Comparing approximate and optimal solution algorithms for the Multi-Level Bin Packing problem

1. How applicable is ILP/CPLEX for solving large instances of MLBP?

We create an Integer Linear Programming (ILP) model formulation for the Multi-Level Bin Packing problem (MLBP), and gather results on the solving time. The results are compared to the performance of simple heuristic-based algorithms. The problem is extended with Fragmentation Constraints to assess the impact of the additional complexity.

- Implement heuristic-based algorithms.
- Construct an ILP formulation for MLBP.
- Investigate a potential Network Flow formulation.
- Implement additional Fragmentation Constraints.

2. The research method

Literature Study:
- Multi-Level Bin Packing and Multi-Level variants.
- Heuristics and Approximation Algorithms.

Experimental Setup:
- Performed in the provided C++ Library.
- Using IBM ILOG CPLEX Optimisation Studio.

CPLEX is an optimisation software package for solving Mathematical Programming formulations.

3. Problem Description

MLBP defines a set of items I, each with a size, and a set of bins B^k for each level $1 \leq k \leq m$.[figure 1] Each bin has properties size, capacity, and cost.

Constraints:
- All items must be packed into a bin of level 1.
- Used bins must be packed into a bin of the next level, until the top-level bins are reached.
- A bin must not exceed its maximum capacity.

Objective Function:
- Minimise the total cost of all used bins at all levels while adhering to these constraints.

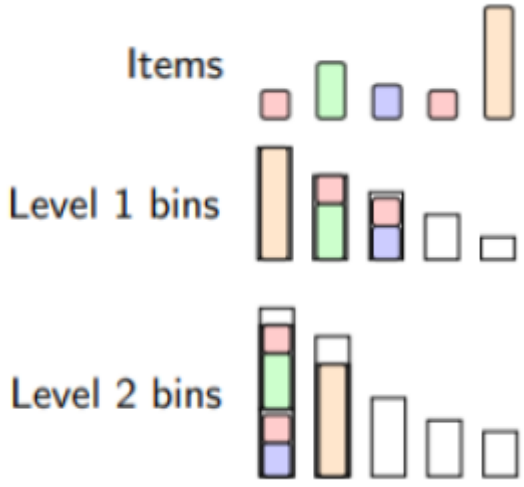

Figure 1: Visualisation of a simple problem instance

4. Important Results

Optimal Solution Algorithms:
- Standard ILP/CPLEX for MLBP can solve medium-sized instances within 3 minutes.
- The Network Flow representation did not improve the average solving time for MLBP.
- The additional complexity of Fragmentation Constraints drastically limits the size of instances that can be solved in time.

Heuristic-Based Algorithms:
- The First Fit and Best Fit heuristics can be applied to MLBP with minimal adjustments.
- Pre-processing improves performance, but the optimality gap is still quite considerable.

Heuristic Algorithms		ILP/CPLEX Algorithms	
Best Fit	37.75%	Standard	46.86 s
First Fit	33.94%	Net. Flow	44.48%

NF is on average 44.48% slower than standard.

5. Conclusions

As the complexity of problems increases, so does the need for specialised algorithms that balance optimality and time cost, depending on the application.

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