COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

Ali Hashemi

for the degree of Doctor of Philosophy (Ph.D.)

"Advanced Data Science and Physics-Based Modeling for Dynamic Systems"

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P.h.D. Dissertation Defense
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DEPARTMENT:
Civil, Environmental and Geomatics Engineering

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ABSTRACT OF DISSERTATION
Advanced Data Science and Physics-Based Modeling of Dynamic Systems

This dissertation focuses on the development of data-driven and physics-based modeling for two distinct significant structural engineering applications: time-varying response estimation and unwanted lateral vibration control. In the first part, I propose a machine learning (ML)-based surrogate modeling to directly predict dynamic responses over an entire mechanical system during operations. Any mechanical and system design, as well as health condition evaluation, requires transient vibration analyses since unwanted or unexpected range of vibrations can disrupt mechanical systems, resulting in faults such as imbalance, misalignment, and failure. However, traditional experiments and modeling calculations are time- and resource-consuming due to high computational cost of numeric methods and non-feasibility of analytical solutions for structures with complex geometry or high number of degree-of-freedom. Therefore, it is imperative to accelerate the process of predicting time-varying responses by utilizing computationally-efficient methods. The use of artificial intelligence (AI), particularly ML and deep learning, can be considered as an efficient means of solving this problem. ML-based surrogate modeling, with its admissible lower consumption cost and robustness to overfitting problems, can provide a feasible approach for projecting a collection of data from real-time measurements of a structure to a mid-fidelity finite element analysis (FEA) of the same system in the field of structural dynamics. In this research, an ML-based surrogate for the FEA approach is developed to forecast the time-varying response, i.e., displacement of a two-dimensional truss structure. Various ML regression algorithms, such as decision trees and deep neural networks, are developed to predict movement over a truss structure, and their efficiencies are investigated. In this dissertation, a novel approach is proposed to combine ML techniques with finite element (FE) method and describe transient systems. Then, the feasibility of substitution FEA with the presented ML-based surrogate model is evaluated.

In the second part, the derivation of a state-of-the-art semi-analytical solution for lateral vibration, and a smart active vibration control system of a wind turbine blade are investigated. The control of unwanted vibration of wind turbine blades is crucial in ensuring highly efficient and cost-effective wind turbines, with increased structure lifetime. In this effort, to simulate the implementation of active control rules on structures, I propose an innovative semi-analytical method for projecting the actual shape of a wind turbine blade to the same scale of a Euler–Bernoulli beam due to the high computational cost of using numerical methods for applying controlling rules to complex structures. In this simulation-based work, virtual piezoelectric (PZT) materials are used as paired actuators-sensors to excite the structures and sense the responses. The PZT actuators-sensors are patched on the surface of the structures in this effort. First, to derive the semi-analytical solution, the Euler-Bernoulli beam theory is employed. The governing equations of the beam with PZT patches are derived by integrating the PZT transducer vibration equations into the vibration equations of the Euler–Bernoulli beam structure. An FE model of the wind turbine blade with PZT patches is developed. Then, a unique transfer function matrix is derived by exciting the structures and achieving responses. The transfer function matrix can map the wind turbine blade to the Euler–Bernoulli beam under the same conditions to find the blade's dynamic responses by solving analytical vibration solutions of the Euler–Bernoulli beam. In the final step, to suppress the transverse vibration of the wind turbine blade, a linear quadratic regulator (LQR) control method is developed in this study. To tune the control actions of the proposed active control system, various weighting factors are used in the designing process of the LQR controller. The state-feedback control law is used to gain the LQR optimal control. The proposed smart active vibration control system contains the PZT ceramic patches as actuators, combined with the LQR controlling system. In the end, the efficiency of the suggested active vibration control system is evaluated.

BIOGRAPHICAL SKETCH
Born in Tehran, Iran
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CONCERNING PERIOD OF PREPARATION & QUALIFYING EXAMINATION

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Published Papers:

Hashemi, A., Jang, J., Hosseini-Hashemi, S. (2022). Semi-Analytical Analysis for Dynamic Behaviors of Wind Turbine Blades Using Transfer Function Methods. In: Topics in Modal Analysis & Testing, Volume 8. Conference Proceedings of the Society for Experimental Mechanics Series. Springer, Cham.

Hashemi, A., Jang, J. (2022). Smart Active Vibration Control System of a Wind Turbine Blade Using Piezoelectric Material. In: Dynamics of Civil Structures, Volume 2. Conference Proceedings of the Society for Experimental Mechanics Series. Springer, Cham.

Hashemi, A.; Jang, J.; Hosseini-Hashemi, S. Smart Active Vibration Control System of a Rotary Structure Using Piezoelectric Materials. Sensors 2022, 22, 5691.