Worst Case Scenario Robust Optimization Utilizing Adaptive Dynamic Taylor Kriging and Differential Evolution Algorithm

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***Abstract*—For the robust optimal design of electromagnetic problems under uncertainties, the robustness evaluation is the critical problem. This paper presents a surrogate model based worst case scenario optimization algorithm, where the adaptive dynamic Taylor Kriging is incorporated to construct a higher accurate surrogate model. Finally, an improved differential evolution algorithm, DE/λ-best/1/bin, is adopted to search for the global robust optimal solution.**

***Index Terms*—Adaptive sampling, basis function, Kriging, multi-objective optimization.**

I. Introduction

Uncertainties in design variables such as manufacturing tolerance and material property cannot be avoidable in engineering problems, so that robust optimizations have attracted increasing attention in electrical engineering [1]. There have been many efforts to deal with expensive computing time such as the worst vertex prediction based worst case optimization (WV-WCO) and gradient index (GI) method. The existing algorithms, however, are not available for a general application since the computational complexity is strongly proportional to the number of uncertain variables and constraints. It is observed that the Kriging technique have been widely used to carry out design optimization [2]. Once the accurate metamodel is constructed, the robustness evaluation can be directly applied without intensive computational burden. In addition, a highly efficient optimization strategy is strongly requisite for the true robust optimal design.

Therefore, the target of this paper is to present a surrogate model based robust optimization algorithm. The performance robustness is measured through applying the WV-WCO to the accurate surrogate model constructed by adaptive dynamic Taylor Kriging (ADTK). Finally, the global robust optimum can be found by one efficient differential evolution algorithm.

II. Surrogate-model Based Robust Optimization

A. Adaptive dynamic Taylor Kriging methodology

With the N sampling data, the ADTK satisfies:

$$\sum_{i=1}^{N}\lambda_i(\mathbf{x})b_k^*(\mathbf{x}_i)=b_k^*(\mathbf{x}),\quad k=0,1,\cdots,K \tag{1-a}$$

$$\begin{aligned}&\sum_{i=1}^{N}\lambda_i Cov[Z(\mathbf{x}_i),Z(\mathbf{x}_j)]+\sum_{k=0}^{K}\delta_k b_k^*(\mathbf{x}_j)\\&=Cov[Z(\mathbf{x}),Z(\mathbf{x}_j)],\quad j=1,\cdots,N\end{aligned} \tag{1-b}$$

where the basis function, $b_k^*(\mathbf{x})$, is optimally selected by BPSO.

Then, if the fitting error of ADTK model is not small enough, new sampling points are selected adaptively among the test points, $\mathbf{X}_{\text{test}}$, based on the following rule using (2)

$$\mathbf{X}_{\text{new}}=\left\{\mathbf{x}\,\middle|\,E_{\text{fit}}(\mathbf{x})>\varepsilon,\ \mathbf{x}\in\mathbf{X}_{\text{test}}\right\} \tag{2}$$

where the tolerance ε is, in this paper, set to 10^{-4} and $E_{\text{fit}}(\mathbf{x})$ is the fitting error for the test point.

B. Worst Case Scenario Optimization Based on ADTK

With the help of the worst vertex prediction, the worst case scenario optimization (WCO) problem subject to a set of constraint functions, $g_i(\mathbf{x})$, i=1,…,m, is formulated as follows:

$$\begin{aligned}&\text{minimize}\quad f_w(\mathbf{x})\equiv f(\mathbf{x}_w)\\&\text{subject to } g_{w,i}(\mathbf{x})\equiv g_i(\mathbf{x}_{w,i})\le 0,\quad i=1,\cdots,m\end{aligned} \tag{3}$$

where $f_w(\mathbf{x})$ and $g_{w,i}(\mathbf{x})$ are the worst objective and the ith worst constraint values in the uncertainty set, respectively.

Based on the above analysis, it is obvious the ADTK model based WV-WCO does not rely on any gradient information and can be coupled to arbitrary simulation tools. The whole flowchart of the proposed robust optimization algorithm is shown in Fig.1. The TEAM Workshop problem 22, which is one design application about the superconducting magnetic energy storage system, is selected to validate the proposed algorithm. The detailed results will be shown in the full paper.

References

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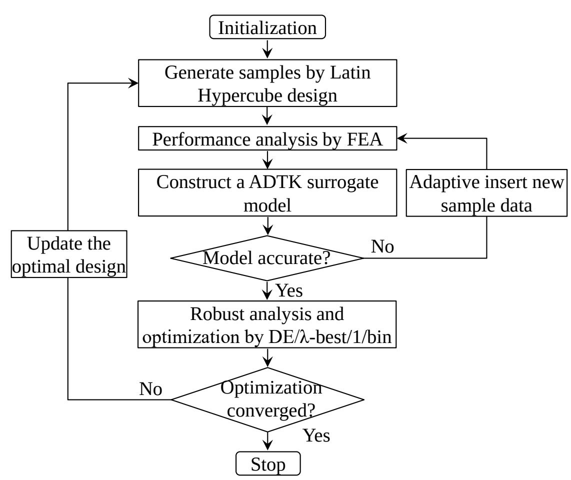

Fig.1 Flowchart of the proposed robust algorithm.