Sequential Linear Programming Coordination Strategy for Deterministic and Probabilistic Analytical Target Cascading

by

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ABSTRACT

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Decision-making under uncertainty is particularly challenging in the case of multidisciplinary, multilevel system optimization problems. Subsystem interactions cause strong couplings, which may be amplified by uncertainty. Thus, effective coordination strategies can be particularly beneficial. Analytical target cascading (ATC) is a deterministic optimization method for multilevel hierarchical systems, which was recently extended to probabilistic design. Solving the optimization problem requires propagation of uncertainty, namely, evaluating or estimating output distributions given random input variables. This uncertainty propagation can be a challenging and computationally expensive task for nonlinear functions, but is relatively easy for linear ones. In order to overcome the difficulty in uncertainty propagation, this dissertation introduces the use of Sequential Linear Programming (SLP) for solving ATC problems, and specifically extends this use for Probabilistic Analytical Target Cascading (PATC) problems.

A new coordination strategy is proposed for ATC and PATC, which coordinates linking variables among subproblems using sequential lineralizations. By linearizing

and solving a hierarchy of problems successively, the algorithm takes advantage of the simplicity and ease of uncertainty propagation for a linear system. Linearity of subproblems is maintained using an L_∞ norm to measure deviations between targets and responses. A subproblem suspension strategy is used to temporarily suspend inclusion of subproblems that do not need significant redesign, based on trust region and target value step size. A global convergence proof of the SLP-based coordination strategy is derived. Experiments with test problems show that, relative to standard ATC and PATC coordination, the number of subproblem evaluations is reduced considerably while maintaining accuracy.

To demonstrate the applicability of the proposed strategies to problems of practical complexity, a hybrid electric fuel cell vehicle design model, including enterprise, powertrain, fuel cell and battery models, is developed and solved using the new ATC strategy. In addition to engineering uncertainties, the model takes into account unknown behavior by consumers. As a result, expected maximum profit is calculated using probabilistic consumer preferences with engineering constraints satisfied.