# Parallel Constrained Multi-Objective Optimization for Ship Design Damage Stability Problem with (In)Expensive Function Evaluations

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## ABSTRACT

Parametric ship design optimization is seen as a challenging task due to complex problem characteristics. Problems often have multiple decision variables, multiple expensive to evaluate conflicting objectives, and are subject to regulatory and volumetric constraints. One example of such a problem has been encountered at C-Job Naval Architects when optimizing the internal layout of a single-hold general cargo vessel [1]. The two objectives of the study are maximization of the survivability of the vessel while simultaneously maximizing the cargo hold volume. The problem has three volumetric constraints, and one regulatory constraint for the required damage stability index. The internal layout of the vessel is modified with 17 variables that influence the positioning of the watertight bulkheads in the transverse, longitudinal, and vertical directions and the location of openings/hatches/vents. The calculation of the volumetric objective and constraints are inexpensive to evaluate, while the regulatory damage stability constraint and objective are time-consuming to evaluate. To speed up this process, three design variants can be evaluated in parallel with the commercial DELFTship software.

Problems like these are typically optimized with surrogate-assisted genetic algorithms like Surrogate Assisted Non-Dominated Sorting Genetic Algorithm (SA-NSGA-II) [2] or with Bayesian optimization algorithms like the Self Adapting Multi-Objective Constraint Optimization algorithm by using Radial Basis function Approximations (SAMO-COBRA) [3]. However, these algorithms by default use surrogates for both the inexpensive and the expensive functions. Since surrogates are approximations of the real objective or constraint functions they make mistakes. To deal with this issue, the SAMO-COBRA algorithm and the SA-NSGA-II algorithm have been extended with an option to directly use the inexpensive functions from the optimization problem.

In this study, SAMO-COBRA and SA-NSGA-II with their extensions, have been tested and compared on a variety of artificially created and real-world-like test functions. After finding a good strategy, the algorithms have been used to optimize the damage stability optimization problem of C-Job Naval Architects. The results show that with the new strategy, the algorithms are faster, propose fewer infeasible designs, and find better Pareto-frontier approximations.

## REFERENCES

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