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Bayesian Design Optimization of Parallel Electric Drivetrain

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In engineering design problems, some decisions need to be made at the early stages while not all factors are known with certainty. However, these choices may influence substantially how the final design of the product will ultimately perform. It is crucial to effectively account for this uncertain information in the design process to avoid additional expenses and time-consuming efforts on reworking/ redesigning the product later on.

This research studies the optimal design parameter selection of an electric drivetrain; where the power of the two motors and the battery capacity have to be decided. The goal is to select these parameters such that the normalized total cost of ownership is minimized while a set of performance constraints are satisfied. The designer is equipped with an expensive black box simulation model of the vehicle, which enables the designer to verify if the design specifications are met for the chosen parameters and returns the corresponding cost of ownership. The simulator's output is affected by other uncertain parameters in addition to the design parameters, resulting in different design attribute values for the same design parameters.

To solve this stochastic constrained optimization problem in the past, engineers have been using the NOMAD solver [1]; in this research, we tackle the problem by employing a novel Bayesian optimization algorithm. We use stochastic kriging [2] to build independent metamodels, and our sequential sampling strategy consists of three novel acquisition functions and three dynamic stopping criteria to consume the expensive computational budget smartly. Our proposed algorithm stands out by achieving optimal solutions with a significantly reduced computational budget while offering more accurate estimations of the cost of ownership and greater robustness, reducing the likelihood of solutions becoming infeasible due to uncertainties in input parameters.

[1] Rosich, A., López, C., Dewangan, P., & Abedrabbo, G. (2022). Robust Design Optimization of Mechatronics Systems: Parallel Electric Drivetrain Application. Proceedings of the Design Society, 2, 1727-1736.

[2] Ankenman, B., Nelson, B.L., Staum, J.: Stochastic kriging for simulation metamodeling. Operations Research 58(2), 371–382 (2010).

This study has supported by the Special Research Fund (BOF) of Hasselt University (grant number BOF19OWB01), and the Flanders Artificial Intelligence Research Program (FLAIR).