AI for Expensive Optimization Problems in Industry

Niki van Stein, Roy de Winter, **Thomas Bäck** and Anna V. Kononova

LIACS, Leiden University, The Netherlands

Summary

The optimization of real-world engineering problems can be a challenging task, due to the limited understanding of problem characteristics and the high computational cost of objectives and constraints. This study proposes an AI-assisted optimization pipeline that addresses these challenges by using proxy functions in order to select and optimize an optimization algorithm and its hyper-parameters. It thereby significantly accelerates the optimization process on the real (expensive) problem. To obtain such proxy functions Exploratory Landscape Analysis (ELA) features are used to characterize the problem's landscape. The ELA features are then used to identify an artificial function that replicates the original problem's properties.

AI Assisted Optimization Pipeline

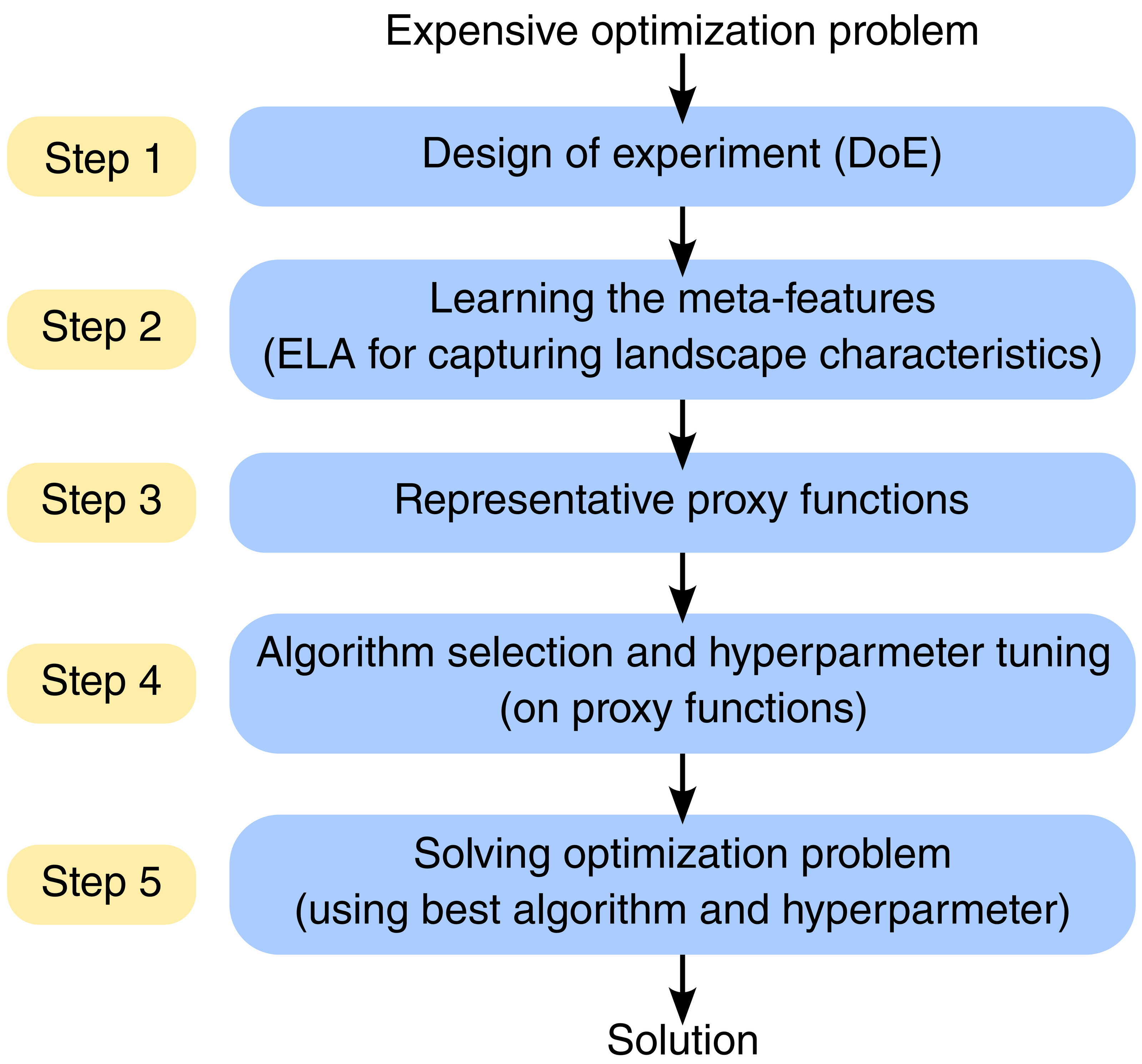
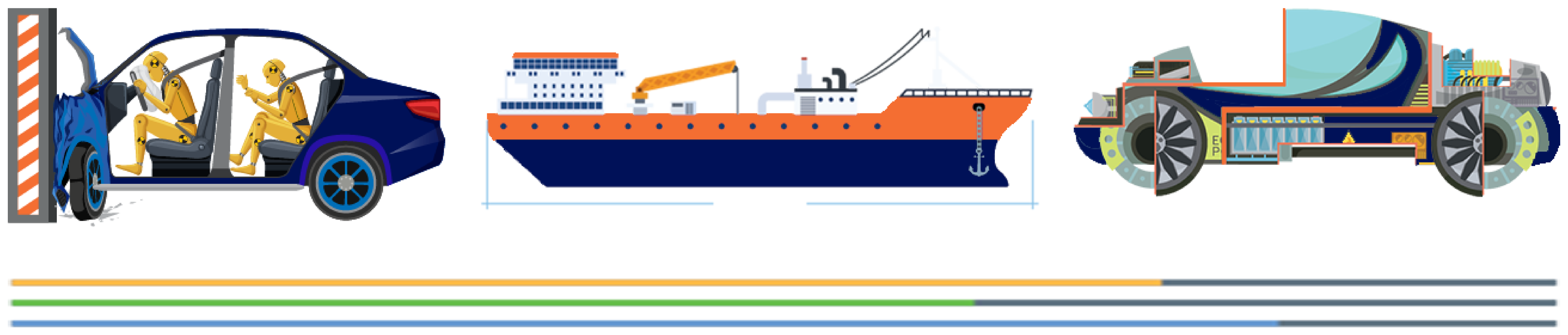


Figure 1. Proposed pipeline using ELA features to find similar proxy functions and to select and hyper-parameter optimize the best optimization algorithm for solving a given expensive black-box optimization problem.

Industrial Applications



Crashworthiness Optimization is a challenging and tedious task with computationally expensive evaluations and multiple objectives and constraints.

Ship Design is finding the ideal size and hull shape that fit all required cargo and technical spaces with minimal operational and capital expenses.

Vehicle Dynamics Optimization Vehicle Dynamics control systems are built based on complex general models. These models need to be optimized, are expensive to evaluate and have multiple objectives.

Results

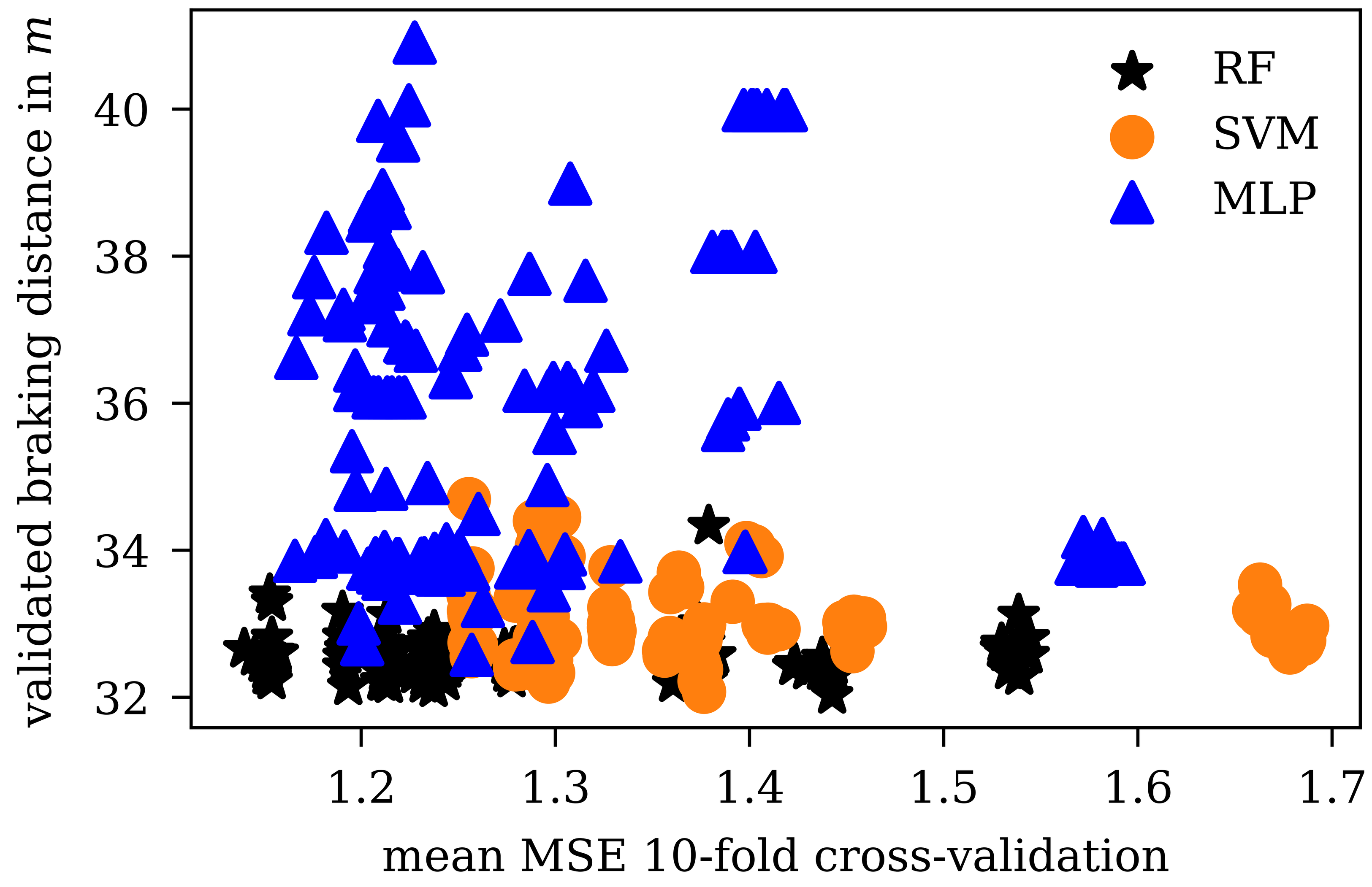


Figure 2. Ninety different response surface models (three machine learning algorithms - random forest RF, support vector machines SVM, multi-layer perceptron MLP, ten runs each, three different DoE sizes) were trained as proxy functions and optimization using a CMA-ES was run on the response surfaces. The plot shows the quality of verified (using the simulator) final optimization results (y-axis) over the quality of the response surface model, measured as mean squared error (x-axis).

Conclusions

- Tuned AI-assisted optimization algorithms perform better than standard algorithms.
- Optimization algorithms can be optimized by using similar (cheap) proxy functions for the search.
- It is possible to find such proxy functions using ELA features.
- With the proposed pipeline, a vehicle body optimization resulted in a weight reduction of 17.75 kg while CPU time was reduced by 65% (compared to the default optimizer).
- Using the proposed approach, the new best breaking distance of 32 meters was found for a vehicle dynamics problem.
- It has been used to optimize an offshore service vessel by reducing the steel-weight by 19% and resistance by 10%.

t.h.w.baeck@liacs.leidenuniv.nl

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