Optimal Decision Trees for the Algorithm Selection Problem

A Dynamic Programming Approach

Author
Giulio Segalini*

Supervisors
Dr. Emir Demirović
Jacobus G.M. van der Linden

Contacts
*g.segalini@student.tudelft.nl

01 Algorithm Selection Problem

Can we choose the best-performing algorithm for a problem instance without running it?

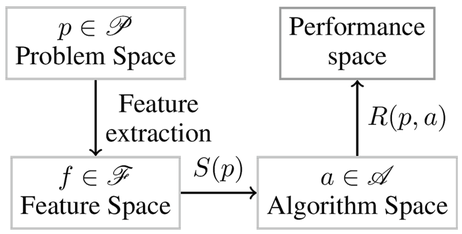

Figure 1:
Summary of the Algorithm Selection Problem

02 Objective

Can we increase scalability in building Optimal Decision Trees to solve the Algorithm Selection Problem using Dynamic Programming [2,3]?

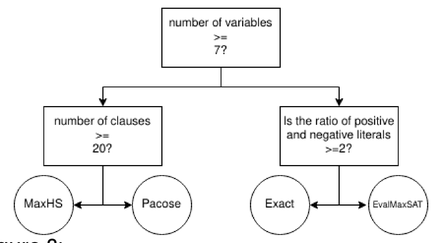

Figure 2:
Small scale example of a possible interpretable tree

03 Methodology

- Define the task that can be used in STreeD[3].
- Implement the task
- Implement regularization to reduce overfitting
- Compare with state-of-the-art[4] on scalability
- Analyse out-of-sample accuracy
- Check different binarization strategies

04 Plots

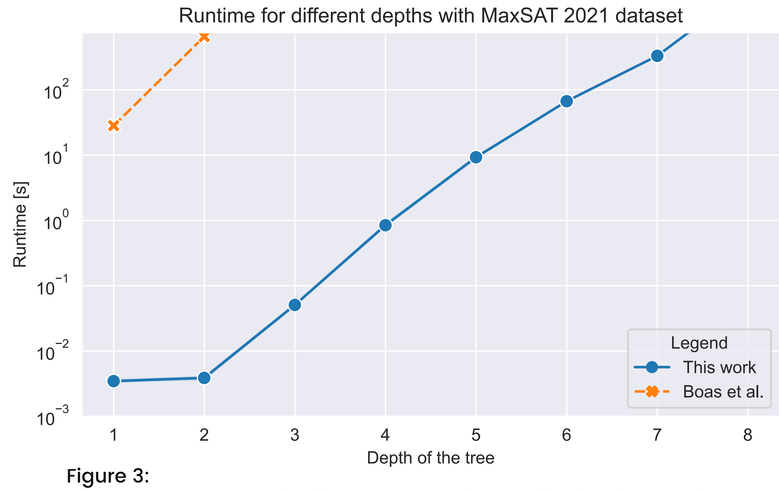

Figure 3:
Runtime comparison for the two competing methods using MaxSAT 2021 dataset

The Dynamic Programming approach **outperforms** the Mixed-Integer-Programming model by a factor of around **100000x**, while optimizing the **same** metric and so obtaining the **same** tree.

05 Results

- The method performs orders of magnitude better than current state-of-the-art
- There is potential for more runtime improvements using bounds-based pruning.
- The model performs well on the tested datasets, but more experiments should be run.
- The model is interpretable and can give us new insights into the nature of NP-Hard problems.

06 Conclusion & Future Work

- A tree can be trained in short times
- Accuracy is comparable to state-of-the-art
- More datasets with larger sizes should be used to analyze out-of-sample performance more accurately
- Bounds-based pruning is present but can be further improved

Related Literature

[1] John R Rice. The algorithm selection problem. In Advances in computers, volume 15, pages 65–118. Elsevier, 1976
[2] Emir Demirovi̇c, Anna Lukina, Emmanuel Hebrard, Jeffrey Chan, James Bailey, Christopher Leckie, Kotagiri Ramamohanarao, and Peter J Stuckey. Murtree: Optimal decision trees via dynamic programming and search. The Journal of Machine Learning Research, 23(1):1169–1215, 2022.
[3] Jacobus GM van der Linden, Mathijs M de Weerdt, and Emir Demirovi̇c. Optimal decision trees for separable objectives: Pushing the limits of dynamic programming. arXiv e-prints, pages arXiv–2305, 2023.
[4] Matheus Guedes Vilas Boas, Haroldo Gambini Santos, Luiz Henrique de Campos Merschmann, and Greet Vanden Berghe. Optimal decision trees for the algorithm selection problem: integer programming based approaches. International Transactions in Operational Research, 28(5):2759–2781, 2021.