Improved Surrogate Model Assisted Differential Evolution with an Infill Criterion

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The increasing complexity of simulation models in engineering as well as Other sciences has pushed forward the development and management of less computationally expensive models, known as surrogate models or metamodels, specially when nature-inspired metaheuristics (NIMH), which require a large number of objective function and constraint evaluations, are used to tackle optimization problems involving design variables with mixed types, low-regularity objective functions, numerous nonlinear implicit constraints and expensive and/or unreliable gradients.

Metamodels can be based on phenomenological simplifications or on data-driven approximation, i.e., an approximated model is formulated based on expensive simulations already performed.

Differential Evolution (DE) is an NIMH that has shown promising results in diverse applications, specially when continuous design variables are considered. DE's main movement operation is based on differences among its candidate solutions (vectors). Although in general good solutions can be obtained, DE requires many calls to the objective function evaluator.
The Surrogate Model Assisted Differential Evolution (SMDE) proposed in [1] generates the offspring using four DE variants from the literature and the survivor is the one with the best (approximate) fitness evaluated via a similarity-based metamodel.

The combination between DE and surrogate models is able to find better solutions when a limited budget is considered, but the approximation quality is strongly influenced by the exact points used to build the metamodel. As a result, a suitable infill criterion for selecting the most appropriate candidate solutions to be exactly evaluated by the expensive simulator is desired. Two well-known infill criteria in the metamodel literature, but still unexplored within DE, are the Probability of Improvement[2] and the Expected Improvement[3]. Basically, they assume that the fitness function is a sample of a Gaussian stochastic process. The distribution of the fitness function value at any untested point can be estimated based on data collected during the previous search.
In this paper a Radial Basis Function Neural Network (RBF) was applied as a surrogate model in the DE scheme proposed in [1], but the main contribution is the application of the mentioned infill criteria in the selection of new candidate solutions.

The problem of weight minimization of truss structures with continuous as well as discrete variables is used to assess the performance of the proposed procedure and the results show that the infill criterion coupled with SMDE is able to find better results and to open new perspectives on the application of DE to complex optimization problems.

References

[1] E. Krempser, H.S. Bernardino, H.J.C. Barbosa, A.C.C. Lemonge, "Differential Evolution Assisted by Surrogate Models for Structural Optimization Problems", in

B.H.V. Topping (Editor), Proc. of the Eighth International Conference on Engineering Computational Technology. Civil-Comp Press, Stirlingshire, UK.
[2] B.E. Stuckman, "A global search method for optimizing nonlinear systems", IEEE Trans. Syst. Man Cybern., vol. 18, no. 6, pp. 965-977, 1988.
[3] J. Mockus, V. Tiesis, and A. Zilinskas, "The application of Bayesian methods for seeking the extremum", in Toward Global Optimization, vol. 2, L.C.W. Dixon and G.P. Szego (Editors), Elsevier, 1978, pp. 117-129.