Memes, Self-generation and Nurse Rostering

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Abstract. This paper presents an empirical study on memetic algorithms in two parts. In the first part, the details of the memetic algorithm experiments with a set of well known benchmark functions are described. In the second part, a heuristic template is introduced for solving timetabling problems. Two adaptive heuristics that utilize a set of constraint-based hill climbers in a co-operative manner are designed based on this template. A hyper-heuristic is a mechanism used for managing a set of low-level heuristics. At each step, an appropriate heuristic is chosen and applied to a candidate solution. Both adaptive heuristics can be considered as hyper-heuristics. Memetic algorithms employing each hyper-heuristic separately as a single hill climber are experimented on a set of randomly generated nurse rostering problem instances. Moreover, the standard genetic algorithm and two self-generating multimeme memetic algorithms are compared to the proposed memetic algorithms and a previous study.

1 Introduction

Genetic Algorithms (GAs), as presented by J. Holland in [28], are very promising for tackling complex problems [24]. There are some shortcomings of generic genetic algorithms, such as premature convergence. The effectiveness of the use of appropriate operators and hybrid approaches is underlined by many researchers to overcome such difficulties. Memetic Algorithms (MAs) embody a class of algorithms that combine genetic algorithms and hill climbing methods [15, 38, 45, 46]. A *meme* represents a hill climbing method to be used within an MA as the local refinement component. Ning et al. [39] concluded from their experiments that the meme choice in an MA influences the performance significantly. Krasnogor [31] extended his previous studies and suggested a *self-generating multimeme* MA for solving problems in the existence of multiple choices for the operators. Each meme encodes an operator and its parameters that a candidate solution will employ during the evolution. In this study, a meme denotes a hill climbing method and its related parameters. Each meme is co-evolved with each candidate solution. The evolutionary process offers a learning mechanism to fully utilize the provided hill climbers [32, 34].

In the first part of this study, the multimeme approach proposed by Krasnogor [33] is tested on a set of benchmark functions. The study aims to answer the following questions:

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- Can the suggested learning mechanism discover useful hill climbers?
- Does a set of hill climbers generate a synergy to obtain the optimal solution?

In the second part of this study, MAs for solving a nurse rostering problem, introduced by Özcan [41], are considered. Özcan extended the study by Alkan and Özcan [5], and suggested templates designing a set of operators, including a self-adjusting violation-directed and constraint-based heuristics, named as VDHC, within MAs for solving timetabling problems. A new heuristic template for managing a set of constraint-based hill climbers is introduced in this paper. Two new instances based on this template are implemented and used as a single hill climber within MAs. Furthermore, two multimeme memetic algorithms (MMAs) are described. The performances of all the proposed algorithms, including the traditional genetic algorithm and the MA provided in [41], are compared. A *hyper-heuristic* is a mechanism used to decide which heuristic to apply from a set of heuristics to a given candidate solution. It is an emerging search and optimization tool [11, 14, 43]. A variety of approaches are used as hyper-heuristics, including meta-heuristics. Several heuristics presented in this study for nurse rostering can be considered as hyper-heuristics used during the hill climbing process to manage a set of hill climbers within MAs.

In the following section, the nurse rostering problem and memetic algorithms, including the multimeme approach are summarized. The relevant details of MAs and the experiments for the benchmark function optimization are explained in Section 3. MAs, including the hill climbers, are described for solving the nurse rostering problem at a Turkish hospital in Section 4. The nurse rostering data and the experimental results are provided in Section 5. Finally, the conclusions are presented in Section 6.

2 Background

2.1 Nurse Rostering Problem

Timetabling problems are real-world constraint optimization problems. Due to their NP complete nature [21], traditional approaches might fail to generate a solution for an instance. Timetabling problems can be represented in terms of a three-tuple $\langle V, D, C \rangle$, where V is a finite set of *variables*, D is a finite set of *domains* of variables and C is a set of *constraints* to be satisfied:

$$V = \{v_1, v_2, \ldots, v_M\}, \quad D = \{d_1, \ldots, d_i, \ldots, d_M\}, \quad C = \{c_1, c_2, \ldots, c_K\}.$$

Solving a timetabling problem instance requires a search for finding the best assignment for all variables that satisfy all the constraints. Thus, a candidate solution is defined by an assignment of values from the domain to the variables:

$$V' = \{v_1 = v'_1, \ldots, v_i = v'_i, \ldots, v_M = v'_M\},$$

where $v'_i \in d_i$ and $d_i \subseteq D_1 \times \cdots \times D_P$, where $P \geq 1$.