

# Application of 2D Packing Algorithms to the Woodwork Industry

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## Abstract

The paper’s objective is to solve the well-known, well-studied problem of 2D Packing applied to the Wood Work industry to reduce waste through a more efficient reintegration of raw materials into the production cycle for this multi-objective strategy, evolutionary and learning processes are explored throughout the problem-solving process.

The Wood Work 4.0 (WW4.0) project aims to develop new approaches to manufacturing furniture, mainly in Small and Medium Enterprises (SMEs). As a sector that modernized by introducing new machines and processes, the management of the internal processes is still at a very archaic stage and impacts the overall operation of the system. Thus, the WW4.0 project aims to develop new approaches that allow the total digitization of the internal processes of the furniture production chain in such a way that integrates them into a global approach.

The 2D packing problem merges the WW4.0 project with the development of optimization algorithms for the scheduling of raw material according to the reference produced at a given moment. With this, it is intended to reduce the waste from cutting wood, be these regular or irregular-shaped cuts. That said, the study offers numerous advantages such as the reuse of raw material, less labor effort at the factory floor level in terms of the search for raw material, such as the positioning of the cut itself, and a possible and subsequent full automation of this area of work.

The problem of 2D Packing is searching for the ideal packing sequence for a set of 2D objects. This problem is considered NP-complex and has a high computational cost. As mentioned above, the objective is to optimize the positioning and use of the raw material to cut using multi-objective strategies and evolutionary and learning processes. This way, the search for papers relevant to the work was carried out.

Zhao et al. (Zhau et al., 2022) [3] present a learning method to solve the 2D packing problem with 2D rectangular objects. The sequence of objects represents the solution, and the layout is built sequentially, piece by piece. Centroid positioning rule techniques are explored with a lower value for the part’s positioning, and then the Q-learning method is applied. Three groups of conditions are defined for the test. The computational results show that the Q-learning approach produces better compactness compared to the stochastic sequence in the layout of the parts.

Gomez and Terashima-Marin (2017) [2] propose three multi-objective evolutionary algorithms to identify sets of hyperheuristics to approximate the Pareto front. Namely, Non-dominated Sorting Genetic Algorithm-II, Strength Pareto Evolutionary Algorithm,

and Generalized Differential Evolution Algorithm. The algorithms were extensively explored in a large set of 2D Packing problems with convex and non-convex irregularly shaped objects under different conditions and configurations. The study presents an analysis where the robustness and flexibility of the strategies outlined are evaluated, obtaining encouraging results compared with a set of simple heuristics usually used in this type of problem.

Fang et al. (2021) [1] propose a strategy based on the Particle Swarm Optimization algorithm where he obtained efficient results with a reduced execution time. Hybrid strategies have been explored with promising results.

As we can see in the research summary, the state-of-the-art is quite advanced when understanding regular shapes but less developed regarding irregular shapes. However, it did not evolve into an algorithm that reuses raw material based on collecting and storing data, which is the study's final objective.

For successful completion of the project, the primary strategy will be the analysis and resolution of each of the topics:

1. Create a matrix representation of the wooden board to be cut.
2. Identify the objects to cut in that matrix and optimize their positioning using optimization tools such as genetic algorithm and particle swarm optimization, among others.
3. Create a database to store all information regarding the leftovers (waste storage represents leftover boards that have already been cut but can be used for some other cuts, reducing waste).
4. Explore multi-objective strategies and measures to assess the robustness and efficiencies of the strategies developed.
5. Optimize the procedure for identifying boards located in the leftovers regarding information like area, dimensions, thickness, material, and direction of the wood veins.
6. Explore the behavior of optimization algorithms in solving 2D packaging problems and incorporate learning strategies to predict parts destined for permanent waste.

Future work includes the performance evaluation of the developed algorithms using actual data.

**Keywords:** Optimization · Combinatorial Optimization · Packing Problems · 2D Packing.

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## References

1. Fang, J., Rao, Y., Liu, P., Zhao, X.: Sequence transfer-based particle swarm optimization algorithm for irregular packing problems. *IEEE Access* **9**, 131223–131235 (2021)

2. Gomez, J.C., Terashima-Marín, H.: Evolutionary hyper-heuristics for tackling bi-objective 2d bin packing problems. *Genet Program Evolvable Mach* **19**, 151–181 (2018). <https://doi.org/10.1007/s10710-017-9301-4>
3. Zhao, X., Rao, Y., Fang, J.: A reinforcement learning algorithm for the 2d rectangular strip packing problem. *J. Phys.: Conf. Ser.* 2181 012002 (2022)