Guest Editorial
Introduction to the Special Issue on Applications and Developments of Novel Technologies in Intelligent Transportation Infrastructure Systems

THE service life and service quality of transportation infrastructures are crucial for the regular function and public safety of transportation systems. Thus, the intelligent and accurate evaluation, prediction, and analysis of transportation infrastructure service conditions have always been hot topics for transportation engineers, where such problems are sometimes hard to be solved using traditional approaches, considering different factors including complex traffic conditions, severe environmental conditions, etc. In recent years, intelligent technologies, including advanced sensors, novel artificial intelligent approaches (deep learning, etc.), the IoT-based monitoring and analysis platform, auto piloting, green energy, synergistic technologies, and systems integrating both traffic and infrastructures monitoring, have emerged as powerful tools in transportation engineering area. These efforts have greatly advanced the service convenience of public transportation, prolonged the service life of transportation infrastructures, and improved the efficiency and safety of transportation systems.

The Intelligent Transportation Infrastructure System (ITIS) is a kind of smart civil infrastructures, which is different from the traditional transportation infrastructures. Currently, most of the applications of novel technologies in ITIS are still under development. This Special Issue aims to gather research results from both academia and industry, and discuss the progress for the current applications and future developments of novel intelligent technologies in transportation infrastructures and systems, and plan to solve some of the most important and necessary problems for intelligent transportation systems community. Specifically, this Special Issue includes the following areas.

I. Intelligent Monitoring and Analysis on the Road Conditions

The service conditions of road have attracted the attentions of the researchers. In [A1], Dong et al. presented a start-of-art review of data analysis used in pavement engineering from more than 200 literatures. They concluded that selecting proper models based on the objectives and available data will be the key for the increasing accumulation of pavement performance data, as well as the big data from automatic pavement evaluations and pavement instrumentation in future practices. In [A2], Ma et al. presented a novel application to real-time modulus evaluation based on asphalt pavement health monitoring with built-in sensors. The results indicate that the proposed modulus evaluation method has a potential to identify the modulus of each pavement structural layer in real time with a convergent and unique solution under a realistic traffic load. In [A3], Wang et al. proposed a new approach of using the full deflection-time history collected by Falling weight deflectometer (FWD) to develop the dispersion curves and obtain the in-situ modulus of layered pavements, referred to as the FWD dispersion curve method. Using two in-service asphalt pavement segments as case studies, it is demonstrated that the FWD dispersion curve method is feasible and accurate in capturing the modulus profile of the asphalt pavements. In [A4], Deng and Shi employed the feedforward neural networks (NNs) with particle swarm optimization (PSO) to predict the rutting performance of asphalt pavement in the State of Idaho. In [A5], Ye et al. used a complete set of processing algorithm to extract the traffic information from the monitored vibration data. The traffic information such as vehicle speed, axle numbers, wheel bases, load position, and traffic flows are obtained. In [A6], Song et al. proposed a new modeling method for road conditions, which includes a ThunderGBM-based ensemble learning model, coupled with the Shapley Additive Explanation (SHAP) method, to predict the International Roughness Index (IRI) of asphalt pavements. In [A7], Yao et al. proposed an innovative maintenance and rehabilitation (M&R) optimization approach for multi-lane highway pavement based on a reinforcement learning (RL) method. In [A8], Luo et al. proposed an inverse analysis method of asphalt pavement field aging based on System Identification (SID) to back-calculate the aging parameters accurately and automatically. In [A9], Tan et al. presented a new pavement rutting deformation monitoring method based on the intelligent aggregate (IA) equipped with high-precision attitude sensor. In [A10], Zhao et al. proposed two approaches to detect the road anomaly using distributed fiber optic sensing (DFOS) technology.

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II. Intelligent Monitoring and Analysis on the Road Cracking

Crack is one of the most important factors that affect the regular service of roads. A timely repair of road crack may eliminate possible traffic accidents caused by the bad service of the infrastructures. In [A11], Han et al. proposed a novel pavement crack image segmentation convolutional neural network, namely, CrackW-Net to segment the pavement crack with satisfactory accuracy. In [A12], Liu et al. suggested a robust crack detection method based on Convolutional Neural Network (CNN) and infrared thermography. An open benchmark dataset was built for crack detection based on three types of images, including visible images, infrared images, and the fusion of visible and infrared images. In [A13], Hou et al. used a combined method to determine the road crack based on traditional image processing method and deep learning. In [A14], Ma et al. proposed an intelligent detection and tracking system for pavement cracks to automatically count the number of cracks. In [A15], Yao et al. presented a new pavement crack detection method based on the You Only Look Once 5th version (YOLOv5).

III. Intelligent Monitoring and Analysis of Other Important Transportation Infrastructures

Besides road, there are many other transportation infrastructures serving for public. Thus, the intelligent monitoring and analysis of these transportation infrastructures are also quite important.

1) For bridges, in [A16], Dan et al. proposed a digital twin system for bridges group in the regional transportation infrastructure network, which is interconnected by measured traffic loads. 2) For tunnels, in [A17], Kong et al. presented the intelligent analysis and prediction for the displacement of stratum and tunnel lining of Qingdao Metro Line 4 by earth pressure balance (EPB) shield tunnel excavation in complex strata. In [A18], Huang et al. proposed a photogrammetric system with advantages of accuracy and efficiency for detection and prevention of tunnel overbreak and underbreak in construction. In [A19], Du et al. presented a dislocation calculation method of shield tunnel based on cross sectional point clouds. 3) For high-speed railways, in [A20], Liu et al. proposed a train-track-trackbed coupling model to investigate the dynamic responses of track structure with the excitation of trackbed settlement with varied patterns. 4) For road underground structures, in [A21], Liu et al. proposed a novel YOLOv3 model with a ResNet50vd-deformable convolution (DCN) backbone and a hyperparameter optimization (HPO) method using Bayesian search to detect pavement concealed cracks in GPR images. In [A22], Liang et al. used an advanced air-coupled 3-D ground-penetrating radar (3D-GPR) to detect expressway to achieve the purpose of rapid, accurate, and nondestructive testing.

IV. Integration of Autonomous Driving and Various Traffic Conditions With ITIS

With the fast development of autonomous driving and considering various traffic conditions, these issues can be well integrated into the regular service of ITIS. In [A23], Du et al. presented a novel spatio-temporal synchronization method of roadside MMW radar–camera and improved the sensing technology in autonomous driving and intelligent transportation systems. In [A24], Wang et al. developed an innovative pavement marking incorporated with binary code to provide autonomous vehicles with accurate and robust localization services. In [A25], Xu et al. proposed a framework based on 3-D human pose estimation to recognize the actions of different roles in the traffic scenes. The action recognition module is based on a dynamic adaptive graph convolutional network, which can realize the action recognition of objects based on 3-D human pose. In [A26], Zheng et al. used a PBNet that combines a point cloud network with a global optimization method. This framework uses the feature information of objects to perform high-precision rough registration and then searches the entire 3-D motion space to implement branch-and-bound and iterative nearest-point methods. In [A27], Tu et al. presented a Digital Twins-Based Automated Pilot for energy-efficiency assessment of intelligent transportation infrastructures. In [A28], Liu et al. presented a Gaussian Process Regression for transportation system estimation and prediction problems. In [A29], Zhang et al. presented a Graph Attention Transformer (Gatformer) to predict trajectories for multiple traffic agents. In [A30], You et al. presented a new pixel-wise visibility estimation paradigm to sense the uneven fog situations in reality, which is more informative than a single-value visibility estimation method. In [A31], Zhou et al. presented a novel deep-learning framework based on CNNs for vehicle detection from roadside Light Detection and Ranging (LiDAR) data. In [A32], Iparraguirre et al. presented the work carried out for the detection of road markings damage using computer vision techniques. In [A33], Yan et al. proposed a novel traffic forecasting algorithm called traffic transformer. The experimental results indicate that the proposed traffic transformer outperforms state-of-the-art methods.

V. Intelligent Energy Harvesting and Optimization on Transportation Infrastructures

In [A34], Li et al. proposed an experimental analysis on the pavement infrastructure material and wireless power transfer. They discovered that the pavement material magnetization changes the active power and efficiency of the WPT (Wireless Power Transfer) system by inductance enhancement and coupling reduction in resonant inductive coupling. And the formulae are modified by two influencing factors: the inductance enhancement factor and coupling reduction factor, which are useful for adjusting the WPT system's component parameters to offset the magnetization impact. In [A35], Tang et al. suggested that Borehole Heat Exchanger (BHE) can be installed in different infrastructures to store or extract energy, such as pavement cooling in summer and de-icing in winter. In [A36], Bi et al. proposed a queueing network-based resource allocation model to comprehensively optimize various types of resources during emergency evacuations. Experiments are conducted in a simulated metro station environment with realistic settings.

In all, this Special Issue presents the latest research and progress in ITIS area. The presented topics, including advanced sensing technologies for transportation infrastructure monitoring, AI techniques for infrastructure maintenance decision-making, green energy harvesting from transportation infrastructures, smart materials for multifunctional infrastructure, are timely and important for transportation infrastructure engineers. We hope that the Special Issue can benefit those who are interested in smart, green and sustainable developments of transportation infrastructures.

We would like to express our sincere gratitude to the Editor-in-Chief, Prof. Azim Eskandarian, and all the editorial board members for the help during the preparation and publication of the Special Issue. We would also like to thank the reviewers for improving the quality of the Special Issue. Transportation infrastructures are in an era of fast development and we hope that this Special Issue can make solid contributions in both theoretical and practical means.

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APPENDIX: RELATED ARTICLES

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