3-D Container Packing with Weight and Multi Drop Constraints

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Presentation Overview

Bin Packing and Application

Definition

The bin packing problem is an optimization problem, in which items of different sizes must be packed into a finite number of bins or containers, each of a fixed given capacity, in a way that minimizes the number of bins used

Type	Application
1-DBP	Cutting Stock, Machine Scheduling
2-DBP	Memory Allocation
3-DBP	Logistics, Container Packing

Table: Applications of Bin Packing

Problem Statement

Formulate, build, and test a heuristic to pack objects, each with its own weight, load bearing, and destination constraints, into a container of fixed dimensions with the **aim of maximising the Volume Utilisation of the container**

Dataset

- OR Library's *Container Loading with Weight Restrictions* Dataset used for testing
- Generated in [Bischoff, 2006]
- Each problem contains:
  - Container dims ($587 \times 233 \times 220$ cm^3)
  - Number of Items
  - Items' dims, allowed orientations & load bearing limits
- Delivery Location randomly generated & added

20 ft ISO Container

Figure: A Standard $587 \times 233 \times 220\ \mathrm{cm}^3$ cargo container

Exponential Nature of Problem

- 3-D Bin Packing is **NP-Hard**, no known polynomial time solutions exist
- The max. number of states possible when n items are packed:

$$s(n) = 6^n . \prod_{k=1}^{n} (2k - 1) \tag{1}$$

- Increases rapidly with n, $s(15) \approx 2.91 \times 10^{27}$

Exponential Nature of Problem Contd.

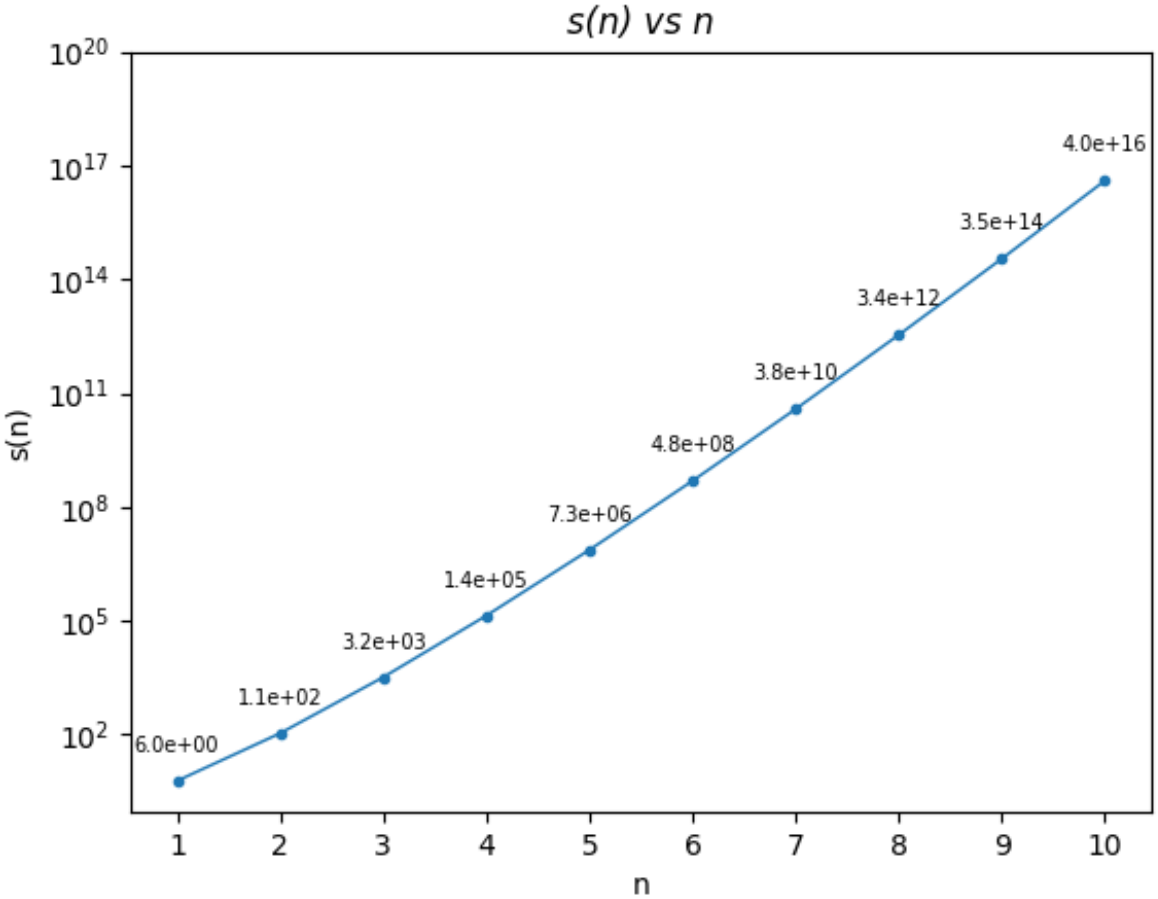

Figure: $s(n)$ vs n

Pruning of Tree

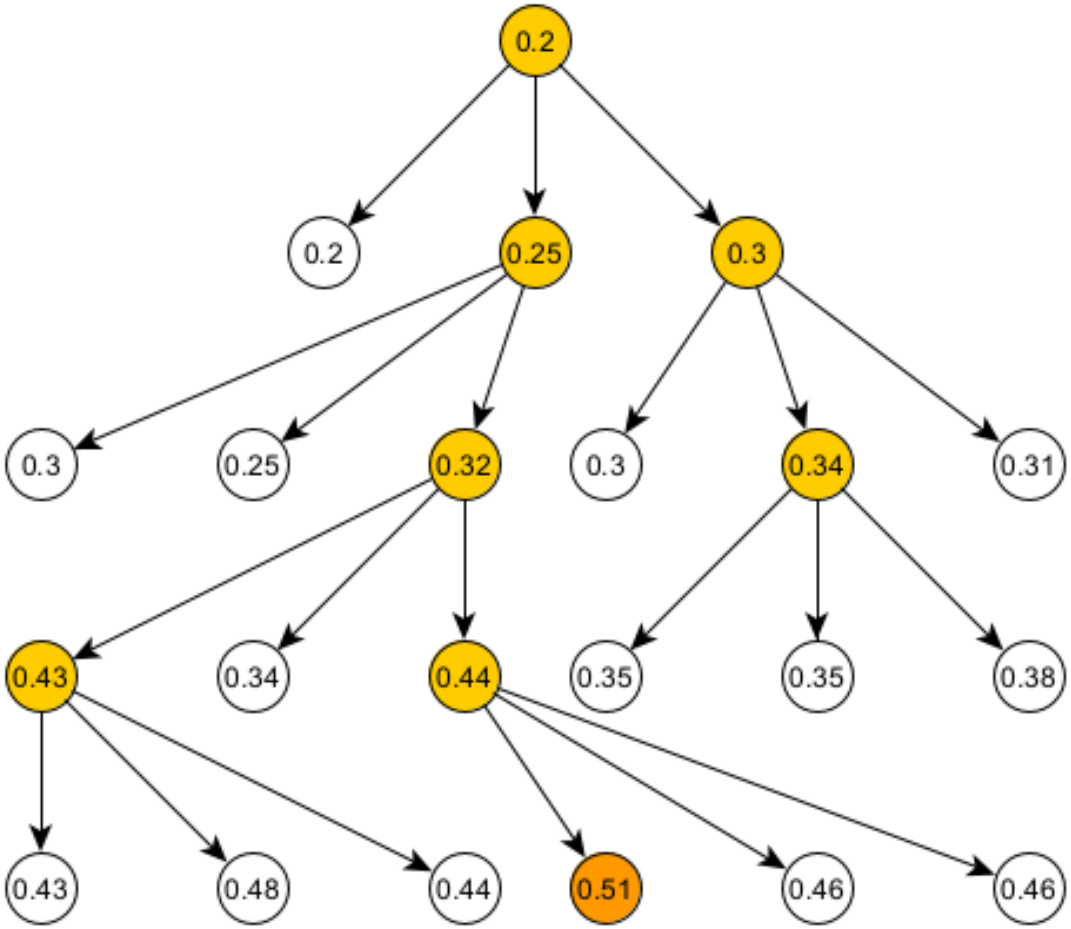

Figure: A tree search with $m = 3$, $t_w = 2$, $n = 4$

Time Complexity

- Tree Search heuristic built on `Python3` and tested
- Pruning based on highest potential VU
- Time Complexity of Algorithm

$$\mathbf{T}_{3D} = \mathcal{O}(t_w \cdot n^3 \cdot d_m^2) \tag{2}$$

- GPU Parallelization applied to obtain improved complexity

$$\mathbf{T}'_{3D} = \mathcal{O}(t_w \cdot n^3) \tag{3}$$

Baselines for Comparison

- [Bischoff and Ratcliff, 1995] generated OR Library's `thpack`
  - tested **without** load and delivery constraints
  - $\mu_{VU} = 0.802$
- [Bischoff, 2006] generated OR Library's `wtpack`
  - tested **without** delivery constraints
  - $\mu_{VU} = 0.854, \sigma_{VU} = 0.043$

Baselines for Comparison Contd.

- [Christensen and Rousøe, 2009] also uses similar Tree Search heuristic
  - tested on `thpack` - **without** load constraints.
  - With 10 delivery locations, $\mu_{VU} = 0.696, \sigma_{VU} = 0.087$
- [Wang and Chen, 2010] uses a hybrid genetic algorithm for 3-DBP
  - tested on `thpack` - **without** load and delivery constraints
  - $\mu_{VU} = 0.811, \sigma_{VU} = 0.038$

Volume Utilisation & Packed Item Ratio

- Tested on OR Library's `wtpack`, generated in [Bischoff, 2006]
- On average, about 60% of the Container was filled, and 65% of the items to be packed were packed

$$\mu_{\text{VU}} = 0.602$$
$$\sigma_{\text{VU}} = 0.127$$
$$\mu_{\text{PIR}} = 0.650$$
$$\sigma_{\text{PIR}} = 0.131$$

Runtime vs n

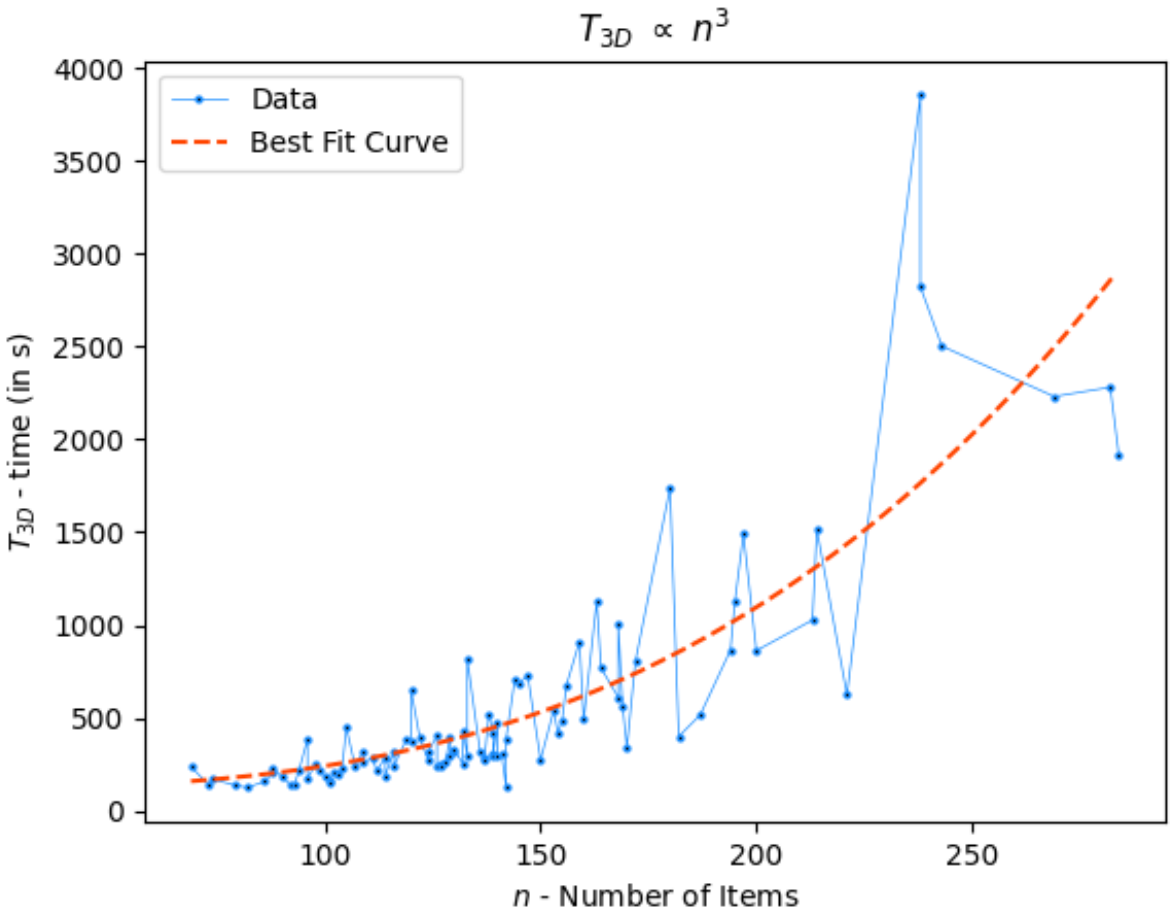

Figure: Time to run ($\mathbf{T}_{3D}$) vs No. of items (n)

Runtime with Parallelisation

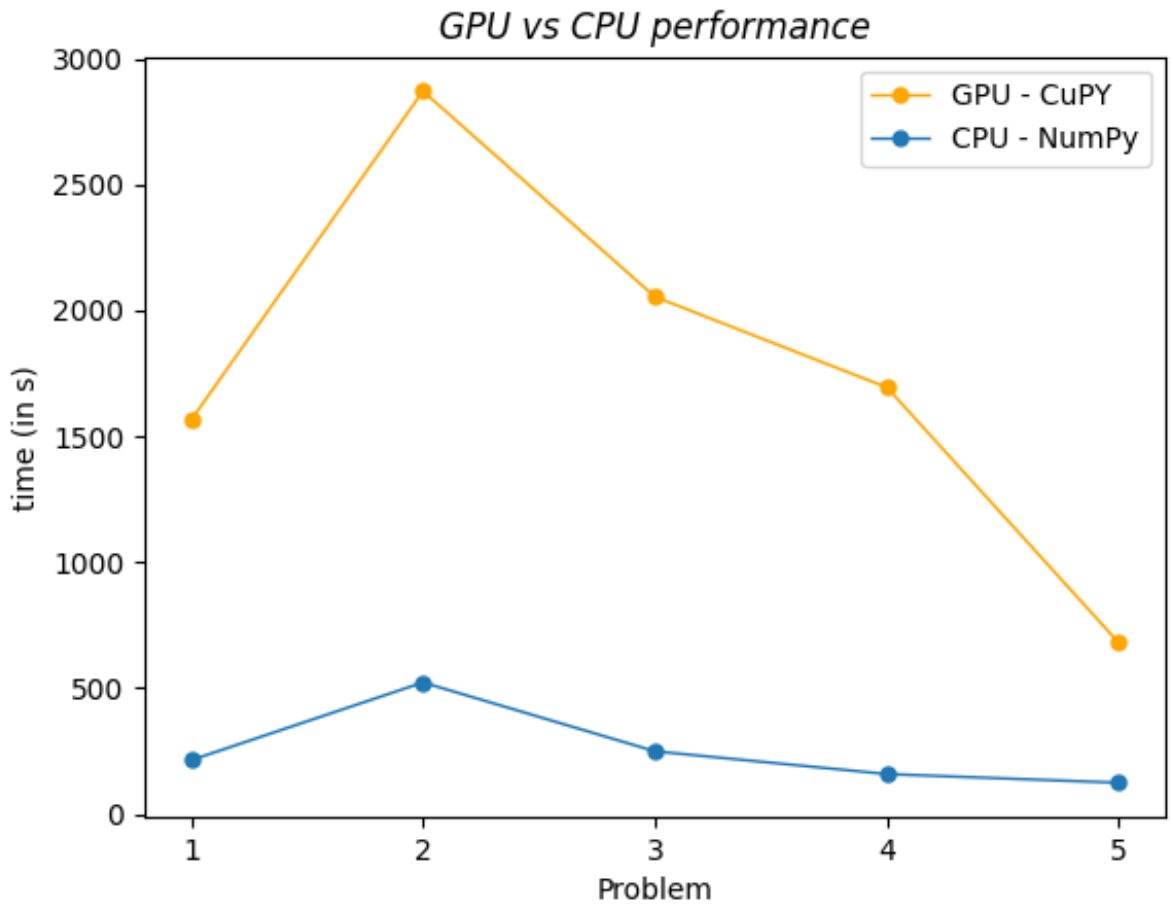

Figure: Time taken to pack the same randomly picked problems from `wtpack1` with and without parallelization

Demo

Demo of the Algorithm working on a demo input

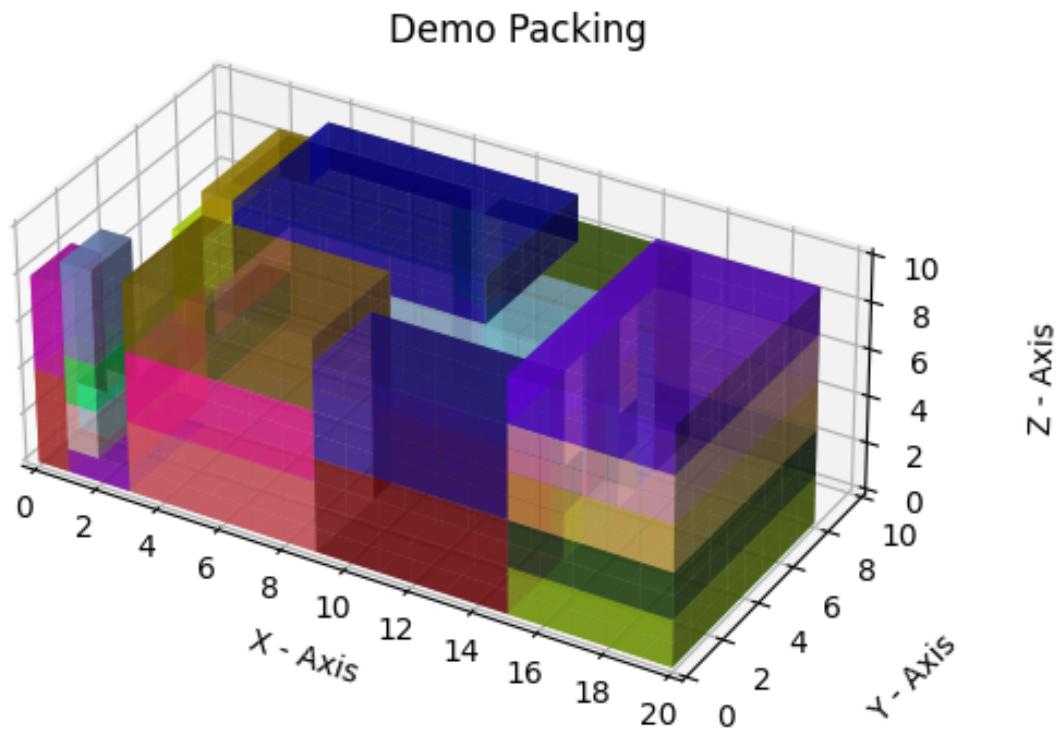

Figure: Packing of Demo Input

References

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Thank You