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Editorial

State-of-the-Art Structural Health Monitoring in Civil Engineering

Raffaele Zinno [1,*] and Eugene J. OBrien [2]

[1] Department of Environmental Engineering, University of Calabria, Ponte Bucci, Cubo 44/A, 87030 Rende, Italy
[2] School of Civil Engineering, University College Dublin, D04 V1W8 Dublin, Ireland; eugene.obrien@ucd.ie
* Correspondence: raffaele.zinno@unical.it

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In the past, when structures contained elements which were prone to deterioration over time (e.g., wood), the maintenance of houses, bridges, etc., was considered vital to allow them to be used safely and to retain their efficacy [1]. With the advent of materials such as reinforced concrete and steel, given their relatively long useful life, periodic and ongoing maintenance has often been considered a secondary element. However, since it was realized that, even for structures made with these materials, their useful life has an end, and that we may be approaching it, planning maintenance has become an important aspect. Thus was born the concept of structural health monitoring (SHM) [2–6].

The goal of SHM is to keep civil engineering works under constant control. To achieve this, multidisciplinary methods have been designed and implemented. In fact, computational mechanics [3]; the static and dynamic analysis of structures, electronics, sensors; and recently the Internet of Things (IoT) and artificial intelligence (AI) have come into play [7–11]. However, it is also important to consider new materials—especially those with intrinsic characteristics of self-diagnosis or nonlinear behaviour and bimodular materials [12]—just as it is important to make use of measurement and survey methods typical of modern geomatics, which also makes use of satellite surveys and uses highly sophisticated laser tools. For these reasons, we proposed this Special Issue which covers all these issues [13–15].

1. About the Present Special Issue

Seven interesting contributions are presented in this Special Issue.

The first paper assesses data-driven damage-sensitive features (DSFs) in terms of their potential to identify earthquake-induced damage and manifest nonlinearity in the response of low-to-midrise residential buildings. It is based on a comprehensive simulated analysis of a nonlinear hysteretic spring-mass system and a half-scale building specimen experimentally tested on a shake table.

The second contribution proposes a wavelet-based approach to detect bridge defects using wavelet energy. Furthermore, a damage index, based on component wavelet energy, is developed to localize the damage. A numerical simulation is modelled to verify the feasibility of the proposed approach, and the results show that the proposed method performs well, even when considering road roughness in vehicle and bridge interaction. Moreover, the effects of road surface profile, vehicle velocity, vehicle mass, noise in the signal, and different damage severities on the proposed approach are investigated. The method shows great potential application in bridge health monitoring using indirect measurements from a moving vehicle.

The third paper introduces a novel method to determine a deflection-based damage indicator for railway tracks and bridges using sensors on in-service trains. The concept uses a type of Inverse Newmark-β integration scheme on data from a batch of trains to convert measured accelerations into deflections at the contact point between track and wheel. This in turn is converted into a Moving Reference Influence Line (MR-IL), i.e., a function describing the deflection at a moving point due to a unit load at an adjacent moving point.

In a series of blind tests using simulated 'data' from an independent research group, the MR-IL functions are shown to be effective in detecting the level of bridge damage.

The paper by Dharap and Nagarajaiah introduces input error function-based observers for the tracking of stiffness degradation in structural members. A modified formulation of the actuator failure detection algorithm results in a unique input error function corresponding to an individual structural member and facilitates the development of a bank of observers to estimate the severity of damage in structural members.

The Guest Editor, Obrien, with his colleagues, Wang and McCrum, have published a paper presenting a new moving force identification (MFI) algorithm that uses measured accelerations to infer applied vehicle forces on bridges. Previous MFI algorithms use strain or bridge deflection measurements, but this approach directly uses accelerations. Statistics of the force histories inferred from accelerations are used in turn as indicators of global bridge damage. The new acceleration-based MFI algorithm (A-MFI) is validated through numerical simulations with a coupled vehicle–bridge dynamic interaction model programmed in MATLAB. A focussed sensitivity study suggests that the results are sensitive to the accuracy of the vehicle velocity data. The inferred Gross Vehicle Weight (GVW), calculated using A-MFI, is proposed as the bridge damage indicator. A real weigh-in-motion database is used with a simulation of vehicle–bridge interaction to validate the concept. The results show that the standard deviation of inferred GVWs has good correlation with the global bridge damage level.

A comprehensive review of the function of AI and its effects on data-based SHM systems, along with those of other technologies, is provided by the other Guest Editor and his co-authors. The influence of ML algorithms, drones, and 3D printers on the way SHM systems work in bridges is the main emphasis of this review.

Blikharskyy et al. conduct a review of digital image correlation and its application to strain measurement in structures. These techniques are non-contact and can provide a full field of deformations. A comparative analysis is carried out on a range of alternative techniques from theoretical and experimental studies.

2. List of Contributions

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