学位論文内容の要旨

学位論文題目 Improvement of Meta-heuristic Algorithms from Hybridization and Novel Selection Operator

数理・ヒューマンシステム科学専攻

氏名 唐　振涛

The No-Free-Lunch theorem proves that no algorithm performs best for various optimization problems. Meta-heuristic algorithm has two behaviors, exploration and exploitation. Exploration is to randomly generate an individual in the search space to explore a promising solution that is not neighbor to the current best solution, which helps to jump out of the current local optima. The exploitation is to search promising solutions in a small region near the current optimal solution, which conducts local search in a promising region and accelerates the convergence of the algorithm. The challenging issue that how to balance exploration and exploitation is the focus of improving the algorithm.

There are many existing methods for algorithm improvement, and this paper focuses on two methods: algorithm hybrid and change of selection method. In algorithm hybrid, spherical search (SS) is the one of newest proposed meta-heuristic algorithms. SS performs search effectively in exploration, but due to the lack of local exploitation ability, it converges slowly and can't exploit the small region around the current promising solution. This paper proposes a novel optimization algorithm, namely SSGSA, which is inherited from the SS and gravitational search algorithm (GSA) to combine the effective exploration and exploitation of each algorithm, respectively. To evaluate the effectiveness of SSGSA, we compared it with the original SS, original GSA, particle swarm optimization, and whale optimization algorithm on the IEEE CEC 2017 benchmark function suit. Experimental results show that the proposed new method outperforms its competitors in terms of convergence speed and solution accuracy. In the change of selection method, wind driven optimization (WDO) is a meta-heuristic algorithm based on swarm intelligence. The original selection method makes it easy to converge prematurely and trap in local optima. Maintaining population diversity can solve this problem well. Therefore, we introduce a new fitness-distance balance-based selection strategy to replace the original selection method, and add chaotic local search with selecting chaotic map based on memory to further improve the search performance of the algorithm. A chaotic wind driven optimization with fitness-distance balance strategy is proposed, called CFDBWDO. In the experimental section, we find the optimal parameter settings for the proposed algorithm. In order to verify the effect of the algorithm, we conduct comparative

experiments on the CEC 2017 benchmark functions. The experimental results denote that the proposed algorithm has superior performance. Compared with WDO, CFDBWDO can gradually converge in function optimization. We further verify the practicality of the proposed algorithm with six real-world optimization problems, and the obtained results are all better than other algorithms.

The main contributions of the paper are as follows: (1) To our best knowledge, we are for the first time to consider an algorithm inherited search dynamics from both spherical search and gravitational search, and successfully utilize both characteristics of each search dynamic, thus achieving an efficient search ability. (2) This study reveals that the co-evolution of two carefully selected search algorithms can perform better than each single one, which gives more insights into the key issues of how to integrate different search dynamics to improve the search performance of optimization. (3) The WDO algorithm is easy to fall into local optima. The fitness distance balance strategy is applied to the WDO, which increases the diversity of the population, jumps out of the local optima, explores better solutions, and improves the exploration ability of WDO. (4) Chaotic local search with memory-based selection can make fully use of the performance of each chaotic map to adaptively choose the best chaotic map for chaotic local search, which improves the exploitation ability of WDO, and well balances the exploration and exploitation abilities to further improve its performance. (5) Aiming at the disadvantages of the original WDO selection strategy, we replace the original selection strategy with a new selection strategy FDB, and propose the CFDBWDO algorithm. Extensive experimental results based on performance comparison with other state-of-the-art algorithms together with the statistical results show the superiority and practicality of the proposed CFDBWDO.

Finally, three valuable findings in the paper are as follows: (1) The incorporated FDB selection method can indeed help the algorithm jump out of the local optima by enriching population diversity, which makes the algorithm converge gradually and improves the exploration ability. (2) The effect of CLS on improving the exploitation ability of the algorithm is limited by comparing the experimental results of CFDBWDO and FDBWDO, which clearly verifies the effects of CLS on WDO. (3) In the large dimensions, CFDBWDO has no significant advantage over AWDO. The possible reason is that the effect of the algorithm on optimizing functions with large dimensions needs further improvement.

【学位論文審査結果の要旨】(唐　振涛)

当博士学位論文審査委員会は，標記の博士学位申請論文を詳細に査読した。本博士論文と従来の論文との類似性指標は 20%であり，剽窃等の問題がないことを確認した。また論文公聴会を令和 5 年 1 月 27 日(金曜日)に公開で開催し，詳細な質疑応答を行って論文の審査を行った。以下に審査結果の要旨を示す。

最適化問題は多くの工学的問題の鍵であり、メタヒューリスティックアルゴリズムは複雑な最適化問題を解決するための効果的な手法である。本論文では，メタヒューリスティックアルゴリズムの性能を向上させるために，混合および選択方法の変更を行った。混合アルゴリズムとは、改良されたアルゴリズムの欠点を他のアルゴリズムの利点に置き換えることで形成されるハイブリッドアルゴリズムである。フィットネス距離バランス選択方式は、集団の多様性を増大させ、アルゴリズムが局所最適に陥ることを回避し、オリジナルのアルゴリズムとは異なる方式の選択を行うことで、局所解からの脱出および解の質向上など、アルゴリズムの改善を図ることができる。

学位論文は 5 つの章で構成されている。第 1 章では、メタヒューリスティックアルゴリズムを紹介し、球形サーチ(spherical search)と風力駆動最適化(wind driven optimization)について総括した。第 2 章では、球形サーチと風力駆動最適化の原理、数式と擬似コードについて具体的に説明した。第 3 章では、重力探索アルゴリズム(gravitational search algorithm)の開発力が高いことを利用して、球形サーチと重力探索アルゴリズムを混合して混合アルゴリズムを形成し、母集団を更新し、球形サーチアルゴリズムを改善する。メモリ選択によるカオス局所探索の開発性能とフィットネス距離バランス選択戦略の探索性能を用いて風力駆動最適化に加え、フィットネスと距離のバランス戦略に基づくカオス風力駆動最適化アルゴリズムを提案し、風力駆動最適化アルゴリズムの開発と探索能力を向上させた。第 4 章では、混合や選択方式の変更が従来のアルゴリズムの性能を大幅に向上させることを実験的に証明した。さらに第 5 章で、結論を出し、将来の研究の見通しと計画について検討した。

当博士論文審査委員会は、研究内容及び研究成果を慎重に吟味した結果，本博士学位申請論文が博士の学位を授与することに十分に値するものと認め，合格と判断した。