

HIGH-DIMENSIONAL BAYESIAN OPTIMIZATION APPLIED TO A SHIP ENERGY SYSTEM

Florian Dugast⁽¹⁾, Stéphane Bénac⁽²⁾, Pierre Marty⁽¹⁾, Pascal Chessé⁽¹⁾

⁽¹⁾Ecole Centrale Nantes

⁽²⁾Naval Group, CEMEP

Keywords: bayesian optimization, energy system design, high-dimension problem

Abstract

The design of a ship energy system can be complex due to multiple design options (e.g choice for component types and numbers) and constraints (e.g environmental, economic, military). The optimization problem that can helps to find an optimal architecture (components and associated connections) is typically referred as a synthesis, design and operation optimization (SDO) problem. As this denomination suggests, the optimization spans on different levels to cover the choice of the architecture structure (components connections), the size of the components and their operating points. While gradient-based methods can handle a large number of optimization variables for such problems, a gradient-free approach is explored here for its ability to handle local minima and non-differentiable functions. Evolutionary algorithms (EA) are usually employed to tackle SDO problems and they provide good results. However, due to the very important number of objective function evaluations involved, their computational cost can become prohibitive if the objective function is too expensive to compute. Therefore, objective functions must be very simple (causal behavior without differential equations or matrix inversions) with EAs, which limits the model capability of representing a realistic physical system. A Bayesian optimization (BO) approach is proposed here to solve SDO optimization problems with a reduced number of objective function evaluations to tackle this issue. The aim is to decrease the number of objective function evaluations by a factor 1000 (few hundreds for BO against few hundred thousand for EA). The principle of Bayesian optimization is to create an approximated and simplified (shorter to compute) version of the objective function – the acquisition function - based on the data points already calculated. Then, the computational cost will rely mostly on the evaluation of the acquisition function than on the calculation of the objective function. The expected advantage of BO is its ability to represent the objective function with few data points while its weakness lies in number of the optimization variables than can be possibly handled. This high-dimensionality challenge is tackled here by a decomposition of the optimization problem into the different modes that represents the ship mission profile. A numerical example is presented for a ship energy system than can achieve propulsion and electricity

production by multiple means (diesel engines or gas turbines either producing electricity or directly connected to the shaft). The effect of the formulation of constraints in the objective function will also be discussed as it can have a strong impact on the optimization results.