Parameter Setting in Evolutionary Algorithms applied to the Multiobjectivised Frequency Assignment Problem

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I. INTRODUCTION

Metaheuristics is a family of approximation algorithms widely used to deal with optimisation problems. Among them, Evolutionary Algorithms (EAs) are one of the most popular approaches. They usually have several components (genetic operators, selection operator, etc.) and parameters (mutation rate, crossover rate, etc.) which must be fixed. Therefore, one of the main drawbacks of EAs is the complexity of their parameter setting. Multiobjectivisation transforms a mono-objective problem into a multi-objective one. Multiobjectivisation is usually applied to avoid stagnation in local optima. Several multiobjectivisation approaches make use of some parameters that must be specified by the user. These more advanced multiobjectivisation methods might improve results for some optimisation problems [1]. However, they introduce more components and parameters into the optimisation scheme so they hinder even more the parameter setting of an EA. In this work, two different instances of the Frequency Assignment Problem [2] (FAP) have been multiobjectivised in order to avoid stagnation in local optima. A novel artificial function based on calculating the Euclidean distance to the nearest neighbour in the population, considering the decision space has been applied. The novelty of this approach resides in the incorporation of a threshold ratio \( (th \in [0,1]) \) which must be specified by the user. Such a multiobjectivisation is named DCN-THR. The main aim of this work has been the control of the parameter \( th \) by different methods. There exist different techniques to carry out this parameter setting. Among them, hyperheuristics are one of the most used approaches [3]. Fuzzy logic systems have also been applied with success to control several parameters of different metaheuristics [4]. Other approaches are based in the self-adaptation of the parameters [5]. In this work the parameter \( th \) has been controlled by a hyperheuristic, a fuzzy logic system, and it has also been self-adapted. In order to obtain better results in less time, a parallel homogeneous island-based model [6] has been applied. Such a parallel model has made use of the fuzzy logic system. Computational results have demonstrated the validity of the parameter setting proposals. The best-known frequency plan for one of the instances of the FAP has been improved.

II. OPTIMISATION SCHEMES

The optimisation schemes applied in this work are based on the Memetic Algorithm (MA) proposed in [7]. Since, the FAP has been multiobjectivised with the DCN-THR approach, a multi-objective algorithm has been applied. By this way, the MA has been implemented starting from the well-known Non-Dominated Sorting Genetic Algorithm II (NSGA-II). To completely define a configuration of such a MA, several components and parameters must be specified. The mutation operator has been the Neighbourhood-based Mutation (NM), and the crossover operator has been the Uniform Crossover (UX). Such operators have been applied with probabilities \( p_m = 0.9 \), and \( p_c = 1 \), respectively. The population size has been fixed to 10 individuals. Finally, the selection operator has been the well-known Binary Tournament.

The optimisation scheme based on the hyperheuristic has applied 6, 11, 21, and 51 different configurations of the MA. The different configurations have been obtained varying the parameter \( th \) uniformly in the range \([0,1]\). In the case of the optimisation scheme based on the fuzzy logic system, it is not necessary to specify different configurations in order to vary the parameter that is going to be controlled. The user only specifies the range of values that the parameter can take (\( th \in [0,1] \)). By this way, the application of the optimisation scheme is more comfortable from the user’s point of view. In addition, three different self-adaptive optimisation schemes have been defined. In this case, the parameter \( th \) has been codified in the genotype of the individual, and the value that such a parameter takes is calculated by three different ways. Finally, a parallel homogeneous island-based model has been applied with the aim of obtaining better results in a lower amount of time. This parallel model has used the optimisation scheme based on the fuzzy logic system.

III. EXPERIMENTAL EVALUATION

The experimental evaluation has been run on HECToR. Experiments have been carried out considering two real instances of Seattle and Denver. However, only results with Seattle are shown. Since experiments have involved the use of stochastic algorithms, each execution has been repeated 32 times, and a confidence level equal to 95% has been used in the statistical tests. Executions have been performed considering 11.5 hours.
In the first experiment, the different parameter setting strategies have been tested. Figure 1 shows the evolution of the mean of the cost for the Seattle instance. For every one of the three parameter setting approaches, the results of the configuration which has presented the best behaviour are shown. It can be observed that the approaches based on the hyperheuristic and on the fuzzy logic system do not present differences between them. However, they present clear differences with the self-adaptive method. This fact can be demonstrated with the Table I. It shows if the row approach is statistically better (↑), not different (↔), or worse (↓) than the corresponding column approach.

In the second experiment, a parallel homogeneous island-based model has been executed together with the fuzzy logic system. The main objective of this experiment is twofold. Firstly, facilitating the application of the approach based on the fuzzy logic system in parallel environments, while obtaining better results in a lower amount of time. Finally, performing a scalability analysis of the approach, and studying the behaviour of such a parallel model depending on the number of invested processors. This experiment has been performed with up to 64 processors. Figure 2 shows the boxplots of the parallel model compared with the sequential version of the approach based on the fuzzy logic system for the Seattle instance. It can be noted that the higher the number of processors the better the results. The statistical tests have demonstrated this fact. Finally, it is worthy to mention that the best-known frequency plan for the Seattle instance has been improved by the usage of this parallel approach.

IV. Conclusions

The results obtained by the models based on the hyperheuristic and on the fuzzy logic system have been statistically better than the self-adaptive model. The approaches based on the hyperheuristic and on the fuzzy logic system have not presented statistical differences. However, from the user’s point of view, it is easier to apply the model based on the fuzzy logic system since they do not have to define different configurations. Only it is necessary to specify the range of values that the parameter which is going to be controlled can take. Finally, the hybridisation between the parallel homogeneous island-based model and the approach based on the fuzzy logic system has allowed obtaining the best-known frequency plan for the Seattle instance (387.704).

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