INTRODUCTION TO THE FOCUSED SECTION ON INTELLIGENT ROBOTICS FOR CIVIL INFRASTRUCTURE

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1. Introduction

Intelligent robots represent the sophisticated incorporation of robotics, cyber physical systems and artificial intelligence. A great variety of intelligent robots are finding exciting applications and playing important roles in civil infrastructure systems. Taking the field of structural health monitoring for example, researchers have investigated the concept of mobile sensors [1, 2], where robots can autonomously or semi-autonomously move sensors around a structure and conveniently change measurement locations. In particular, small-size crawling and flying robots have been investigated for structural monitoring and inspection [3-6]. Meanwhile, intelligent robotics and machinery of much larger size are also playing an important role in construction and maintenance of civil infrastructure. Furthermore, the combination of robotics, electronics, network systems, pattern recognition, and intelligent computing has also thrust a significant amount of work in smart structural technologies [7]. Containing articles in both theoretical and practical/experimental development, this focused section aims to disseminate current advances of various robotics technologies for civil infrastructures.

2. Articles in this focused section

The article "Robotic Sensing and Object Recognition from Thermal-Mapped Point Clouds" presents an innovative method for robotic sensing and object recognition from thermal-mapped point clouds, using thermal data from infrared camera to fuse 3D point clouds. A novel robotic hybrid system is developed. The multimodal data is combined with a data fusion process based on texture mapping. The automatic object recognition is performed by two cases including segmentation with thermal data and classification with scanned geometric features. The research results show that the proposed method is validated with the scan data collected from an entire building floor, and the thermal integrated object recognition approach can achieve better performance than a geometry only-based approach for objects in the tested environment including humans, display monitors and light fixtures.

The article "Wall-Climbing Robot for Non-Destructive Evaluation Using Impact-Echo and Metric Learning SVM" studies the application of the Impact-Echo (IE) acoustic inspection method in non-destructive evaluation and detection of the concrete structure. The authors present a novel climbing robot, namely Rise-Rover, to perform automated IE signal collection from concrete structures and IE signal analyzing based on machine learning techniques. Rise-Rover is an inspection robot with a novel and enhanced absorption system to support heavy load, and crawler-like suction cups to maintain high mobility performance while crossing small grooves. Various signal processing methods, including Fourier transform and wavelet transform for feature detection from collected IE signals, are investigated, and a distance metric learning based support vector machine (SVM) approach is newly proposed to automatically classify the IE signals. Field tests on a concrete bridge deck have demonstrated the efficiency of the proposed robot system in automatic health condition assessment for concrete structures.

The article “RABIT: Implementation, Performance Validation and Integration with Other Robotic Platforms for Improved Management of Bridge Decks” presents a highly integrated large robotic system for concrete bridge deck inspection. Traditional inspection is mainly performed by human inspectors that operate individual hardware platforms. In comparison, besides vision sensing, the RABIT system integrates a multitude of platforms into one autonomous system, including electrical resistivity, ground-penetrating radar, impact echo and ultrasonic surface wave method. Such integration significantly increases the productivity and data resolution for bridge deck inspection, making it possible to simultaneously capture a plurality of concrete deterioration processes that may take place in the field. This unprecedented incorporation of a multitude of large sensor arrays offers exciting new opportunity for the condition monitoring of transportation infrastructure.

The article “Reconfigurable Swarm Robotic Systems for Structural Health Monitoring: A Brief Review” surveys the features, typical applications and present statuses of the development of reconfigurable swarm robots (RSR). This authors have summarized the main advantages of RSR: being modular, on-site reconfigurable, multifunctional, incrementally assemble-able, reusable, fault-tolerant, and even repairable on the orbit. The review article argues that RSR offer great potential and advantages from the perspective of monitoring and assessment of civil and mechanical systems. Moreover, a roadmap for future research has also been outlined based on the limitations of the current methods and anticipated needs of future inspection systems.

The article by Goorts et al., entitled “Structural Control using a Deployable Autonomous Control System”, is another demonstration of novel robotics applications in civil structures. As noted by the authors, this deployable autonomous control system is particularly suitable for situations in need of a temporary control setup. While conventional control devices, either passive, semi-active, or active, are often permanently installed at fixed locations on a structure, this article proposes to use an Unmanned Ground Vehicle (UGV) as a mobile control devices for reducing structural vibration. Equipped with an electro-mechanical mass damper, the UGV can automatically travel around and choose an optimal location for applying damping force to the structure. With vision sensors onboard, the UGV simultaneously locates and maps the structural environment it travels in. A movable/deployable control device particularly provides the advantage of multi-modal control by optimally choosing its desired location. Another apparent advantage is less dependence on an accurate structural dynamics model, which often can be difficult to obtain for large civil structures. The innovative concept has been successfully validated using a 16.7m-long pedestrian bridge.

3. Summary and conclusion

We believe that intelligent robots will continue to generate exciting and impactful applications on civil infrastructures. These may include high-efficiency operation of large infrastructures, mobile sensor network and robotic inspection for civil structures, smart materials and intelligent structures, robotic rehabilitation of large civil structures, and novel actuation and control techniques for construction machinery and construction automation, among others.

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