Applying Computational Intelligence to Optimisation Problems in a Warehouse Environment. Case Study: The Container Loading Problem

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In a warehouse, the container loading problem poses the challenge of optimally selecting and packing groups of palletized goods into containers while satisfying a number of practical constraints (e.g. keeping the total weight of selected goods within the accepted limits for containers). Computational Intelligence techniques help us find good quality solutions to this problem very quickly; thus leading to faster loading times. In addition, the optimal loading of individual containers results in an overall reduction in labour time and the number of containers required which in turn leads to a reduction in the total cost of hiring labour and containers.

AIM AND GOAL

The aim of this study is to use Computational Intelligence techniques to find near-optimum solutions to the Container Loading Problem while considering very relevant practical constraints. The solutions produced should be practically feasible and the container layouts generated should be desirable and safe to load.

THE PROBLEM IN PRACTICE

Our palletized goods are heavy and require fork-lift trucks for movement, stacking and loading. A loading operation requires multiple trips from the warehouse to the container and even in a perfect scenario still takes a reasonable amount of time to complete. It is therefore of great benefit to cause a reduction in the time spent deciding what goods to load and how to load them.

Figure 1. Palletized goods stored in the warehouse

Figure 2. Palletized goods arranged in a container

Figure 3. Fork-lift trucks are required to move and stack (heavy) palletized goods

Practical constraints considered

- Container weight limit
- Multiple pallet orientations
- Pallet stackability
- Pallet stack stability
- Maximum number of pallets in stack
- Maximum height for pallet stacks
- Complete shipment of certain pallet groups

ALGORITHM DESIGN

We devise a hybrid algorithm as a collaborative combination of algorithms to solve the problem. The hybrid algorithm consists of a *selection* algorithm: a genetic algorithm that handles the selection of goods that maximise the weight capacity of the container; a *stacking* algorithm: a greedy algorithm that stacks goods on top of each other according to specific rules; a *packing* algorithm: a genetic algorithm integrated with a rectangle packing algorithm that attempts to pack stacks completely into a container; a *layout generation* algorithm that generates 2D layouts representing the loaded goods; and an *entropy* algorithm, that calculates derived entropy values for generated layouts and aids in the selection of the best layout.

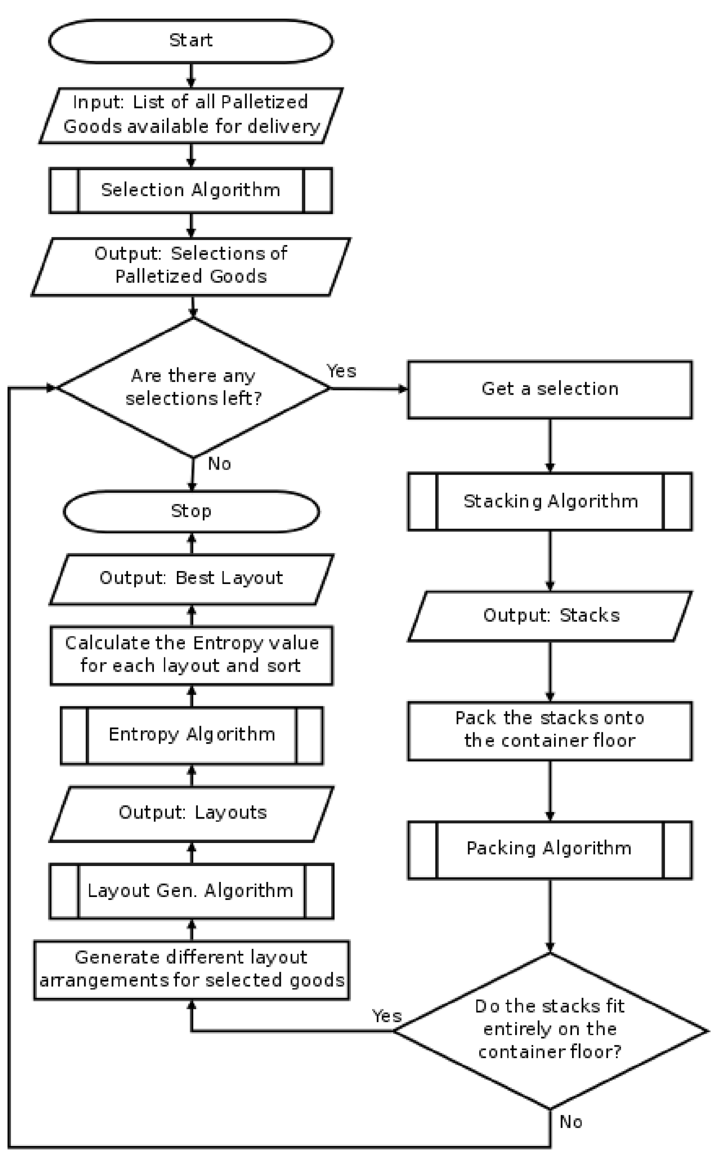

Figure 4. Algorithm Overview

EXPERIMENTS & RESULTS

In our experiments, we run the hybrid algorithm 50 times over 15 problem sets. Figures 5 and 6 show the average-case values for weight utilisation and computation time across the problem sets. *Hybrid algorithm 1* and *Hybrid algorithm 2* are instances of the algorithm that consider all constraints except the stacking constraint, and all constraints respectively.

Generated layouts are rated using calculated entropy values; these values are a measure we derived that rate layouts in terms of their disorderliness. To assess the validity of this measure we show the generated layouts in groups to experienced loaders and have them rate the layouts in terms of their perceived orderliness and desirability to load. We then observe the correlation between the calculated entropy values and the loaders' own perception of orderliness.

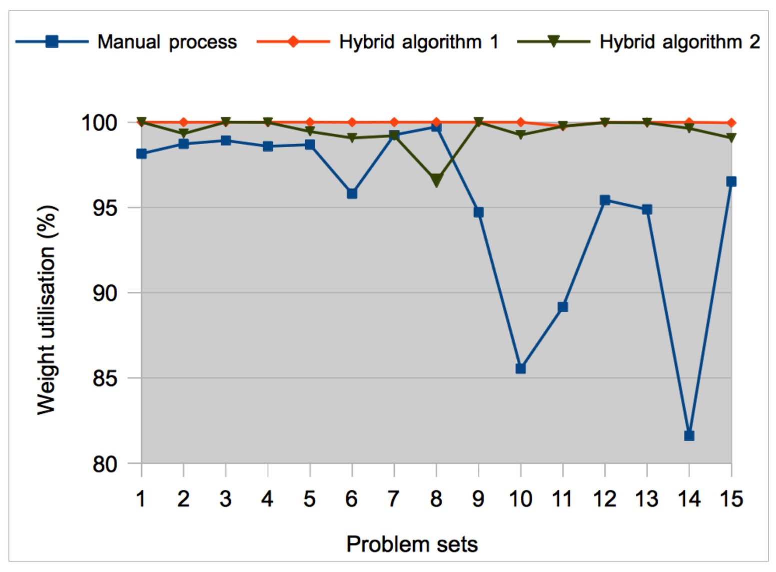

Figure 5. Weight Utilisation Comparison

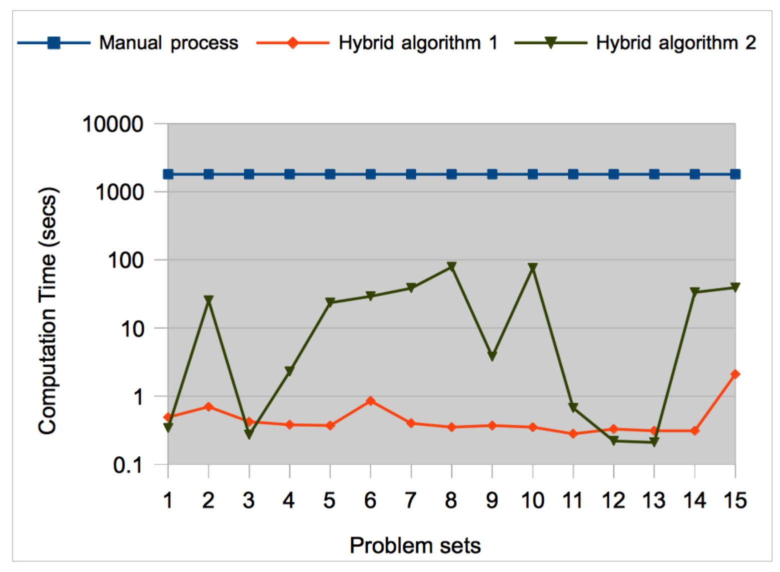

Figure 6. Computation Time Comparison

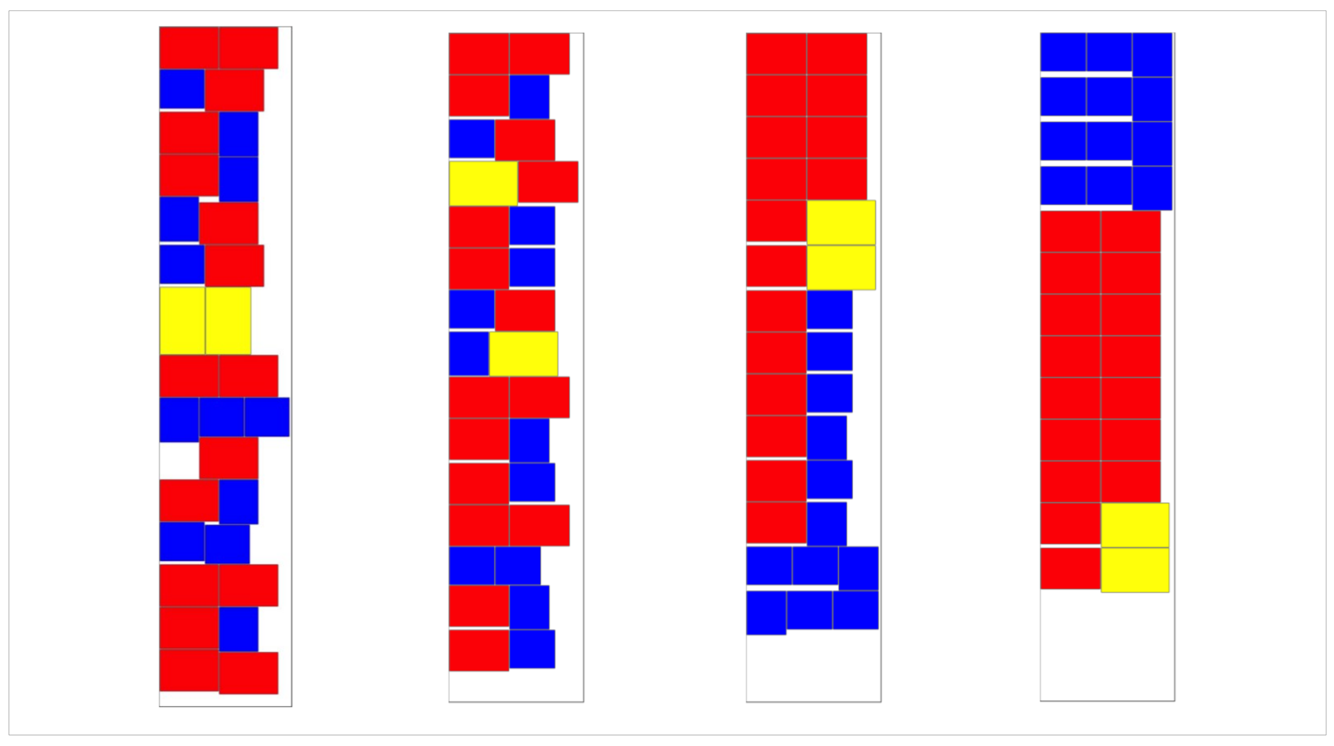

Figure 7. Different generated 2D layouts for the same set of selected goods

Our results show that the hybrid algorithm consistently achieves near-maximum container weight utilisation within a couple of minutes when considering all the practical constraints identified. The tests also show that there is a high correlation between our entropy measure and the loaders' concept of order for the layouts.

CONCLUSION

In this study, we devise a hybrid algorithm using Computational Intelligence techniques to address a complex real-world problem. The devised algorithm is tested using real warehouse data from a manufacturing company and it takes into account a number of practical constraints that are very relevant in the real world. The solutions obtained so far have been found to be practically feasible and are obtained in very reasonable time.

ACKNOWLEDGEMENTS

Funding for this project has been provided by the Logistics Department in NSK Europe Ltd. We recognize the very significant roles played by NSK's United Kingdom Distribution Centre team and their manager, and we gratefully acknowledge with thanks all the support received.

STAR Science & Technology Annual Research Conference 2015

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