BRIDGE CRACK LOCALIZATION USING WIRELESS SENSOR NETWORKS

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Localizing the cracking point is very important and valuable for investigating the reason and progress of bridge collapse [1], however, most of the current techniques for bridge surveillance using either visual monitoring or wired sensor systems are relatively expensive to deploy, vulnerable to damage and inconvenient to operate.

Wireless sensor networks [2] owning the features of low cost, easy deployment, self-organize, and robust is a promising technology for infrastructure surveillance purpose [3]. It is also an effective tool for event source localization, e.g., bridge crack point positioning. The sensor nodes can be deployed either attached on the surface of the bridge or embedded in the bridge body, without any wiring. Equipped with sensitive acoustic sensors and cooperating with digital band-pass filters for sensing frequency selection, sensor nodes with crack point locating in the sensing range are able to detect the acoustic wave signals emitted from the crack point. With multiple detections at different sensor nodes, the source location of the acoustic event (crack point) can be estimated based on both the locations of sensor nodes and time-stamps or node sequence obtained from acoustic event propagation.

For networks with accurate time synchronization among all the sensor nodes in the network, range-based methods can be applied for achieving sub-centimeter localization accuracy. The idea for range-based solutions is to estimate the location of the acoustic event source based on time difference of arrival (TDOA) computation. However, accurate time synchronization is expensive to maintain in the system. For systems demanding low sensor node cost and extremely low duty cycle for energy efficiency, only rough time synchronization is available. In this case, range-free methods based on node sequence processing [4] can help to localize the source of the crack with medium accuracy. Sensor nodes, the sensing range of which cover the crack point, detect the acoustic wave propagation at different time instance due to diverse distances between each sensor node and the event source (the crack point). This naturally gives out an ordering of in-the-field sensor nodes. Known the precise locations of the sensor nodes, the possible location area for the event source can be inferred by processing the node sequence.

This paper will focus mainly on technical questions about localization with and without accurate in-network time synchronization. We will give out the basic ideas and algorithms for event source positioning using wireless sensor nodes, and provide system evaluations about how the wireless sensor network system can detect the event, e.g., bridge crack, and localize the event source. The research of this project is supported by NSF and accomplished by the Minnesota Embedded Sensor Systems (MESS) research group at the department of Computer Science and Engineering in the University of Minnesota.

References

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ACOUSTIC EMISSION: SIGNATURES OF DAMAGE

ARRAY SIGNAL PROCESSING TECHNIQUES FOR ACOUSTIC EMISSION ANALYSIS ON LARGE CONCRETE STRUCTURES

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The method of acoustic emission is especially difficult to implement on large concrete structures because of the heterogeneous nature of the material. Sensor arrays used in traditional AE analyses contain sensors distributed over the entire structure, but the scattering and attenuation of stress waves in concrete makes it difficult to gain meaningful information from this configuration. This paper discusses array signal processing techniques such as beamforming and velocity spectral analysis (VESPA) which can be applied to data collected from a small aperture array where the inter-element spacing is much less than source to receiver distances. These techniques were originally developed for applications such as communications, sonar, and exploratory seismology and are now applied the method of AE. Using these tools, the direction of arrival of incoming waves can be found and the arrivals of different wave phases can be identified.