11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

A Modified Adaptive Sampling Method for Reliability-Based Design Optimization Using SVM Model

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Abstract

For problems with implicit limit state functions encountered in engineering applications, it is difficult to perform reliability-based design optimization (RBDO) due to the high computational cost in evaluating the probability of failure and its gradient.

As a popular machine learning method for classification, regression and other learning tasks, support vector machine (SVM) has been widely applied to replace practical black-box function in RBDO. In order to construct the SVM model more efficiently, Basudhar and Missoum [1] developed the adaptive sampling strategy, which selects the sequential sample point on the predicted limit state constraints with maximum minimum distance from existing training points. To further enhance the accuracy and efficiency of RBDO based on SVM model, the modified adaptive sampling (MAS) method is proposed in this study.

In MAS, after initial sampling using Latin hypercube sampling (LHS) method, a modified adaptive sampling strategy with two sampling criterions is developed to refine the SVM model. The first criterion is sampling within the region which is defined by two envelopes along the predicted limit state constraints rather than confining the sequential sampling points strictly on the predicted limit state constraints in adaptive sampling method, where the support vectors can be easily found in this region. The second criterion is sampling new point which has the maximum distance to the nearest existing support vector because the support vectors are more important than the ordinary sampling points. In the proposed method, the new sample points which are most likely modifying the obtained limit state constraint will be selected. Combined with the constructed SVM model, Monte Carlo simulation (MCS) is used to calculate the probability of failure and its gradient value with respect to design variable at the current design point. Then the sequential linear programming (SLP) is used to decouple the RBDO nested structure to get the optimal design.

In order to verify the accuracy and efficiency of the proposed MAS method for RBDO, three numerical examples are tested and compared to standard value, Latin Hypercube sampling method and adaptive sampling method. Standard value directly calls the true performance functions or computer simulations. Though the calculation of standard value needs more computational cost than the SVM model based RBDO methods, it can ensure the accuracy of the results. Also, the proposed MAS method is applied to an engineering problem about the honeycomb structure crashworthiness design. Through the comparative result, it can be seen that the proposed method is very accurate and efficient.

References

[1] Basudhar A. and Missoum S., Adaptive explicit decision functions for probabilistic design and optimization using support vector machines, Computers & Structures, 86(19), 1904-1917, 2008.