YEDITEPE UNIVERSITY
Faculty of Engineering
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Term Project Report

CSE480/591: Optimization with Metaheuristics

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Project Title: 1D Bin Packing Problem

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1. Selected Problem and Motivation

This project focuses on the One-Dimensional Bin Packing Problem (1D-BPP), a well-known NP-hard combinatorial optimization problem. It models many real-world tasks such as minimizing storage space, container loading, or memory-allocation optimization. The objective is to assign a set of items with given sizes into the fewest possible fixed-capacity bins without exceeding any capacity limit.

The 1D Bin Packing Problem is chosen because it has a clear mathematical structure yet allows creative metaheuristic exploration. It is also a classic optimization problem that is easy to visualize and test, which makes it ideal for experimenting with different algorithms and comparing their performance.

From a student perspective, it offers a good balance between implementation difficulty and conceptual clarity. It is complex enough to be interesting, but still manageable to code, analyze, and present meaningful results within the project timeline.

2. Formal Problem Definition

In the 1D Bin Packing Problem, we decide which bin each item will be placed into. Each item must be assigned to exactly one bin, and no bin capacity can be exceeded.

2.1 Decision Variables

Let $x_{ij} = 1$ if item i is placed in bin j, and 0 otherwise. Here:

- $i = 1, 2, \ldots, n$ represents the items,
- $j = 1, 2, \ldots, m$ represents the bins (where m is an upper bound on the number of bins).

Let $y_j = 1$ if bin j is used, and 0 otherwise.

2.2 Objective Function

The main objective is to minimize the total number of bins used:

$$\min \sum_{j=1}^{m} y_j$$

In the metaheuristic implementation, the fitness function is defined as:

$$f = B + \alpha \times capacityviolation$$

where B is the number of bins used and α is a penalty coefficient discouraging infeasible solutions.

2.3 Constraints

1. **Assignment constraint:** Each item must be placed in exactly one bin.

$$\sum_{j=1}^{m} x_{ij} = 1 \quad \forall i$$

2. **Capacity constraint:** The total size of items in a bin cannot exceed its capacity C.

$$\sum_{i=1}^{n} s_i x_{ij} \leq C \quad \forall j$$

3. **Bin usage constraint:** If a bin is not used, no items can be assigned to it.

$$x_{ij} \leq y_j \quad \forall i, j$$

3. Dataset or Benchmark Instances

Benchmark Instances: The Falkenauer dataset (Falkenauer, 1996) from the OR-Library will be used as the primary benchmark. It provides standardized 1D bin packing problem instances with item counts ranging from 60 to 500 and bin capacities of $C = 100$.

Synthetic Instances: Additional synthetic datasets will be generated using uniformly distributed item sizes:

$$s_i \sim U(10, 100)$$

with bin capacity:

$$C = 150$$

The difficulty level of each instance will be controlled using a tightness factor $\alpha \in [0.4, 0.9]$, which determines how full the bins can become.

4. Example Scenario / Problem Instance

To illustrate the structure of the One-Dimensional Bin Packing Problem (1D-BPP) and provide a concrete test case for the metaheuristic algorithms developed in this project, we construct a small but representative problem instance. The instance includes seven items with heterogeneous sizes and a fixed bin capacity, reflecting the typical characteristics of benchmark BPP datasets while remaining simple enough for step-by-step algorithmic analysis.

This instance contains items whose sizes vary between small (12) and relatively large (45), creating natural packing difficulty and multiple feasible arrangement combinations. The bin capacity is set to 60, enabling meaningful exploration–exploitation behavior in local search metaheuristics. Although the instance is small-scale, it captures the essential

Table 1: Example instance for the 1D Bin Packing Problem

Item	**Size**
1	22
2	17
3	45
4	12
5	38
6	27
7	19
Bin Capacity	**60**

constraints of 1D-BPP and will be used throughout the project to demonstrate and compare the performance of algorithms such as Hill Climbing and Tabu Search.

5. References

References

Falkenauer, E. (1996). A hybrid grouping genetic algorithm for bin packing. *Journal of Heuristics*, 2(1):5–30.