Chapter 2
Optimization of the Vertex Separation Problem with Genetic Algorithms

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ABSTRACT

The Vertex Separation Problem (VSP) is an NP-hard combinatorial optimization problem in the context of graph theory. The importance of studying VSP lies in its close relation with other problems. Thus, VSP has important practical applications in the contexts of very large scale integration design, computer language compiler design, natural language processing, order processing of manufactured products and bioinformatics. Up to our knowledge, there are only two trajectory-based metaheuristic algorithms for VSP documented in the literature. The main contribution of this chapter is that we extend the available heuristics to solve VSP by proposing a genetic algorithm (GA). It is of particular interest to study the impact of four different crossover operators in the algorithm performance. The experimental results showed that the order-based crossover is the best. Moreover, the best GA variant was compared with the best algorithm for VSP: GVNS. The results of this comparison showed that GVNS outperforms our best GA variant by approximately 1.54 times in solution quality.

INTRODUCTION

The vertex separation problem (VSP) is an NP-hard combinatorial optimization problem (Lengauer, 1981) that asks for a linear ordering of the vertices of an input graph that minimizes the maximum number of vertex separators at each position of the ordering (Díaz, Petit, & Serna, 2002). VSP has important practical applications since it is strongly related to other important problems in a variety of contexts such as VLSI design (Leiserson, 1980; Linhares & Yanasse, 2002), computer language compiler design (Bodlaender, Gustedt, & Telle, 1998), natural language processing (Kornai & Tuza, 1992), order

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processing of manufactured products (Lopes & de Carvalho, 2010) and bioinformatics (Luque & Alba, 2005). Perhaps, one of the most important applications of VSP is the optimization of the layout area required to assemble a set of logical gates on an electronic circuit. Specifically, this application requires to assign a set of circuit nodes (gates) in an optimal sequence such that the number of tracks needed to cover the interconnection of the gates is minimized (De Oliveira & Lorena, 2002). In order to illustrate this application, consider the example depicted in Figure 1.

In this example there are nine gates and seven nets. The nets represent the interconnection of the gates. The gate numbers are presented at the top of each figure. In Figure 1a is presented a configuration (ordering) of the gates such that the number of tracks required is seven. In other words, each net occupies one track in the circuit. Conversely, Figure 1b presents another configuration in which only five tracks are needed to connect the circuit completely. In this configuration two nets can share the same track. More precisely, the nets $\{4,6,9\}$ and $\{1,2,5,8\}$ (highlighted in red) occupy the second track and the nets $\{6,9\}$ and $\{5,7,8\}$ (highlighted in blue) share the fifth track. Notice that this example exhibits the importance of looking for a linear ordering of the gates such that the maximum number of tracks is minimized, and hence, the layout area is optimized.

The main contribution of this chapter is the extension of the available heuristics to solve VSP by proposing a genetic algorithm. This is the first population-based metaheuristic algorithm to solve stochastically VSP. It is also proposed a crossover operator based on the path relinking methodology. Three different crossover operators from the literature are compared with our crossover proposed. In order to assess the performance of our algorithm proposed, three computational experiments were conducted. The objective of the first two experiments is to evaluate the impact of each crossover operator. In both experiments, our crossover operator was ranked number two while the well-known order-based crossover was the best one. In addition, our best genetic algorithm variant, the one with the order-based crossover, was compared to the best algorithm for VSP available in the literature, GVNS. The results clearly

Figure 1. a) One possible ordering of the gates that requires seven tracks to allocate all the nets. b) Another possible ordering of the gates, this ordering only requires five tracks (optimal ordering). The gate numbers are at the top of the figures. This example was taken from (De Oliveira & Lorena, 2002)