Model based design of experiments and monitoring systems for parameter identification of structures

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Summary

It is becoming increasingly necessary to give statements about health or residual capacity of existing structures. With the advent of better technology, it is now also possible to think about structural monitoring not only during the useful life and operation of structures, but also during the design phase. In both situations, it is necessary to decide what and where to measure in order to get the most useful results for an acceptable cost. The Fisher Information Matrix, FIM, and the associated optimality criteria from classical optimal experimental design theory gives a measure for optimal setups. The goal here is to select, in the context of parameter identification, an appropriate experimental design, and then quantify confidence of conclusions drawn from the updated, yet inevitably flawed, numerical models. Ultimately, this paper seeks to answer a fundamental question posed to all engineers: what does this mean for my structure and for those who may use it.

Keywords: Monitoring; design of experiments; parameter identification; model quality.

1. Introduction

Existing structures are ageing being pushed to and beyond the design life, while new structures are stretched to new limits. In both situations, it is necessary to make statements about health or residual capacity of structures. This could be to determine necessary retrofits, to check safety levels, or even to confirm that the in operation behaviour matches the predicted design behaviour. For making these kinds of conclusions, responses must be measured and data collected and analysed. This leads to the questions of what, when and where to measure in order to get the most useful results for an acceptable cost. With the advent of better and cheaper technology, it can be tempting to ignore the question of optimal monitoring design and blindly measure everywhere. Unfortunately, the costs of time and installation of monitoring systems, which may require special equipment for access, can far exceed the measuring devices alone. If hard to reach areas of structures are ignored immediately, leaving only accessible ones, the general question of sensor placement becomes easier since the number of possibilities are reduced. However, an optimal setup based on a subset of possible locations may yield results that are not useful. For this reason, it is also necessary to predict the implications of the measurements on model parameters and responses.

While it can be argued that true optimal experiment design does not exist especially in an unrestricted domain, an optimal setup can be proposed subject to certain constraints. Classical optimal design theory shows that quantifiable characteristics, ultimately defined through parameter sensitivities, can give a measure for optimal setups. This leads to the Fisher Information Matrix, FIM, and the associated optimality criteria. Another approach from probabilistic information theory defines a quantity related to what exists in the data: the so-called information entropy. Both procedures provide a way of ranking setups in order to make decisions. There are, of course, drawbacks in any technique that may be applied. The purpose here is not to say which one is best or to propose vast improvements, nor is it the goal to directly detect damage or to conclude

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