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ORIGINAL ARTICLE

Q-learning whale optimization algorithm for test suite generation with constraints support

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Abstract

This paper introduces a new variant of a metaheuristic algorithm based on the whale optimization algorithm (WOA), the *Q*-learning algorithm and the Exponential Monte Carlo Acceptance Probability called (QWOA-EMC). Unlike WOA, QWOA-EMC permits just-in-time adaptive selection of its operators (i.e., between shrinking mechanism, spiral shape mechanism, and random generation) based on their historical performances as well as exploits the Monte Carlo Acceptance probability to further strengthen its exploration capabilities by allowing a poor performing operator to be reselected with probability in the early part of the iteration. Experimental results for constraints combinatorial test generation demonstrate that the proposed QWOA-EMC outperforms WOA and performs competitively against other metaheuristic algorithms.

Keywords Combinatorial testing · Constrained software testing · Meta-heuristic · Test case generation · Whale optimization algorithm · Reinforcement learning · *Q*-learning algorithm

1 Introduction

As part of the quality assurance exercise, testing is an important activity within the software development lifecycle. Although desirable to ensure conformance to specification, exhaustive testing is practically impossible to resource and timing constraints. Many sampling-based approaches have been proposed in the literature to minimize tests (e.g., equivalences partitioning and boundary values analysis). Although useful, much of the existing sampling approaches do not address fault due to interaction (termed *t*-way testing, whereby t indicates the interaction strength).

To date, considering *t*-way testing as an optimization problem, many metaheuristic-based strategies have usefully been developed in the literature. The performance of each metaheuristic-based *t*-way strategy often depends on its backbone algorithm. Owing to its robust global search capability, the Whale Optimization Algorithm (WOA) is a suitable choice as the backbone algorithm for our new *t*-way strategy. However, a closer look reveals the following limitations: (i) the three whale operators' selection is solely based on a fixed probability and amplitude change as a function of iteration [1]. Using probability and amplitude change as selection control can be problematic when they do not portray the search process's current need, (ii) no information can be inferred or manipulated on the historical performance of each WOA operator, and (iii) WOA also does not provide an effective way to go out of local optima [1].

Addressing these issues, this paper proposes an ensemble of the *Q*-learning algorithm with the WOA. More precisely, the *Q*-learning algorithm replaces the controlling parameters of WOA in order to balance between exploration and exploitation search. Additionally, the acceptance probability of the Exponential Monte Carlo algorithm (EMC) [2, 3] is embedded to reconsider the worst-performing operator in the early iteration to explore more search regions.

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