Towards the Smart Railway: Interactive Wireless Smart Sensor Systems for Structural Health Monitoring of Railroad Bridges

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- **Background / Motivation**

"Imagine whisking through towns at speeds over 100 miles an hour, walking only a few steps to public transportation, and ending up just blocks from your destination." - President Obama

On April 16, 2009, the United States Government announced a new vision for the rail industry. This intercity plan called for expansion of railway networks, as well as upgrading of existing railways to support higher speed passenger trains. A hurdle for this plan is the fact that existing railway networks in the United States are quite old. Over 40% of privately owned railway tracks are built over 100 years (GAO, 2007). Bridges are a critical component of this network. As a result, development of monitoring strategies to ensure their structural integrity of railroad bridges has renewed urgency.

Recent advances in low-cost wireless sensing and data acquisition technology have made it possible to instrument large civil infrastructure systems with dense arrays of wireless sensors. Compared to traditional structural health monitoring (SHM) using wired systems, wireless smart sensor (WSS) systems offer a number of attractive features: (i) cost-effective, (ii) ease of installation, (iii) highly decentralized data collection with computational capabilities (Rice et al., 2010). Yet, due to hardware and software limitations, only a limited number of full-scale deployments exist, and these focus mainly on highway bridges. Railroad bridges are different from highway bridges in that the bridge experiences more interactions between the train loads and the bridge structure, and the loads of train are much heavier and repetitive. The potential of WSS techniques to realize SHM systems suitable for railroad bridges needs can realized by a state-of-the-art cyber physical system (CPS).

A new vision for the railway system equipped with CPS, proposed in this research, aims to establish a sustainable system that yields highly user-friendly information from real-time interactions between the WSSs on the substructure and the sensor networks on the train.

- **Proposed research/ work**

The proposed research targets to develop hardware and software for WSSs to establish early warning and detection of damage in railroad bridges. Damage in a massive structure, such as a railroad bridge, are local in most cases and hard to detect even with dense array of sensors. In the management of railroad bridges, knowing the accurate status of the structure and its remaining life is most critical. Due to the large bridge to train weight ratio and the trainload characteristics,

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the train changes the bridge during its passage; monitoring only the bridge without considering the train is insufficient.

In the CPS envisioned for SHM, the train should be able to inform the bridge of its characteristics beforehand. In addition, the bridge should estimate its health through real-time computing using the train information and the interactions, and inform the anomalies to the other CPS system of interests for further actions, e.g., control the traffic, close the bridge, request the bridge owner for replacement of bridge elements, or redistribute the loads for the following trains. To realize such serviceability the system should overcome the following challenges:

(1) Train network: The train network must be able to self-characterize its load distributions, speed, and geographical information using a limited numbers of sensors. Upon achieving the objective information, the network should wirelessly inform the bridge through reliable communication. While the train is on the bridge, the network should time synchronize with the bridge network, measure the signals from the sensor network and transmit to a server.

(2) Bridge network: Each sensor distributed at the key locations of the bridge should be aware of its expected behavior with respect to the train information received prior to the train passage. As the train passes, the bridge should re-estimate and update its health by processing the sensor signals from both the bridge and train networks. The network should inform only aggregated and condensed information to the user, while preserving key measurements.

(3) WSS System: The system should be reliable, sustainable, and cost-effective. The system should also require real-time computing/communication to detect anomalies and outliers and inform the users. Processes should be selective to detect and inform damages but should not cause delays of the traffics while achieving the objective information.

- **Potential impact in/to CPS**

The smart railway system will have significant impact in CPS by interrelating infrastructure, smart systems, and users/operators. The infrastructure will have the potential to optimize and redistribute the limited sources with increased safety, bridge retrofit can focus on the elements with the problems, and trains can run safely at faster speeds. Smart sensor technologies will evolve to offer required information in reliable, robust and cost-effective ways. The users will benefit from increased safety, fast services from unified railway network. The new railway systems equipped with CPS will further benefit the design of dynamic living of next era.

Reference

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