

Surgery planning using branch-and-price algorithm accelerated using machine learning

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Motivation

With operating rooms (OR) accounting for over 40 % of a hospital's total expenses, the status quo of manual surgery planning using pen and paper is no longer sustainable. Furthermore, the real-life unpredictability of healthcare requires the creation of systems that can quickly adapt to sudden situations such as urgent surgeries.

Optimization techniques hold the promise to revolutionize this process. The branch-and-price algorithm is one of such techniques. However, its complexity, especially for longer time horizons, is still a bottleneck and demands hours of computation. Luckily, there is a huge unexplored potential to enhance this algorithm with machine learning (ML), exploiting the hidden patterns of the underlying problem.

Our goal is to develop an optimization algorithm that efficiently solves the problem of surgery planning to optimality in a time-efficient manner utilizing machine learning.

Results

To evaluate the effectiveness of the algorithm, we constructed a synthetic data generator that accurately reflects real-world scenarios. To obtain credible parameters, we did a **comprehensive data survey of real plans used in the University Hospital of Hradec Kralove.**

The experiments show that the developed algorithm is able to obtain optimal solutions in a manner of minutes/hours. Additionally, the ML-boosted method significantly outperforms the baseline method. We achieved a **reduction of up to 48 % in the number of solved pricing problems and up to 17 % in the computation time.**

Contributions

- * Under review publication in European Journal of Operational Research.
- * Research made in cooperation with Ghent university, Czech institute of informatics, robotics and cybernetics, and University Hospital of Hradec Kralove.
- * Novel formulation of the complex problem of surgery scheduling leading to more optimal schedules in a shorter time compared to manual scheduling.
- * Unique application of ML to the field of operational research, where it was not utilized in a similar manner before.

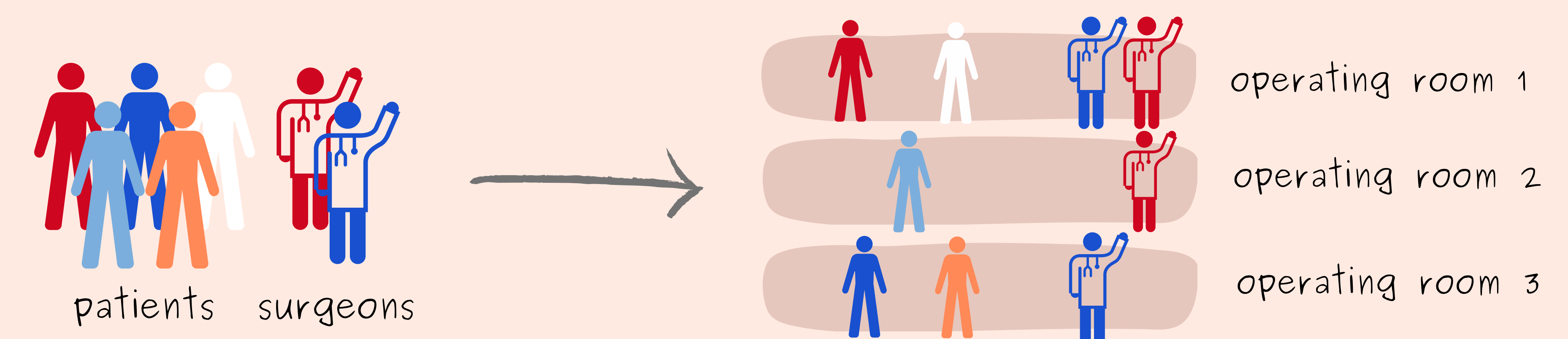
Methodology

Given: surgeons, patients, operating rooms, planning horizon

Do:

1. **assigning phase** — assign patients to available ORs in a given planning horizon considering the availability of surgeons and patients,
2. **sequencing phase** — given the sets of patients assigned to one OR, determine the optimal order in which surgeries should be performed.

We formulate this problem as an integer linear program. However, it contains a massive number of variables and constraints. Therefore, we decompose it using Dantzig-Wolfe decomposition and apply the branch-and-price algorithm.



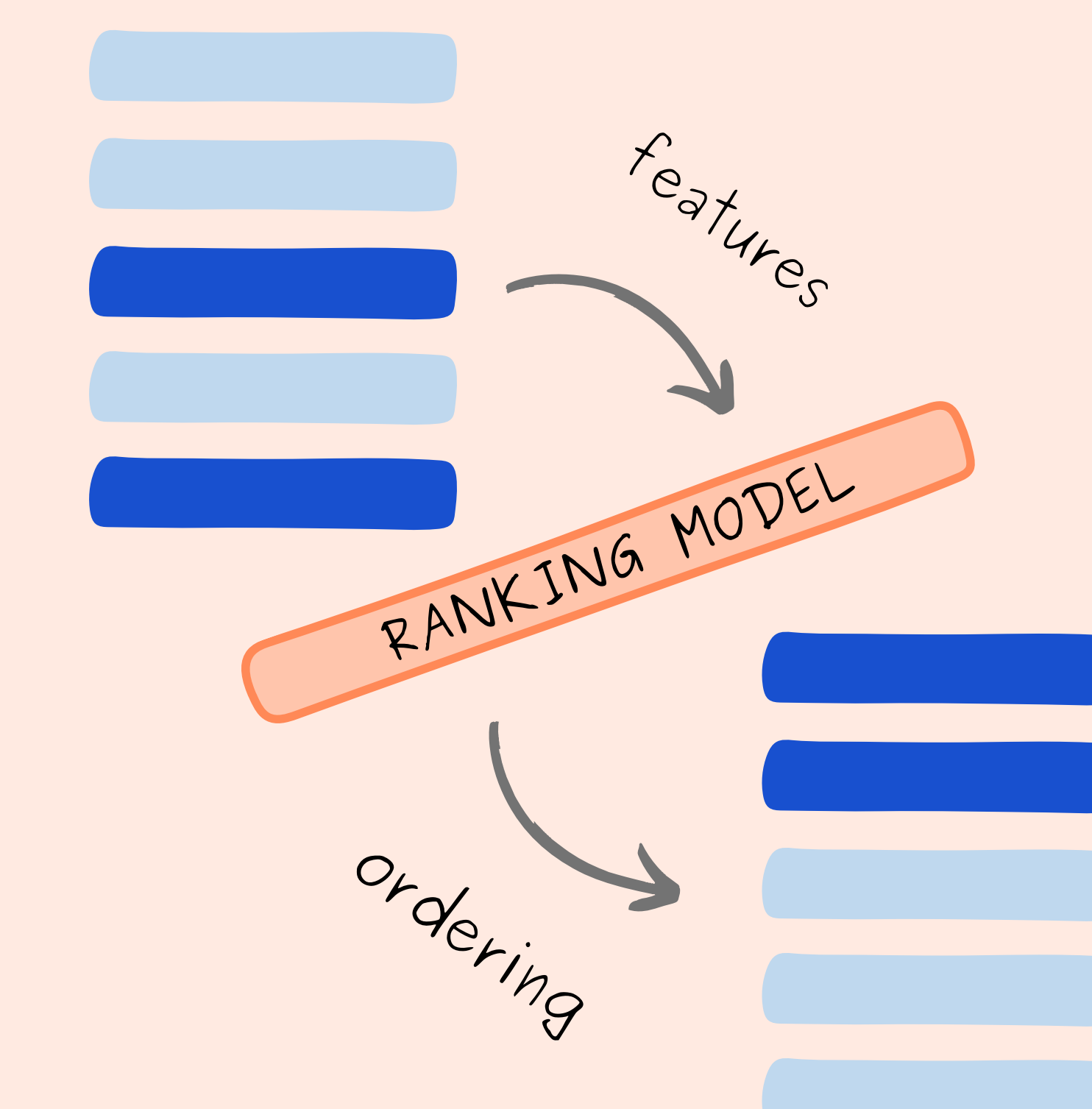
Branch-and-price

Main idea: instead of handling all variables at once, leave a set of them out and generate potentially beneficial ones on the fly by iteratively repeating two stages:

1. **master problem** — combine available columns together,
2. **pricing problem** — generate a new column that improves the current solution of the master problem.

The process is repeated as long as a new column is found.

Machine learning



Observation: There is one pricing problem for every OR, and each pricing problem may or may not generate a new column → we do not know in advance which pricing problem will do → pricing problems are solved until a new column is not found → many pricing problems are solved in every iteration.

Solution: use a ML-based ranking model to reduce the number of solved pricing problems by advising the order for the search so that a new column is found as early as possible.