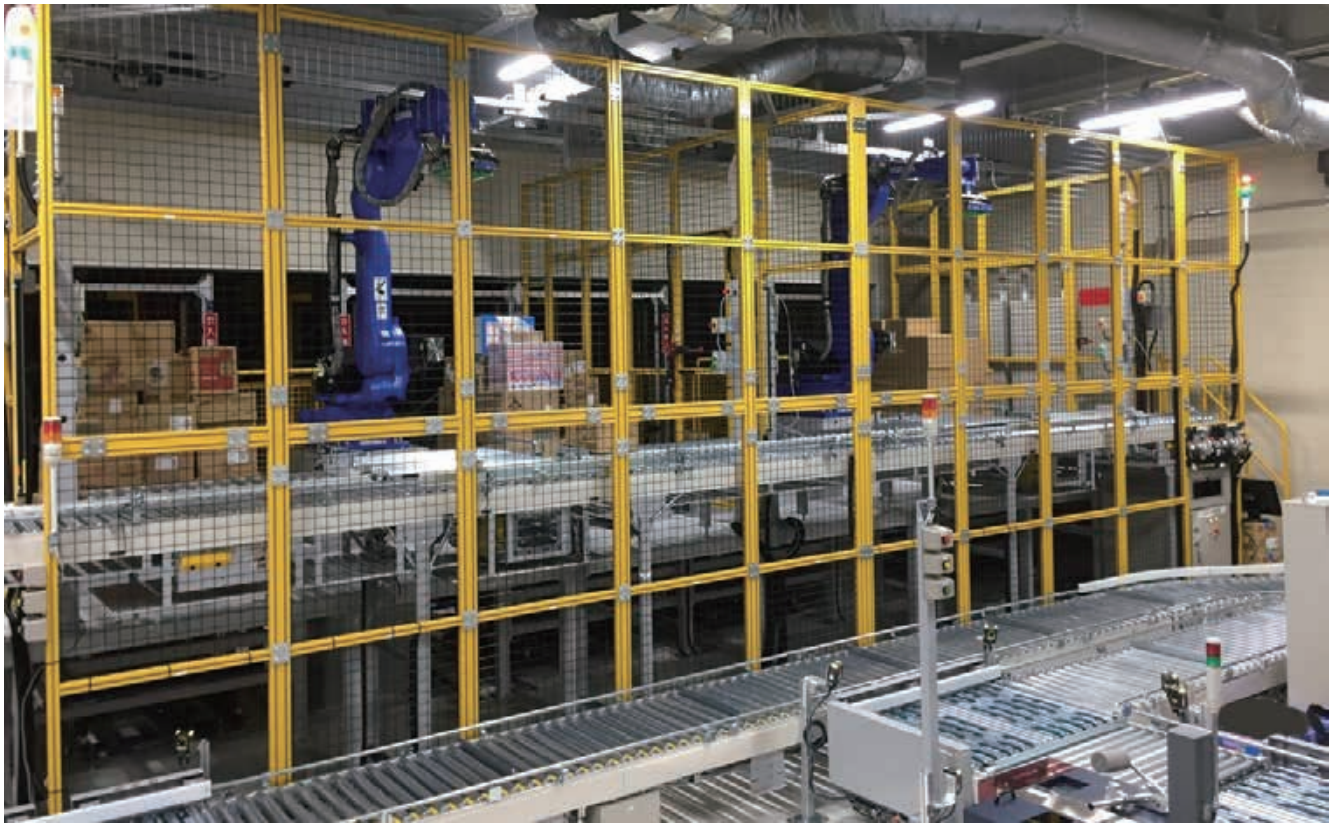
An AI-Enhanced System Assisting Tiresome Depalletizing Works

High performance robot that utilizes AI (deep learning) promoting unmanned or manpower-saving operations in logistics AADS: IHI AI Auto Depalletizing System

Recently, labor shortages are an urgent issue in the logistics sector. Now, IHI has developed and has started selling a new robot system for logistics-related tasks, particularly a system for depalletizing (unloading boxes from a pallet) operations that require heavy work.



AADS in operation

Current situation of labor shortages in the logistics sector

Recently, in Japan, serious labor shortages due to a decreasing birthrate and aging population are a troubling issue. According to one research, 45.4% of companies need more regular employees, and 29.4% need more non-regular employees ("Survey of Corporate Trends against Labor Shortages" Teikoku Databank, Ltd. (2017.7)). In particular, another report "The Bank of Japan's quarterly Short-term Economic Survey of Principal Enterprise in Japan (2017.12)" cited that the logistics sector is the second worst one in terms of labor shortage, referring to the employment conditions index, among all business sectors.

Among the many logistics operations, the depalletizing operation of cardboard boxes stacked on pallets requires such heavy work, which may cause work-related accidents such as backaches. This makes it hard to secure the necessary

manpower. Even if the necessary manpower is secured, the retention rate of workers is low. Therefore, robot-empowered unmanned or manpower-saving operations are eagerly anticipated.

Developing a depalletizing system

Responding to above demands, IHI Corporation, IHI Logistics & Machinery Corporation and Kinema Systems Inc. (USA) jointly developed a new AI (particularly deep learning) -enhanced depalletizing system (AADS: IHI AI Auto Depalletizing System) in June 2017 and this system was launched in December 2017.

We have already received inquiries from many customers. One of our customers in the domestic logistics business has employed the above system as a part of an automated warehouse, which starts full-scale operation in the spring.

Overview of AADS

Manual depalletizing operation is seemingly easy, but since complete automation via robots is so difficult — particularly recognizing cardboard boxes — the process has used humans to handle this work in many cases.

The procedure of AADS is summarized as follows: ① Stereoscopic images are taken via 2D/3D camera installed atop of pallets, ② The size and position of the cardboard boxes are recognized via AI, which is based on the experience and knowledge learned by using past data, ③ The optimal moving path and speed of the robot's arm are determined by considering the load and, ④ The boxes sucked up by a vacuum gripper installed at the tip of the robot's arm and is then transported along the shortest path avoiding any collision with peripheral apparatuses.

The features of AADS are as follows:

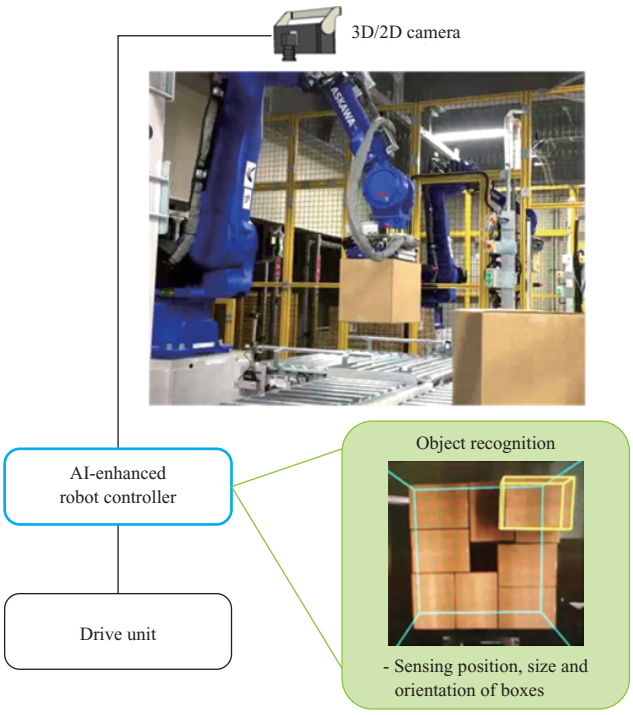
(1) Easy pre-registration

The most emphasized feature of the AADS is the applicability to mixed loading pallets that have cardboard boxes with different sizes or surface designs. By utilizing AI, it is no longer necessary to pre-register geometric and image data of cardboard boxes or teach operation for robots, which are required for conventional depalletizing systems. This AI-enhanced system only needs to pre-register maximum and minimum sizes (Width (W), Length (L) and Height (H)) and maximum weight for the depalletizing operation. Conventional systems require pre-registered image data of cardboard boxes to recognize. However, customers didn't like engaging in this tedious operation. Some customers were only able to process 10% or less of all the pallets using their automation system. By applying AI to object recognition, the above problem of tedious pre-register tasks was successfully resolved.

In the case of un-mixed loading, where a single kind of cardboard boxes are stacked, only registering the size and the weight of the box enables a higher level of recognition accuracy, and also enables unnecessary motion such as raising the boxes too high, to be minimized. This makes it possible to transport at higher speeds.

On the surface of the cardboard boxes in Japan, a unique design is often printed for each product, but this design sometimes makes recognition difficult. For example,

AADS (IHI AI Auto Depalletizing System)



System configuration of AADS

when the color or the pattern on the top surface differs clearly from right and left, one box tends to be misrecognized as two boxes. Even for such special designs, additional learning makes it possible to properly recognize the box. Furthermore, since the above learning process considers lighting changes, the change of image dependent on lighting is acceptable.

In this manner, by utilizing AI to recognize objects, we were able to establish a depalletizing system that responds to lighting or design changes without wasting time on detailed pre-registering.

(2) Improving depalletizing performance

The depalletizing capacity of the AADS mentioned above is picking up 450 boxes an hour, which is 30% more than IHI's conventional system without AI.

This is mainly due to adopting AI. Prior to employing AI, it took 2 to 5 seconds to recognize, during which time robots had to wait. However, after employing AI, the waiting time has nearly been eliminated and robots are able to work without waiting.

The vacuum gripper with many suction cups is employed to grab cardboard boxes. Usually an anti-swing supporting device is used in addition to vacuum cups, but we adopted only vacuum cups as a grabbing device in order to save the operation time for grabbing and considering it important not to decrease the transportation speed. However, in order to secure stable grabbing even when the surface of cardboard box is uneven or perforated, we arranged many small vacuum cups that cover the lowering of suction capacity of vacuum cups at uneven or perforated parts.

In addition, considering the load limit of the vacuum cup, a feature for automatically calculating the optimal transport speed to carry safely and securely was implemented. As a result, lighter boxes are transported quickly and heavier ones slowly.

The optimal path of the robot arms are automatically selected so that they avoid obstacles like peripherals and reach the target point in the minimum amount of time. In the past, it was necessary to teach the path to robots manually, but the path was not always optimal and it took time teaching the path. Meanwhile, by using the automatic generation feature of the optimal path, obstacles can be visualized on the simulator and avoided, which makes it possible to reduce the work time on site.

(3) Transportable cardboard box

Two choices of robots are available: 4-degrees-of-freedom one for horizontally placed cardboard boxes, and 6-degrees-of-freedom one applicable to tilted cardboard boxes.

In addition, the size of the robots depends on the pallet size and the cardboard box size. Available combinations of robot sizes and limit sizes of cardboard boxes are shown in the table below. Because the limit loads of these robots are sufficient, the weight of the cardboard boxes is not such an important factor in selecting the robot.

Even if the size of the cardboard boxes is within the designed range, the box size is sometimes smaller than the size of the vacuum gripper installed at the end of the robot arm. If a larger vacuum gripper tries sucking a smaller box without particular consideration, it may suck multiple boxes at one time. To avoid this problem, the sucking operation must be done from periphery to center boxes one by one. To suck smaller boxes by using larger vacuum gripper securely, the position of the vacuum gripper is determined such that both edges of the cardboard box and the vacuum gripper is coincide and the protruded part does not coincide with another box. In this manner, one vacuum gripper is able to cover a wide range of cardboard box sizes.

In addition, the cardboard boxes are longitudinally placed on the conveyor for stable transportation.

(4) Self-recovery function

Sensors such as cameras are installed on the robot, which have a self-check feature to check their soundness. In particular, when restarting after earthquakes, it is possible that the camera alignment may be misaligned, so it will be automatically checked.

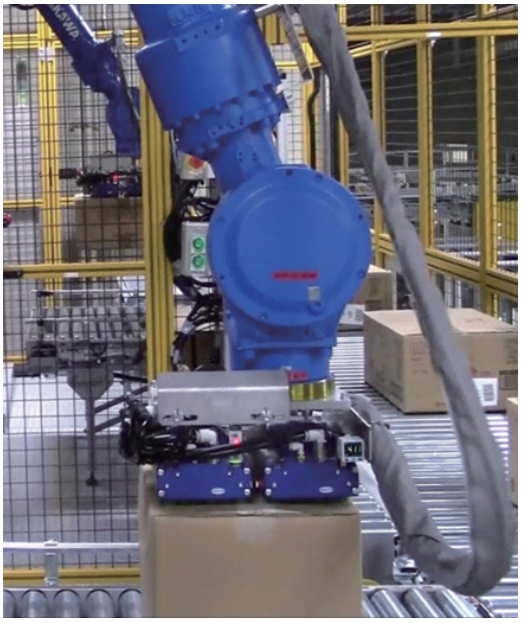
Robots in operation may stop temporarily if they experience some trouble. In particular, when a robot in operation stops while grabbing a cardboard box, the box has to be manually unloaded, but it's hard to recover to the normal condition. In such cases, the box can be unloaded according to the following procedure: If the robot can judge its soundness by itself, ① verify the soundness of the robot and ② stop after safely unloading the box. If

Un-mixed loading pallet

Mixed loading pallet

	Unit	Maximum	Minimum
Middle robot	mm	W700 × L600 × H400	W325 × L200 × H150
Large robot	mm	W700 × L600 × H600	W225 × L180 × H100

Size of tested cardboard box



Vacuum gripper

the robot cannot, ③ operate slowly, only when the inching button is pushed, while making sure of the safety.

Either way, it is not necessary for workers to enter into the area inside the safety fence and safety is secured. Thanks to these features, workers are able to operate AADS safely, even if they have no professional knowledge on how to use robots via pendant or controller.

(5) Cooperation with peripheral logistics equipment

IHI Logistics & Machinery Corporation offers a series of logistics equipment for container cases of cardboard boxes, i.e. Shuttle & Server (a multi-story high-speed sorting machine), Robostack (multi-story automated warehouse), etc. in addition to AADS. By combining these products with above mentioned new robot system, we are promoting the unmanned or manpower-saving operations in logistics in cooperation with our customers.

Future developments

This time we have applied AI technology to a logistics robot system for the first time. As a result, it is clear that it is possible for this system to recognize objects flexibly by using only simple input data and it also has a very high processing speed.

We have been focusing our efforts on developing particular systems for logistics, but AI technology is obviously promising to raising the added value of other IHI Group products, which will surely lead to creating new businesses.

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