A prediction-based heuristic for the Minimum Branch Vertices Spanning Tree Problem

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1 Introduction

The MBVST problem, introduced in [3], is motivated by the design of optical networks. The optical Broadcast communication in based on spanning trees. If the degree of an optical node is strictly greater than two, then the light signal must be split by a sophisticated switch. As the number of used switches implies an increment of the optical network cost, a minimization of this number is often required. Considering a connected graph G representing the optical network, the MBVST problem aims to find a spanning tree of G with a minimum number of branch vertices. This problem is known to be NP-hard, therefore different heuristic algorithms were proposed [5, 6]. In this paper, we introduce an heuristic algorithm based on the edge prediction to obtain an approximated solution which is sightly better then the best known method proposed in [4].

2 A prediction based heuristic

ILP formulation There are different Integer Linear Programming ways of modelize the problem. We decided to use the flow-based formulation described in [2].

Proposed heuristic Our heuristic is a three-stage heuristic conformed for an initial preprocessing, an edge prediction phase and a final postprocessing phase.
The basic structure of the edge prediction phase consists in predicting the probability of each edge to belong to the optimal spanning tree. Then, the one with highest probability that do not create a cycle if it is added to the already built forest is included in the solution. This process will be repeated until all nodes are connected, obtaining a spanning tree. We highlight that some features, if they not change when adding new edges to the forest, can be reused from the first feature gathering to reduce the computational cost of the heuristic. The prediction part of heuristic aims to estimate

$$\mathcal{P}(X_{e,T}|I(e), I(u), I(v), I(T)), \tag{1}$$

in order to forecast if an edge is on the optimal spanning tree by knowing information about the edge, the nodes that it connects and the already built forest that is part of the spanning tree. In order to increase the accuracy of our predictive model and heuristic, we consider new estimations for each new edge that we want to add. This allows us to include in the predictions features that might change like the number of edges incidents to a node that were already included in the spanning tree.

Model selection To build our predictive model for the equation (1), we use the xgboost algorithm over the obtained data due to its good properties like a high accuracy with tabular data and its speed. Another property that lead us to choose this algorithm is its facility to measure the importance of each variable. This feature importance could be useful to indicate the important features to take into account in future research on processing or to build new heuristics.

Computational results To evaluate our heuristic accuracy, we used the large instances from [1]. These graphs have from 600 to 1000 nodes and for each number of nodes five different densities are considered. Also, we compare them with the [4] heuristic, which is, as far as we know, the one giving better results. For this heuristic, we define only one start. Otherwise, it requires more time than our heuristic.

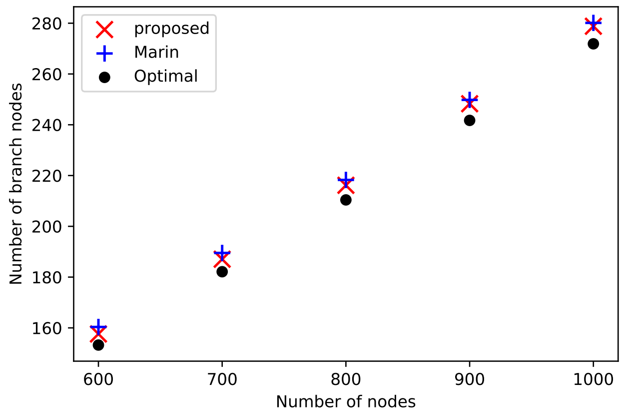

FIG. 1. Comparison of the heuristics and the optimal solution depending on the number of nodes.

From the Figure 1, we can observe that our proposed heuristic returns a spanning tree of with sightly less branch nodes than Marin's heuristic.

3 Conclusion

We proposed a first prediction-based heuristic for the Minimum Branch vertices spanning tree problem. This heuristic gives slightly better results than the best heuristic known in the literature [4]. This rising first use of the prediction to solve the MBVST problem pushes to try to improve the accuracy of the edge forecasting by selecting a more significant features.

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