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Identification of Structural Parameters Using Symbolic Time Series Analysis and Intelligent Algorithms

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Abstract

Structural Health Monitoring (SHM), a field inaugurated in aerospace engineering in the late 20^{th} century through mechanical engineering towards civil engineering communities. As the process of implementing a damage detection strategy, SHM has received increasingly attention and interest in the civil engineering with prominent technology development and promising economic attraction. Even as research on SHM chugs along, challenges remain before they can be applied to civil engineering structures.

This dissertation presents a new approach for damage identification of structures using symbolization-based intelligent algorithms.

To implement the concept, a two-phase approach is proposed.

In the first phase, a "Symbolization-based Negative Selection" (SNS) algorithm that combines the advantages of symbolic time series analysis (STSA) and negative selection (NS) is proposed for detecting the abnormal states of a building structure. In SNS, no prior knowledge of the structure's abnormal state is needed. Only the response of the structure in a current normal state is used as input data. In addition, this approach works fine even with one sensor, so it is highly practical and flexible.

In the second phase, after knowing the damage occurrence, we need to determine the damage location and quantity. The method for this stage was named as “Symbolization-based Differential Evolution Strategy” (SDES). Differential evolution

(DE) strategy employed here is intended to minimize the distance between SSHs (state sequence histogram) that are transformed from raw acceleration data of a real structure and candidate models. Accuracy of the method is theoretically studied and explained including the effects of parameters. SDES was numerically compared with Particle Swarm Optimization (PSO) and DE with raw acceleration data. These simulations revealed that SDES provided better estimates of structural parameters when the data was contaminated by noise.

Moreover, in order to prove that the method is indeed applicable to realistic problems, the computing strategy for SHM is experimentally verified. Two different structural models, small model and large steel model, are utilized to verify the proposed approach. Experiments using the small model were conducted at our Laboratory, damage cases were considered for different locations and degrees of damage. Data of the experiments using the steel model (carried out under the US–Japan cooperative structural research project on Smart Structure Systems) was used to further verify the proposed methodology.

Finally, the conclusion is given. The damage identification using symbolic time series analysis and intelligent algorithms is proposed, and it can detect, localize and quantify the damage accurately. The symbolization of data alleviates the effects of harmful noise, employment of the intelligent algorithms make the whole procedure adaptively and efficiently. Comparisons with existing methods show that our proposed methodology is indeed a powerful tool for damage identification of building structures.