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EDITORIAL

AI Assists Operation and Maintenance of Future Cities

Han-Wei Zhao[1,2,3]

[1] *State Key Laboratory of Safety, Durability and Healthy Operation of Long Span Bridges, Southeast University, Nanjing, Jiangsu, 211189, China*

[2] *Key Laboratory of Concrete and Pre-stressed Concrete Structures of the Ministry of Education, Southeast University, Nanjing, Jiangsu, 210096, China*

[3] *Teaching and Research Section of Intelligent Construction, Southeast University, Nanjing, Jiangsu, 211189, China*

Currently, most cities around the world have entered an era when construction and operation go forward equally. The extremely high maintenance costs and carbon emissions greatly constrain the development of modern cities. The rapid development of artificial intelligence (AI), big data, intelligence materials and other theories and technologies [1] has facilitated the intensive and less-manned operation and maintenance of urban and rural infrastructure. The massive data observed from multi-modal sensors can provide support for the state evaluation of structures and other entities within the generalized system of infrastructures. Robots and smart materials make it possible to instantly control systems of infrastructures. AI-assisted operation and maintenance will become a core theme for future cities with resilience to sudden disasters and long-term deterioration. And the key breakthrough points of intelligent operation and maintenance for future cities mainly focus on AI-based perception and control technologies.

AI-based perception is the first step of intelligent operation and maintenance for future cities. The structure of infrastructure is a complex system with the high order of statically indeterminate, which obeys the basic principles of mechanics. And it is always in a time-varying state of mechanical equilibrium during its service. With the increase of the operation time of infrastructures, the structure will inevitably deteriorate due to various erosion/disasters, and at the same time change the mapping

*CORRESPONDING AUTHOR:
Han-Wei Zhao, State Key Laboratory of Safety, Durability and Healthy Operation of Long Span Bridges, Southeast University, Nanjing, Jiangsu, 211189, China; Key Laboratory of Concrete and Pre-stressed Concrete Structures of the Ministry of Education, Southeast University, Nanjing, Jiangsu, 210096, China; Teaching and Research Section of Intelligent Construction, Southeast University, Nanjing, Jiangsu, 211189, China; Email: civil_hwzhao@seu.edu.cn

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relationship between its input (load) and output (response). Due to the increasing size and complexity of the structure, the model of representation for the degree of structural degradation using the changes in the input-output mapping relationship will gradually exhibit significant high-order nonlinear characteristics, and the mining and modeling works are difficult to complete via classical theories. Therefore, establish the mapping relational model between structural multi-scale input-output behaviors based on the deep learning of multi-source big data of observation [2] (e.g., monitoring, detection, or any others), then mine the long-term evolution details behind the variation in mapping relational model, are the keys to perception of infrastructure degradation.

AI-based control is the second step of intelligent operation and maintenance for future cities. The structural control of cities' infrastructures includes event/disaster-advance resilience improvement (by energy dissipation devices) and event/disaster-after repair (by robots or smart materials). Whether it is the advanced control by energy dissipation devices or the after control by robots or smart materials, the basic logic-link of works is from identification to decision, then to control. According to the requirements of the operation and maintenance task, intelligent-control devices (i.e., energy dissipation devices, robots, reinforcing or repairing devices using smart materials) need independently or collaboratively complete processes on the active identification and measurement of targets, the intelligent learning and decision making based on multi-modal data of identification, and the precise control of devices' action under the strong interference of environment. Therefore, theoretical methods and core algorithms of identification, modeling, planning, decision-making, automatic control, and group cooperation of multi-agents [3] for intelligent-control devices should be researched and developed.

Finally, after conducting the two steps of key mentioned above, a comprehensive model of big data is needed to integrate all the information in perception and control, so that all information could form an organic unity. The building information model (BIM) and digital twin (DT) [4], as important theories and tools of information integration for physical entity proposed since the 20th century, have demonstrated their strong capabilities in the full life-cycle management of product information in the field of industry. Based on DT or BIM system, the aggregation and allocation of multi-source heterogeneous information can be conducted in the perception and control of cities' operation and maintenance. With the help of DT or BIM system, perception information can assist with improving control accuracy, while control information can optimize perception strategies in turn.

Additionally, cities' infrastructures and their natural and social environments form a symbiosis. Behaviors of infrastructures and humans in them will influence the changes of the surrounding environment, while the abnormality and deterioration of the surrounding environment will adversely influence the in-service state of the infrastructures and the senses of humans. Based on the massive observation data with multiple sources and multiple models, the intelligent model of the DT (or BIM) system that reflects the infrastructures and surrounding environments can be synchronously established to realize the holographic risk perception and the early warning [5] of dangers for the system of infrastructures and surrounding environments.

With the assistance of the most advanced AI technologies, the bottleneck problems (e.g., fusion of multi-modal data of observation, feature extraction from multi-source heterogeneous data, nonlinear mapping modeling between system's macro and micro behaviors, robots' control in structural inspection and repair, intelligent control of phase-change materials, and so on) in the core links of the operation and maintenance of cities can be overcome. Based on the research, energy consumption and maintenance costs of infrastructures during operation can be reduced, and the service life of infrastructures will be extended. The era of Smart City and Carbon Neutral for the whole world will come earlier.

Conflict of Interest

The author declares that there is no conflict of interest.

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