Using measurements to reduce model uncertainty for better predictions

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 models. Newer proposals, such as standard applications of Bayesian inference, are also not accurate, particularly when results are used to predict behavior through extrapolation.

This paper describes a breakthrough data-interpretation strategy that is compatible with the types of uncertainties that are commonly associated with behavior models of large civil-engineering structures. It is based on the well-founded scientific strategy of model falsification. Through comparing predictions of many thousands of model instances at each measurement location, a set of candidate models that are capable of explaining measurements is identified. Approximate uncertainty analyses determine which model is excluded from the candidate model set through explicitly accounting for the sources of systematic bias that are associated with model assumptions and idealized boundary conditions.

In civil-engineering structures, systematic uncertainty is correlated between measurement types as well as locations and furthermore, values of these correlations are difficult to determine. When correlations are assumed to be zero, model falsification leads to a conservative estimate of the candidate model set, thus resulting in a unique quality of robustness with respect to unknown information.

Model falsification is illustrated and compared with results of Bayesian updating using the example of a one-span beam that is measured for deflection at various locations. Finally, fatigue-life predictions of a full-scale bridge are used to demonstrate practical advantages.