I-RBDO Code for Reliability Analysis & Reliability-Based Design Optimization

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This seminar introduces the Iowa Reliability-Based Design Optimization (I-RBDO) code. The I-RBDO code can solve both design optimization categories: (1) sensitivity-based RBDO and (2) sampling-based RBDO. A Graphical User Interface (GUI) is introduced for users to easily use the I-RBDO code. The I-RBDO code is applicable to general engineering modeling & computational simulations with uncertainties of system input variables by treating the computational simulation codes as black-boxes. For generation of input models for uncertainty, the weight-based Bayesian method with two-step procedure is used in identifying the marginal and joint input distributions. The joint input distributions are modeled using copulas. For the sensitivity-based RBDO, the Performance Measure Approach (PMA) with the inverse reliability analysis is implemented. Further, the Dimension Reduction Method (DRM) is used to improve accuracy of the inverse reliability analysis so that an accurate MPP point can be searched.

In ARC Thrust Area 3, we are currently carrying out integration of Iowa developed durability analysis code DRAW with a commercial LS-DYNA FEA code for a large scale parallelization for durability analysis since TARDEC has unlimited license of LS-DYNA on TARDEC High Performance Computing (HPC) for survivability analysis. The DRAW and LS-DYNA will be integrated with the I-RBDO via a very simple ASCII interface file to provide instruction to other users how their CAE codes can be integrated with the I-RBDO code.

Adaptive Virtual Support Vector Machine for Reliability Analysis of High-Dimensional Problems

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In this study, an efficient classification method is developed for reliability analysis while maintaining an accuracy level similar to or better than the existing surrogate modeling methods. The sampling-based reliability analysis requires only the classification information – a success or a failure – but the surrogate modeling methods provide response function values as their output over the region, which requires more computational effort. The problem is even more challenging when dealing with high-dimensional problems due to the curse of dimensionality. In the newly proposed virtual support vector machine (VSVM), virtual samples are generated near the limit state function. These function values are used for approximations of virtual samples to improve accuracy of the resulting VSVM decision function. By introducing the virtual samples, VSVM can overcome the deficiency in existing classification methods (i.e., SVM) where only classified function values are used as their input. The universal Kriging method is used to obtain virtual samples to improve the accuracy of the decision function for highly nonlinear problems. A sequential sampling strategy that chooses new samples near the limit state function is integrated with VSVM to maximize the accuracy. Examples show the proposed adaptive VSVM yields better efficiency in terms of modeling and response evaluation time and the number of required samples; while maintaining similar level or better accuracy, especially for high-dimensional problems. It is noted that, the response sensitivity cannot be directly obtained from the SVM or VSVM result since these are classification methods. Thus, SVM or VSVM cannot be directly used for even deterministic design optimization, let alone RBDO. However, VSVM can and will be integrated with the stochastic sensitivity analysis method based on the score function obtained from the copula for system level RBDO.
Next-generation parametric reduced-order models (NX-PROMs) are proposed for fast reanalysis to predict the dynamic response of complex structures which suffered thickness variations caused by design changes or damage in one or more components. Parametric reduced-order models developed previously have two important challenges to overcome to improve accuracy and performance: (a) the transformation matrix is not mathematically stable, (b) the Taylor series parameterization techniques do not capture thickness variations of the structure modeled with solid-type elements due to the highly nonlinear dependence on thickness changes. Thus, herein, a new transformation matrix and novel parameterization techniques are proposed. Usual reduced-order models have an additional challenge, namely large number of interface degrees of freedom (DOF). To address that challenge, a novel approach to reduce the interface DOF is proposed.

Next, the NX-PROMs are used to develop a robust signal processing approach for damaged vehicles with structural variability. The approach assumes that vibration-type data is collected. This data is used in a novel combined sensor selection and signal processing methodology. The new methodology resolves two key issues for complex structures with variability: (1) decides which field data channels are statistically optimal to be used based (e.g. in Monte-Carlo approaches), and (2) establishes which data channels should correlate and how. The overall algorithm is based on a generalized version of the effective independence distribution vector. Also, the correlations among channels are used for noise rejection. NX-PROMs are used to address the presence of variability and account for their effects on the data collected from various channels.

Numerical results are presented for a realistic model of a HMMWV frame with parameter variability and a crack. NX-PROMs are applied to capture the vibration characteristics of the structures with volume variation due to design modifications. Robust signal processing techniques are demonstrated for the selection of statistically optimal measurement locations (used in Monte-Carlo techniques).