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A New Approach to Model Validation for Design Optimization

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1. Abstract
A major challenge in engineering design optimization is that the utilized computational and/or simulation models for quantifying objective and constraint values must remain adequately accurate in very large design spaces, both in terms of dimensionality and range. In the engineering design community, adequate accuracy of the models is usually assessed by validation approaches that compare model predictions to experimental data. We believe that this approach to model validation for design optimization purposes has several drawbacks:

1. Model predictions are compared to experimental data only at few points. This may be inadequate for large number of model inputs (dimensionality) that constitute the design optimization variables and parameters and vary within large intervals (range).
2. Model predictions are typically compared at points where experimental data are already available and new tests are usually not conducted. However, these points may not be relevant to the optimal design, which is determined by intersecting active constraint boundaries that may lie far away from the test points.
3. If new tests are conducted for model validation, they are all performed before the optimization process by distributing the test points across the design space in an attempt to fill it using design-of-experiments. However, numerical optimization algorithms generate a sequence of design candidates until they converge to an optimal design according to termination criteria, desired accuracy and/or computational budget (e.g., maximum number of iterations). They rarely visit the entire design space. Testing at points distributed over the entire design space may be therefore, irrelevant, and thus wasteful.
4. A-priori validation (and utilization of all available testing resources) is done with respect to a fixed number of model inputs. This implies that we cannot conduct optimization with additional model inputs as design variables and/or robustness studies that require varying model inputs originally used as design parameters.

In this talk, we present a new sequential design optimization methodology that utilizes calibration-based model validation in local subdomains of the design space. The methodology proceeds iteratively by using test data at a design point, constructing around it a local domain in which the model is considered valid, and optimizing the design within the local domain. If the optimal design associated with the local domain lies on the boundary of the domain, a new iteration is conducted with the optimal design serving as the new center point. The process either converges if the optimal design lies in the interior of the local domain or is terminated if testing resources are exhausted (still providing a feasible design that is optimal with respect to a part of the design space).
The premise of this paradigm is that testing resources are utilized more efficiently. Moreover, it enables the consideration of additional model inputs as variables during the optimization process and robustness studies with respect to model inputs since testing resources are not exhausted a-priori but can be managed and allocated as the design optimization process progresses.

2. Keywords: Design optimization, modeling and simulation, validation and calibration, local trust regions