On Quality Performance of Heuristic and Evolutionary Algorithms for Biobjective Minimum Spanning Trees

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ABSTRACT

In this paper, we consider a biobjective minimum spanning tree problem (MOST) and minimize two objectives - tree cost and diameter - in terms of Pareto-optimality. We assess the quality of obtained MOEA solutions in comparison to well-known diameter-constrained minimum spanning tree (dc-MST) algorithms and further improve MOEA solutions using problem-specific knowledge.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods and Search—*Heuristic Methods*; G.1.6 [**Optimization**]: Stochastic programming.

General Terms

Algorithm, Design, Experimentation.

Keywords

Combinatorial optimization, multiobjective optimization, genetic algorithm, heuristics, spanning tree.

1. WORK SUMMARY

As the dc-MST problem is NP-hard for all values of k; $4 \leq k \leq (n-2)$, where k and n are diameter and number of nodes in the tree respectively, many heuristics/metaheuristics have been proposed to solve the problem. For example, Deo and Abdalla [1] proposed two heuristics One-Time Tree Construction (OTTC) and Iterative Refinement (IR), research group of Raidl et al. [2, 3] proposed solutions using a Randomized Greedy Heuristic (RGH), genetic algorithms (GA), and others.

These studies considered a single objective, single constraint problem and yielded a single optimal solution for particular *value* of a diameter constraint. It made it impossible to assess the quality of solutions and performance of the algorithm over entire range of the Pareto-front. Thus, the claims are localized and cannot be generalized for the complete extent of the solution space. We argue that it must be considered as a multiobjective optimization problem so that the performance of the algorithm and quality of solutions may be assessed over entire range.

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GECCO'07, July 7–11, 2007, London, England, United Kingdom.
ACM 978-1-59593-697-4/07/0007.

In this work, we adapted OTTC, IR and RGH to obtain a (near-) optiaml Pareto-front instead of solving for a specific diameter. We solved the problem using MOEA with edge-set [3] and level-encoding [2] schemes. OTTC, IR and MOEA with edge-set obtained solutions in the whole range of Pareto-front but the solutions of OTTC and IR were comparatively poorer. RGH and MOEA with level encoding obtained solutions which were comparatively better but limited in a small range of Pareto-front. None of the approaches including MOEA yielded good solutions along the whole Pareto-front. We considered a reference set consisting of the best solutions obtained by all the methods and assessed the solutions quantitatively. The metrics values were quite impressive and indicating good quality.

Further, we analyzed the search space and not only defined the range but also obtained both the extreme solutions of *true* Pareto-front. We defined a local search heuristic too based on arc-exchange; it searches the neighborhoods of a solution for improvement. We incorporated extreme solution in the initial population along with other random generated solutions and local search heuristic in MOEA. Now, the MOEAs obtained comparatively bettter solutions in whole range of the Pareto-front; MOEA with level encoding solutions were comparatively better than edge-set. We quantitatively assessed the newly obtained solutions too using a reference set obtained in a similar way. Surprisingly, the metrics values were very similar to the previous ones for MOEAs though the solutions were much superior.

We obtained good quality solutions, in comparison to well-known heuristics, by hybridizing MOEAs with problem specific knowledge and found that it is difficult to get quality solutions for *hard, unknown* problems and it is more difficult to assess the quality of solutions in absence of any *known* reference set as metrics may be misleading.

2. REFERENCES

[1] N. Deo and A. Abdalla. Computing a diameter constrained minimum spanning tree in parallel. In *CIAC 2000*, volume 1767 of *LNCS*, pages 17–31, 2000.

[2] M. Gruber, J. V. Hemert, and G. R. Raidl. Neighbourhood searches for the bounded diameter minimum spanning tree problem embedded in a VNS, EA and ACO. In *GECCO 2006*, pages 1187–1194, 2006.

[3] G. R. Raidl and B. A. Julstrom. Greedy heuristics and an evolutionary algorithm for the bounded diameter minimum spanning tree problem. In *SAC 2003*, pages 747–752, 2003.