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Electronic Notes in DISCRETE MATHEMATICS

Electronic Notes in Discrete Mathematics 63 (2017) 381–388 www.elsevier.com/locate/endm

Minimizing Profile of Graphs Using a Hybrid Simulating Annealing Algorithm

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Abstract

The profile minimization problem is a graph layout problem that consists of finding a linear arrangement (labeling) of vertices of a graph such that the sum of profiles of all vertices is minimum. The profile of a vertex can be defined as the difference of the position of its left most neighbor and the position of that vertex in the linear arrangement. It is an NP-complete problem with applications in the areas where the reordering of rows and columns of a sparse matrix is required in order to reduce the storage space. In this work, we propose a hybrid simulated annealing algorithm with the aim of profile reduction of a given graph by incorporating spectral sequencing for generating the initial solution. Experiments conducted on some benchmark graphs show that our algorithm outperforms the best existing algorithm in some cases and is comparable for rest of the instances. It also attains the optimal values for some classes of graphs with known optimal results.

Keywords: spectral sequencing, profile minimization, simulated annealing, sparse matrices

https://doi.org/10.1016/j.endm.2017.11.035

1 Introduction

The Profile Minimization Problem (PMP) was proposed as a way to reduce the amount of storage of sparse matrices [3]. In the area of numerical analysis, it is desirable for many engineering applications to reorder the rows and columns of very large sparse symmetric matrices in such a way that their non-zero entries lie as close as possible to the diagonal leading to reduction of storage space and eventually helping improve the performance of several common operations [8]. Specifically, the profile of a symmetric matrix M of order n is $\sum_{i\in[n]}(i - p_i)$, where p_i is the index of the first non-zero entry in row i. The relation between profile of a symmetric matrix and the profile of a graph can be seen in [3].

In this paper, a Hybrid Simulated Annealing Algorithm for Profile Reduction (HSAPR), for the ordering of sparse symmetric matrices has been proposed which encompasses the features of spectral sequencing and simulated annealing in it. Experimental tests conducted on different classes of standard graphs, confirm that the proposed algorithm yields ordering that gives better quality results as compared to the existing approaches. The basic idea of HSAPR consists of building a globally good layout using spectral sequencing and improving it locally through simulated annealing. It is designed in such a way that it improves the existing simulated annealing technique for PMP [5] by using a better initial solution, using a large neighborhood than generating the neighbors by swap of two vertices only and by an efficient profile computation described in section 3.

Pioneering work for minimizing profile was given by Cuthill and Mckee (CM) [2] which was based on exploiting level structure of a graph. For a recent survey on PMP, one may refer to [1]. Recent work for PMP includes a scatter search metaheuristic that exploits the network structure of the problem [7]. They have reported their results comparing them with the best state-of-art approaches.

In section 2, a formal definition of the profile minimization problem is given. Section 3 is dedicated to the proposed algorithm. Results together with analysis of experiments are discussed in section 4. Finally, conclusion and scope for future work is presented in section 5.

[1] Thanks to UGC for RGNF fellowship [RGNF-2014-15-SC-UTT-74975]
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