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Optimization of wind turbine tower using adaptive algorithm configuration

CHANGWU HUANG[1], HAO BAI[2*†], LUJIE SHI[2], YOUNES AOUES[2]

1. Department of Computer Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China [0000-0003-3685-2822]
2. Laboratory of Mechanics of Normandy (LMN), INSA Rouen Normandy, Rouen 76000, France [0000-0003-3546-8802]

* Presenting Author

† Corresponding Author: Hao Bai, hao.bai@insa-rouen.fr

Abstract: This paper aims to solve the black-box optimization problem by using an optimization algorithm with adaptive hyperparameter tuning. The method is applied to a real-world optimization problem in the wind industry to validate its effectiveness. The results reveal that the proposed method is much effective than the other genetic algorithms in solving optimization problems in applied science.

Keywords: Black-box optimization, Wind turbine tower, Differential evolution, Adaptive parameter control

1. Introduction

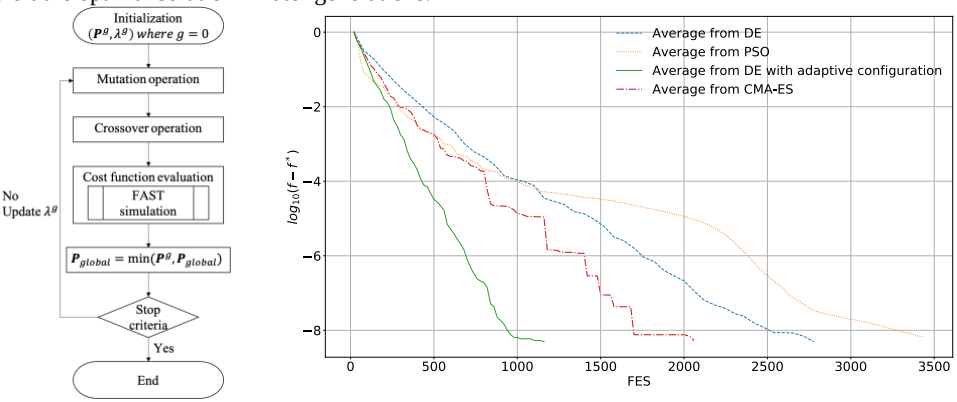
Black-box optimization has always been a tough problem in engineering since it superposes a time-consuming procedure (such as computational mechanics, computational fluid dynamics, etc.) on an optimization loop. To tackle this problem, some researchers propose to replace the numerical models with surrogate models to reduce the demand in time and physic materials. However, these techniques remain an approximate solution comparing to that calculated directly by the numerical models. Another approach is to develop adaptive optimization algorithms which adjust their hyperparameters dynamically during the searching procedure and reduce consequently the need for trial-and-error.

In this paper, an adaptive optimization algorithm with automatic parameter control is proposed based on differential evolution (DE) algorithm. The algorithm is applied to solve a real-world optimization problem in the wind industry and compared to other genetic algorithms in terms of solution quality and optimization effectiveness.

2. Results and Discussion

The objective of the optimization is to minimize the tower mass with respect to the probability of fatigue failure. The initial design is borrowed from [1] where a 140 m reinforced concrete tower is involved to support a 3 MW wind turbine. The dynamic analysis is carried out by using a numerical simulation tool FAST [2]. As a population-based algorithm, the proposed optimization algorithm initiates the initial population $\mathbf{P}^0$ by Latin Hypercube Sampling method in the design space then updates the optimal solution $\mathbf{P}_{\text{global}}$ at each generation $\mathbf{g}$. The relative error between 2 consecutive generations is calculated. When the error falls below 10^{-8}, the optimization is considered as converted.

The initial configuration for optimization algorithm $\boldsymbol{\lambda}^0$ is selected randomly in a single run. It will be updated periodically when the stop criteria are not met. The hyperparameters from mutation operation and crossover operation are tuned in the way to explore the search space in early generations and to exploit the optimal solution in later generations.



(a) Workflow of the adaptive optimization

(b) Optimization performance of the proposed method compared to other algorithms (DE, PSO and CMA-ES) for 25 random runs

Fig. 1. Workflow and results comparison

The overall workflow of the proposed algorithm is illustrated in Fig. 1(a). Fig. 1(b) compares the proposed method with some other population-based optimization algorithms, i.e., DE [3], PSO [4], and CMA-ES [5]. The optimization performance is evaluated by repeating each algorithm 25 times with a random initial population and initial hyperparameters.

It is clear that the slope of the proposed method (green line) is larger than the others which indicates that the proposed DE with adaptive configuration converges more quickly to reach the global optimum. In 25 runs, the averages cost function evaluations (FES) for the proposed method is around 1 000 while the others require more than 1 500 evaluations to reach the same quality of the solution. On the other hand, for a given number of FES, the proposed method offers always the best quality of the solution among all algorithms.

3. Concluding Remarks

In this paper, a population-based adaptive optimization algorithm is proposed to address the black-box optimization problem. The proposed method is used to solve a real-world optimization problem involving numerical modelling. The time consumption in terms of function evaluation is much reduced by comparing to other genetic algorithms. Further investigations on the adaptability of the proposed method for other time-consuming tasks should take place.

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