Sensing Technology for Automatically Tracking Location of Objects in Warehouses

Kazuhide Yoshihara

In warehouses, manufacturing, and other businesses that store goods, managing the location of those goods can easily become a person-dependent task, and problem of lost goods occur daily. There are various reasons for losing track of goods, but in most cases, the location of goods is recorded by people using a system or ledger and due to human error, the location is forgotten to be recorded or incorrectly recorded. Moreover, in small warehouses, there are cases where management of storage locations relies on a person's memory, and when the track of goods is lost, time is consumed on searching, which can lead to other problems such as delay in shipment[1].

This article provides an overview of an automatic inventory positioning system*[1] that uses sensing technology to automatically track the location of goods and other objects to solve the aforementioned problems. Additionally, the article introduces ways to solve problems that arise when using RF tags and QR codes*[2].

Overview of Automatic Inventory Positioning System

The automatic inventory positioning system under development by OKI is based on a normal smartphone and provides automatic tracking of goods both indoors and outdoors utilizing either RF tags or QR codes (**Figure 1**).

To use the system, a smartphone and RFID reader are installed on a material handling equipment (MHE), such as a forklift, which moves the goods, and RF tags or QR codes are attached to the goods to be tracked.

Positioning of goods is performed upon detection of an RF tag or QR code by the smartphone. For positioning outdoors, a global navigation satellite system (GNSS) is used, and indoors, beacons or RF tags are used depending on the environment. In addition to automatically tracking the locations of goods, the system also supports other functions necessary for storage operation such as shipping/receiving operations and inventory management.

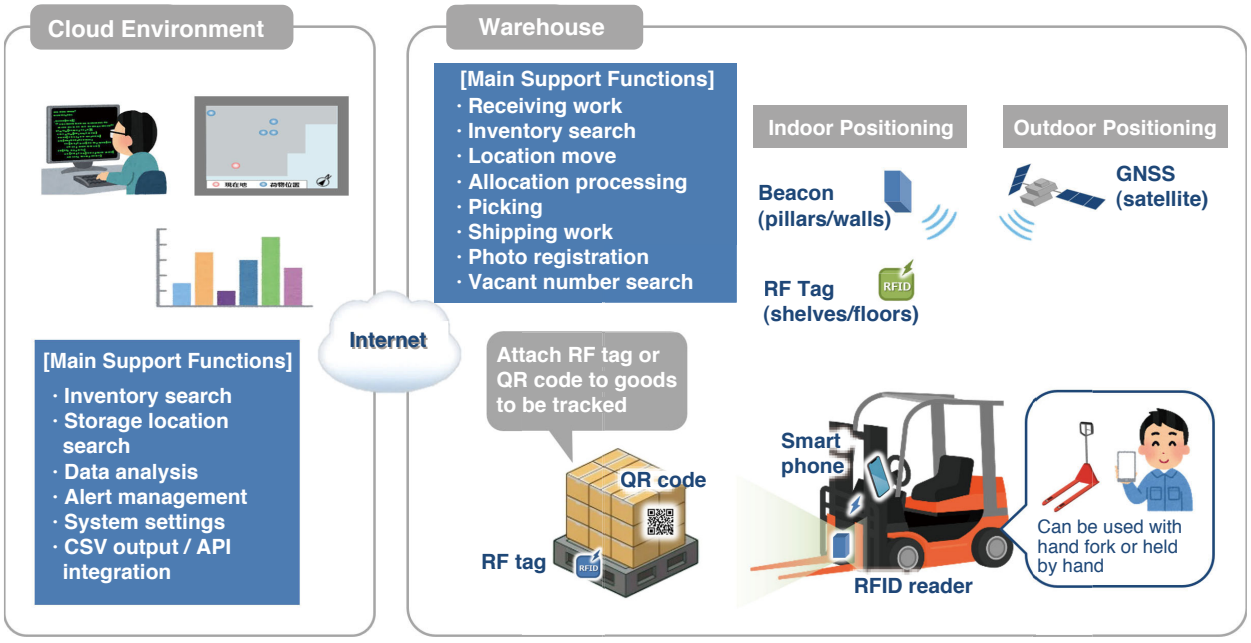

Figure 1. Overview of Automatic Inventory Positioning System

*1) OKI's automatic inventory positioning system is scheduled to be provided as a service platform in January 2025. The service name, "SHO-XYZ," is derived from "easily track the shozai (location) of objects." OKI is currently applying for trademark registration.

*2) "QR code" is a registered trademark of DENSO WAVE INCORPORATED in Japan and other countries. All other product and service names are trademarks or registered trademarks of their respective companies.

Mechanism of Automatic Tracking using RF Tags

The use of RF tags for automatic tracking requires RF tags to be attached to the goods or the pallets used for moving the goods. Additionally, the MHE must be equipped with an RFID reader and a smartphone. When the RFID reader on the MHE detects an RF tag of the goods, positioning is started by the smartphone using GPS if outdoors, or using beacons or location information from the RF tag if indoors. The system records the location when the movement of the goods is completed and contact with the RF tag is lost. An example of automatic positioning using an RF tag is shown in **Figure 2**.

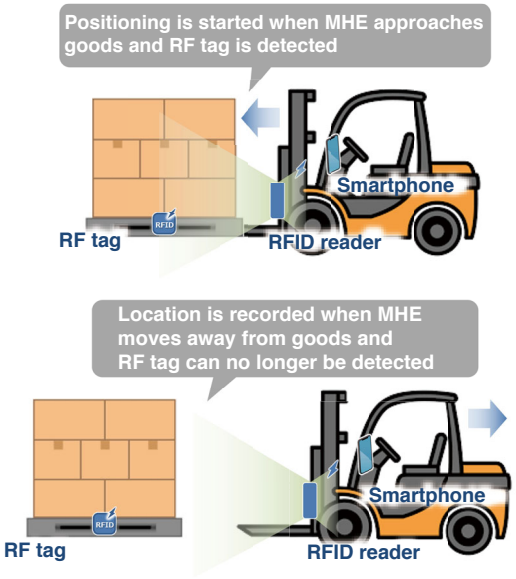

Figure 2. Automatic Positioning using RF Tag

In addition to the example shown in **Figure 1**, RF tags can also be used in other ways such as attaching an RF tag to the interior of a car and having the driver carry a smartphone or RFID reader to track the vehicle. This usage example is shown in **Figure 3**.

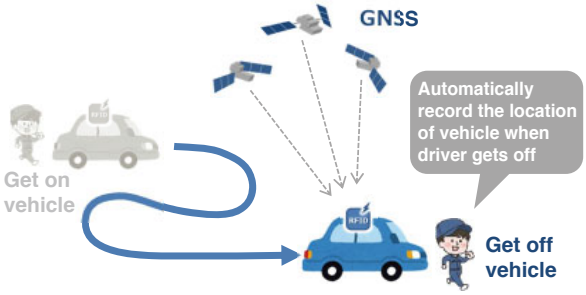

Figure 3. Automatic Positioning when Tracking a Vehicle

Problem with using RF Tags for Tracking and Solution

RF tags are an automatic recognition technology that uses wireless signals to read and write IC tags without physical contact. While it has the advantage of being able to detect multiple RF tags at once, it is not possible to single out a particular RF tag for tracking. In the case of automatic tracking using RF tags attached to goods, if no measure is taken, automatic tracking will start unnecessarily just by approaching the goods, and unwanted data updates will occur (**Figure 4**). Therefore, a function to detect only the RF tag of the target goods was realized by determining whether the goods are the intended target based on the intensity of the RF tag's signal and number of receptions.

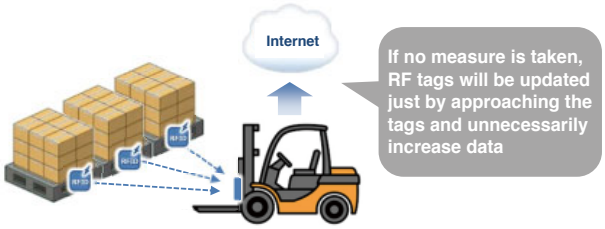

Figure 4. Problem of Detecting Nearby RF Tags

Mechanism of Automatic Tracking using QR Codes

In order to use QR codes for automatic tracking, QR codes must be attached to the goods to be tracked and the MHE must be equipped with a smartphone. When a QR code is detected by the smartphone camera during the moving of goods, tracking becomes possible in the same way as an RF tag. An example of automatic positioning using a QR code is shown in **Figure 5**.

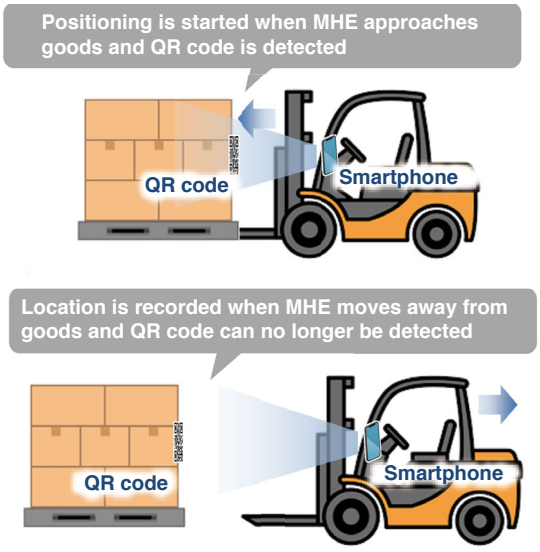

Figure 5. Automatic Positioning using QR Code

Problem with using QR Codes for Tracking and Solution

The target goods can be identified by adjusting the smartphone's camera angle. However, since the QR code is affixed to the side of the goods, if the distance between the QR code and the camera becomes too close during movement, recognition of the QR code may be lost (**Figure 6**).

To determine whether goods are being moved or not, when a QR code is detected, the system determines the size of the QR code and changes in the view angle. This makes it possible to properly determine whether the goods are in the process of being moved or the move has been completed even if the distance between the QR code and the camera is too close for recognition.

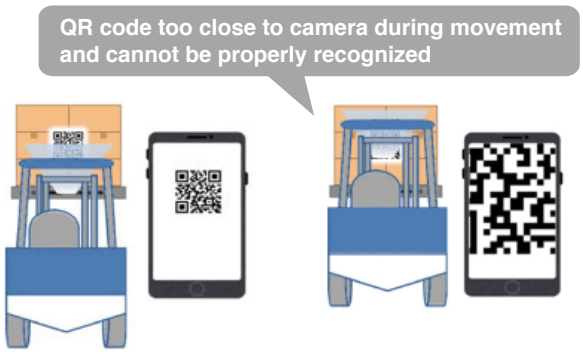

Figure 6. QR Code Not Detectable during Movement

Positioning Accuracy of Satellite Positioning Systems

When the goods are being moved outdoors, a satellite positioning systems are used. Since November 2018, the Michibiki Quasi-Zenith Satellite System (QZSS), known as the Japanese version of the GPS, has been in operation with four satellites. With the previous GPS, errors of several tens of meters could occur depending on the external environments such as weather and buildings, but since the QZSS went into operation, a stable positioning accuracy of within 5 meters has been ensured (**Figure 7**)[2].

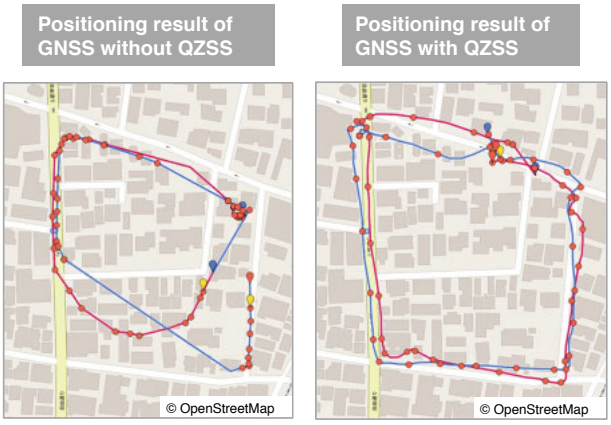

Figure 7. Positioning Accuracy Improvement with QZSS

Positioning Accuracy of Beacons and RF Tags

Indoors, positioning is performed using beacons or RF tags depending on the environment. However, when beacons are used, signal intensity can become unstable due to the effects of multipath propagation that is caused by the floors and walls. As a result, positioning accuracy is significantly worse than satellite positioning systems (**Figure 8**)[3].

Therefore, unstable multipath are removed by using the difference in signal intensity between direct signals and signals reflected from the floors and walls, and remaining multipath are used as data for three-point positioning to improve accuracy.

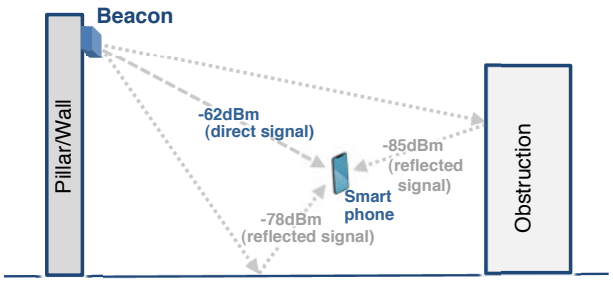

Figure 8. Occurrence of Multipath

Furthermore, when installing beacons on pillars and walls, depending on the location, there may be areas where only reflected signals reach the smartphone (**Figure 9**).

Ideally, the installation locations should be carefully planned to avoid any signal blind spots, and it is best to install the beacons on the ceiling or other locations with as few obstructions as possible. Unfortunately, this necessitates detailed design and installation work at high places, which increase time and construction costs required for implementation. Therefore, when using beacons, they are installed in accordance with the guidelines and at 10m intervals. After installation, signal calibration is performed at the center of each area. In sections only reachable by reflected signals, a mechanism is introduced to correct the attenuated signal intensity. This way, even indoors, it is possible to achieve positioning accuracy equivalent to that of satellite positioning systems including QZSS.

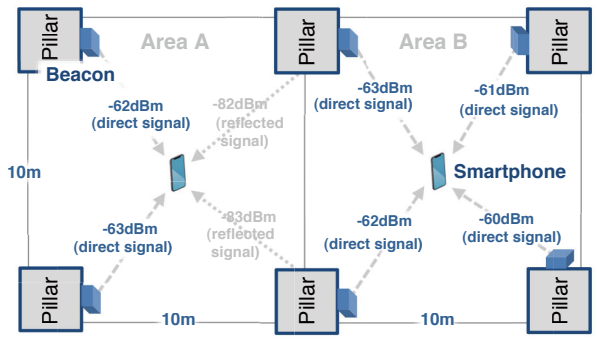

Figure 9. Attenuation of Signals Due to Blind Spots

Regarding the use of RF tags as a location ID for positioning, the location of goods can be accurately determined by attaching metal-compatible RF tag (for location ID) to each lot such as a shelf or storage area where the goods are stored (**Figure 10**).

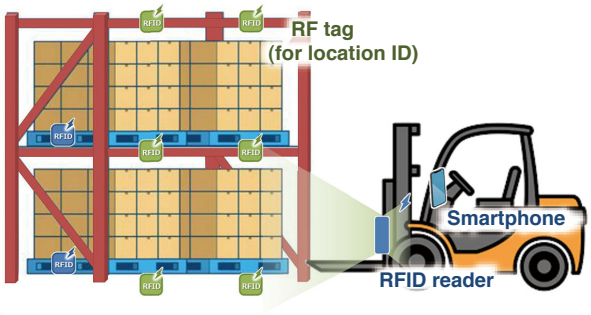

Figure 10. Positioning using RF Tags for Location ID

Future developments

This article presented an overview and the features of the automatic inventory positioning system that uses sensing technology to automatically track the location of objects. As shown in **Figure 1**, the system also supports functions such as shipping/receiving operations and inventory management, which are necessary for storage operations of goods, with the use of just a smartphone. A plan is now in progress to deploy the system as a warehouse management system (WMS) for businesses that have refrained from adopting a management system due to the cost of dedicated terminals.

Currently, there are two patterns for indoor positioning: beacons and RF tags. However, utilizing sensing technology currently under research, OKI is working to realize a more accurate positioning system without relying on beacons. Sensors built into smartphones will be used to autonomously determine the position of forklifts based on the position information from RF tags attached to the floor along the route of the forklifts (**Figure 11**). ◆◆

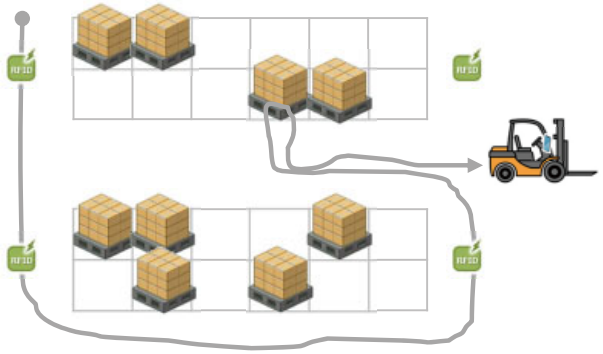

Figure 11. Autonomous Positioning Based on RF Tags Attached to Floor

References

1) The Japan Warehousing Association Inc.: Towards a Sustainable Logistics (in Japanese)
https://www.meti.go.jp/shingikai/mono_info_service/sustainable_logistics/pdf/009_02_03.pdf
2) QZSS is Becoming a Seven-satellite Constellation
https://qzss.go.jp/en/overview/services/seven-satellite.html
3) Geodetic Department, Geospatial Information Authority of Japan, Ministry of Land, Infrastructure, Transport and Tourism: BLE Beacon Placement Guidelines for Indoor Positioning (in Japanese)
https://www.gsi.go.jp/common/000198740.pdf

Authors

Kazuhide Yoshihara, Business Development Department, Innovation Business Development Center

TIPS【Glossary】

MHE
An abbreviation for “material handling equipment,” a general term for work machines used to make logistics operations more efficient.

Beacon
A small device that emits Bluetooth signals.

QR code
A matrix-type two-dimensional code that is widely used around the world for data reading and in-store payment.

RF tag
RFID system reads data using wireless signals (electromagnetic signals) to identify and manage objects. RF tag is a component of the RFID system, and it communicates with an RFID reader to provide information.