Using measurement to reduce model uncertainty for better predictions

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Abstract

Accurate models of real behaviour that are determined through measurements help engineers avoid expensive interventions and structural replacement. Model calibration by “curve-fitting” measurements to predictions is not appropriate for full-scale structures. This paper compares two population methods that can include modelling and measurement uncertainties using a simple example of a one-span beam. Standard applications of Bayesian inference that involve assumptions of independent zero-mean Gaussian distributions may not lead to accurate predictions, particularly when extrapolating. Another method, error-domain model falsification provides more reliable, albeit more approximate, predictions – especially when prediction is extrapolation. An example of a full-scale bridge illustrates the usefulness of the methodology in a real situation through improvements to fatigue-life estimates compared with design-type calculations without measurements.

Keywords: sensor data interpretation, system identification, model falsification, Bayesian inference, interpolation, extrapolation

1 Introduction

Modern trends of material sustainability and greater economy have encouraged infrastructure retrofit and repair over replacement. These activities have increased the need for accurate knowledge of real structural behavior. Better knowledge can be obtained through judicious measurements and appropriate model-based data interpretation.

Traditional interpretation strategies are not compatible with the type of uncertainties that are commonly associated with structural behavior models. The vast majority of model-based identification strategies involve minimising the difference between predictions and measurements using curve-fitting techniques of various levels of sophistication to obtain one calibrated model of behaviour [1-3]. Unfortunately, it is rare that this strategy results in a model that is useful for applications beyond the loading conditions and the range of data that was used for the calibration.

Model-based identification is essentially diagnosis and as a result, it is intrinsically ambiguous [4]. There can be many explanations for measurements taken from complex systems. Therefore, population approaches (evaluation of many model instances) are most appropriate. Bayesian inference [5] is the most widely studied population approach. Over the past ten years

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