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Innovative Applications of O.R.

A Clustering Search metaheuristic for the Point-Feature Cartographic Label Placement Problem

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ABSTRACT

The Point-Feature Cartographic Label Placement (PFCLP) problem consists of placing text labels to point features on a map avoiding overlaps to improve map visualization. This paper presents a Clustering Search (CS) metaheuristic as a new alternative to solve the PFCLP problem. Computational experiments were performed over sets of instances with up to 13,206 points. These instances are the same used in several recent and important researches about the PFCLP problem. The results enhance the potential of CS by finding optimal solutions (proven in previous works) and improving the best-known solutions for instances whose optimal solutions are unknown so far.

1. Introduction

The Point-Feature Cartographic Label Placement (PFCLP) problem has a great importance for applications which use computational resources to generate maps, as for example, georeferencing systems, web applications, etc.

The PFCLP problem is classified in the literature as *NP – Hard* (Marks & Shieber, 1991) and according to Ribeiro and Lorena (2008b), it consists in organizing points on maps avoiding overlaps of labels and providing clarity in viewing and understanding of the map. The labels contain information of objects to be displayed in cartographic maps, networks, graphs or diagrams (Wolff, 1999).

Fig. 1 shows a map of São Paulo State (Brazil) with districts and roadways. The labels indicate the name of the districts and the gray districts indicate that their labels are overlapped.

One way to improve the map view is moving the labels to specific positions close to their respective points which are known as "candidate positions". The candidate positions represent the possible locations where the label of a point can be placed, respecting a cartographic pattern.

Fig. 2 illustrates the cartographic pattern proposed by Christensen, Marks, and Shieber (1995). This pattern is one of the most known and used in the literature. The regions 1–8 indicate the candidate positions for labeling the point. Each position has a number indicating its cartographic preference, and position 1 is the most suitable, i.e. the smallest number indicates the best position. Starting from this pattern, the point-labeling problem can be defined as a combinatorial problem which must select candidate positions to label the points.

In the PFCLP problem, overlapping labels may be accepted or not. When overlaps are not accepted, we can keep the size of the labels and label the greatest number of points without overlapping. In this case, the PFCLP problem is a special case of the traditional Maximum Independent Set Problem (Ribeiro, Mauri, & Lorena, 2011; Strijk, Verweij, & Aardal, 2000; Zoraster, 1990). We also may decrease the size of the labels such that all of them fit without overlap. Here, the objective is to find the maximum scale factor for the label size such that a labeling without conflict is generated (Klau & Mutzel, 2003).

Overlaps are allowed in several papers about the PFCLP problem, and so, all points must necessarily be labeled. Consequently, two approaches are identified: minimize the number of conflicts (Ribeiro & Lorena, 2008a, 2008b) and maximize the number of conflict-free labels (Alvim & Taillard, 2009; Mauri, Ribeiro, & Lorena, 2010). In this paper, we consider that last approach for which a mathematical model is available in Mauri et al. (2010).

This paper aims to present a new alternative to solve the PFCLP problem. A Clustering Search (CS) metaheuristic is proposed using a Simulated Annealing algorithm as part of its structure.

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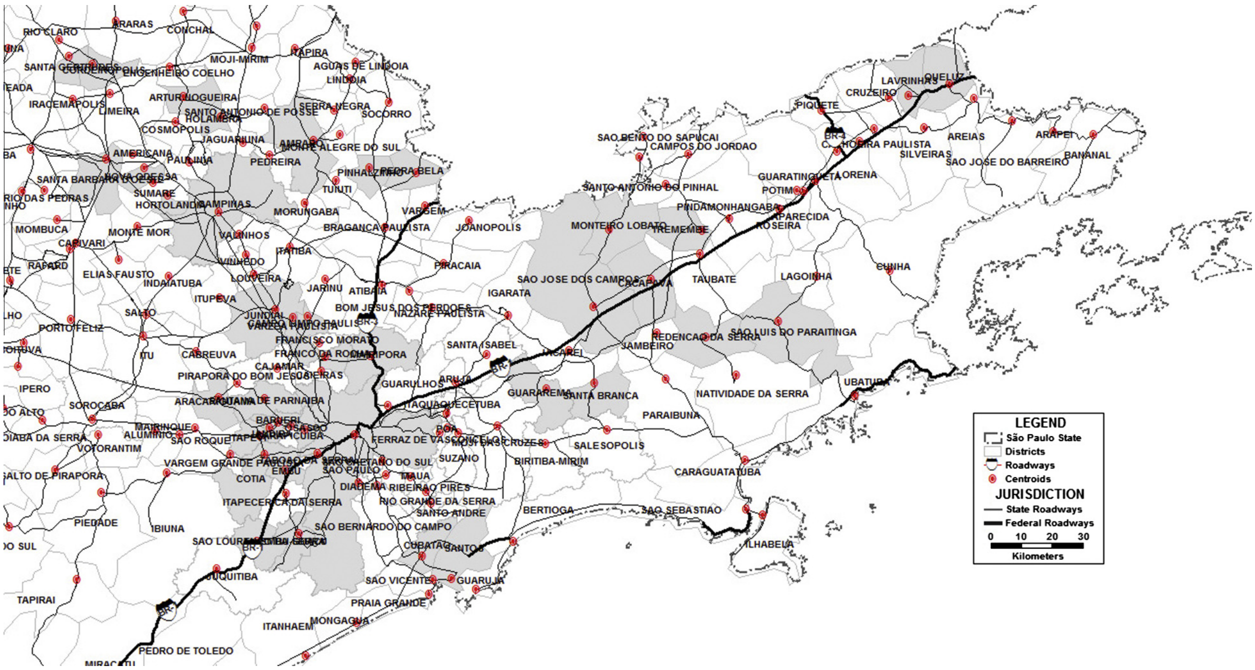

Fig. 1. Map of São Paulo state: overlaps are highlighted by gray polygons (Ribeiro & Lorena, 2008b).

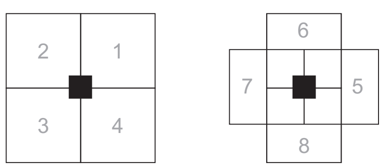

Fig. 2. Cartographic pattern proposed by Christensen et al. (1995).

The CS was chosen because it has been presenting good results for different types of combinatorial optimization problems and it was not used to solve the PFCLP problem.

Our results are compared with those obtained by several methods presented in recent researches found in the literature. The CS performance is highlighted by finding equal or better solutions for practically all instances.

The remainder of this paper is organized as follows. Previous approaches to PFCLP problem are reviewed in Section 2. The proposed CS is described in Section 3 and computational results are reported in Section 4. Our conclusions are summarized in Section 5.

2. Literature review

In the literature, we can find several researches about the PFCLP problem. In this section, we present some major works about the problem.

Christensen et al. (1995) presented one of the first and major work about the PFCLP problem. They used different heuristic algorithms to solve the problem. Verner, Wainwright, and Schoenefeld (1997) used Genetic Algorithms reporting good results for some instances. These results were improved by a Tabu Search proposed by Yamamoto, Câmara, and Lorena (2002) which was applied to instances with up to 1000 points. Since then, these instances have been used in several papers as follows. Yamamoto and Lorena (2005) applied the Constructive Genetic Algorithm proposed by Lorena and Furtado (2001) providing better results than those presented by Yamamoto et al. (2002).

A GRASP (Greedy Randomized Adaptive Search Procedure) was proposed by Cravo, Ribeiro, and Lorena (2008) which presented new solutions for the PFCLP problem. Ribeiro and Lorena (2008a, 2008b) proposed a Lagrangian Relaxation with Clusters (LagClus) and a Column Generation approach. The optimality for some instances were proven and new best solutions were reported.

Alvim and Taillard (2009) applied the POPMUSIC (Partial Optimization Metaheuristic under Special Intensication Conditions) proposed by Taillard and Voss (2001) to solve the PFCLP problem. The POPMUSIC divides the problem into subproblems and a Tabu Search (based on that one proposed by Yamamoto et al. (2002)) is applied to solve them. Several variations of POPMUSIC and Tabu Search were reported. The authors presented new best solutions for the known set of instances proposed by Yamamoto et al. (2002), and they also proposed a new set of instances with 13,206 points to be labeled.

Mauri et al. (2010) presented new approaches to solve the PFCLP problem. They proposed a mathematical model and a solution method based on the Lagrangian decomposition. The authors found best solutions and proven the optimality for many instances with up to 1000 points. The model proposed by Mauri et al. (2010) was improved by Ribeiro, Constantino, and Lorena (2009) which inserted some inequalities to strengthen the mathematical formulation, and better solutions for the instances with 1000 points were found.

Recently, Oliveira, Urrutia, and Noronha (2009, 2010) proposed a Backtracking heuristic and an Iterated Local Search (ILS), achieving the best results for the instances with 1000 and 13,206 points.

A summary of these methods and their results is reported in Section 4 where a comparison is provided.

3. Clustering Search

The Clustering Search (CS) algorithm is a hybrid metaheuristic proposed by Oliveira and Lorena (2007) that employs clustering for detecting promising areas of the search space. It generalizes the Evolutionary Clustering Search proposed by Oliveira and Lorena (2004) substituting the evolutionary algorithm by metaheuristics such as Simulated Annealing, GRASP, and Tabu Search.