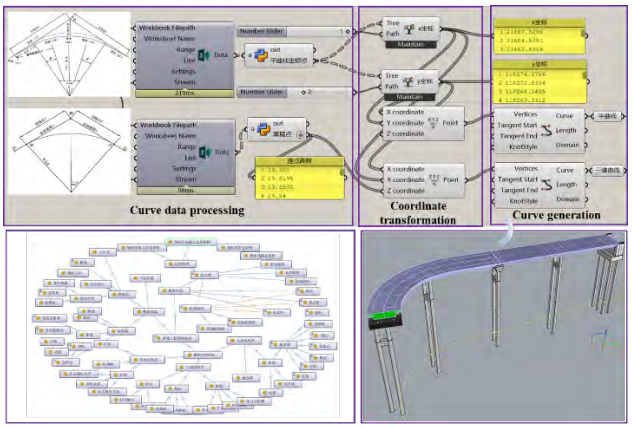

Fig.2. Rail Bridge BIM Model Generation

[1]Yang M , Zhao Q , Zhu L ,et al.Semi-automatic representation of design code based on knowledge graph for automated compliance checking[J].Computers in Industry, 2023.

Track condition management based on in-service vehicle vibration

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[1] Graduate School of Nihon University
[2] Department of Mechanical Engineering, College of Industrial Technology, Nihon University

The condition of railway tracks is important to ensure the safe operation of trains. Thus, track condition needs to be managed through frequent monitoring and maintenance work on the tracks. Currently, it is difficult for regional railways in Japan to carry out proper track management due to a lack of manpower and a deteriorating business environment. In response to these problems, a system has been developed to monitor track conditions by installing a sensing device on in-service trains and measuring car body vibration, as shown in Fig. 1. However, the acceleration measured on the car body is affected not only by the track condition but also by the running speed, making it difficult to determine the threshold values required for track management.

In this study, a method is proposed to automatically calculate threshold values for determining faulty track condition by setting significance levels for measured car body accelerations using a chi-square distribution. The proposed method is applied to actual measured car body accelerations on a regional railway in Japan. In order to determine outliers using the chi-square distribution, the significance level was set to less than 5%, and a threshold value of 3.84 was obtained. The outlier exceeding the threshold value of 3.84 was detected on September 8, 2021, from the time variation of the indicator $a(x_i)$, squared Z-score of the measured car body vertical acceleration. The result is shown in Figure 2.

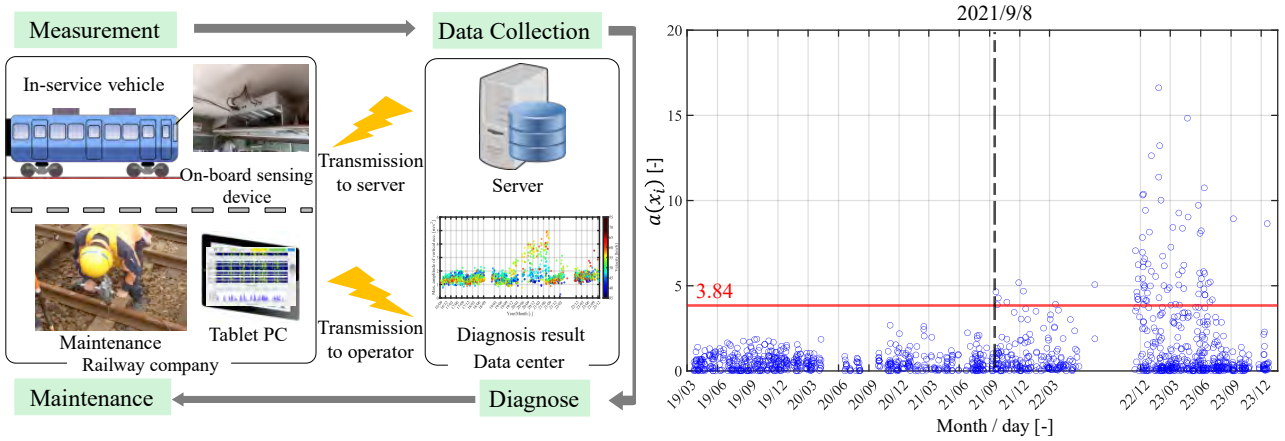

Fig.2. Detection of faulty track condition from car body vertical acceleration.

A Fault-Diagnosis Method for Railway Turnout Systems Based on Improved Autoencoder and Data Augmentation

Mengyang Li[1], Xinhong Hei[1], Wenjiang Ji[1], Lei Zhu[1], Yichuan Wang[1] and Yuan Qiu[1]
[1]School of Computer Science and Engineering, Xi'an University of Technology

Railway turnout system (RTS) is a key component of transportation infrastructure, playing an important role in train route conversion. The widespread deployment of RTS has accumulated a large amount of historical data.[1] It promotes the development of data-driven fault diagnosis methods intelligentization and automation, and improve the reliability and safety of railway. However, the significant challenge in data-driven fault diagnosis is to effectively extract deep features from noise data and accurately identify failure modes despite unbalanced datasets. To address these challenges, we focus on unbalanced data and propose a fault-diagnosis method that combines an improved Auto-Encoder (AE) with data augmentation, as shown in Fig.1. The improved AE is to smooth the noise and extract deep features, thereby mitigating the noise fluctuations caused by the physical characteristics of the data. Then, synthetic minority oversampling technique (SMOTE) is utilized to effectively expand the fault types and solve the problem of unbalanced datasets. Furthermore, the health state is identified using a Softmax classification model trained with the balanced characteristic data, which improves diagnostic precision and generalization ability. Finally, experiments are conducted on a real power curve dataset for turnout based on a railway station in China, and the average diagnostic accuracy reaches 99.13% superior to SOTA, as shown in Fig.2.

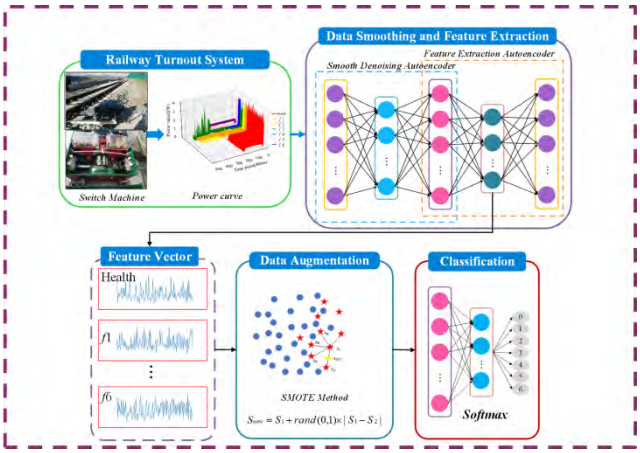

Fig.1. The framework of the proposed fault diagnosis method.

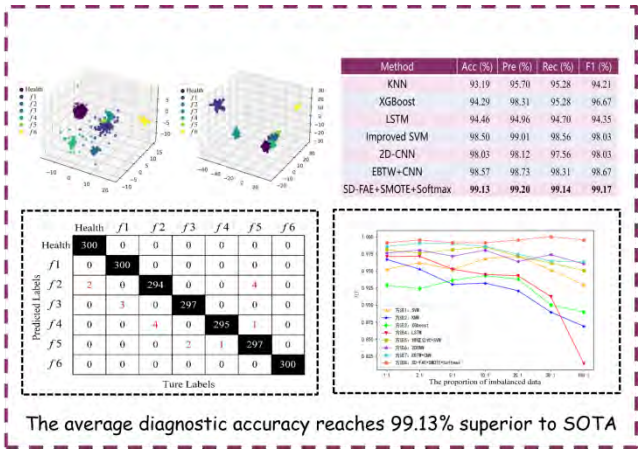

Fig.2. Experimental Result

[1] An Intelligent Fault Diagnosis Method based on Curve Segmentation and SVM for Rail Transit Turnout[J]. Journal of Intelligent & Fuzzy Systems.

Analysis of Braking Patterns Considering Delays in Moving Block Systems Using Simulation

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In recent years, a moving block signaling system has been introduced in Japanese urban railways, allowing for shorter train intervals compared to fixed block systems. Moving blocks enable operations at the minimum interval between trains. However, it is empirically known that approaching the preceding train at the highest possible speed is not the best way to minimize intervals. Nakamura[1] analyzed brake patterns that shorten intervals using genetic algorithms, but under ideal conditions where both trains follow the same curve and the departure time of the preceding train is fixed. In reality, delays at stations can prevent ideal operations, potentially increasing travel time and inter-station stop time.

To address this, we seek optimal brake patterns considering delays and inter-station run curves. Given the difficulty of finding optimal patterns for all delays and run curves, we use a simulator to recreate delayed conditions and test multiple brake patterns, analyzing tendencies that shorten intervals. The simulator evaluates brake patterns under station delay conditions based on travel time and inter-station stop time. Using a two-stage deceleration method, we tested various deceleration speeds and distances. Results shown in Fig. 1 indicate that with a 5-minute station delay, travel time and inter-station stop time trade-off at low deceleration speeds (below 20 km/h), but both decrease compared to single-stage deceleration around 45 km/h.

[1] Nakamura, H.: Derivation of minimum headway driving pattern on moving-block system by utilizing genetic algorithm, Transportation Systems, 1-3, pp.747–752, 1997

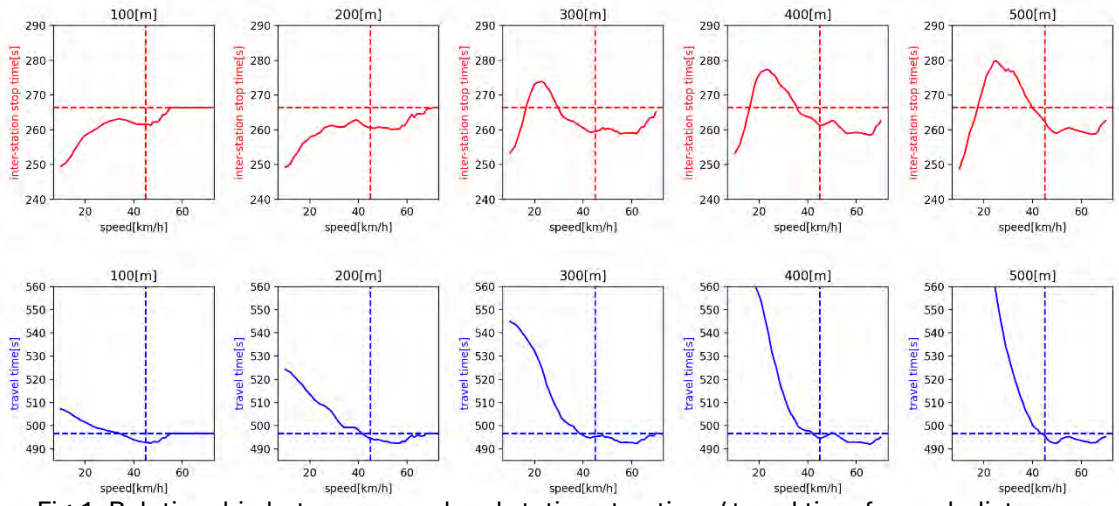

Fig.1. Relationship between speed and station stop time / travel time for each distance

A robust multi-objective optimization framework for rail profiles considering uncertainty

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Due to site constraints, metro lines usually have a large percentage of small radius curves. As subway lines experience increasing transportation density, the damage to rails in small-radius curve sections becomes more severe, particularly with regards to rolling contact fatigue (RCF) and rail side wear. In order to further improve the wear resistance of the rail, a metro vehicle-track dynamic simulation model was established in Simpack. And, the worn rail profiles were optimized by a multi-objective deterministic optimization (MDO) method. The MDO result indicates that the optimized rails performed better than the corresponding worn rails. However, the deterministic optimal design is likely to become unacceptable when considering the uncertainties of running conditions. To solve this problem, a multi-objective robust optimization (MRO) method which employs machine learning, NSGA-II, “3-sigma” robust design and Monte Carlo simulation (MCS) was developed. Then, the rail profiles were optimized by this robust optimization method (ROM). The comparison of the Pareto fronts of the MDO and ROM shows that the robust optimal rails are more reliable than the deterministic optimal rails. The robust optimal rail not only has excellent wear resistance but also has high reliability of safety.

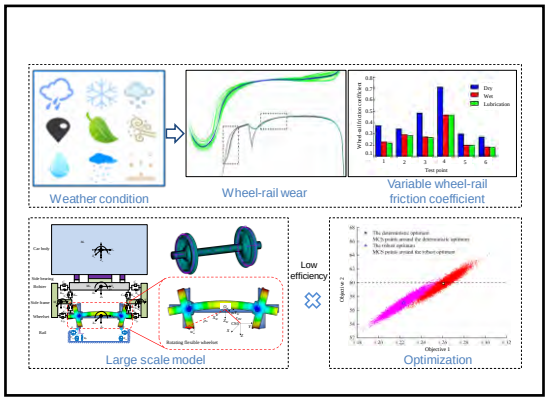

Fig.1. Complex and uncertain running conditions of railway vehicles.

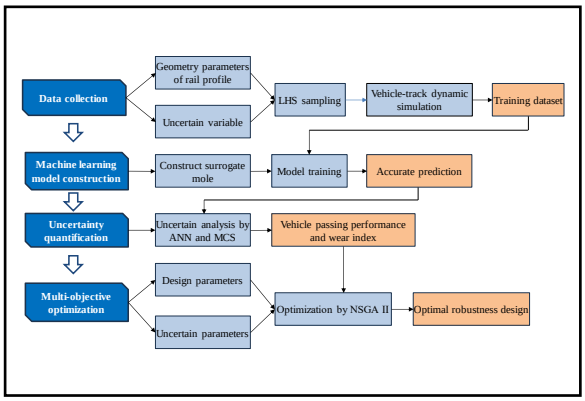

Fig.2. Robust optimization framework of rail profiles.

Faults and Disturbances Identification in Co-Phase Power Supply System

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The Co-Phase Power Supply Train-Grid Electrical Coupling System (CPPS-TGECS) addresses the issues of neutral section and negative sequence in electrified railways. However, the introduction of power electronic devices termed as Co-Phase Power Supply (CPPS) devices complicates the electrical coupling in the Train-Grid Electrical Coupling System (TGECS). Rapid and accurate detection and identification of anomalies in the TGECS and CPPS devices are prerequisites for analyzing disturbances and faults in CPPS-TGECS, which is crucial for ensuring the safe and stable operation of the system. Traditional analysis methods focus solely on internal inverter faults or train-grid electrical coupling electrical anomaly, which leads to an inability to analyze their coupling relationship and may result in misdiagnosis. Additionally, the lack of practical data hinders the application of traditional algorithms. Therefore, this paper proposes a zero-shot learning-based method for diagnosing faults and disturbances in CPPS-TGECS. By simultaneously collecting three electrical signals, the method enables comprehensive analysis of abnormal operation states in Co-Phase power supply system. The TimesNet-based feature extraction channel is designed for better extraction of electrical signal features. And proposed method tackles the problem of missing composite operational samples using zero-shot learning algorithms. The experimental results show that our method achieves an identification accuracy of 99.16% for seen types and 96.50% for unseen types. As validated by engineering examples, this study demonstrates, for the first time, the successful implementation of faults and disturbances identification tailored to Co-Phase power supply system.

Analysis of Low Frequency Oscillation in Co-phase Power Supply Systems

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In high-speed railroads, the Co-phase Traction Power Supply System (CTPSS) provides guidance on solving power quality problems and eliminating phase breakers. Its operation schematic is shown in Fig. 1. However, CTPSS introduces large-scale power electronics on the power supply side of the train-grid system, which makes the train-grid electrical coupling relationship complicated and prone to system instability. To explore the problem, the dq frame impedance of the CTPSS is derived and the low-frequency stability of the system is analyzed based on the impedance stability criterion. First, the equivalent circuit of the CTPSS is derived and its control strategy is presented. Second, the modular modeling technique is employed to derive the small-signal model of CTPSS. The accuracy of the model is verified by impedance measurement method. Then, the effect of power electronic devices on system stability is analyzed based on the generalized Nyquist criterion. Finally, the CTPSS model is constructed in MATLAB simulation platform, and the experimental results verify the correctness of the theoretical model.

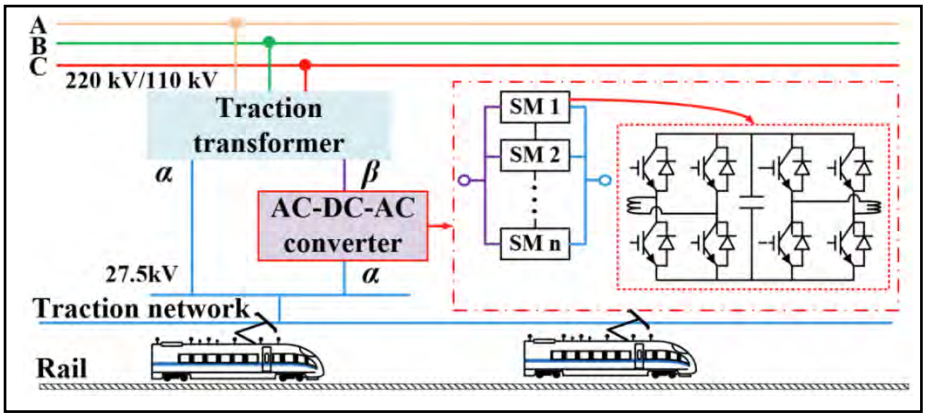

Fig.1. Schematic diagram of CTPSS.

Study on the mechanism of fatigue crack initiation in rail steels considering crystalline plasticity at micro-nano scale

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To investigate the mechanism of rolling contact fatigue crack initiation in rail materials at the micro-nano scale, this study developed an improved Cohesive Zone Model - Crystal Plasticity Finite Element (CZM-CPFE) model. This model incorporates factors such as grain orientation, crystal plasticity, and misalignment between neighboring grains. Simulation parameters were obtained through quasi-in situ uniaxial tensile tests and fatigue crack growth experiments. The model analyzed the crystal mechanical response and grain boundary damage under rolling contact loading conditions, and its accuracy was validated. The study then explored the crystal mechanical response characteristics, grain boundary damage mechanisms, and fatigue crack growth mechanisms of rail materials under cyclic rolling contact loads. The simulation results were compared with field data on rail damage to elucidate the causes of rolling contact fatigue crack initiation. Additionally, an analysis of factors influencing grain boundary fatigue damage was performed, including the effects of grain diameter, grain diameter standard deviation, and initial microstructure. This provided preliminary insights into the impact of rail microstructure on fatigue crack initiation.

Furthermore, to clarify the grain damage evolution mechanism under cyclic loading, molecular dynamics was used to construct a microscale friction damage analysis model for rail materials, with model accuracy validated by wear rate experimental results. The model was employed to analyze the mechanical response characteristics at the microscale, such as microscopic friction forces, atomic strain, and stress responses, revealing factors affecting the microscopic mechanical response of rails. The study also investigated the microscale friction damage mechanism, including phase transitions, point defects (vacancies), line defects (dislocations) distribution, and dislocation evolution mechanisms under frictional loading. This analysis discussed the impact of microscale rail material damage on service performance and identified key factors influencing grain boundary fatigue and micro-crack initiation under wheel friction loads.