Efficient computational strategies for the life-cycle optimization of nonlinear dynamical systems subject to random excitation

A robust life-cycle performance optimization of nonlinear oscillators subject to random excitation relies on accurate loss estimation over a wide range of damage levels. Determining their optimal design to minimize the total expected life-cycle cost requires an efficient estimation of the (*i*) system stochastic response and (*ii*) expected cost of failure accounting for the variability of the excitation magnitude. As Monte Carlo simulation is prohibitive in this task, especially when the system dimensionality is large, semi-analytical stochastic engineering dynamics techniques, such as statistical linearization, can estimate the system stochastic response at a reduced computational cost within a Performance-Based Design Optimization (PBDO) [1-2] framework by resorting to accurate approximation/linearization of nonlinear equations of motion of systems subject to random stationary/non-stationary excitation. Nevertheless, the PBDO formulation requires the estimation of expectations over high-dimensional probability spaces, which compromises the performance of deterministic gradient-based optimization methodologies due to the computational cost of computing high-dimensional integrals.

This seminar discusses an efficient PBDO framework for determining the optimal parameters minimizing the total expected life-cycle cost of diverse nonlinear dynamical systems subject to stationary or non-stationary excitation. In this framework, statistical linearization approximates the statistical moments of the stochastic response displacement and velocity of multi-degree-of-freedom systems for estimating the system response up-crossing rate. Furthermore, computationally efficient estimation of the expected cost of failure is attained with arbitrary Polynomial Chaos Expansion (aPCE) [3], an efficient uncertainty propagation method constructed over an orthogonal polynomial basis determined from only the raw moments of the random variables. Combining statistical linearization with aPCE has the potential to reduce the computational cost of a single evaluation of the objective function; however, to avoid the excessive number of calls of the objective function and to reduce the chances of falling into a local minimum early in the optimization process, stochastic/meta-heuristic optimization approaches are employed to promote an efficient exploration of the design space when searching for the optimal set of parameters. Numerical examples will be presented together with a thorough discussion on the computational performance of the developed methodologies.

References

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Short bio

Prof. Ketson dos Santos holds a PhD and an MPhil in Civil Engineering & Engineering Mechanics from Columbia University (USA). He also obtained his MS degree from the University of São Paulo (Brazil) and his BS from the Federal University of Alagoas (Brazil), both specializing in Civil Engineering with a focus on structural engineering. His expertise lies in pioneering computational and semi-analytical methods tailored to estimate the stochastic response of nonlinear dynamical systems at reduced computational cost. Additionally, he is involved in the development of signal processing and data analysis techniques to assess the properties of complex dynamical systems under uncertainties. Prof. dos Santos is at the forefront of advancing state-of-the-art methods in surrogate modeling and uncertainty quantification by employing cutting-edge techniques based on Euclidean and non-Euclidean data to unravel the intricacies of inherent low-dimensional structures in complex systems under uncertainties.