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Good practice proposal for the implementation, presentation, and comparison of metaheuristics for solving routing problems

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ABSTRACT

Researchers who investigate in any area related to computational algorithms (both defining new algorithms or improving existing ones) usually find large difficulties to test their work. Comparisons among different researches in this field are often a hard task, due to the ambiguity or lack of detail in the presentation of the work and its results. On many occasions, the replication of the work conducted by other researchers is required, which leads to a waste of time and a delay in the research advances. The authors of this study propose a procedure to introduce new techniques and their results in the field of routing problems. In this paper, this procedure is detailed, and a set of good practices to follow are deeply described. It is noteworthy that this procedure can be applied to any combinatorial optimization problem. Anyway, the literature of this study is focused on routing problems. This field has been chosen because of its importance in real world, and its relevance in the actual literature.

1. Introduction

Today, optimization problems receive much attention in artificial intelligence. There are various types of optimization, such as linear [1], continuous [2], numerical [3], or combinatorial optimization [4]. Usually, the resolution of problems arisen in these areas entails a great computational effort. Besides that, many optimization problems are applicable to real world situations. For these reasons, many different methods developed to be applied to these problems can be found in the literature.

In this way, route planning is one of the most studied fields in artificial intelligence. Problems arisen in this field are usually known as vehicle routing problems, which are a particular case of problems within combinatorial optimization subject. It is important to highlight that combinatorial optimization is the most suitable branch of optimization for facing routing problems, since the option of treating the variables as discrete ones permits a faithful adaptation. On the other hand, the use of another type of optimization, such as continuous optimization, which requires continuous variables, could lead to a less reliable adaptation.

In line with this, the comparison between different metaheuristics for solving routing problems is a complex task, since many factors must be taken into account. This fact creates a lot of controversy and can lead to much confusion and bad practices. Despite this, it is hard to find a methodology or procedure that helps researchers to describe and compare their metaheuristics in a reliable manner. In this way, the aim of this paper is to propose a procedure to facilitate an accurate comparison between different metaheuristics. It is noteworthy that these good practices are focused on routing problems. For this reason, the literature of this study is oriented to this kind of problems. This field has been chosen due to its importance in the real world, and its great relevance in the literature. Finally, we want to clarify that this study is an extension of the work presented in [5] for the International Joint Conference SOCO-CISIS-ICEUTE'14. In the present work, several additional good practices are proposed, and the presented literature is updated. Additionally, some of the good practices proposed in [5] have been modified and supported with additional cites in order to facilitate their understanding.

As has been mentioned, until now, few methodologies and good practices have been proposed in the literature related with heuristics and metaheuristics. In [6], a small section about the evaluation of heuristics related to the Vehicle Routing Problem with Time Windows can be found. In this section, some advices to perform a fair comparison between different heuristics are described. The difference between this work and our proposal is that we have focused our attention in metaheuristics, instead of heuristics. Additionally, the bibliography of our paper covers a wider field, generalizing to all vehicle routing problems. Kendall et al. [7] also mentioned the difficulty of finding standards in optimization research in terms of good laboratory practices. In this case, authors suggest

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a concrete set of recommendations that the community should adopt in order to enhance the replicability of studies. The difference between this valuable work and the present paper is that we have focused in one specific branch of optimization and a concrete family of problems. Furthermore, we have not only centered on good practices related to laboratory experiments. Besides that, we also propose some good practices to consider when implementing, and presenting, different techniques for comparison. In [8], some good research practices to follow in the development of novel metaheuristics are described. Finally, some articles can be found in the literature proposing methodologies to perform correct statistical tests. In [9], for example, a practical tutorial on the use of non-parametric statistical tests for comparing evolutionary and swarm intelligence algorithms is presented. In addition, in [10], a method for statistically compare different heuristics or metaheuristics is presented. The goal of that article is to propose a methodology to perform statistically correct and bias-free comparisons. In line with this, and being aware that this is not the sole objective of our paper (since we have addressed all the development-experimentation phase), a special mention to statistical tests is made in our paper.

The structure of this paper is as follows. In Section 2, the background that motivated this study is described. After that, in Section 3, the steps to follow in the implementation and presentation of metaheuristics are explained. In Section 4, how the results should be accurately presented is explained. This paper ends with the conclusions of the study, its utility, and our planned future work (Section 5).

2. Background

As has been mentioned in the introduction, route planning is a hot topic inside artificial intelligence. The different problems arisen in this field produce a huge amount of works annually in both international conferences [11,12], and journals [13–15]. In addition, they inspire the edition of several technical reports [16], and scientific books [17,18]. It is noteworthy that two of the most studied routing problems are the Traveling Salesman Problem (TSP) [19], and the Vehicle Routing Problem (VRP) [20], which are the focus of a great number of studies in the literature [21,22].

The importance of routing problems can be justified in two ways: their inherent scientific interest, and the social interest they generate. On the one hand, most of the problems arising in this field have a great computational complexity. Being NP-Hard, the resolution of these problems is a major challenge for the scientific community. On the other hand, routing problems are usually designed to tackle real world situations related to logistics and transports. This is the reason because their efficient resolution entails a social and a business profit.

In line with this, several approaches can be found in the literature to address these problems efficiently. Arguably, the most successful techniques are the exact methods [23,24], heuristics and metaheuristics. On the one hand, exact methods are search methods that track all the solution space to always find the optimal solution. These techniques are only valid for simple problems, or for relaxation of more complex problems. Otherwise, the execution times of these kind of methods are computationally inadmissible.

Furthermore, a heuristic is an optimization technique that solves a problem using specific information and knowledge of that problem. In this way, heuristics explore the space of feasible solutions intensifying the search in the most promising areas. This process is made with the intention of achieving good optimization results quickly. Generally, these techniques are used to solve well-known problems with simple formulations, such as standard TSP or the basic VRP, because of the difficulty of finding appropriate heuristics to real problems with complex objective functions and constraints.

Finally, a metaheuristic is an optimization technique that solves a specific problem using only general information and knowledge common to a wide variety of optimization problems with similar characteristics. Metaheuristics explore the solution space in order to achieve good optimization results with independence of the problem. For this reason, it is prudent to affirm that metaheuristics are more appropriate to solve real world problems with complex formulations, since they do not use any specific information of the problem in the exploration of the space of feasible solutions. Metaheuristics can be applied in a wide range of fields, such as transport [25–28], medicine [29], or industry [30,31]. Some of these algorithms are based on a single search, such as Simulated Annealing [32] and Tabu Search [33], and some others are based on a multiple search (population based algorithms), such as genetic algorithm (GA) [34,35], ant colony optimization (ACO) [36], particle swarm optimization (PSO) [37–39], or imperialist methods [40]. Besides these, in the last years many new population techniques have been proposed, such as the Bat Algorithm (BA) [41,42], the Gravitational Search Algorithm [43,44] or Firefly Algorithm (FA) [45,46]. Metaheuristics can also be classified in search based algorithms and constructive algorithms. Search based algorithms start from an initial complete solution or an initial set of complete solutions which are modified until reaching a final solution, while constructive algorithms start from a partial solution or a set of partial solutions which are built until reaching an final complete solution.

As has been mention, many different metaheuristics can be found in the literature. These days, some of the most used ones are the population based techniques. Leaving aside the classical approaches, such as the GA or the ACO, some of the most popular methods in the current scientific community are the PSO, BA, harmony search (HS) [47], FA or flower pollination algorithm (FPA). Many studies can be found in the literature focused on these techniques. The PSO [37] is one of the most used swarm based technique, developed under the inspiration of the behavior of bird flocks, fish schools and human communities. It works with a population (called swarm) of candidate solutions (called particles), and the movements of every particle are guided by a parameter called velocity. Furthermore, BA is population technique, proposed by Yang in 2010 [41], which is based on the echolocation behavior of microbats, which can find their prey and discriminate different kinds of insects even in complete darkness. On the other hand, the HM [47] mimics the improvisation of music players, and it was conceptualized using the musical process of searching for a perfect state of harmony. Moreover, FA is a population technique first developed by Yang in 2008 [45], which is inspired on the flashing behavior of fireflies. This flashing behavior acts as a signal system to attract other fireflies. Finally, FPA is an evolutionary technique inspired by the pollination process of flowers [48]. These metaheuristics have been frequently used in recent years to solve routing problems [49–52]. Since the main goal of this paper is not to describe deeply these techniques, we refer readers to any of the papers cited in this work to collect further information.

As has been pointed, on the one hand, heuristics are ad-hoc techniques which are focused on the resolution of one specific problem. Metaheuristics, however, can be applied to a wide variety of real problems whose complexity prevents developing appropriate heuristics. In this sense, the comparison among heuristics is simpler than the comparison among metaheuristics. No matter which the nature of heuristics is, or the parameters and features utilized, the best heuristic will be the one that obtains the best results in a reasonable time. Anyway, as can be seen in [6], the comparison of heuristics can also lead to problems if the results are not presented properly. On the other hand, the comparison between different metaheuristics is a complex process. Despite its importance, few papers related to this critical task can be found in the