Computational Intelligence - Excercise 3
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1 Non-Trivial ACO steps

In our solution to the Bin Packing Problem using Ant Colony Optimization, we read an article[1], from which we implemented the following features:

1.1 Modeling The Problem

We modeled the graph for the ants as relations between item sizes (items that sit in the same bin).

1.2 Updating the Pheromone Trail

Only the best ant is allowed to place pheromone after each iteration. The amount placed is given by the fitness of the solution built by that ant ($f(s^{best})$). Pheromone is placed for every two item sizes i and j that are in the same bin within the solution of s^{best}. Meaning, $\tau(i,j)$ can be updated more than once. The update of the pheromone can be described in the following formula:

$$\tau(i,j) = \rho \cdot \tau(i,j) + m \cdot f(s^{best}) \tag{1}$$

In this formula, m is the number of times i and j go together in the bins of s^{best}

1.3 Building a Solution

Every ant starts with the set of all items to be placed and an empty bin. It adds the items one by one to this bin, until none of the items left is small enough to fit in. Then the bin is closed, and a new one is started. The probability that an ant k will chose an item of size j as the next item for its current bin b in the partial solution s is given by:

$$p_k(s,b,j) = \begin{cases} \frac{[\tau_b(j)]\cdot[\eta(j)]^\beta}{\sum_{g\in J_k(s,b)}[\tau_b(g)]\cdot[\eta(j)]^\beta} & \text{if } j \in J_k(s,b) \\ 0 & otherwise \end{cases} \tag{2}$$

In this equation, $J_k(s,b)$ is the set of items that qualify for inclusion in the current bin b. They are the items left after partial solution s is formed, and are small enough to fit b. $\eta(i,j)$ is the item size j.

$\tau_b(j)$ is described as:

$$\tau_b(j) = \begin{cases} \frac{\sum_{i\in b}\tau(i,j)}{|b|} & \text{if } b \neq \{\} \\ 1 & otherwise \end{cases} \tag{3}$$

1.4 Fitness Function

Our fitness function:

$$\frac{\sum_{n=1}^{N}(F_i/C)^k}{N} \tag{4}$$

In this equation, N is the number of bins, F_i the total contents of bin i, and C the maximum contents of a bin (in both problems given to us, $C = 150$). k is the parameter that defines how much stress is put on the nominator of the formula (how well packed are the bins) as opposed to the denominator (the total number of bins). From the same article[1], we learned $k = 2$ gave good results.

This function not only determines the quality of a solution based on how many bins it used, but also based on 'how well-packed are the bins'?

2 Results

A table describing the solutions found by our implementation for each of the required dimensions:

N	bins	Iterations	Solution
120	49	77	[[98, 49], [79, 60], [78, 72], [93, 49], [73, 42, 33], [80, 70], [85, 55], [84, 57], [62, 70], [94, 55], [85, 57], [45, 74, 30], [80, 69], [84, 36, 29], [92, 58], [46, 91], [90, 60], [83, 42, 25], [98, 43], [64, 84], [93, 57], [84, 46, 20], [98, 45], [41, 82, 27], [81, 66], [91, 58], [86, 57], [78, 71], [27, 38, 39, 41], [73, 73], [79, 44, 24], [62, 55, 32], [76, 74], [84, 43, 23], [73, 42, 35], [96, 50], [38, 83, 28], [96, 44], [43, 37, 69], [87, 58], [70, 80], [69, 43, 38], [78, 47, 25], [32, 41, 36, 33], [78, 42, 30], [67, 82], [59, 42, 39], [49, 26, 33, 36], [30, 23]]
250	101	82	[[100, 50], [100, 50], [100, 49], [99, 49], [99, 49], [98, 52], [98, 52], [98, 49], [98, 49], [98, 48], [98, 48], [98, 47], [98, 47], [97, 53], [97, 53], [97, 53], [96, 53], [96, 53], [95, 55], [95, 55], [95, 55], [94, 55], [94, 55], [93, 57], [93, 57], [92, 58], [92, 58], [92, 58], [91, 59], [91, 59], [90, 60], [90, 60], [90, 60], [88, 62], [88, 62], [87, 62], [86, 64], [85, 65], [85, 65], [85, 64], [84, 66], [84, 66], [84, 66], [84, 61], [84, 61], [83, 67], [83, 67], [82, 68], [82, 67], [82, 67], [81, 69], [81, 69], [81, 69], [81, 69], [80, 70], [80, 70], [80, 70], [80, 70], [80, 70], [80, 70], [79, 71], [79, 71], [79, 67], [79, 60], [78, 72], [78, 72], [78, 72], [78, 60], [78, 60], [78, 58], [76, 74], [76, 74], [75, 75], [74, 73], [73, 73], [73, 57], [57, 57, 36], [57, 57, 36], [53, 47, 47], [46, 46, 46], [46, 45, 45], [45, 45, 45], [44, 44, 44], [43, 43, 43, 20], [43, 43, 43, 20], [43, 42, 42, 23], [42, 42, 42, 24], [42, 41, 41, 26], [41, 41, 39, 29], [39, 39, 39, 33], [39, 38, 38, 35], [38, 38, 38, 36], [38, 37, 37, 36], [36, 36, 35, 33], [33, 33, 32, 32], [32, 32, 30, 30, 25], [30, 30, 30, 29, 29], [28, 27, 27, 27, 27], [27, 25, 25, 24, 24, 23], [23, 23, 23, 22, 22, 22], [20, 20]]

References

[1] F. Ducatelle, "Ant colony optimization for bin packing and cutting stock problems," *Master of Science, School of Artificial Intelligence, Division of Informatics, University of Edinburgh*, 2001.