Response Surface Modelling for Efficient Structural Optimization

This article may be found at
http://www.soton.ac.uk/~cedc/posters.html

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UTP for design

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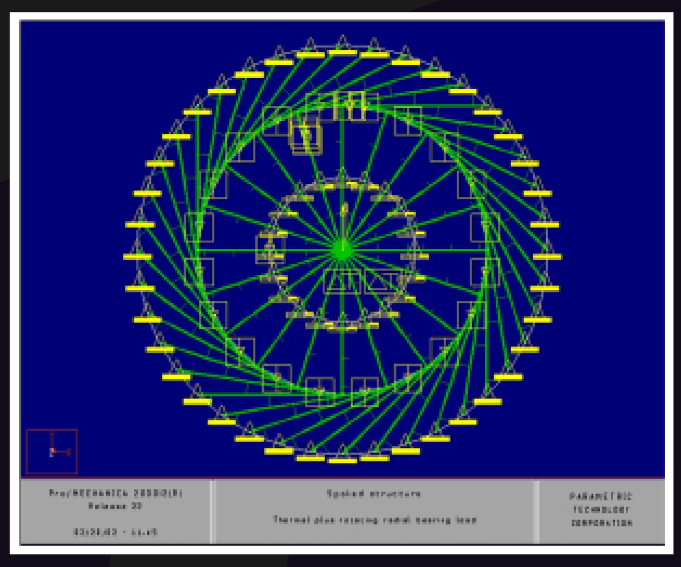
Approximation Methods

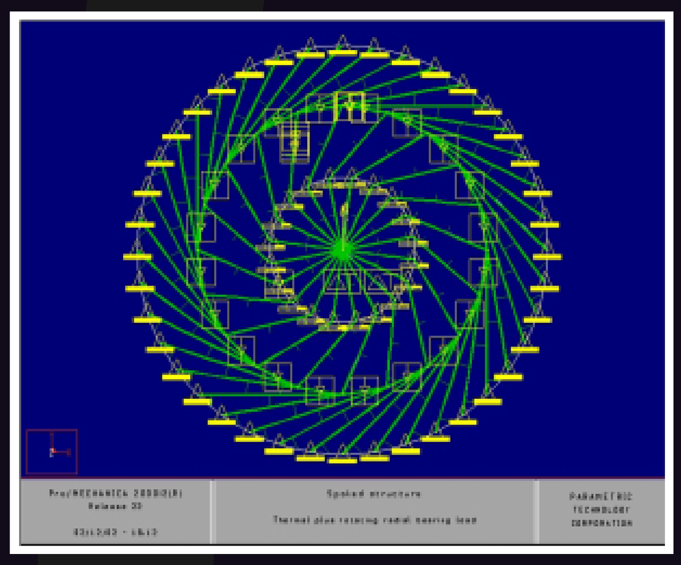
Designers are under ever-increasing pressure to produce better designs in shorter time-scales. Most scope for design improvement is during the preliminary design phase, where less sophisticated models are invoked for the analysis of a design. At a final design stage only one analysis of the design is often possible, so it is essential that during the preliminary phase a good design satisfying all necessary constraints be chosen.

The idea of producing a "better" design leads naturally to the idea of optimisation. At a preliminary design stage a finite element model or a CFD analysis would typically be used for evaluating the design. Yet even at this early stage, the cost of running the computational model often proves to be a bottleneck to the efficient direct use of optimisation methods. An alternative strategy is required.

This motivates the use of approximation methods whereby an inexpensive surrogate replaces the expensive analysis code. First, a design-of-experiments (DoE) methodology is used to highlight a limited number of selective values of the design parameters that define the geometry. The analysis code is then run for these inputs in order to gain information on the behaviour of the response. Armed with this information, an approximation can be constructed which is very cheap to compute. This approximation can then replace the original analysis for the purposes of optimisation.



Initial geometry

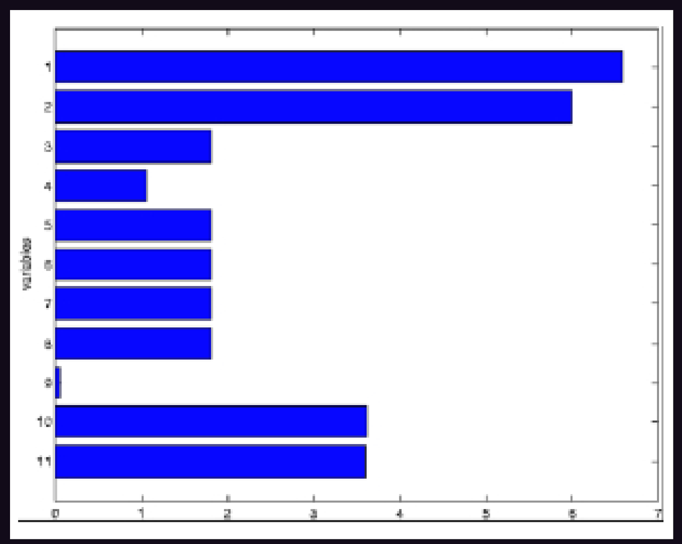


Optimum geometry

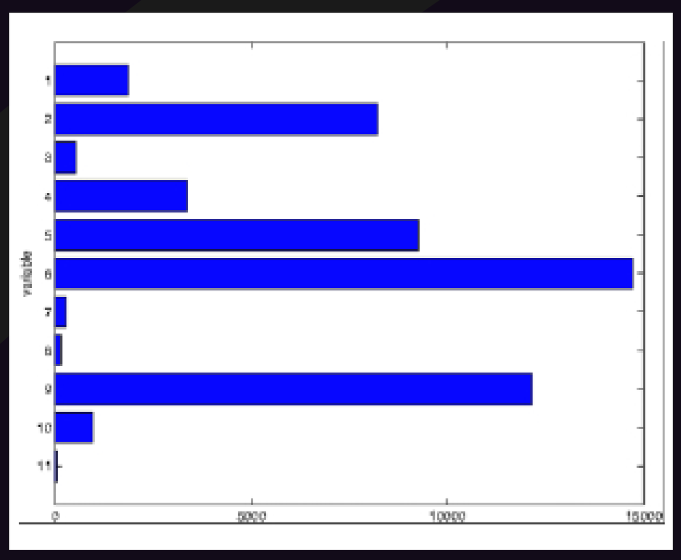
As an example, we consider a spoked structure. This model, provided by Rolls-Royce, is subjected to realistic loadings. Four design variables define the geometry of the structure. This model is first parameterised and optimised using Promechanica. Direct optimisation is a relatively time consuming strategy, so secondly the parametric model is optimised by making use of approximation methods. The optimum design is again found, this time with over a five-fold saving in computational cost.

Statistical Screening Studies

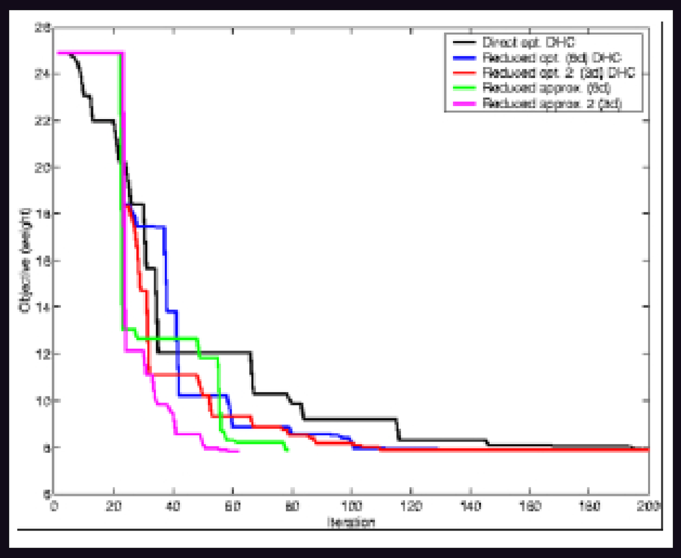
One potential problem with the above approach is the accuracy of the resulting approximation given the limited information available. This is particularly the case in higher dimensions, so strategies to overcome this problem are under investigation. One such strategy is a statistical screening study that attempts to highlight the important design variables in a computationally efficient manner. We can then consider approximating this reduced dimensional problem. This naturally leads to more accurate approximations and more efficient optimisation. We consider the same structure above with extra design variables (now 11) and a different loading. Results of the screening study are shown for both weight (the objective) and stress (the constraint). Various convergence histories are shown. A combination of screening and approximations works best.



Screening study applied to total mass.



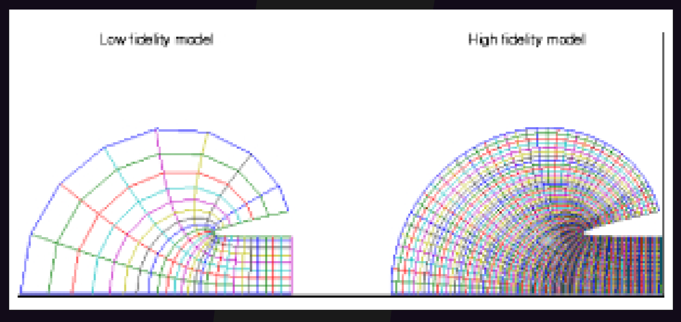
Screening study applied to Von Mises stress.



Convergence histories.

Multifidelity Models

A second way of increasing the accuracy of the approximation to a high fidelity computer simulation is through the use of a low fidelity model. This low fidelity model is generally much cheaper to compute but lacks some accuracy. However, it can give a rough indication as to the behaviour of the high fidelity model's response. Combining low fidelity models and approximation methods in a so called "correction response surface" approach can provide a good way of achieving high accuracy with a modest computational cost. This is another area of active research.



Example of a low and high fidelity mesh.

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