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Challenges in the Application of Computer Simulations Models for Design Optimisation

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Editorial

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INTRODUCTION

Over the past few decades, there has been tremendous growth in the computing power, both in terms of speed and memory capacity. Hardware capacities have been increasing ten times every five years, processing power doubles every two years while the costs have fallen by one tenth over every five years. Sophisticated simulation models and software have been common place in every engineering discipline. For example, software like ANSYS FLUENT has become the main stay for numerical flow simulation. Parallel computing and cloud or cluster computing technologies have also grown side by side to make computer simulations cheaper with lesser turn-around time. At the same time, with increasing complexity of modern engineering systems, it has also become abundantly necessary, to adopt a global integrated approach right from the beginning, in any major design and development process. Tight coupling and interaction between different engineering disciplines, besides considerations such as environmental, societal, manufacturing, and reliability constraints are a huge challenge. This has given birth to the area of multi disciplinary optimsation. Above all these, invariably, cost considerations override.

Increasing complexity of systems and higher demand for accuracy, make engineering design challenging due to lack of “design applicable” theoretical models and the high computational cost of accurate simulation. Simulation-driven design becomes a must for growing number of engineering fields. There is a growing temptation to apply the simulation techmiques to evolve optimum designs. Some specific areas impacted by computer simulation are electromagnetic analysis, structural analysis of automobiles computational fluid mechanics, aircraft engine thermal analysis, micro-machine device performance analysis, virtual surgery in bio medical engineering, to name a few. The benefits that accrue from simulation are many. Simulation models can handle increasingly complex geometries, realistic design conditions which are not amenable to ground testing and other sophisticated design requirements. Simulation models are becoming more and more reliable, efficient and flexible and result in the reduction of cost of overall development, by reducing the amount of testing. The price that we pay for these are that they are computationally expensive and high memory demanding besides being time- consuming. They are also amenable to “numerical “noise and are mostly designed to be stand-alone software codes and cannot be easily coupled with optimization software and also with other discipline-specific software. They need trained manpower to run them and can be invariably used at best as a “black-box”. Moreover their source codes are never available and any modification needed cannot be incorporated. Simulation softwares fail unexpectedly every now and then, due to faulty inputs or software bugs. The number of design variables can be large and software’s tools aren’t validated enough. Some of the causes for noisy data are often the discretisation of continuous domain into discrete cells, truncation errors round off errors due to finite precision representation, incomplete convergence of iterations, variable fidelity models.

“Can we combine the capabilities of these simulation tools with a powerful optimiser and exploit them to create best (optimum) designs? “ Is the question that lingers uppermost in any designer’s mind. Linking an optimizer to a simulation model will take a prohibitive amount of computing time, even if all the latest technological computing might is available. A cheap-to-compute model for the limited amount of data generated by a computer intensive costly simulation software tool (a metamodel or a surrogate model) is the only hope of the designer to carry out a optimization task. The given “function” in this context is invariably only a set of inputs and the corresponding outputs from the simulation software runs, in the form of a table of numerical data.

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The simulation software themselves depend on a sophisticated state-of-the-art mathematical models, built into them. Hence surrogate model is a simple model for a complicated model!! However, it replicates the original sophisticated computer simulation model in the entire design space. Optimum found by using the surrogate model is expected to be as close as possible to that which has been found using the sophisticated model. Simple, yet powerful and highly useful, for practical optimisation exercises, the surrogate model should aid the designer, at the cost of slightly extra computations, to identify the potential optimum zones, in the design space. It helps him to gain insight into the design problem, identify the relative importance of various parameters and study the interactions among the various design parameters. It can also help to bridge seamlessly computer simulation data along with experimentally acquired data and data obtained from all other possible sources. Number of simulation runs that are required as input, can be tailored to the available computational budget and by choosing a well designed sampling plan. Various methods to develop surrogate models for computer simulation data are , response surface methodology, artificial neural networks, radial basis functions, kriging etc., A sample surrogate model for two variables constructed based on simulation data set (shown on the left in the figure below, is shown on the right. Use of surrogate models helps the designer to carry out the design optimisation tasks using the knowledge gained from the sophisticated computer simulation models in several disciplines in a systematic way (Figure 1).

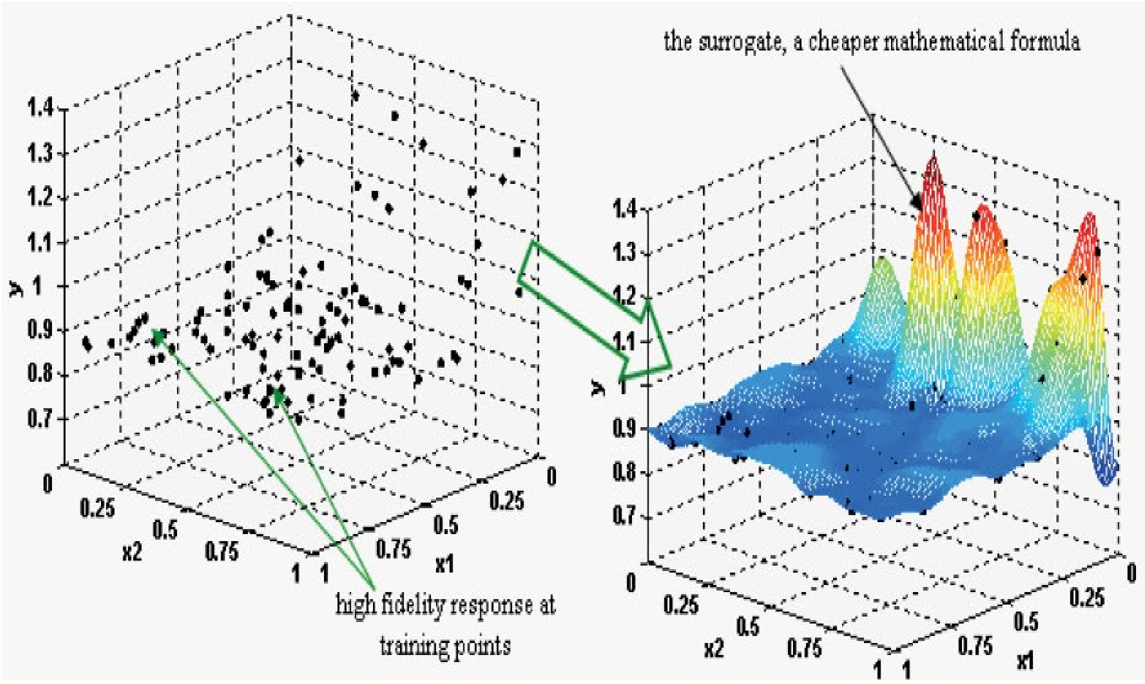

Figure 1: A sample surrogate model for two variables constructed based on simulation data set.