NSGA-HYBRID Performance Evaluation

A comparison of modeFrontier's NSGA-II and HYBRID MDO algorithms for a single-objective design problem, using autonomous optimisation parameters

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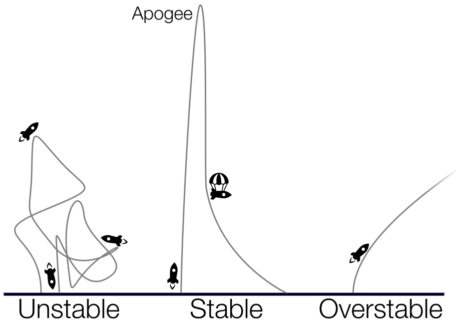
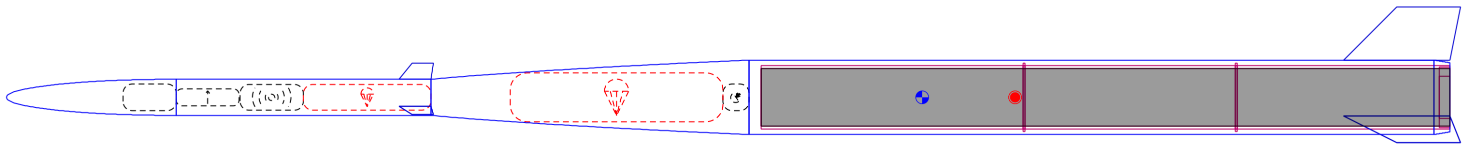
Introduction

The optimization of high-powered rockets is a challenging task, where several design variables must be adjusted to achieve a stable solution and maximize the apogee (altitude) of the rocket. In this study, the NSGA-II and HYBRID algorithms in modeFrontier were evaluated as potential tools for optimizing rocket design.

Since the apogee maximization problem is single-objective, algorithms tailored for multi-objective optimization were not considered appropriate. After exploring the range of algorithms available in modeFrontier for single-objective problems, the NSGA-II and HYBRID algorithms were identified as the most promising. They are suitable for problems involving discontinuities in the objective function and are relatively computationally efficient. Given that openRocket simulations can run quickly, virtual design evaluation using response surface methodologies (RSMs) was not considered as a favorable option.



To evaluate the relative performance of each algorithm, a complex rocket design called the 'APEX-K Kinetic Dart' was used. The design was to be optimized for maximum apogee, with input variables including the length of each body tube and nosecone, and the heights of both sets of fins.



NSGA-II

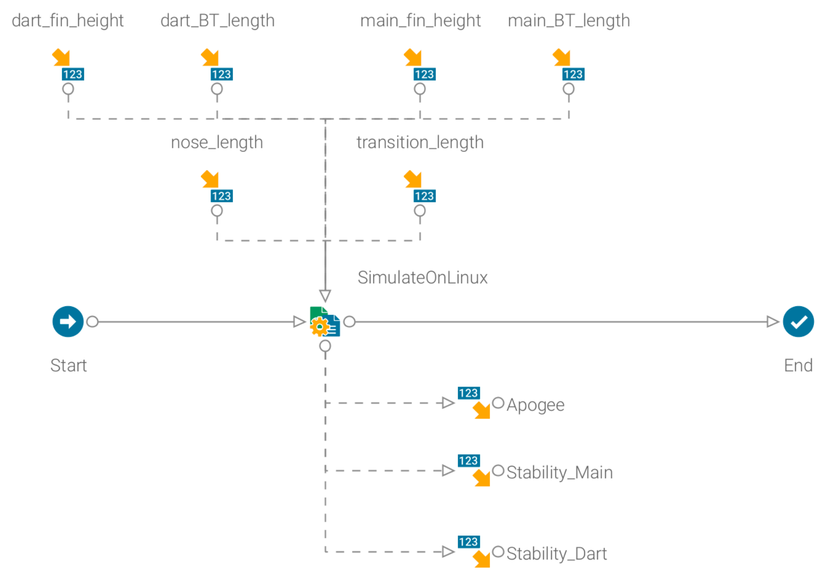
The NSGA-II algorithm employs a "smart non-dominated sorting strategy" to reduce the number of computations required. For this test, the 'autonomous' mode was used for simplicity, which implements automatic stopping criteria to identify when an optimal solution has been reached. The NSGA-II algorithm reached a significantly better optimum solution, conducting more evaluations than the HYBRID algorithm for this workflow.

HYBRID

The modeFrontier HYBRID algorithm combines a genetic algorithm with an SQP optimizer, which is appropriate for both single and multi-objective problems. The sorting strategy used in HYBRID is the same as that used in NSGA-II, and an additional GA operator is used to insert the SQP algorithm, which runs in parallel with the GA. HYBRID uses modeFrontier's AFilterSQP algorithm, which is adapted for multi-objective problems using different techniques. The goal of this investigation was to evaluate whether the addition of SQP optimization improves the results obtained by the genetic algorithm. HYBRID was operated in 'autonomous' mode for simplicity and consistency with the NSGA-II implementation, with stopping criteria defined in a similar manner to the NSGA-II autonomous mode.

Workflow

The same workflow was used for both algorithms, with six input parameters set as variables for optimization and three output parameters measured. Constraints were used to enforce stability at launch and separation of the dart and the lower stage. The simulations were executed on a remote Linux server using the easyDriver node, with results extracted from an output text file.

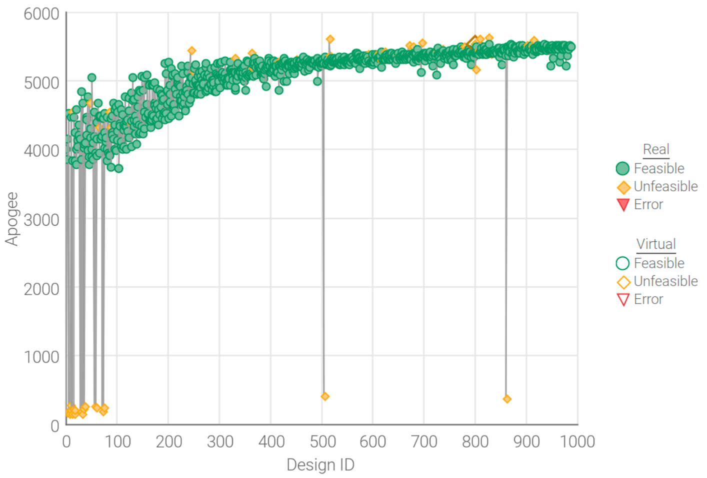


Results

Filtering the NSGA-II results to the first 628 designs, the maximum apogee (satisfying constraints) was 5421m, which is less than the value HYBRID reached for the same number of evaluations. This suggests that the HYBRID algorithm approaches optima faster than NSGA-II, but its automatic stopping criteria perform worse for this case. It may be possible to adjust the HYBRID stopping criteria or use self-initialization to run the algorithm for a greater number of evaluations. Although HYBRID is faster, it requires a similar number of evaluations to find an optima compared to NSGA-II. Running the HYBRID algorithm up to 953 evaluations would be an interesting next step in this investigation, helping to understand the extent to which this holds true.

	NSGA-II	HYBRID
Design Evaluations	953	628
Feasible	872 / 92%	560 / 89%
Unfeasible	81 / 8%	68 / 11%
Max' Apogee (satisfying constraints)	5539 m	5461 m
Minimum distance to constraints	4%	16%

NSGA-II



HYBRID