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Interval uncertain optimization of structures using Chebyshev meta-models

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ABSTRACT

This paper proposes a new optimization method for the design of structures under uncertainty. Interval model is used to represent structures consisting of uncertain-but-bounded parameters. The interval uncertain problem is formulated as a nested double-loop optimisation procedure, in which both the design variables and parameters of the structure are regarded as interval numbers. It is well known that the nested double-loop optimisation will be computationally prohibitive. To overcome this shortcoming, the interval arithmetic is used in the inner loop to calculate bounds of interval functions, to eliminate the inner optimization. However, the interval arithmetic is characterized with overestimation as a result of its intrinsic wrapping effect. To this end, the high order Taylor inclusion function is introduced to compress the overestimation related to the wrapping effect. Since it is hard to calculate the coefficients of high order derivatives in the Taylor inclusion function, a Chebyshev meta-model is proposed to approximate the function values at specified interpolation points rather than directly evaluate the higher-order derivatives. The Chebyshev approximation is expected to have a higher numerical accuracy and computational efficiency. In the numerical implementation, the interval arithmetic is first applied to find the bounds of the approximated Taylor inclusion function, and then an efficient optimization algorithm is developed in the outer loop by combining a Genetic Algorithm together with a mathematical programming. Typical numerical example is used to demonstrate the effectiveness of the proposed method in the design optimization of structures subject to uncertainty.

Keywords: Optimization of structures; interval uncertainty; Chebyshev meta-model; Taylor inclusion function