Linear Linkage Encoding in Grouping Problems: Applications on Graph Coloring and Timetabling

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Abstract. Linear Linkage Encoding (LLE) is a recently proposed representation scheme for evolutionary algorithms. This representation has been used only in data clustering. However, it is also suitable for grouping problems. In this paper, we investigate LLE on two grouping problems; graph coloring and exam timetabling. Two crossover operators suitable for LLE are proposed and compared to the existing ones. Initial results show that LLE is a viable candidate for grouping problems whenever appropriate genetic operators are used.

1 Introduction

In spite of the satisfactory performance of Evolutionary Algorithms (EA) on many NP optimization problems, the same achievement is not usually observed on grouping problems where the task is to partition a set of objects into disjoint sets. This is because the commonly used representations usually suffer from redundancies due to the ordering of groups. Moreover the genetic material might easily be disrupted by the genetic operators and/or by the rectification process after the operators are applied.

Timetabling problems are real-world NP-hard [7] problems. Discarding the rest of the constraints, attempting to minimize the timetabling slots while satisfying the clashing constraints turns out to be a graph coloring problem [19]. For this reason, new representation schemes and operators used in graph coloring are also of interest to the researchers in the timetabling community.

In the paper, we are investigating a recently proposed encoding scheme for grouping problems, Linear Linkage Encoding (LLE) [6]. LLE has only been tested on small clustering problem instances, and authors claim that the LLE performance is superior to Number Encoding (NE), the most common encoding scheme used in grouping problems. Unlike NE, LLE does not require an explicit bound on the number of groups that can be represented in a fixed-length chromosome. The greatest strength of LLE is that the search space is reduced considerably. There is a one-to-one correspondence between the chromosomes and the solutions when LLE is used. Consequently the aim of this paper is to present the

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potential of the LLE representation on grouping problems. Previous studies denote that traditional crossover operators do not perform well. Therefore, a set of new crossover operators suitable for LLE are also tested on a set of problem instances including Carter's Benchmark [5] and DIMACS Challenge Suite [17].

This paper is organized as follows. We first define the grouping problems and common representations for them. The fundamentals of LLE is followed by the definition of the graph coloring problem. Then the operators of the algorithm with special crossovers are presented. Computational experiments and conclusions are given at the end of the paper.

2 Grouping Problems

Grouping problems [8] are generally concerned with partitioning a set V of items into a collection of mutually disjoint subsets V_i of V such that

$$V = V_1 \cup V_2 \cup V_3 \cup \ldots \cup V_N \text{ and } V_i \cap V_j = \emptyset \text{ where } i \neq j.$$

Obviously, the aim of these problems is to partition the members of set V into N different groups where $(1 \leq N \leq |V|)$ each item is in exactly one group. In most of the grouping problems, not all possible groupings are permitted; a valid solution usually has to comply a set of constraints. For example in graph coloring, the vertices in the same group must not be adjacent in the graph. In the bin packing problem, the sum of the sizes of items of any group should not exceed the capacity of the bin, etc. Hence, the objective of grouping is to optimize a cost function defined over a set of valid groupings. In both graph coloring and bin packing the objective is to minimize the number of groups (independent sets and bins respectively) subjected to the mentioned constraints.

Grouping problems are characterized by the cost function based on the composition of the groups. An item in isolation has little or no meaning during the search process. Therefore, the building blocks that should be preserved in an evolutionary search should be the groups or the group segments.

2.1 Representations in Grouping Problems

The most predominant representation in grouping problems in both evolutionary and local search methods is Number Encoding (NE). In NE, each object is encoded with a group id indicating which group it belongs to. For example the individual 2342123 encodes the solution where first object is in group 2, second in 3, third in 4, and so on. However, it is easy to see that the encoding 1231412 represents exactly the same solution, since the naming or the ordering of the partition sets is irrelevant. The drawbacks of this representation are presented in [8] and it is pointed out that this encoding is against the minimal redundancy principles for encoding scheme [23].

Another representation for grouping problems is Group Encoding (GE). The objects which are in the same group are placed into the same partition set.