

Graph-Based Deep Decomposition for Overlapping Large-Scale Optimization Problems

Xin Zhang[✉], Member, IEEE, Bo-Wen Ding, Xin-Xin Xu, Jian-Yu Li[✉], Student Member, IEEE, Zhi-Hui Zhan[✉], Senior Member, IEEE, Pengjiang Qian[✉], Senior Member, IEEE, Wei Fang[✉], Member, IEEE, Kuci-Kuci Lai, and Jun Zhang[✉], Fellow, IEEE

Abstract—Decomposition methods play a critical role in cooperative co-evolutionary algorithms (CCEAs) for solving large-scale optimization problems. Although some well-performing decomposition methods have been designed based on the interactions among variables (laV), their grouping accuracy is still limited due to the poor performance on the overlapping problems and the computational roundoff errors of laV in the implementation. To deal with these limitations, a graph-based deep decomposition (GDD) method is proposed to obtain more accurate grouping results, especially for the overlapping problems. On the one hand, the GDD mines the laV information and obtains the minimum vertex separator of the interaction graph of variables, so as to group variables deeply and recursively. On the other hand, the GDD has the ability of fault tolerance to deal with the computational roundoff errors of laV and can improve the grouping accuracy. For better experimental studies of overlapping problems, a novel overlapping function generator is designed with the random and complicate overlap type, and two new metrics are proposed to evaluate the grouping accuracy. Comprehensive experiments show that GDD can greatly improve the grouping accuracy and help CCEAs perform better than other existing algorithms, especially on the overlapping

problems. In addition, the GDD is highly fault tolerant and can divide problems accurately even on the inaccurate laV.

Index Terms—Cooperative co-evolutionary algorithms (CCEAs), decomposition methods, evolutionary computation, large-scale optimization problems (LSOPs).

1. INTRODUCTION

WITH data growing explosively, large-scale optimization problems (LSOPs) have aroused increasing attention and become a hot research topic in many systems engineering fields [1], [2], [3], such as the multiobjective optimization of large-scale capacitated arc routing problems [4], the constrained optimization of the large-scale power system [5], and the large-scale optimization of the supply chain system [6], [7]. Compared with the traditional optimization problems, a much larger number of decision variables need to be optimized in the LSOPs. In this case, the increase of the problem size causes it difficult to obtain the global optimal solution within the limited computation resources, e.g., within the maximal number of fitness evaluations [8], [9], [10].

Since evolutionary computation algorithms (including evolutionary algorithms [11], [12] and swarm intelligence algorithms [13], [14]) are skilled in maintaining the solution diversity and finding optimal solutions in global optimization [15], [16], [17], [18], [19], [20], [21], they have been widely studied and extensively applied to solve the LSOPs [22], [23], [24]. EAs used for the LSOPs can be classified into two main categories according to whether decompose the problems. The first category of EAs takes the LSOP as a whole and does the main work on the design of effective learning strategies. These learning strategies are proposed to improve the solution diversity and find the optimal solutions [25], [26], [27], [28], [29].

The second category of EAs, usually called cooperative co-evolutionary algorithms (CCEAs), decomposes the LSOPs into several subproblems and then solves subproblems by different subpopulations [30], [31]. The decomposition of LSOP can reduce the search space of each subproblem and improve the search efficiency of CCEAs [32]. The most important part of CCEAs is the decomposition method that aims to put the interacting variables of the problem into the same group and divide the non-interactive variables into different groups. Each group is

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Xin Zhang, Bo-Wen Ding, Pengjiang Qian, and Wei Fang are with the School of Artificial Intelligence and Computer Science and the Jiangsu Key Laboratory of Media Design and Software Technology, Jiangnan University, Wuxi 214122, China.

Xin-Xin Xu is with the School of Computer Science and Technology, Ocean University of China, Qingdao 266100, China.

Jian-Yu Li and Zhi-Hui Zhan are with the School of Computer Science and Engineering, South China University of Technology, Guangzhou 510006, China, also with Fuzhou Laboratory, Guangzhou 510030, China, and also with the Guangdong Provincial Key Laboratory of Computational Intelligence and Cyberspace Information, Guangzhou 510006, China (e-mail: zhanapollin@163.com).

Kuci-Kuci Lai is with the Department of Business Administration, Chaoyang University of Technology, Taichung City 413, Taiwan (e-mail: laikuci.tw@gmail.com).

Jun Zhang is with Zhejiang Normal University, Jinhua 321004, China, and also with Hanyang University, Ansan 15388, South Korea.

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Decomposition Of Large Scale Problems

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