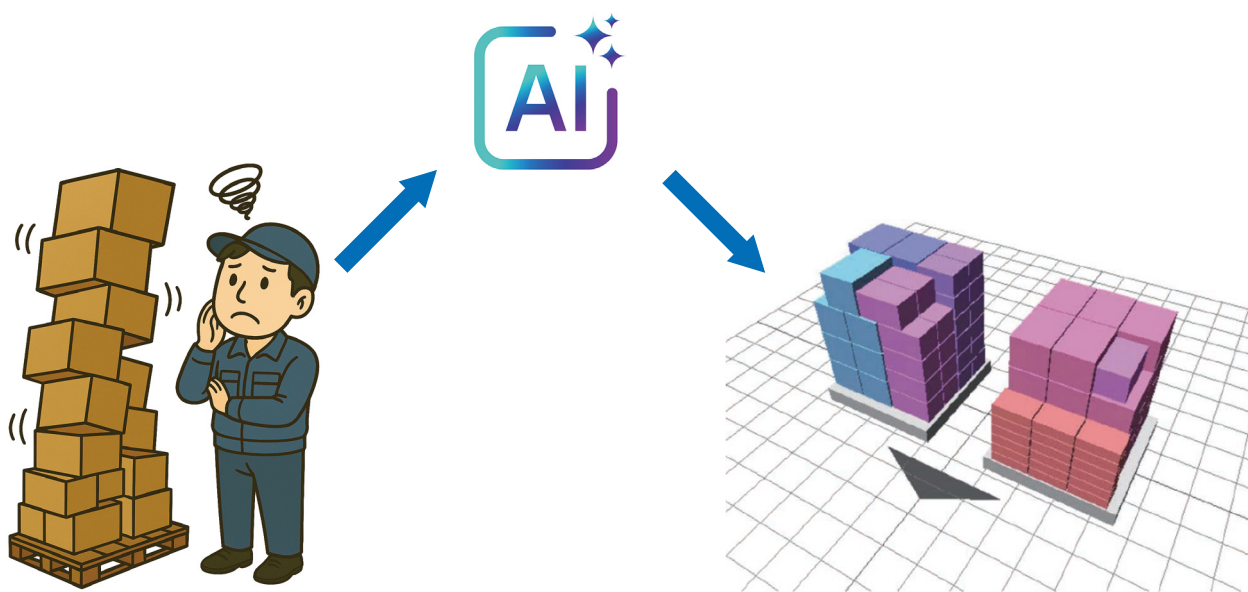


Automated Planning of Mixed-Load Palletizing Using Artificial Intelligence

Automating palletizing operations in logistics warehouses through integration with robots

The IHI Group has developed a palletizing system capable of mixed-loading of multiple types of items as one of its logistics automation solutions. By integrating robots with AI that can instantly generate palletizing plans considering load efficiency, stability, and inspectability, the system achieves full automation of mixed-load palletizing operations that previously relied on the experience of skilled workers.



Example computation of mixed-load palletizing planning algorithm

Addressing labor shortages in the logistics industry

In the logistics industry, worsening labor shortages have created a strong demand for automation and labor-saving solutions. To address this social issue, the IHI Group is promoting logistics automation solutions that integrate AI with robots.

Item loading (palletizing) is one of the most physically demanding tasks in the logistics process. It requires gripping heavy items and working in stooped postures, placing a significant physical burden on the workers. In addition,

“mixed-load,” a method in which multiple types of items are stacked on a single pallet, has been increasing in recent years. This approach requires consideration of multiple factors, including load efficiency, stability (resistance to item shifting), and inspectability. As a result, manual palletizing planning is prone to inconsistency, even under identical loading conditions.

To address these issues, the IHI Group offers a palletizing system capable of mixed loading. In this system, AI takes into account item characteristics such as type, shape, and weight to rapidly compute the optimal placement and loading sequence, while robots execute the operation precisely



Palletizing system

according to the plan. Implementing this system enables both labor-saving solutions and consistent quality in the palletizing process.

Challenges in mixed-load palletizing

One of the key technologies that make up the mixed-load palletizing system is the “mixed-load palletizing planning AI.” This AI generates the placement location and loading sequence of each item based on information about the item to be loaded including shape, quantity, and placement constraints.

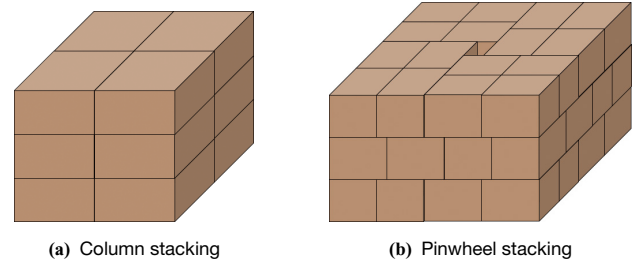
For “single-load” palletizing where only one type of item is placed on a pallet, the optimal loading plan can be pre-computed based on the item and pallet geometries. In contrast, mixed-load involves different item types and quantities for each operation, requiring a plan that accounts for factors such as load efficiency, stability, and inspectability to be generated quickly each time. Furthermore, the planning must also consider the robot’s mechanical structure, geometry, and control precision to determine placement locations and loading sequences that prevent interference, damage, and load shifting.

Mixed-load palletizing planning can be mathematically formulated as a combinatorial optimization problem. However, obtaining the optimal solution within a practically acceptable computation time remains difficult.

Mixed-load palletizing planning algorithm

To realize the mixed-load palletizing system, we independently developed a mixed-load palletizing planning algorithm based on a mathematical optimization method known as “metaheuristics.” Metaheuristics is a method for efficiently finding practical solutions to combinatorial optimization problems that are difficult to solve exactly in a short time. By combining metaheuristics with domain knowledge of the target products and services, a high-performance algorithm can be achieved.

Specifically, rather than determining the placement for each item individually, we adopted a method that groups



(a) Column stacking (b) Pinwheel stacking
Example of item stacking pattern used by the algorithm

multiple items into blocks based on stacking patterns widely used in logistics warehouses, such as column stacking and pinwheel stacking, and determines the placement of each block. This approach improves load efficiency, stability, and inspectability, while simultaneously reducing computation time. In addition, referencing the on-site manual palletizing adjustments often performed by workers, the system automatically makes fine-tuned placement adjustments after an initial plan is generated, including height leveling.

The loading sequence is determined by rigorously considering the robot’s mechanical structure, geometry, control precision, the resulting motion constraints, and potential interference with the items. This provides a mathematical guarantee that palletizing operations can be executed by the robot. In terms of performance, the algorithm achieves computation times of under one second on a standard computer, enabling real-time generation of plans and palletizing operations. In addition, the algorithm includes a mechanism that automatically adjusts internal parameters affecting performance based on the input data. This allows continuous operation without manual parameter tuning, even when the characteristics of items in the warehouse change, for example due to seasonal variations.

Future outlook

This technology is applicable not only to logistics warehouses but also to other fields that require efficient item placement, such as factories and construction sites. In the future, we aim to expand its use into these new domains and leverage our AI-based palletizing planning technology to contribute broadly to society by reducing labor requirements and enhancing safety.