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ASSESMENT OF STRATEGIES FOR DESIGN OF EXPERIMENTS AND DATA FITTING TECHNIQUES FOR RESERVOIR ENGINEERING PROBLEMS

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ABSTRACT

Reservoir Engineering problem is a challenging issue due to the following aspects: nonlinearity, multi-reservoirs, multi-periods, multiobjective and uncertainty.

In general, the numerical simulation of such engineering problems tend to have high computational cost in a single simulation process. Therefore any procedure which requires a multiple numerical simulations as optimization, uncertainty quantification could be prohibitively expensive. Approximation strategies [1-3] are pointed in the literature as a powerful tool to overcome above mentioned problems and are increasingly being used in simulation based procedure to overcome high computational cost and to ameliorate the numerical noises that commonly arise in such problems.

The basic idea is to construct a mathematical simplification to the original (costly) problem. This simplified model is then used in engineering design applications to provide insight on the overall trends of the objective and constraint functions over the investigated design domain space. Since this acts as a surrogate to the original problem, this is commonly referred to as surrogate model, meta-model or approximated model.

Typically approximation modeling techniques are grouped into functional and physical (hierarchical fidelity) categories. The first techniques encompass different approaches such as data fit, polynomial series, and reduced basis methods. The physical category involves physical-based models.

This strategy combines high-fidelity and low-fidelity analysis generating a response surface from high-fidelity analysis performed at the samplings (small number) of points generated by a suitable pre determined design of experiments (DOE) [3] approach. Clearly this approach distinguishes the use of high-fidelity model for response calculations at the samplings and the use of the low-fidelity model for the several responses functions/gradients evaluations. Data fitting models considering several strategies (interpolation or regression) will be the focus of present work.

The polynomial models use the regression model and a least square approach to build the analytical approximated form. The main advantages pointed in literature for such approach are that over a small portion of the parameter space, a low-order polynomial model is often an accurate approximation to the data trends and that the least square procedure serves to smooth

out noise in the data. In general, such forms have more local behavior.

Kriging models are data fit based approximations that have become popular [1-3]. The central idea of kriging is that the sample response values exhibit spatial correlation with response values modeled by a Gaussian process around each sample location. Due to such consideration, global approximation type can be obtained for most kriging models. The main advantages pointed for such scheme are: the ability to accommodate irregularly space data, the ability to model functions with many peaks and valleys together with the exact interpolation of the given sample response.

Another type of data fit based approximations is the one that employ radial basis functions through an interpolation procedure similar to kriging. The functions chosen for the basis can take many forms from which multiquadratic, Gaussian and thin plate spline are the most commonly used approaches [3]

The first step on the construction of a data fitting based metamodel is to generate the sampling points. These are unique locations in the design space determined by a design of experiments (DOE) [1-3] approach. In such locations the response values of the high fidelity model will be obtained to construct the approximated model (by instance, kriging interpolation is very influenced by the sampling location).

The samplings selection is a very important stage to build a reliable meta-model. Specifically for high computational cost function evaluations one must seek for an effective samplings plan, which means the minimum number of points that ensure a meta-model with good accuracy. Commonly considered approaches are Monte Carlo, Quasi Monte Carlo, Latin Hypercube sampling (LHS), orthogonal array, centroidal voronoi tessellation (CVT) [1-3]. In this work CVT, QMC and LHS samplings will be used for comparison purposes.

In reservoir engineering, one problem of great interest is the dynamic optimization of producing scheduling, considering constraints at platform´s total rates. In this application common outputs of interest are the net present value (NPV) of the field and the bottom hole pressure at the wells. The approximation strategies discussed here will be used to build surrogate models for both functions.

In the process of building a metamodel special attention has to be given to the construction of the predictor together with the strategy for design exploration. Therefore, it is advised to perform an assessment of the model accuracy prior to its use as a surrogate model, as for instance for optimization purposes.

The present work will explore such issues. The three different data fitting strategies mentioned above will be employed and   different schemes for DOE will be investigated. Two model assessment strategies are implemented to check if a particular created model is adequate.

In subsequent studies these models will be considered for optimization and uncertainty quantification.

REFERENCES

[1] T.W. Simpson, J.D. Peplinski, P.N. Koch, and J.K. Allen, “Metamodels for computer based Engineering Design: Survey and recommendations”, Engineering with Computers Vol. 17:129-150, (2001)

[2] Haftka et all., “Special Issue on Approximations in Optimization of Structural and Multidisciplinary Optimization”, Structural and Multidisciplinary Optimization Journal. (2004).

[3] Andy J. Keane and Prasanth B. Nair, Computational Approaches for Aerospace Design: The pursuit of Excellence, Willey (2005)