Paper Summary: “Learning the Characteristics of Engineering Optimization: Problems with Applications in Automotive Crash”

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This paper examines the challenges of understanding the characteristics of real-world designing optimization issues. The study presents an approach for characterizing these issues, centering on ten instances from car crashworthiness optimization. By computing characteristic Exploratory Scene Examination (ELA) highlights, the authors appear that these ten crashworthiness issue occasions show scene highlights that are distinctive from classical optimization benchmark test suites. Utilizing clustering approaches, the creators illustrate that these ten issue occasions are clearly particular from the BBOB test capacities. Further analysis reveals that, as far as ELA is concerned, they are most similar to a class of artificially generated functions. The authors propose using these artificially generated functions as scalable and fast-to-evaluate representatives of real-world problems.

The paper presents an approach to characterize nonlinear technical optimization problems, specifically focusing on 10 representative cases from automotive crashworthiness optimization. The authors use ELA to compare three benchmark problems, Auto Impact Resistance, BBOB, and an artificially generated problem set. They show that the collision safety problem is most similar to a class of artificially generated functions, unlike his BBOB test functions. The authors propose to use these artificially generated functions as scalable and rapidly evaluated representatives of real problems to design optimization algorithms for specific real problem classes. increase.

The challenge of choosing the most time- and resource-efficient algorithm for a given optimization problem is also known as the Algorithm Selection Problem (ASP). Previous work on ASP has been based primarily on academic benchmarking facilities such as BBOB test set. However, little work has been done to study algorithm selection in the realm of expensive black-box optimization. The authors aim to develop a general optimization pipeline for the automobile crashworthiness optimization problem, including algorithm selection and configuration and argue that a proper understanding of the problem characteristics is essential in achieving this goal. Why us Exploratory Landscape Analysis (ELA) approach to characterize the complexity of continuous optimization problems? The advantage of using this is that they defined six classes of low-level features that can be computed cheaply to numerically quantify the landscape features of an unknown optimization problem. These features include y distributions, level sets, metamodels, local search, curvature, and convexity. ELA has so far been used to understand the optimization landscape for neural architecture search tasks, categorize BBOB problems, analyse the problem space of various benchmark problem sets, verify representativeness of BBOB test function sets for hyperparameter tuning problems, and multi- Investigate the desired optimization problem. However, no previous work has applied his ELA to the optimization problem of automobile crash behaviour.

The authors use a one-shot optimization approach, where optimization is carried out based on an initial set of fixed sample points in a Design of Experiments (DoE), without evaluating new sample points in the process. To characterize an automotive crashworthiness optimization problem instance, the authors design their pipeline based on two crucial aspects: the computation of ELA features on the problem instance, and problem characterization based on the corresponding ELA features. This allows them to compare the ELA features computed on the crashworthiness problem instance with those computed on established academic benchmark functions, such as the BBOB functions. Also allowing them to characterize the crashworthiness problem instance by identifying the BBOB function(s) with similar ELA features. The authors use the noise-free BBOB problem set from the BBOB 2009 workshop, consisting of 24 real-parameter single-objective benchmark functions of different complexity. The four central sections of the pipeline are described in detail in the paper, including data pre-processing, computation of ELA features, problem characterization, and analysis of the results.

The experimental setup section of this paper describes the optimization problem being crashworthiness optimization of a rocker panel with respect to side crash against a pole. The authors use Finite Element (FE) simulation data generated by BMW during several recent development projects, solved with the commercial code LS-DYNA. Four rocker panels with similar design (D1-D4) and three different load cases were investigated, where the side pole was positioned at different locations (P1-P3). In total, the authors consider 10 representative problem instances, where the Design of Experiments (DoE) for each problem instance was generated with the Modified Extensible Lattice Sequence (MELS) sampling method. The quality of a rocker panel design is evaluated by quantifying its structural crashworthiness through four objectives: maximum force, intrusion, energy absorption, and rotation. The authors independently compute 68 ELA features for each of the ten automotive crashworthiness optimization problem instances and consider the mean ELA feature values computed based on a bootstrapping strategy to minimize the effects of random sampling in ELA. For the same reason, they also consider the ELA feature values averaged across the first 20 instances for each of the 24 BBOB functions.

The results showed, in terms of landscape characteristics, the BBOB functions were not representational of their nonlinear automobile crashworthiness problem situations. The crashworthiness problem classes were not sufficiently characterised by the BBOB problem set. They conducted an examination by clustering 1,000 artificial functions and applied their pipeline to ten instances of car crashworthiness problems. In comparison to the BBOB functions, they discovered that a number of artificial functions were clustered in the same groupings as the crashworthiness objectives and had a smaller Euclidean distance. They came to the conclusion that they could discover artificial functions that were adequately reflective of the cases of their crashworthiness concern.

One possible drawback of the experiment setup could be that the car models and loads are not diverse enough (such as including different models such as trucks, SUV, minivan etc). The positions of the poles are limiting as well. Only three side positions are included in the calculations, front and back end left out of the equation. Out of the 1000 artificial functions, only few clusters can be identified from the figure. The ratio is too low between AF and AF_low. More research and further studies need to be done.

Finally, the authors develop an automated pipeline based on 10 real-world representative problem instances for optimizing car crash safety and use them to generate landscape properties or ELA features, with those of established academic benchmark functions such as the BBOB problem set. Through hierarchical clustering. Their results show that all crash safety problem cases are decoupled from his BBOB test function, indicating that the BBOB problem set is not suitable for characterizing crash safety problem cases. increase. As a result, the authors continue their investigation using artificial function generators that can create test functions with landscape properties similar to instances of crash problems. In future work, the authors plan to develop automatic design of optimization algorithms for real engineering optimization problems using artificial functions with similar landscape properties.

References

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