Ph.D. in Information Technology
Thesis Defense

May 29th, 2025
At 10:30 a.m.
Room Castigliano – Building 5

Davide CROCI– XXXVI Cycle

ADVANCED OPTIMIZATION ALGORITHMS FOR LAST-MILE LOGISTICS
Supervisor: Prof. Ola Jabali

Abstract:

This thesis presents a set of innovative optimization algorithms tailored to address complex and large-scale problems in modern last-mile logistics. Our contributions advance the theoretical understanding of these problems and provide practical insights directly applicable to real-world settings. The thesis is structured around three main methodological chapters, each corresponding to a tackled problem. In Chapter 3, we introduce the Balanced p-Median Problem (BpMP), a bi-objective variant of the p-median problem where p facilities must be located to serve a set of n customers with unitary demand. The considered objectives are minimizing the average traveled distance between customers and facilities and minimizing the mean absolute deviation of the number of customers assigned to each median. We formulate the BpMP as a bi-objective mixed-integer linear program, and use a weighted sum method to generate a representative set of Pareto optimal solutions. Considering the single-objective subproblem solved by the weighted sum method, we develop a primal-dual algorithm that handles large-scale instances by combining a Lagrangian relaxation heuristic within a variable neighborhood search metaheuristic. We demonstrate the effectiveness of the proposed formulation and algorithm on test instances from the literature, as well as on a series of large instances derived from an industrial application of districting for last-mile delivery. In Chapter 4, we study the Distributor's Pallet Loading Problem (DPLP), where a set of cuboid-shaped items is packed in identical pallets, satisfying several practical requirements. In particular, each item may be arranged in multiple orientations, must maintain static stability, and may withstand a limited weight. Furthermore, the combined weight of the items in each pallet must not exceed its total weight limit. We consider first minimizing the number of used pallets, and second maximizing their average pack density. We develop a beam search algorithm for the DPLP called Tetris Beam Search (TBS), which is based on a new constructive heuristic for the same problem called Tetris Heuristic (TH). We evaluate TBS on generated test instances from the literature, where it significantly outperforms other competing methods. TBS reduces the average number of open bins by 22% and increases the average pack density by 15%. Notably, these improvements are realized while saving more than 95% in average computational time. Finally, we present results evaluating the proposed algorithm's effectiveness on large-scale real instances obtained from an industrial partner. Lastly, in Chapter 5, we study the family of Three-Dimensional Packing Problems with Sequence Constraints (3DBPPS), where a set of cuboid-shaped items must be packed into bins while ensuring a feasible sequence of operations for their physical loading exists. The sequence must ensure that each item is loaded without colliding with any previously placed items, accounting for the physical constraints of the device performing the packing. We first consider the key subproblem of the Physical Packing Sequence Problem (PPSP), in which the three-dimensional layout of items is given, and the goal is to determine a feasible loading sequence. We propose two MILP models, a Constraint Programming (CP) model, and a heuristic algorithm for PPSP. All proposed methods exploit a tailored precedence multigraph to simplify handling real-world constraints. We apply these methods to multiple PPSP settings such as manual container loading and pallet loading with robotic grippers. We validate the effectiveness and efficiency of our methods by comparing them against a state-of-the-art algorithm on generated sets of instances. Additionally, we demonstrate that standard three-dimensional packing algorithms often fail to produce bins for which a feasible loading sequence exists. To address this limitation, we propose two novel strategies to embed our heuristic for the PPSP into standard 3DBPP algorithms in order to generate bins for which a feasible loading sequence always exists. We integrate our strategies into four state-of-the-art 3DBPP algorithms and benchmark them against a standard strategy from the literature, showing that both achieve superior performance in solving the 3DBPPS.

PhD Committee

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