# Ant Colony Optimisation and Local Search for Bin Packing and Cutting Stock Problems

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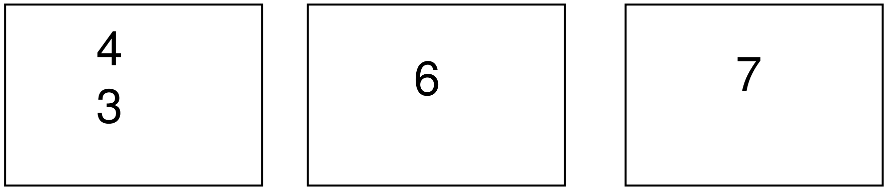
# Bin Packing Problem (BPP)

- Placing things in bins.
- Bins have a maximum volume they can hold.
- We want to minimise the bins that we need to use.
- Real World Applications include:
  - Filling Containers
  - Loading Trucks
  - Creating Backup files in removable media

# BPP Example

We have items with the values 3,4,6,7 and a maximum bin size of 10

Inefficient Solution:




Optimized Solution:

# Cutting Stock Problem (CSP)

- We have a slab/store of resources.
- We also have a list of stock items we need to cut.
- We want to see how we can best cut our stock to limit the amount of wastage we need.
- Real World Applications include:
  - Stock generation (e.g. Paper, Wood, Metal sheets, etc.)

# CSP Example

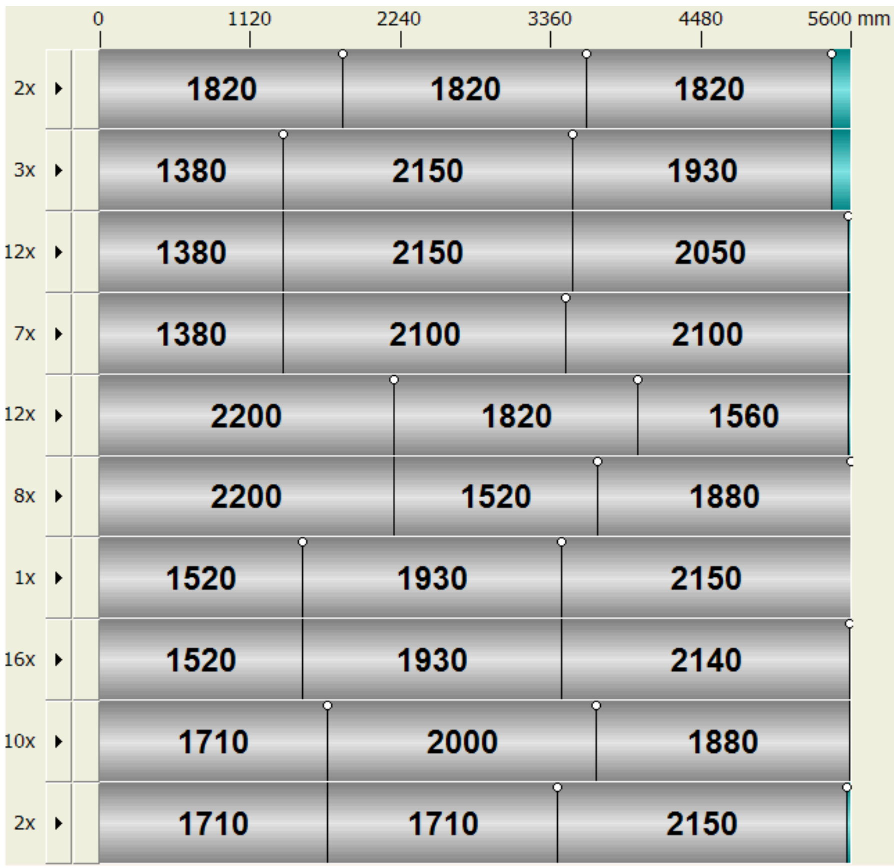
A paper machine can produce an unlimited number of master (jumbo) rolls, each 5600 mm wide. The following items must be cut:

| Width | Rolls |
|---|---|
| 1380 | 22 |
| 1520 | 25 |
| 1560 | 12 |
| 1710 | 14 |
| 1820 | 18 |
| 1880 | 18 |

| Width | Rolls |
|---|---|
| 1930 | 20 |
| 2000 | 10 |
| 2050 | 12 |
| 2100 | 14 |
| 2140 | 16 |
| 2150 | 18 |
| 2200 | 20 |

# CSP Example

There are 308 possible patterns for this small instance.
The optimal answer requires 73 master rolls and has 0.401% waste.



# What are the similarities and differences?

- Both have partitions they need to fit in a certain space (also see knapsack problem).
- The format of the items is different.
- This difference in items is enough to make a significant change in the implementation of most algorithms.

# Traditional Methods used for BPP

- Heuristics
  - First Fit Decreasing
  - Best Fit Decreasing
  - Martello & Toth Reduction Procedure (MTP)
- Evolutionary Approaches
  - Falkenauer's HGGA (Genetic Algorithm)

# Traditional Methods used for CSP

- Linear Programming
  - Inspired by Column Generation Algorithms (developed by Gilmore and Goromy).
- Sequential Heuristic Procedures
  - Most construct one pattern at a time then implement it as many times as they can.
  - This continues until all of the stock is cut.
- Evolutionary Approaches
  - Liangs et Al.'s EP

# Ant Colony Solution

- For these algorithms CSP will be treated in the same manner as BPP.
- The pheromone trail will refer to the favourability of having and object of size x to an object of size y.
- Only the best ant is allowed to place pheromone
- The heuristic they used was a modified FFD algorithm.

# The fitness function used

- The fitness function determines how good the solution was and how much pheromone should be placed.
- Many solutions have a value of the optimal + 1 and so it does us no good to rate these with the same strength.
- $F(s) = \sum_{i=0}^{N} (Fi/C)^{k} \; / \; N$
  - N = Total number of bins
  - C = Max contents of a bin

# Ant Colony Parameters

- Optimal Parameters used:
  - $\beta = 2,5,10$
  - $\rho = 0.95$
  - $\gamma$ = ceiling(500/n)
  - k = 2
  - nants = n

# ACO Results for BPP

Bins indicates how far the solution was above the optimum:

| Prob | HGGA | | MTP | | ACO | |
|---|---|---|---|---|---|---|
| Problem Sets | Bins | Time | Bins | Time | Bins | Time |
| u120 | +2 | 381 | +2 | 370 | +2 | 376 |
| u250 | +3 | 1337 | +12 | 1516 | +12 | 1414 |
| u500 | 0 | 1015 | +44 | 1535 | +42 | 1487 |
| u1000 | 0 | 7059 | +70 | 9393 | +70 | 9272 |

# ACO Results for CSP

| Prob | EP | | | ACO | | |
|---|---|---|---|---|---|---|
| | Avg | Best | Time | Avg | Best | Time |
| 6a | 80.8 | 80 | 347 | 79.0 | 79 | 166 |
| 7a | 69.0 | 68 | 351 | 69.0 | 68 | 351 |
| 8a | 148.1 | 147 | 713 | 146.0 | 145 | 714 |
| 9a | 152.4 | 152 | 1679 | 151.0 | 151 | 1652 |
| 10a | 220.3 | 219 | 4921 | 218.9 | 218 | 4925 |

# Improving on ACO

- It has been shown that ACO algorithms can be improved by Local Search algorithms (LSA).
- The LSA used here destroyed the least n filled bins and tried to distribute these items over the bins remaining.
- Any free items are distributed into new bins.
- This continues until there is no improvement from the solution before the search to the solution after the search.

# HACO Parameters

- Optimal Parameters used:
  - $\beta = 2$
  - $\rho = 0.75$
  - $\gamma = 1$
  - $k = 2$
  - nants = 10
  - bins = 4

# HACO results for BPP

| Prob | HGGA | | MTP | | HACO | |
|---|---|---|---|---|---|---|
| | Bins | Time | Bins | Time | Bins | Time |
| u120 | +2 | 381 | +2 | 370 | 0 | 1 |
| u250 | +3 | 1337 | +12 | 1516 | +2 | 52 |
| u500 | 0 | 1015 | +44 | 1535 | 0 | 50 |
| u1000 | 0 | 7059 | +78 | 9393 | 0 | 147 |
| u2000 | - | - | - | - | 0 | 531 |
| u4000 | - | - | - | - | 0 | 7190 |
| u8000 | - | - | - | - | 0 | 43746 |

# HACO Results for CSP

| Prob | EP | | | HACO | | |
|---|---|---|---|---|---|---|
| | Avg | Best | Time | Avg | Best | Time |
| 6a | 81.8 | 80 | 347 | 79.0 | 79 | 1 |
| 7a | 69.0 | 68 | 351 | 68.0 | 68 | 1 |
| 8a | 148.1 | 147 | 713 | 143.0 | 143 | 5 |
| 9a | 152.4 | 152 | 1679 | 149.0 | 149 | 10 |
| 10a | 220.3 | 219 | 4921 | 215.0 | 215 | 249 |

# Local Search Effect

- Is the Ant Colony adding anything?
- How will the local search algorithm perform on its own.
- We still had the original pheromone matrix entries but no pheromone update occurred.

# Local Search Results for BPP

| Prob | HACO | | No Memory | |
|---|---|---|---|---|
| | bins | time | bins | time |
| u120 | 0 | 1 | 0 | 1 |
| u250 | +2 | 52 | +6 | 166 |
| u500 | 0 | 50 | +5 | 432 |
| u1000 | 0 | 147 | +10 | 1850 |
| u2000 | 0 | 531 | +43 | 19286 |
| u4000 | 0 | 7190 | +118 | 131137 |

# Local Search Results for CSP

| Prob | HACO | | | No Memory | | |
|---|---|---|---|---|---|---|
| | avg | best | time | avg | best | time |
| 6a | 79.0 | 79 | 1 | 79.0 | 79 | 24 |
| 7a | 68.0 | 68 | 1 | 68.0 | 68 | 1 |
| 8a | 143.0 | 143 | 5 | 144.0 | 144 | 1064 |
| 9a | 149.0 | 149 | 10 | 150.0 | 150 | 997 |
| 10a | 215.0 | 215 | 249 | 216.8 | 216 | 1707 |

# Evaluation

- The hybrid ACO algorithm is comparable to the best known heuristic solutions.
- It is also much faster which allows us to implement problems of much bigger size.
- The Ant Colony adds a significant amount of improvement from the local search algorithm alone.