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(71) Applicant Hangzhou Dachuan Intelligent Technology Co., Ltd.

Address Working Station 014, Floor 2, Building 4, No 1, Street 8,
Economic and Technological Development Zone,
Hangzhou, Zhejiang Province, 310018

(72) Inventors Yuerong ZHAO, Meiyang LIU

(74) Patent Agency Shanghai Jingsheng Intellectual Property
Agency Co., Ltd. 31253

Agent Ziling FENG

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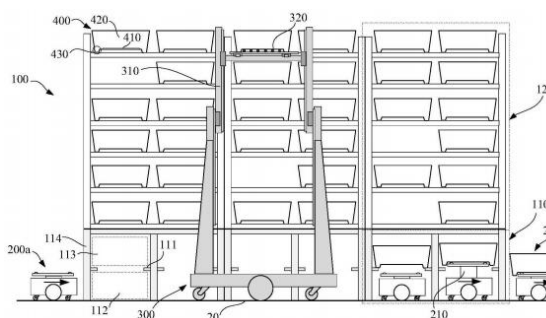
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(54) Title of the Invention

UNMANNED WAREHOUSING SYSTEM AND INBOUND
AND OUTBOUND METHOD THEREFOR

(57) Abstract

Disclosed in the present invention are an unmanned warehousing system and an inbound and outbound method therefor, which solve the problems of complex deployment, inconvenient maintenance, and high cost of the existing system. In an embodiment of the system, a two-layer channel support frame is provided below a shelf, wherein a lower layer is used to automatically guide a trolley to pass through, an upper layer is used for the temporary cache or passage of a standardized container, and an interlayer support plate runs through along the length or width direction of the entire shelf. When an outbound process of items is implemented, a stacking vehicle automatically travels to a designated shelf and aligns with the same, and the standardized container on the shelf is picked up by means of a pickup mechanism. Then, the container is lowered onto the upper layer of the support frame to cache the container on the support plate. Subsequently, an auto-guided trolley travels through the lower layer



CN 109987366 A

of the support frame to a position below the container to separate the container from the support member by hoisting the container before entering a sorting site through a channel and a laneway. The steps are reversed for an inbound process. This system is easy to deploy, convenient to maintain, and low in cost. A large number of robots operate concurrently by means of a dispatching system, so that the overall efficiency is high.

1. An unmanned warehousing system, characterized by: picking up items placed on shelves and transporting the items to a sorting site to complete an outbound process, or transporting the items from the sorting site to the shelves and storing the items on the shelves to complete an inbound process, and comprising:

at least one shelf, a front surface of which an item can be picked up or placed on;

at least one standardized container for storing scattered items;

at least one auto-guided trolley for transporting the standardized container to a specified position;

at least one stacking device capable of picking up and placing items on the shelves, including the standardized container; and

a management terminal that supplies handling instructions to the auto-guided trolley and the stacking device;

the unmanned warehousing system being characterized in that:

the shelf is provided with:

a multi-layer rack for storing items, including the standardized container; and

at least one channel support frame arranged below the multi-layer rack and fixed on the ground, wherein the channel support frame is a first-type channel support frame, a second-type channel support frame, or a third-type channel support frame;

the first-type channel support frame comprises a plurality of upright columns and at least two support members fixed on the upright columns and can provide a cache space for the standardized container, and a row gap, which is parallel to the front surface of the shelf and runs through the shelf, is formed between the support members in a horizontal direction;

the second-type channel support frame comprises a plurality of upright columns and at least two support members fixed on the upright columns and can provide the cache space for the standardized container, and a column gap, which is perpendicular to the front surface of the shelf and runs through the shelf, is formed between the support members in the horizontal direction;

the third-type channel support frame comprises a plurality of upright columns and at least four support members fixed on the upright columns and can provide the cache space for the standardized container, and a row gap, which is parallel to the front surface of the shelf and runs through the shelf, and a column gap, which is perpendicular to the front surface of the shelf and runs through the shelf, are formed between the support members in the horizontal direction;

the standardized container comprises:

a storage portion for accommodating scattered items;

at least two docking portions distributed on the periphery of a side surface or bottom surface of the standardized container, and used for docking from top to bottom on the support members on two sides of a gap in a channel support frame and maintaining positions thereof; and

a hoisted portion for being connected with a hoisting portion of the auto-guided trolley;

an overall outer size of the standardized container is smaller than an internal space size of the channel support frame, and the standardized container can be moved horizontally into and out of the channel support frame;

the auto-guided trolley is provided with a driving portion, a control portion, and the hoisting portion that can be automatically raised and lowered; the control portion causes the auto-guided trolley to travel by means of the driving portion; and the control portion causes the hoisting portion to be connected with or separated from the hoisted portion of the standardized container by raising and lowering the hoisting portion to realize hoisting or dropping of the standardized container; and

the stacking device comprises the driving portion, the control portion, a lifting platform, and a grabbing component, the control portion causes the stacking device to move between the shelves and align with a designated position on the front surface of the shelf by means of the driving portion, causes the grabbing component to align with a designated height of the shelf by means of the lifting platform, and extends into the rack of the shelf and the channel support frame by means of the grabbing component to grab and place items.

2. The unmanned warehousing system according to claim 1, characterized in that:

the number of shelves is greater than 1, the shelves are composed of a shelf row set comprising several shelf rows and provide, for the automatic guide trolley and the stacking device, the cache space for placing the standardized container, and the shelf rows are first-type shelf rows, second-type shelf rows, third-type shelf rows, or a combination of the above three types of shelf rows;

the first-type shelf row refers to a shelf row formed by transversely connecting a plurality of shelves with the first-type channel support frame and an optional number of shelves with the third-type channel support frame;

the second-type shelf row refers to a shelf row formed by transversely connecting a plurality of shelves with the second-type channel support frame and an optional number of shelves with the third-type channel support frame;

the third-type shelf row refers to a shelf row formed by transversely connecting a plurality of shelves with the third-type channel support frame; and

among the three types of shelf rows, the first-type shelf row and the third-type shelf row can provide a row channel for the auto-guided trolley carrying the standardized container to travel under the shelves, and the second-type shelf row and the third-type shelf row can provide a column channel for the auto-guided trolleys carrying the standardized container to travel under the shelves.

3. The unmanned warehousing system according to claim 2, characterized in that:

the shelf row and a stacking row laneway form a shelf-laneway combination; the shelf-laneway combination is a first-type shelf-laneway combination or a second-type shelf-laneway combination; the first-type shelf-laneway combination is composed of two shelf rows placed face to face in parallel and the stacking row laneway left in the middle of the two shelf rows to allow the stacking device to pass through, and the grabbing component of the stacking device has an ability to grab and place items from the racks of the shelves on two sides and the channel support frame; and the second-type shelf-laneway combination is composed of a shelf row and the stacking row laneway left next to the front surface of the shelf row to allow the stacking device to pass through, and the grabbing component of the stacking device has an ability to grab and place items from the rack of the shelf on one side and the channel support frame.

4. The unmanned warehousing system according to claim 3, characterized in that:

the channel support frame below the two shelf rows in the first-type shelf-laneway combination is the second-type channel support frame or the third-type channel support frame, and the two shelf rows are aligned left and right, so that the column gap on the channel support frame and the stacking row laneway space between the shelf rows form the column channel that allows the auto-guided trolley carrying the standardized containers to pass through the entire shelf-laneway combination in a straight line.

5. An unmanned warehousing system, characterized by:

picking up items placed on shelves and transporting the items to a sorting site, or transporting the items from the sorting site to the shelves and storing the items on the shelves, and being provided with:

several shelves, front surfaces of which an item can be picked up or placed on;

at least one movable bracket for caching items;

at least one auto-guided trolley for transporting the bracket to a specified position;

at least one stacking device capable of picking up and placing items on the shelves and the bracket; and

the management terminal that supplies handling instructions to the auto-guided trolley and the stacking device; the unmanned warehousing system being characterized in that:

the shelf is provided with a multi-layer rack and at least one channel support frame, the channel support frame is arranged below the multi-layer rack and fixed on the ground, and the channel support frame comprises a plurality of upright columns,

the movable bracket comprises:

the storage portion located in an upper half of the bracket and used for accommodating items;

a support portion distributed on the periphery of a lower part of the storage portion, which can be in contact with the ground to support the storage portion; and

a hoisted portion for being detachably connected with a connecting portion of the auto-guided trolley;

an overall outer size of the movable bracket is smaller than an internal space size of the channel support frame, the movable bracket can be moved horizontally into and out of the channel support frame, and the movable bracket can be docked inside the channel support frame and maintain a position thereof by means of the contact between the support portion and the ground;

the auto-guided trolley is provided with the driving portion, the control portion, and a hoisting portion that can be automatically raised and lowered; the control portion causes the auto-guided trolley to travel by means of the driving portion; and the control portion causes the hoisting portion to be detachably connected with or separated from the hoisted portion of the movable bracket by raising and lowering the hoisting portion to realize hoisting or dropping of the movable bracket;

the stacking device comprises the driving portion, the control portion, the lifting platform, and the grabbing component, the control portion causes the stacking device to move between the shelves and align with a designated position on the front surface of the shelf by means of the driving portion, causes the grabbing component to align with a designated height of the shelf by means of the lifting platform, and extends into the rack of the shelf and the interior of the channel support frame by means of the grabbing component to grab and place items;

the shelves are transversely connected to form several shelf rows, the shelf row and the stacking row laneway form the shelf-laneway combination; the shelf-laneway combination is the first-type shelf-laneway combination or the second-type shelf-laneway combination; the first-type shelf-laneway combination is composed of two shelf rows placed face to face in parallel and the stacking row laneway left in the middle of the two shelf rows to allow the stacking device to pass through, and the grabbing component of the stacking device has an ability to grab and place items from the racks of the shelves on two sides and the channel support frame; the second-type shelf-laneway combination is composed of a shelf row and the stacking row laneway left next to the front surface of the shelf row to allow the stacking device to pass through, and the grabbing component of the stacking device has an ability to grab and place items from the rack of the shelf

on one side and the channel support frame; and the channel support frame below the shelf row runs in all direction, which provides the row channel and the column channel for the auto-guided trolley carrying the standardized container to travel under the shelves through the entire shelf-laneway combination.

6. An inbound and outbound method for an unmanned warehousing system, using the unmanned warehousing system according to any one of claims 1-5, characterized in that:

the stacking device and the auto-guided trolley in the unmanned warehousing system receive and execute the handling instructions from the management terminal;

the handling instructions received by the stacking device from the management terminal comprises stacking starting and ending positions of a target item, information of the stacking starting and ending positions comprises a position of the shelf in a row laneway and a position of the target item placed on the rack and the channel support frame, the stacking device automatically travels to and aligns with the shelf at the stacking starting position, and acts to cause the grabbing component to align with the target item placed on the rack or the channel support frame by means of the lifting platform, and pick up the target item, and then, the stacking device automatically travels to and aligns with the shelf at the stacking ending position, acts to cause the grabbing component to align with the stacking ending position by means of the lifting platform, and places the target item on the corresponding rack or in the channel support frame;

the handling instructions received by the auto-guided trolley from the management terminal are of types comprising at least an outbound instruction and an inbound instruction and have instruction content comprising transport starting and ending positions where the target item is located, the transport starting and ending positions being positions of a channel support frame or a site outside the shelf; the unloaded auto-guided trolley that receives the outbound handling instruction moves forward along a designated path, passes through the row channel, the column channel, the row laneway or the column laneway, and travels to a position below an item docked in the channel support frame at the transport starting position, the hoisting portion is then raised to be connected with the hoisted portion of the standardized container or the movable bracket to hoist the standardized container or the movable bracket, and then the auto-guided trolley carries the standardized container or the movable bracket and travels along the unblocked row channel or column channel to a site outside the shelf to complete an outbound process;

the auto-guided trolley carrying the standardized container or the movable bracket, which receives the inbound handling instruction, travels from the transport starting position outside the shelf to near the shelf corresponding to the transport ending position, and travels along the row channel or the column channel into the channel support frame corresponding to the transport ending position, and the hoisting portion is lowered to cause the standardized container or the movable bracket to be docked in the channel support frame to complete an inbound process; and

the auto-guided trolley that completes the handling instruction waits in place, continues to execute a next handling instruction received, or returns to a designated area.

7. The inbound and outbound method for the unmanned warehousing system according to claim 6, characterized in that: the types of the handling instructions received by the auto-guided trolley from the management terminal further comprise a shift instruction for reducing blockage of the row channel or the column channel to improve channel utilization; the unloaded auto-guided trolley that receives the shift instruction travels along a given row channel or column channel to a position below an item docked in the channel support frame at the transport starting position, the hoisting portion is then raised to be connected with the hoisted portion of the standardized container or the movable bracket to hoist the standardized container or the movable bracket, and then the auto-guided trolley carries the standardized container or the movable bracket and travels to other transport key positions in the channel support frame, so as to cause the standardized container to be docked at a new cache space to complete a shift process; and the auto-guided trolley that completes the handling instruction waits in place, continues to execute a next handling instruction received, or returns to the designated area.

8. The inbound and outbound method for the unmanned warehousing system according to claim 6, characterized in that: the auto-guided trolley and the stacking device use the space of the channel support frame in a time-shared manner by means of a pre-registration mechanism; the stacking device submits in advance, to the management terminal, a space use application regarding position information of the channel support frame where the stacking device needs to stay and a starting time, before the grabbing component of the stacking device needs to extend into the channel support frame, and takes action after the application is confirmed by the management terminal; when the auto-guided trolley carrying the standardized container or the movable bracket travels along the row channel and is about to enter a next channel support frame in front, the auto-guided trolley submits a space use application regarding a starting time of passing through the channel support frame to the management terminal in advance and takes action after the application is confirmed by the management terminal; the management terminal analyzes the submitted space use application in units of the channel support frame, sends confirmation information to the stacking device or the auto-guided trolley when spatial or temporal interference does not occur, or sends the confirmation information to a high-priority device when the interference exists, and the corresponding channel support frame space is marked as predetermined occupancy while the confirmation information is sent; and the auto-guided trolley and the stacking device submit a space release application when leaving one of the channel support frames.

9. The inbound and outbound method for the unmanned warehousing system according to claim 6, characterized in that: the auto-guided trolley and the stacking device use the stacking row laneway space in the shelf-laneway combination in a time-shared manner by means of a registration mechanism; the stacking device submits a space use application regarding position information of the stacking row laneway space where the stacking device needs to pass through

and stay, a starting time, and an ending time to the management terminal in advance, and takes action after the application is confirmed by the management terminal; when the auto-guided trolley travels along the column channel and is about to pass through the row laneway where a stacking vehicle travels, the auto-guided trolley submits a space use application regarding a starting time of passing through the stacking row laneway and a space opposite to the stacking row laneway to the management terminal in advance; the management terminal separately analyzes the use applications for two consecutive spaces submitted by the auto-guided trolley, sends confirmation information to the auto-guided trolley when spatial or temporal interference does not occur in either space, and the corresponding two spaces are marked as predetermined occupancy while the confirmation information is sent; and the auto-guided trolley and the stacking device submit a space release application while leaving one of the above spaces.

UNMANNED WAREHOUSING SYSTEM AND INBOUND AND OUTBOUND METHOD THEREFOR

Technical Field

[0001] The present invention relates to the technical field of warehousing, especially to an unmanned warehousing system and an inbound and outbound method therefor.

Background Art

[0002] The core of automated warehousing is the efficient and automated transportation of items between shelves and sorting workstations. At present, many warehouses have begun to implement automation, and are equipped with a large number of mechanical devices, such as integrated shelves, shuttle vehicles, stackers, forklifts, auto-guided trolleys or AGVs, conveyor belts, etc., which reduces labor costs and improves the sorting efficiency of warehousing. However, these solutions are not satisfactory enough.

[0003] An automated warehousing solution using mobile robots makes less site modification than those with the integrated shelves and shuttle vehicles, making it easier to deploy and realize high-concurrency operations, which results in its popularity in some situations. Such a solution can be classified into a single-type mobile robot solution and a multi-type robot collaboration solution including at least one mobile robot, depending on the type of mobile robots used.

[0004] The solution adopting single-type mobile robots is advantaged by easy modularization and standardization, so that a faulty device unit can be replaced quickly. Amazon's Kiva robot system is a typical example. Patent US7826919 introduces using a submersible auto-navigation trolley to move unitized shelves, realizing "goods to people." However, in the solution, the whole shelf is handled, requiring each mobile trolley to be provided with a high load capacity, which greatly increases the device cost. In addition, the shelf should not be too high or it will easily tip over during movement, which restricts the improvement of warehousing capacity. The solution in Patent JP2004277062 owned by Panasonic in Japan is to use single-type mobile robots with lifting platforms and fork means to connect with shelves. However, the number of shelf layers generally does not exceed three to ensure robot movement stability, which limits the storage capacity of warehouses together with the high cost of a single mobile robot.

[0005] The multi-type robot collaboration solution including at least one mobile robot can take advantage of different robots' strengths. The solution in Patent US10138060 owned by Amazon is to mount on the back of each shelf a modularized two-degree-of-freedom leveling mechanism and a telescoping pusher, which can be moved to a position and push items from the inside out; on the other hand, an auto-guided vehicle is mounted with a lifting platform, which can align with a shelf layer after moving to a specified shelf position, so as to catch items before the items are transported to a sorting workstation. The solution has a long deployment cycle, high costs, and low reliability. The solution in Patent US9550624 owned by Dematic in USA is to use a mobile trolley equipped with a joint mechanical arm and a mobile trolley with multi-layer storage baskets to cooperate with each other. The latter follows the former, which transfers items from a shelf to a

storage basket. In this solution, despite the easiness of deploying basically without on-site modification, the joint mechanical arm is limited in the pickup range with a low load capacity and a high cost. The solution proposed by Knapp in Germany in Patent EP3170773 is to reserve some space at positions of the bottom layer on both sides of an automatic three-dimensional warehouse for movable multi-layer shelves to be docked therein. A laneway stacker puts items into shelves from the three-dimensional warehouse, and a mobile trolley moves to a position below the shelves to hoist the shelves and then transports them to sorting workstations. The solution requires the installation of the three-dimensional warehouse, leading to a high deployment cost. Also, the three-dimensional warehouse cannot continue to work in the case of internal failure. The mobile trolley can only move in the periphery of the three-dimensional warehouse but not enter its internal space. Moreover, the periphery has less space reserved for deployment, and it is thus unable to increase throughput and efficiency by increasing the number of mobile trolleys.

[0006] To sum up, most of the existing solutions need complex deployment, requiring on-site modification and the installation of a large number of auxiliary electromechanical devices. The devices cannot continue to operate in the case of failures, and it is inconvenient to maintain them. Or, although the on-site modification is not required, a large number of costly heavy-load mobile trolleys or robotic arms need to be configured. Complex deployment, inconvenient maintenance, and high costs all limit promotion.

Summary of the Invention

[0007] To solve the above technical problem, an unmanned warehousing system and an inbound and outbound method therefor are disclosed in the present invention. The technical solution of the present invention is implemented as follows:

[0008] An unmanned warehousing system using mobile robots and caching apparatuses and an inbound and outbound method utilizing caching apparatuses to improve operation efficiency are provided, wherein an outbound process is completed by picking items placed on a shelf and transporting them to a sorting site, or an inbound process is completed by transporting items from the sorting site to the shelf and storing them on the shelf. The unmanned warehousing system is provided with: at least one shelf, a front surface of which an item can be picked up or placed on; at least one standardized container or a movable bracket for storing scattered items; at least one auto-guided trolley for transporting the standardized container to a specified position; at least one stacking device capable of picking up and storing items on the shelf; and a management terminal for supplying handling instructions to the auto-guided trolley and the stacking device. The unmanned warehousing system is characterized in that: the shelf is provided with a multi-layer rack and at least one channel support frame; a cache space for the standardized container to be docked therein is formed in the interior of the channel support frame, while a row channel, a column channel, or both the row and column channels are provided for the auto-guided trolley carrying the standardized container or the movable bracket to travel under the shelf; and the management terminal dispatches a stacking vehicle to transfer the items, including transfer of the standardized container between the shelf and the cache space, and dispatches the auto-guided

trolley to complete inbound, outbound, and shift processes of the standardized container or the movable bracket.

[0009] Compared with the prior art, the unmanned warehousing system and the inbound and outbound method therefor provided by the present invention achieve efficient transportation of “goods to people” by means of the cooperation of fewer mobile stacking vehicles and more small auto-guided trolleys to complete sorting and transportation of the items, with the help of the cache space below the shelf. The system has the advantages including the following: the existing traditional shelves continue to be used without the addition of wires and auxiliary electromechanical devices; on-site modification is substantially negligible, especially suitable for temporary warehouses; the small auto-guided trolleys only need to transport the items rather than the entire shelf, and only a small load capacity is thus required, so that the cost can be greatly reduced; for the auto-guided trolley and the stacking device, standardized mature products may be used for immediate maintenance outside the site in the case of failure without affecting the continued operation of the whole system. In addition, mobile robots can adopt auto-navigation technology, and it is possible not to mount any navigation assistance device that requires a wire power supply. Such a warehouse can be relocated, expanded, and changed in layout at any time, with characteristics like high flexibility, short implementation cycle, and convenient demolition, transfer, and expansion.

Brief Description of the Drawings

[0010] To more clearly explain the technical solutions in the embodiments of the present invention or the prior art, the drawings to be used in the description of the embodiments of the present invention or the prior art will be briefly introduced below. Obviously, the drawings to be described below are only an embodiment of the present invention. For those of ordinary skill in the art, other drawings may be obtained based on those drawings without any inventive skill.

[0011] FIG. 1 is a top view of an unmanned warehousing system in Embodiment 1 of the present invention and a schematic diagram of the principle of an auto-guided trolley performing inbound and outbound operations when it runs along a row channel under a shelf;

[0012] FIG. 2 is a front view of the working principle of the unmanned warehousing system in Embodiment 1 of the present invention;

[0013] FIG. 3 is the side view of the working principle of the unmanned warehousing system in Embodiment 1 of the present invention;

[0014] FIG. 4 is a schematic diagram of a typical channel support frame with a fixed structure of support members in Embodiment 1 of the present invention, wherein FIG. 4a is a channel support frame providing a cache space for a single standardized container, FIG. 4b is another channel support frame providing the cache space for the single standardized container, FIG. 4c is a channel support frame providing a cache space for two standardized containers, and FIG. 4d is another channel support frame providing the cache space for the two standardized containers;

[0015] FIG. 5 is a schematic diagram of several typical standardized containers that can be placed on a support member, in Embodiment 1 of the present invention, wherein FIG. 5a is a top

view and side view of a standardized storage basket, FIG. 5b is a top view and side view of a standardized stack plate, and FIG. 5c is a top view and side view of a standardized bracket;

[0016] FIG. 6 is a schematic structural diagram of a grabbing component of a stacking vehicle for forking a standardized container on both sides, in Embodiment 1 of the present invention, wherein FIG. 6a is a schematic structural diagram of the grabbing component in a retracted state, FIG. 6b is a schematic structural diagram of the grabbing component when a fork on one side is extended out, and FIG. 6c is a schematic structural diagram of the grabbing component when a fork on the other side is extended out;

[0017] FIG. 7 is a schematic diagram of a typical channel support frame with a fixed structure of support members in Embodiment 2 of the present invention, wherein FIG. 7a is a channel support frame providing a cache space for two standardized containers, and FIG. 7b is another channel support frame providing the cache space for the two standardized containers; FIG. 8 is a top view of an unmanned warehousing system in Embodiment 2 of the present invention and a schematic diagram of the principle of an auto-guided trolley performing inbound and outbound operations when it runs along a column channel under a shelf;

[0018] FIG. 9 is a top view of an unmanned warehousing system in Embodiment 3 of the present invention and a schematic diagram of the principle of an auto-guided trolley performing inbound and outbound operations when it runs along a row direction in a trolley-special row laneway and runs along a column channel under a shelf;

[0019] FIG. 10 is a top view of an unmanned warehousing system in Embodiment 4 of the present invention and a schematic diagram of the principle of an auto-guided trolley performing inbound and outbound operations when it runs along a row channel and a column channel under a shelf;

[0020] FIG. 11 shows a movable bracket with support legs adopted in Embodiment 5 of the present invention;

[0021] FIG. 12 is a chart of a basic workflow of a management terminal in an inbound and outbound method of the present invention;

[0022] FIG. 13 is a chart of a basic operation flow of a stacking vehicle in the inbound and outbound method of the present invention;

[0023] FIG. 14 is a chart of a basic operation flow of an auto-guided trolley in the inbound and outbound method of the present invention.

[0024] In the figures above, reference signs indicate respectively:

[0025] 10-warehousing system; 20-ground; 30-worker; 50-sorting station; 60-mobile robot maintenance station;

[0026] 100-multi-layer shelf; 110-channel support frame; 120-multi-layer rack; 111-support member; 112-auto-guide trolley passage space; 113-cache space; 114-upright column; 116-movable bracket;

[0027] 200-auto-guided trolley; 200a-unloaded auto-guided trolley; 200b-auto-guided trolley carrying an item (a standardized container or a movable bracket); 210- hoisting platform;

[0028] 300-stacking vehicle; 310- lifting platform; 320-grabbing component;

[0029] 400-standardized container; 410-matching component; 420-storage space; 430-docking member;

[0030] 11-shelf row; 12-stacking row laneway; 13-shelf-laneway combination; 21-trolley-special row laneway; 22-general row laneway; 23-row channel; 31-shelf column; 32-column laneway; 33-column channel;

[0031] 70a-first-type cell; 70b-second-type cell; 70c-third-type cell; 70d-fourth-type cell.

Detailed Description of the Preferred Embodiments

[0032] The technical solutions in the embodiments of the present invention will be clearly and completely described with reference to the drawings in the embodiments of the present invention. Obviously, the embodiments described are only part of the embodiments of the present invention rather than all of the embodiments. Based on the embodiments of the present invention, all other embodiments obtained by those of ordinary skill in the art without inventive skill, are within the scope of protection of the present invention.

[0033] The same parts therein are indicated by the same reference signs. It should be noted that, the words used in the description below, “front,” “back,” “left,” “right,” “up,” and “down,” refer to the directions in figures, and the words, “bottom” and “top,” “inside” and “outside,” each refer to the direction toward or away from the geometric center of a specific part.

[0034] Embodiment 1:

[0035] As shown in FIG. 1, Embodiment 1 of the present invention provides an unmanned warehousing system based on mobile robots and cache spaces and an inbound and outbound method, involving a sorting system for warehousing. The warehousing system 10 includes a dispatch control system not shown in the figure, a plurality of multi-layer shelves 100, a plurality of auto-guided trolleys 200, a plurality of stacking vehicles 300, optional sorting workstations 50, etc. The auto-guided trolleys 200 and the stacking vehicles 300 are generally powered by built-in batteries.

[0036] Each auto-guided trolley 200 and each stacking vehicle 300 communicate with the dispatch control system via a wireless communication network. The auto-guided trolley 200 and the stacking vehicle 300 rely on their own sensors, such as a laser radar, a visual sensor, a magnetic wire reader, etc., and use navigation signs arranged in a warehouse, such as reflective bars, QR codes, RFID patches, etc., to realize automatic movement and positioning, such as QR codes affixed on the ground and shelves. The plurality of auto-guided trolleys 200 cooperate with the plurality of stacking vehicles 300 to pick up and transport standardized containers 400 on the shelves 100 to the sorting workstations 50, which is called an outbound process or a container delivery process, or to transport the standardized containers 400 from the sorting workstations 50 to the shelves 100 and store them on the shelves 100, which is called an inbound process or a container recovery process. At the sorting workstations 50, workers 30 or sorting arms not shown in the figure take out items to be outbound from the standardized containers 400 or place the items to be inbound into the standardized containers 400. To show the distinction, 200a represents

unloaded auto-guided trolleys 200, and 200b represents auto-guided trolleys 200 carrying the standardized containers 400.

[0037] Shelves are placed in rows and columns to improve the plot ratio. In general, a plurality of modular shelves 100 are horizontally connected into a shelf row 11, and a stacking row laneway 12, which is mainly for stacking vehicles 300 to travel and operate and occasionally for auto-guided trolleys 200 and workers to pass through, is provided in front of each shelf row 11. Two shelf rows are usually placed face to face to share a stacking row laneway 12 in the middle thereof. The combination of the stacking row laneway 12 and all the shelf rows 11 facing the row laneway is defined as a shelf-laneway combination 13.

[0038] Generally speaking, two adjacent shelf-laneway combinations 13 preferentially adopt a back-to-back layout to improve the plot ratio. However, it is not absolute. A laneway such as a relatively narrow trolley-special row laneway 21 not shown in the figure may also be spared in the middle of the adjacent shelf-laneway combinations 13 to facilitate trolleys to pass through at a high speed. Furthermore, general row laneways 22 are reserved between a shelf-laneway combination 13 and the walls of the warehousing system 10 for auto-guided trolleys 200 and stacking vehicles 300 to travel or park.

[0039] Furthermore, shelves aligned in a longitudinal direction are defined as a shelf column 31. In a row direction, several shelf columns are arranged as a column laneway 32, mainly for auto-guided trolleys 200 and stacking vehicles 300 to run in a column direction. The width and quantity of column laneways 32 depend on actual situations. Generally, several narrow column laneways may be designed for auto-guided trolleys 200 to travel, but at least one column laneway is wide enough to ensure stacking vehicles 300 to travel from one stacking row laneway 12 to another stacking row laneway 12.

[0040] In FIG. 1, the thin lines and solid arrows above or in front of auto-guided trolleys 200 indicate the current paths or directions of the auto-guided trolleys, and the thick lines and solid arrows in front of stacking vehicles 300 indicate the current paths and target positions of the stacking vehicles. It can be seen from the figure that stacking vehicles 300 can travel to other row laneways through column laneways 32. The absence of arrows in front of auto-guided trolleys 200 and stacking vehicles 300 generally means working in place or on standby. The dotted line displayed on the center line of each shelf row is used to indicate the row channel 23 for auto-guided trolleys 200 under the shelf, which is a path parallel to the stacking row laneway 12. In addition, some thin lines without arrows in the figure are used to indicate walking paths commonly used by auto-guided vehicles 200.

[0041] At sorting sites, auto-guided trolleys 200 usually wait in place after transferring standardized containers 400 to sorting workstations 50 until the sorting workstations 50 return the sorted standardized containers 400, and then the trolleys transport the standardized containers 400 back to the corresponding shelves 100.

[0042] In addition, the warehousing system 10 also includes mobile robot maintenance stations 60 for the repair and maintenance of auto-guided trolleys 200 and stacking vehicles 300, etc. The warehousing system 10 is also provided with a plurality of charging piles not shown in the figure,

allowing auto-guided trolleys and stacking vehicles to be charged nearby when the power is insufficient.

[0043] As shown in FIGS. 2-3, above shelves 100 are multi-layer racks 120, with each layer divided into several parts. The figure shows two storage compartments, each storing one standardized container 400, which refers to storage baskets, boxes, and stack plates whose size meets a certain size requirement. Containers 400 usually have items inside but may also be empty to store items. A stacking plate or bracket with a longitudinal groove not shown in the figure may be placed in advance on the storage compartment to facilitate stacking vehicles 300 to grab containers 400 and other items. The placement position of a standardized container 400 on a shelf 100 is generally not on the central axis of the shelf but closer to stacking row laneways 12 because the width of the standardized container 400 is less than that of the shelf, which reduces the overturning moment of stacking vehicles 300 in picking up and placing items, improving the lateral stability of stacking vehicles while shortening the time of picking and placement.

[0044] Several modular channel support frames may be mounted below a shelf 100. In the figure, two modular channel support frames 110 are mounted. The channel support frames may be a modular mechanical structure independent from the shelf or part of a custom shelf. Support members 111 are mounted on upright columns 114 of each channel support frame 110. Generally speaking, the height of a trolley is about 250 mm, and support members 111 may be placed at positions on the upright columns 114 that are slightly higher than the trolley.

[0045] Support members 111 divide the space inside channel support frames 110 into an auto-guided trolley passage space 112 and a cache space 113 for docking standardized containers, wherein each cache space 113 may dock one standardized container 400, and standardized containers 400 can also pass through between adjacent cache spaces. Therefore, cache spaces 113 are also the passage space for standardized containers 400. A threshold does not exist between a channel support frame 110 and the ground 20, allowing auto-guided trolleys to pass through in the auto-guided trolley passage space 112. A horizontal gap is spared between support members 111, making the auto-guided trolley passage space 112 connect the cache space 113 in the row direction of the shelf to form a row channel 23 in that direction to allow auto-guided trolleys 200 carrying customized containers 400 to travel.

[0046] A lifting platform 310 with a large lifting range is mounted above a stacking vehicle 300 and has a grabbing component 320 that can grab standardized containers 400 on different layers of a shelf 100. The width of a stacking vehicle 300 is slightly narrower than that of a stacking row laneway 12, and its grabbing components 320 can grab standardized containers 400 and items on shelves 100 on both sides of a stacking row laneway 12. At the lowest position of the lifting platform 310, grabbing components can place standardized containers 400 into cache spaces 113 on both sides. With a reasonably designed structural dimension of support members 111 of a channel support frame 110 and standardized containers 400, it is not difficult to realize the idea that an unloaded auto-guided trolley 200 can run through below grabbing components 320 of a stacking vehicle 300 when the grabbing components 320 extend into a cache space 113.

[0047] As shown in FIGS. 1-3, several stacking vehicles 300 travel in a straight line and operate along stacking row laneways 12, performing actions like positioning, lifting, and grabbing to transfer standardized containers 400 in a vertical direction between a rack 120 and a cache space 113. A stacking vehicle 300 is not limited to one row laneway but travels to other stacking row laneways 12 by entering column laneways 32 from a stacking row laneway 12. A stacking vehicle 300 may continue a next sorting task after placing standardized containers 400 into an idle cache space 113 under shelves on both sides of a stacking row laneway 12 without waiting for auto-guided trolleys 200. Meanwhile, a plurality of auto-guided trolleys 200 travel in stacking row laneways 12, column laneways 32 and auto-guided trolley passage spaces 112 inside channel support frames, performing actions like positioning, hoisting, dropping, and carrying to transfer standardized containers 400 between cache spaces 113 and sorting workstations 50 or from one cache space 113 to another cache space 113 to reduce blockage. It is easy to draw that an auto-guided trolley 200b with standardized containers can travel on row channels 23 as long as the cache space 113 ahead is not occupied.

[0048] An auto-guided trolley 200 is a small mobile robot with auto-navigation ability, usually driven by a differential gear train, and equipped with four universal wheels. Such a trolley is characterized by a small size and a low cost. In addition, trolleys are generally designed in symmetrical so that they can turn in place. However, the specific driving form is not limited thereto, and may also be an omnidirectional drive wheel train and others. As shown in FIG. 1, in this embodiment, an auto-guided trolley 200 preferentially travels in column laneways 32 and auto-guided trolley passage spaces 112, never entering stacking row laneways 12 to avoid path conflicts with stacking vehicles 300.

[0049] An auto-guided trolley 200 also has a short-stroke hoisting platform 210, which may be lowered down for trolleys slipping into a position directly below standardized containers 400 in channel support frames 110. The hoisting platform 210 rises to cooperate with matching components 410 at the bottom of standardized containers 400 and hoists up the standardized containers 400 so that they are separated from support members 111, and the standardized containers 400 can thus move along with trolleys 200 and travel along the shelf row or column direction. To further improve the alignment accuracy of the hoisting platform 210 and the bottom of a standardized container 400, a QR code may be affixed on the bottom of the standardized container 400, and a camera is mounted on the hoisting platform 210, so that a positioning deviation is calculated through a visual processing algorithm, and accurate alignment is achieved by adjusting the position of an auto-guided trolley or the hoisting platform.

[0050] FIG. 4 is a schematic diagram of a typical fixed structure support member on a channel support frame in Embodiment 1 of the present invention. The support member 111 on the channel support frame 1 generally uses a metal plate fixed to an upright column 114, and standardized containers 400 may be docked above the metal plate. The channel support frames in FIGS. 4a and 4b are designed to provide a cache space for a single standardized container 400. The channel support frames in FIGS. 4c and 4d are designed to provide a cache space for two standardized containers 400. However, evidently, the combination of these channel support frames may provide

a cache space for more standardized containers. For the channel support frames shown in FIGS. 4a and 4c, auto-guides trolleys 200b carrying standardized containers can move in the row and column directions; while for the channel support frames shown in FIGS. 4b and 4d, auto-guided trolleys 200b carrying standardized containers can only move in the row direction parallel to the long metal plate. The advantage of the solutions shown in FIGS. 4b and 4d is that the rigidity of channel support frames can be improved. However, path planning directions for auto-guided trolleys are less than that those of the solutions shown in FIGS. 4a and 4c. Therefore, the solutions can be selected according to actual needs. Furthermore, to keep a good positioning accuracy when the standardized container is docked, some additional position-limiting components not shown in the figure are usually provided on the metal plate, such as bumps or grooves matching the bottom shape of the standardized container.

[0051] The standardized containers 400 in this embodiment are a variety of storage baskets, boxes, stacking plates, brackets, and the like, which can be placed into cache spaces 113. FIG. 5 is a schematic diagram of three typical types of standardized containers 400 that can be placed on the support members 111 in Embodiment 1 of the present invention from a top view and a horizontal view. Specifically, FIG. 5a is a storage basket, a deformation of the standardized containers 400 in FIGS. 2-3, with the docking member on the flange on the side of the container. FIG. 5b is a typical stacking plate with a groove on the upper surface to facilitate a fork to pull out after putting items down. FIG. 5c is a lightweight bracket above which items are generally not stacked. It is used to hold other containers unable to dock separately, and bottom corners thereof can be docked on support members 111. These typical standardized containers have the following basic characteristics: matching components 410, which can be connected with the hoisting platform 210 of an auto-guided trolley, are arranged at the bottom, and usually located at the bottom center. The working form of the matching components 410 includes pin-hole matching, electromagnet adsorption, mating based on anti-slip pads or devil pastes, etc. For instance, the bottom of a standardized container 400 has a tapered counterbore, and the corresponding position at the top of the hoisting platform 210 has a tapered protrusion. The counterbore and the protrusion form a pin-hole matching when aligned with each other. Also, for example, patches are embedded at the bottom of a standardized container 400, and an electromagnet is mounted at the corresponding position on the top of the hoisting platform 210. Inside or above a standardized container 400 is a storage space 420 in which items can be placed. Around or below a standardized container 400 is a necessary docking member 430 for support members 111 to be docked thereon. A standardized container 400 should also have a grabbed component or structure (not shown in the figure) for being grabbed by the grabbing components 320 of a stacking vehicle 300 depending on the working pattern of grabbing components 320, depending on the working form of the grabbing components 320. For instance, two wooden strips can be placed in advance at the position on a shelf where standardized containers 400 are placed if the grabbing components 320 of a stacking vehicle pick through forks, and iron sheets can be embedded on the side of a standardized container if the grabbing components 320 adopt electromagnet adsorption.

[0052] FIG. 6 is a schematic structural diagram of stacking vehicle grabbing components 320 that pick, via forks, standardized containers on both sides in Embodiment 1 of the present invention. The function of picking via forks on both sides is necessary for commercialized narrow-lane stacking vehicles with many conventional design options available. The figure presents a relatively simple solution to illustrate that stacking vehicles 300 can take out standardized containers 400 from a shelf on either side of a stacking row laneway 12 and then place them on a shelf on the opposite side, not limiting the present invention. FIG. 6a is a schematic structural diagram of a grabbing component 320 in a retracted state, wherein a fork 321 that can extend to the right and a fork 322 that can extend to the left are above the grabbing component. Below both forks is a motor-driven linear moving module, where the fork 322 has an additional small-stroke lifting device 323, including 2 drive-motors 3231 and two sets of scissors-type telescoping mechanisms 3232. The drive-motors 3231 may raise or lower the scissors-type lifting mechanism 3232 through a speed reducer and a screw drive. As shown in FIG. 6b, the fork 321 may extend to the right when the small-stroke lifting device 323 lowers down and to the left when the small-stroke lifting device 323 rises. In practice, electromagnet and others may also be used to help a stacker grabbing component pick standardized containers on both sides. In detail, iron sheets may be fixed on the side of a standardized container 400 and an electromagnet sucker may be provided on a grabbing component. The standardized container 400 is adsorbed when the electromagnet sucker is powered and released if the electromagnet sucker is out of power. Further, grabbing components may also be designed into a combination of forks and electromagnets, or the like.

[0053] In Embodiment 1, stacking vehicles 300 and auto-guided trolleys 200 use the standardized container cache space 113 of a channel support frame 110 in a time-shared manner to improve the inbound and outbound efficiency of standardized containers 400. Various simple and complex strategies can be comprehensively adopted.

[0054] A simple strategy refers to setting, in advance, fixed sections of a line of cache spaces, respectively for inbound and outbound processes, and using the cache spaces in a time-shared manner, including but not limited to the following strategies:

[0055] Strategy 1: The cache space under the same shelf row is divided into left and right sections for inbound and outbound processes of the standardized containers 400, respectively, where the right half of the cache space is used to deliver standardized containers 400 and the left half is used to recover standardized containers 400. Both delivery and recovery queues adopt the rule of placing standardized containers 400 sequentially from the right to the left end. If an auto-guided trolley 200 entering from the leftmost end is an unloaded auto-guided trolley 200a, it will first hoist and transport the standardized container 400 at the rightmost end, and if the trolley is an auto-guided trolley 200b carrying standardized containers 400, it will first deliver the container 400 to an idle cache position of the recovery queue in the foremost. Then, the trolley drops the standardized containers 400 before travelling to a position below the standardized containers 400 to be outbound at the rightmost end of the delivery queue. After that, the lifting platform is raised to take the standardized containers 400 away. If there is not any standardized container 400 to be

outbound at the right end, the trolley 200 waits or continues to move forward to other shelves that needs to be outbound.

[0056] Strategy 2: The cache space under the two rows of shelves in a shelf-laneway combination is used for inbound and outbound processes of the standardized containers 400, respectively. For instance, a stacking vehicle 300 places from right to left the standardized containers 400 to be delivered for sorting in the cache space 113 on one side of a stacking row laneway 12, and an auto-guided trolley 200 places from left to right the standardized containers 400 to be recovered for the inbound process in the cache space 113 on the other side. The auto-guided trolley 200b carrying the container to be inbound may continue to run to the cache space on the other side for delivery after placing the standardized container 400 in the cache space on one side.

[0057] The simple strategies are reliable and avoid possible motion interference between the grabbing components 320 of a stacking vehicle 300 and an auto-guided trolley 200, but often in rather low efficiency. Other more complex strategies, including but not limited to the following, may be applied in practice:

[0058] Strategy 3: The cache space under the same shelf row is not divided into fixed sections, and stacking vehicles 300 and auto-guided trolleys 200b with items uses the idle cache space in a time-shared manner for inbound and outbound processes of the standardized containers 400 via one end out and one end in, the right end out and the left end in, or the right end in and the left end out. Stacking vehicles 300 are responsible for finding the nearest idle position without interference. For example, a stacking vehicle 300 places the standardized containers 400 removed from a shelf 100 in an appropriate idle position at the further left end of moving auto-guided trolleys 200b carrying items or waits for all the moving auto-guided trolleys 200b with items running through the current idle position. A plurality of unloaded auto-guided trolleys 200a enter under a shelf from the left end and lift and transport the standardized containers 400 for outbound at the right end of the queue; the lifting platform lowers down after the auto-guided trolleys 200b carrying the containers to be inbound deliver and place the standardized containers 400 first to and in an idle cache space at the right end of the queue. Then, the trolleys continue to move to a position below the standardized containers 400 to be sorted at the rightmost end before the hoisting platform rises again to take them away.

[0059] Potential collisions may occur since the stacking device and auto-guided trolleys carrying standardized containers need to use the cache space below shelf rows. In addition to running in a time-shared manner at the dispatch level, auto-guided trolleys 200 also run an obstacle avoidance algorithm to ensure safety and reliability. Generally speaking, stacking vehicle path planning has a higher priority. Therefore, auto-guided trolley path planning will be adjusted based on the information on stacking vehicle path planning. For instance, when an auto-guided trolley carrying standardized containers drives along the row channel below a shelf row and is about to enter the next channel support frame ahead, the auto-guided trolley confirms the absence of obstacles, such as other auto-guided trolleys or standardized containers, in the next channel support frame according to the information obtained via wireless communication and through its sensor system.

The information of periods and positions the grabbing components of the stacking device can reach and stay in the forward cache space obtained through wireless communication is compared with the information of periods and positions experienced by self when passing through the cache space ahead, resulting in the entrance to the next channel support frame if no interference occurs.

[0060] Embodiment 2:

[0061] FIG. 7 is a schematic diagram of typical fixed structure support members of channel support frames in Embodiment 2 of the present invention. For the channel support frame shown in FIG. 7a, standardized containers 400 may be docked above the support members and move in the row and column directions, which is characterized by more flexible auto-guided trolley path planning. For the channel support frame shown in FIG. 7b, standardized containers 400 can be docked above the support members but move only in the column direction parallel to the long metal plate, which is characterized in that the rigidity of channel support frames can be improved.

[0062] FIG. 8 is a schematic diagram of the principle of the whole item sorting system and auto-guided trolleys running along the column direction under the shelf in Embodiment 2 of the present invention. Different from Embodiment 1, the column channel 33 where auto-guided trolleys 200 travel in FIG. 7 passes through the stacking row laneway 12 for stacking vehicles 300 to run. Therefore, a path planning algorithm is needed to avoid the collision between auto-guided trolleys 200 and stacking vehicles 300 and ensure the high operation efficiency of the entire system.

[0063] Below is a basic planning algorithm. Obtain the information on the stacking vehicles and space occupancy on the route ahead from the dispatch control system when an auto-guided trolley 200 has reached the edge of a stacking row laneway 12 the trolley is about to enter. Then conduct an analysis, continuing the calculation if the auto-guided trolley passage space 112 and the cache space 113 opposite to the stacking row laneway 12 allow the trolley to enter to determine whether the time for passing through the stacking row laneway 12 is intersected with the time for stacking vehicles 300 to running through this section of the row laneway. Move forward if there is no intersection. Otherwise, run the algorithm above again after waiting for some time. The algorithm requires a stacking vehicle 300 to release its path planning in the incoming few seconds to the dispatch control system in advance. The auto-guided trolley 200 has more opportunities to cross the row laneway since it takes only a few seconds to pass through the stacking row laneway 12, and the stacking vehicle 300 does not occupy and pass through the position for a relatively long time. The whole system can operate with higher efficiency.

[0064] After the auto-guided trolley 200 enters the opposite auto-guided trolley passage space 112, the next step is based on the carrying of standardized containers and the occupancy of the cache space ahead. For example, the trolley transports containers if the cache space 113 in front has standardized containers 400 to be shipped and the trolley is empty. The trolley puts the containers in the cache space 113 if the trolley carries containers before moving forward one space and hoisting and delivering the standardized containers 400 in the forward space to the next position.

[0065] The embodiment is characterized by a simple dispatch algorithm without setting too many column laneways 32, especially suitable for a warehouse that has fewer rows but longer shelves.

[0066] Embodiment 3:

[0067] FIG. 9 is a schematic diagram of the principle of the whole item sorting system and auto-guided trolleys running along the row direction on the trolley-special row laneway and under the shelf in Embodiment 3 of the present invention. The embodiment generally adopts the same fixed structure support members shown in FIG. 7a as in Embodiment 2.

[0068] Different from Embodiment 2, the embodiment adds several trolley-special row laneways 21 between two shelf-laneway combinations 13. In FIG. 8, one trolley-special row laneway 21 is added, and auto-guided trolleys 200 enter the laneway from one end in turn and turn in place after reaching a designated shelf column. Then, the trolleys enter the corresponding column channel 33. The counterclockwise and clockwise arrows on a trolley indicate the trolley is turning in the position toward the column channel 33 to enter the cache space 113 below the shelf 100. In particular, a plurality of adjacent trolley-special laneways 21 are used to switch auto-guided trolleys to other trolley-special row laneways, making it easier to find a shorter driving path.

[0069] The benefit of this embodiment lies in shorter column channels 33 for auto-guided trolleys 200, the less time and frequency for auto-guided trolleys crossing through stacking row laneways 12, and the higher turnover speed of auto-guided trolleys 200 than Embodiment 2, despite a reduction in the space for placing shelves, thus improving the operation efficiency.

[0070] Embodiment 4:

[0071] FIG. 10 is a schematic diagram of the principle of the whole item sorting system and auto-guided trolleys running along the row and column directions under the shelf in Embodiment 4 of the present invention. This embodiment generally adopts the fixed structure support members as shown in FIG. 7a.

[0072] As shown in FIG. 10, at the position where the dotted lines intersect, an auto-guided trolley 200 may switch between the row direction and the column direction, including the switch between trolley-special row laneways 21 and column channels 33 and between column channels 33 and row channels 23. Route switching can usually reduce blockage and shorten the turnover time. Switching the driving direction does not bring a problem to auto-guided trolleys because auto-guided trolleys 200 can be small enough to turn in the auto-guided trolley passage space 112. Moreover, standardized containers 400 can switch between the row and column directions in the cache space 113 of the channel support frame 110 as long as it is ensured that the standardized containers 400 keep away from the channel support frame 110 at a certain safe distance.

[0073] For example, an auto-guided trolley 200 is driven by the differential gear train. The equivalent diameter of the trolley 200 is less than the short side of the channel support frame 110. When the trolley 200 travels to the center of the channel support frame 110, the trolley 200 may turn in place without movement interference. The auto-guided trolley 200 carrying standardized containers 400 switches between the row and column directions along the traveling direction by

performing a series of actions, including dropping and docking the standardized containers on the support members, the trolley turning 90° in place, and hoisting the standardized containers.

[0074] For example, an auto-guided trolley 200 adopts the drive wheel train, including known forms like the omnidirectional drive wheel train, which keeps the trolley body still in place but switches the traveling direction between the row and column directions. For example, the omnidirectional drive wheel train composed of Mecanum wheels is adopted. When the trolley moves to the center of the channel support frame, the direction of the trolley body remains unchanged, but the moving direction is switched between the row and column directions by adjusting the speed of each Mecanum wheel.

[0075] For example, two sets of separate drive wheels mounted at an angle of 90° are adopted, and when one set of drive wheels is lowered and comes into contact with the ground, the other set is separated from the ground. Also, for example, a drive wheel train consisting of differential gear trains with vertical rotary shafts is adopted, each set of differential gear trains connected to an upper vehicle body by a bearing coaxial with a vertical rotary shaft thereof. When two wheels of each set of differential gear trains reversely rotate at an equal speed, the differential wheel changes its direction but does not produce horizontal thrust and torsion torque on the vehicle body. Therefore, the direction and position of the vehicle body will not change, and the differential wheel is turned by 90°. After turning, the switch between row direction and column direction is completed.

[0076] This embodiment is a general form of the previous three embodiments, allowing an auto-guided trolley to choose among all possible paths, which provides the dispatch control system with the maximum search space. The auto-guided trolley may also travel on row laneways as long as a safe distance is kept from stacking vehicles. However, the dispatch algorithm involved is relatively redundant. The dispatch algorithm is a method in which a space is used in a time-shared manner. Therefore, a method of space use in a time-shared manner applied by the present invention will be introduced after Embodiment 5. A discretized spatial unit, a cell, is introduced in FIG. 10 to explain the method above. The cells mainly include the following types: a first-type cell 70a, corresponding to the intersection of a row channel and a column channel; a second-type cell 70b, corresponding to the intersection of a stacking row laneway and a column channel; a third-type cell 70c, corresponding to the intersection of a trolley-special row laneway and a column channel; and a fourth-type cell 70d, corresponding to the intersection of a general row laneway and a column channel. Each cell is projected as a rectangle on the ground, and its midpoint is located in the intersection of a row axis and a column axis. The width of the cell on one side is the width of the column channel, and the width of the cell on the other side is the width of the row channel or row laneway where the cell is located. The cell concept can be applied to embodiments with missing column channels and row channels because it is assumed that column channels or row channels exist in these embodiments, but some channels are prohibited from being passed through.

[0077] Embodiment 5:

[0078] In Embodiments 1-4, the combination of a support member 111 and a standardized container 400 may be replaced by a movable bracket 116 with support legs, which provides a cache

space for items. The application of the movable bracket 116 mainly targets some relatively special user needs. For example, a shelf is too high to increase channel support frames, support members are not easily added to existing shelf columns, or items are not expected to be held in a storage basket or stacking plate to compress the height of a shelf layer, and the characteristics of a movable bracket, such as docking at any time, are expected to be utilized.

[0079] FIG. 11 shows one of the simplest structures of a movable bracket 116, a quadrangle table having four legs. However, the length, width, and height of the movable bracket are less than those of the channel support frame, and the height thereof is greater than that of an auto-guided trolley for the trolley to travel beneath. The top of the table board is generally designed with grooves, enabling the fork of a stacking vehicle to pull out after putting down items. The lower surface of the table board is provided with hoisted matching components, which, together with the hoisting platform 210 of an auto-guided trolley, may form a separable matching. The working form of the matching components includes pin-hole matching, electromagnet adsorption, mating based on anti-slip pads or devil pastes, etc. To enable a movable bracket to be more stably parked on the ground and maintain its position, paired matching components are usually mounted between table support legs and the ground, such as the following pin-hole fit, including a conical hole at the bottom of table support legs and a conical bulge on the ground.

[0080] A stacking vehicle 300 can directly place items taken out from a shelf into a movable bracket 116 because an additional standardized container is not used. On the other hand, a plurality of idle movable brackets need to be parked under the shelf as the readily available items cache space to make stacking vehicles 300 always have idle movable brackets 116 to place items. In this case, blockage happens frequently because auto-guided trolleys with movable brackets will encounter more movable brackets when passing through support channels. Therefore, auto-guided trolleys usually need to choose the path planning according to situations. There are four main path planning methods: a first path planning method is that a trolley travels in a row channel 23, a movable bracket it carries is first unloaded before removing the movable bracket in front; a second path planning method is that a trolley carrying a movable bracket enters a stacking row laneway 12 along which the trolley travels to finally enter a column laneway 32, which requires the coordination with stacking vehicle path planning to avoid collision with stacking vehicles; a third path planning method is that a trolley carrying a movable bracket enters a position below another shelf after running through a stacking row laneway 12; and a fourth path planning method is that a trolley-special row laneway 21 or a general row laneway 22 next to a shelf is utilized. The fourth planning method has the shortest route, but the involved row laneway needs to be reserved, causing a reduction in the available storage area of a warehouse. When the outbound process is performed, an auto-guided trolley 200 hoists a movable stand 111 in the cache space and moves to the row laneway outside the shelf-laneway combination along the row direction. When the inbound process is performed, the auto-guided trolley 200 delivers the movable stand 111 from the row laneway outside the shelf-laneway combination to the cache space. The main difference between this embodiment and Patent EP3170773 is that shelves are transversely connected to form shelf rows. The channel support frame under a shelf row provides row and column channels for auto-guided

trolleys carrying movable brackets so that the auto-guided trolleys carrying the movable brackets can enter or exit the shelf along the row or column channels and share the stacking laneway space with the stacking device.

[0081] Despite the simple structure and the easiness of implementation, this embodiment covers a large area, so it is usually combined with other embodiments.

[0082] Description of remarks

[0083] Below are some remarks about Embodiments 1-5:

[0084] In the top view of the unmanned warehousing system in Embodiments 1-5, all auto-guided trolleys 200 head in one direction. However, in practice, the trolleys can drive in two directions, mainly forward driving, because in actual deployment, for cost-saving consideration, only the front of trolleys has laser radar sensors, which can better actively avoid obstacles when driving forward. However, trolleys can be positioned accurately, so backward driving is also feasible. Two-way driving allows auto-guided trolleys to better plan routes, such as turning over a standardized container 400 between adjacent cache spaces, thereby improving the system efficiency.

[0085] In Embodiments 1-5, stacking vehicles are not limited to wheel stacking vehicles, and may be other mobile stacking devices, such as inverted stackers. An inverted stacker walks through a track mounted above a laneway, and the track connects the top of shelves on both sides of the laneway by means of metal structures, or hangs under a laneway ceiling where it is located, by means of metal rods. The embodiments listed above may be combined with each other on the premise of no contradictions. Those skilled in the art may combine the technical features in different embodiments based on the drawings and the explanations of the embodiments above.

[0086] Basic process of inbound and outbound method

[0087] Embodiments 1-5 adopt the charts of the basic flows of the inbound and outbound method shown in FIGS. 12-14. FIG. 12 is a chart of a basic workflow of a management terminal, FIG. 13 is a chart of a basic workflow of a stacking vehicle, and FIG. 14 is a chart of a basic workflow of an auto-guided trolley. The inbound and outbound method proposed by the present invention adopts such a working principle as space use in a time-shared manner. The details of the inbound and outbound method differ when using different spatial granularity. Generally speaking, the smaller spatial granularity, the higher efficiency. For example, two devices at a small distance pass through a cell in turn. However, for better understanding, an explanation is made by taking the cell in FIG. 10 in Embodiment 4 as the spatial granularity, and assuming that only one device can use one cell at one time.

[0088] At S602, the management terminal separately issues handling instructions to several specified stacking devices and several auto-guided trolleys according to actual needs. At S604, the management terminal receives space use applications submitted from the auto-guided trolleys and stacking devices in a warehouse. Next, at S606, the management terminal conducts an interference analysis by cells. Common interference scenarios include a situation where both stacking devices and auto-guided trolleys want to enter a channel support frame, a situation where auto-guided trolleys hope to enter a stacking row laneway temporarily, a situation where different auto-guided

trolleys need to enter the same cell, and so on. At S608, the management terminal issues corresponding instructions to corresponding devices according to interference analysis results, mainly including confirmation information, rejection information, and shift instructions. The device receiving the confirmation information can enter the corresponding cell, while the device receiving the rejection information waits for a certain period to apply again. At S610, the management terminal updates information on cell occupancy and reservation. S604 is usually performed asynchronously, so it is advisable to assume that the management terminal runs S606 every 100 ms and conducts an interference analysis of all the space use applications received during the previous 100 ms. When a plurality of devices apply for the right to use the same cell, the rule of “first come, first served” or “priority per higher grades” generally prevails. A cell is not allocated if it is occupied or reserved by a device or item until a signal of space release is submitted when the device or item leaves. However, in some cases, the management terminal may also send instructions to corresponding devices to ask them to leave or a shift instruction to an auto-guided trolley to move the item away. In some cases, the space use application submitted by a mobile device needs to include a set of connected cells. For instance, when an auto-guided trolley passes through a stacking row laneway, it is necessary to reserve the second-type cell 70b on the stacking row laneway and the first-type cell 70a opposite to the stacking row laneway. At S608, the management terminal sends the confirmation information to the auto-guided trolleys only when the two cells are free from interference.

[0089] At S702, a stacking device waits for a handling instruction from the management terminal. The handling instruction received by the stacking device from the management terminal includes stacking starting and ending positions of target items, standardized containers, or ordinary items, which further include information on the position of a shelf in a row laneway and the positions of a target item on a rack and a channel support frame. The stacking device travels automatically, and submits a space use application to the management terminal at S704 for entering n cells ahead. Here, n is an integer greater than 0. After the application is confirmed by the management terminal at S706, at S708, the stacking device is moved forward by n cells, and the forward direction is switched and the height of the lifting platform is adjusted as needed. Switching the forward direction means a switch between the row and column directions. S704-S708 are repeated until the shelf at the stacking starting position is located and aligned at S710. Then, grabbing components are aligned with the target items placed on the rack or in the channel support frame through the action of the lifting platform. At S712, it is determined whether the grabbing operation needs to extend into the channel support frame. If not, S720 is executed, including placing a container or an item on a rack at the end of an inbound instruction and picking up a container or an item from a rack at the start of an outbound instruction. If the grabbing operation needs to extend into the channel support frame, a space use application for entering the channel support frame is submitted to the management terminal at S730. After the application is confirmed by the management terminal at S732, S734 is executed, including extending grabbing components into the channel support frame at the start of an inbound instruction, picking up containers from support members or items from movable brackets, and extending grabbing components into the channel

support frame at the end of an outbound instruction, placing a container on a support member or an item on a movable bracket. Then, at S740, it is determined whether the current specified position is a starting or ending position. If it is the starting position, the stacking device travels automatically to the stacking ending position by repeating the steps from S704. If it is the ending position, it indicates the completion of the handling instruction, and the stacking device continues to execute a next handling instruction or waits in a standby state for a handling instruction.

[0090] At S802, an auto-guided trolley waits for a handling instruction from the management terminal. The type of the handling instruction includes at least outbound and inbound instructions, and usually further includes shift instructions, i.e., moving standardized containers or movable brackets in channel support frames to reduce blockage in row or column channels for improving the channel utilization. The content of the instruction includes transport starting and ending positions where a target item is located, and optional intermediate paths. To be specific, the transport starting and ending positions are the position of a channel support frame or outside shelves. An unloaded auto-guided trolley receiving an outbound handling instruction travels automatically, and submits a space use application for entering n cells ahead to the management terminal at S804. Here, n is an integer greater than 0, usually 1 or 2. The trolley runs along a given row channel, column channel, row laneway, or column laneway at S808 after the application is confirmed by the management terminal at S806. The trolley is moved forward by n cells and the forward direction is switched as needed. Switching the forward direction refers to a switch between the row and column directions. S804-S808 are repeated until the trolley is located at a specified position at S810, and actions are performed at S812. At this point, the auto-guided trolley raises the hoisting portion to be connected with a hoisted portion of the standardized container or the movable bracket to hoist the standardized container or the movable bracket if it is at the starting point of an outbound instruction or a shift instruction, i.e., the auto-guided trolley is now at a position under the items docked in the channel support frame at the transport starting position. At this point, the auto-guided trolley docks the standardized container on the support member of the channel support frame or the movable bracket on the ground by lowering the hoisting portion if it is at the ending portion of an inbound instruction or a shift instruction. The auto-guided trolley performs relevant actions according to sorting workstation requirements if it is at the ending point of an outbound instruction or the starting point of an inbound instruction, usually a sorting workstation. At S814, it is determined whether the current specified position is a starting or the ending point. If it is the starting point, the trolley travels automatically to the handling ending position by repeating the steps from S804. If it is the ending point, it indicates the completion of the handling instruction, and the auto-guided trolley continues to execute a next handling instruction, waits in a standby state for a handling instruction, or returns to a specified area. Generally speaking, the auto-guided trolley executing a shift instruction is an unloaded trolley. However, an auto-guided trolley carrying items may also perform a shift instruction after docking all the items it carries, and then hoist the docked items again when completing the instruction and continue to execute the original task.

[0091] It should be noted that, the above are only preferred embodiments of the present invention and are not used to limit the present invention. Any modification, equivalent replacement, and improvement, among others, within the spirit and the principle of the present invention shall be encompassed in the scope of protection of the present invention.

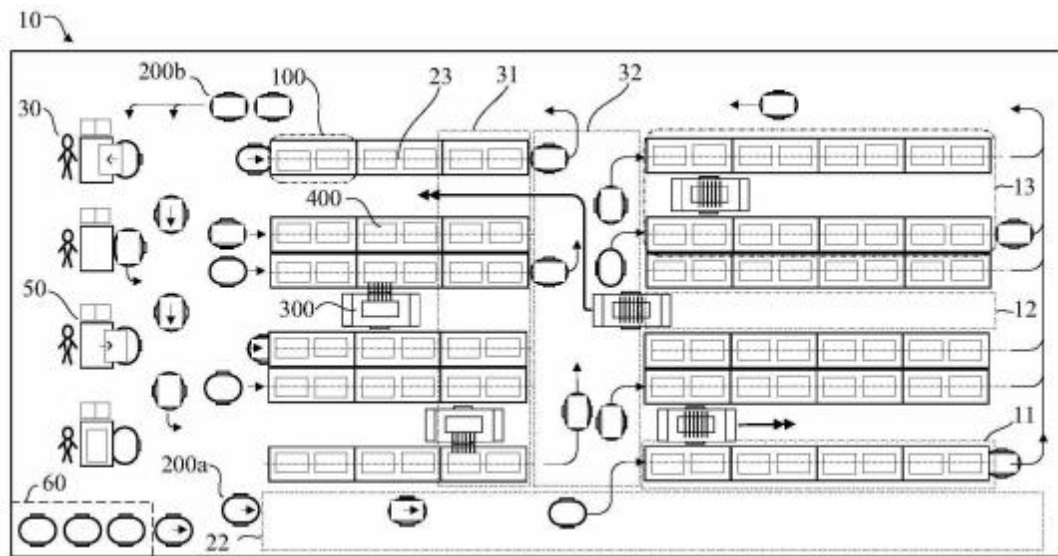


FIG. 1

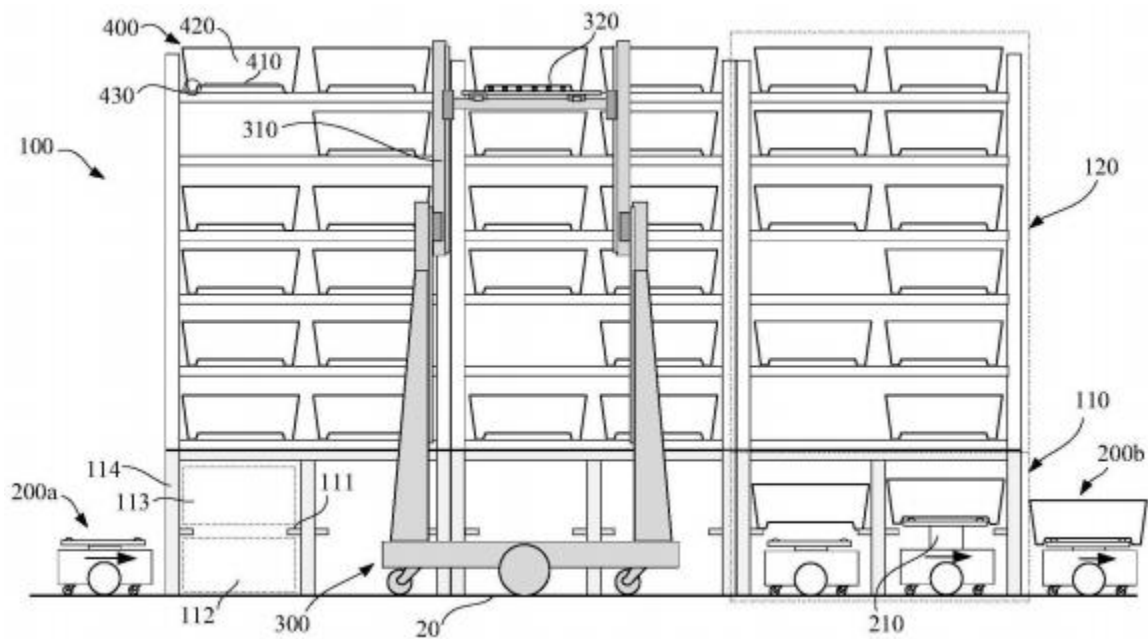


FIG. 2

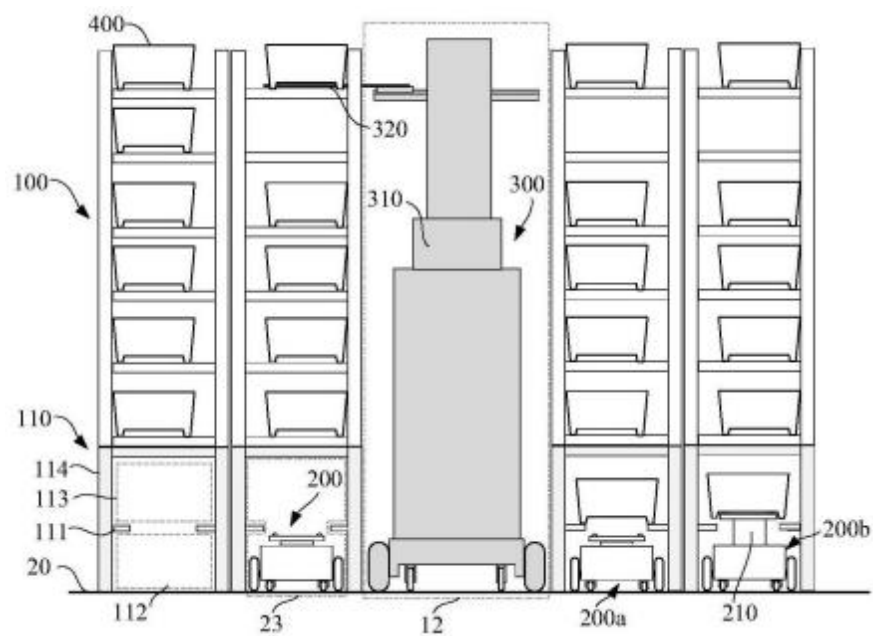


FIG. 3

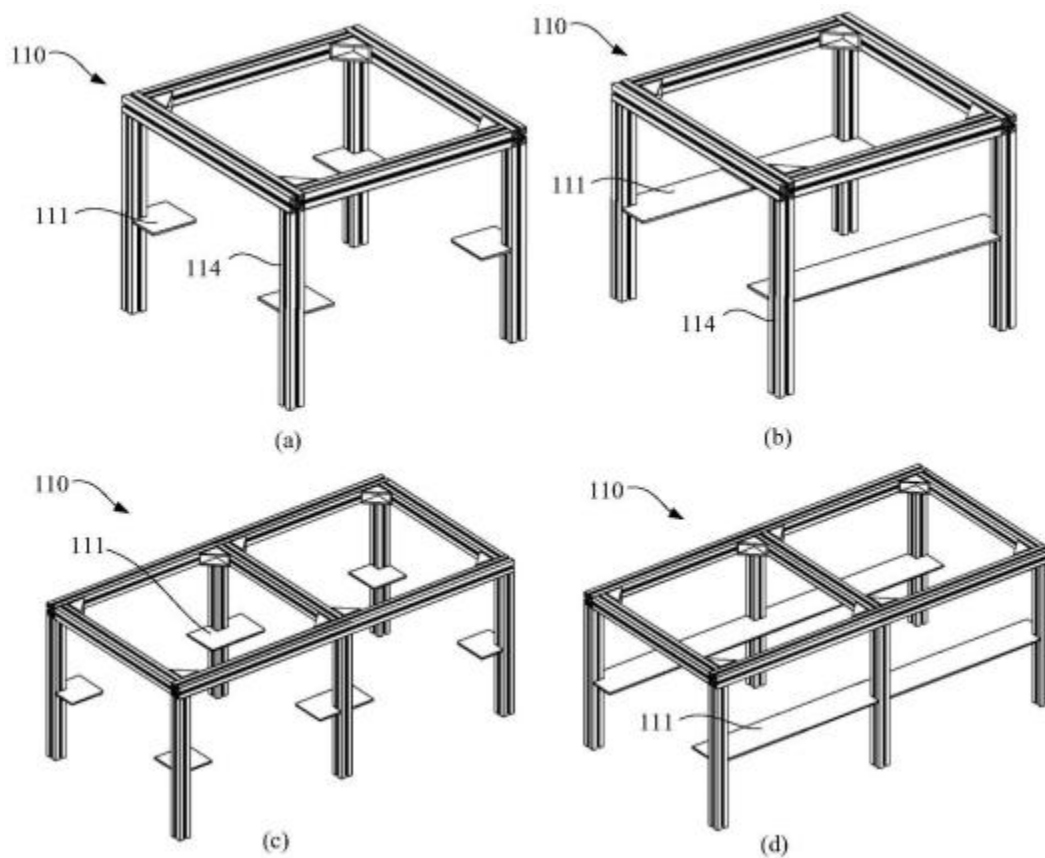


FIG. 4

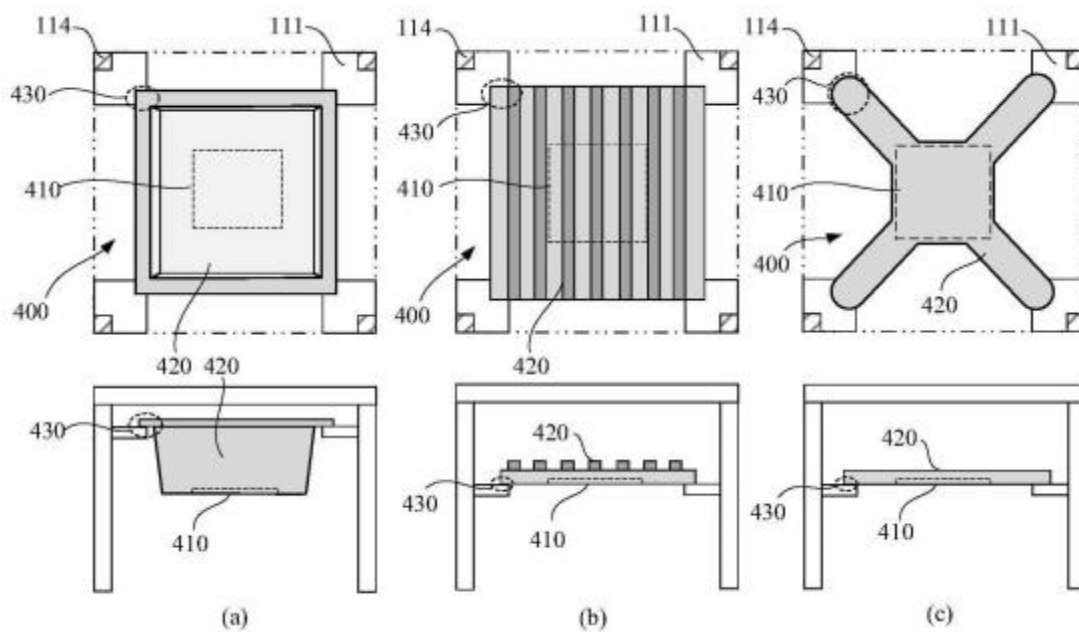


FIG. 5

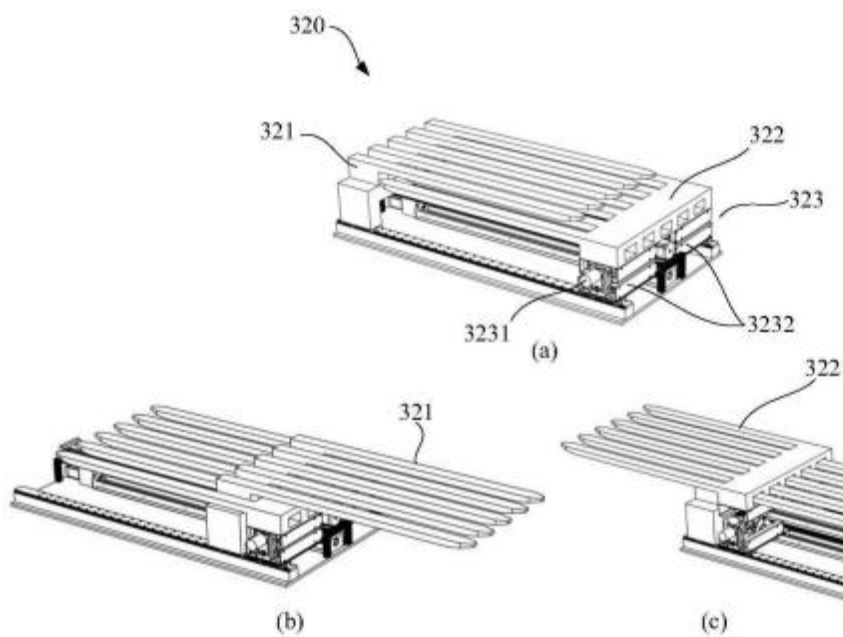


FIG. 6

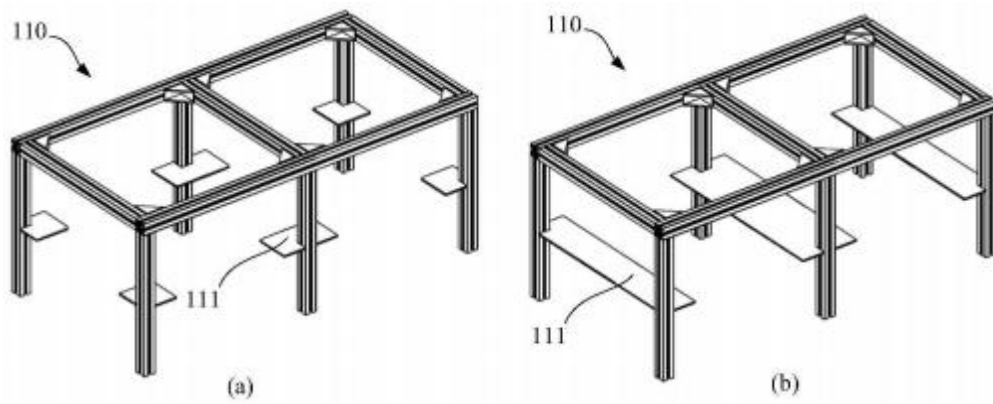


FIG. 7

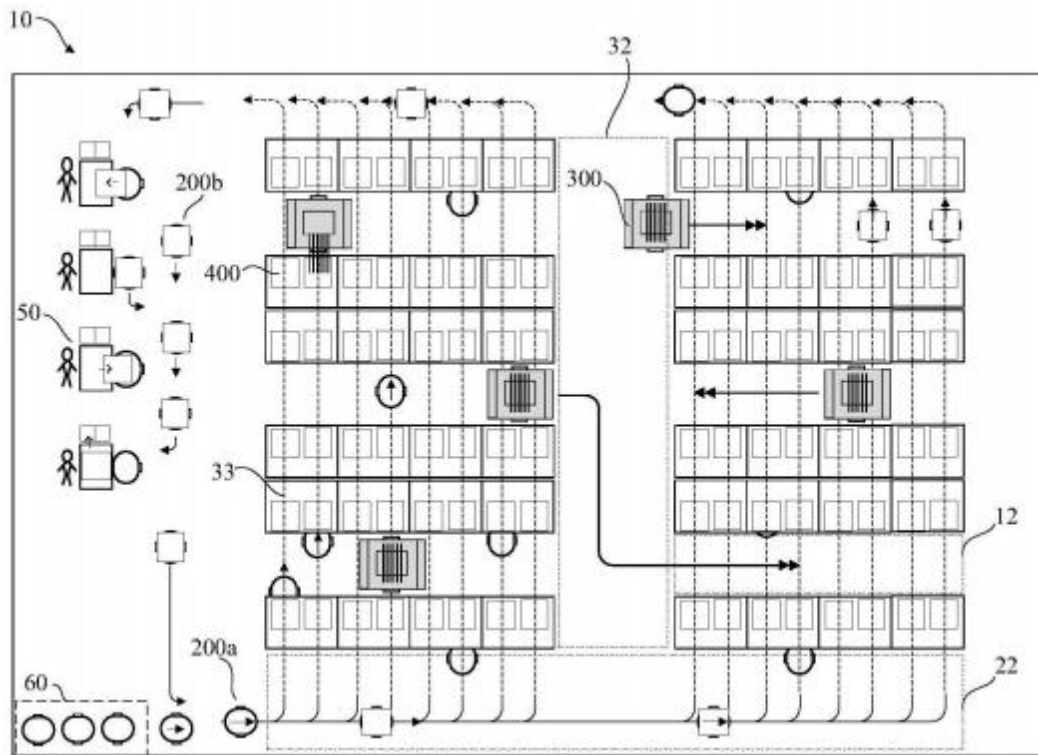


FIG. 8

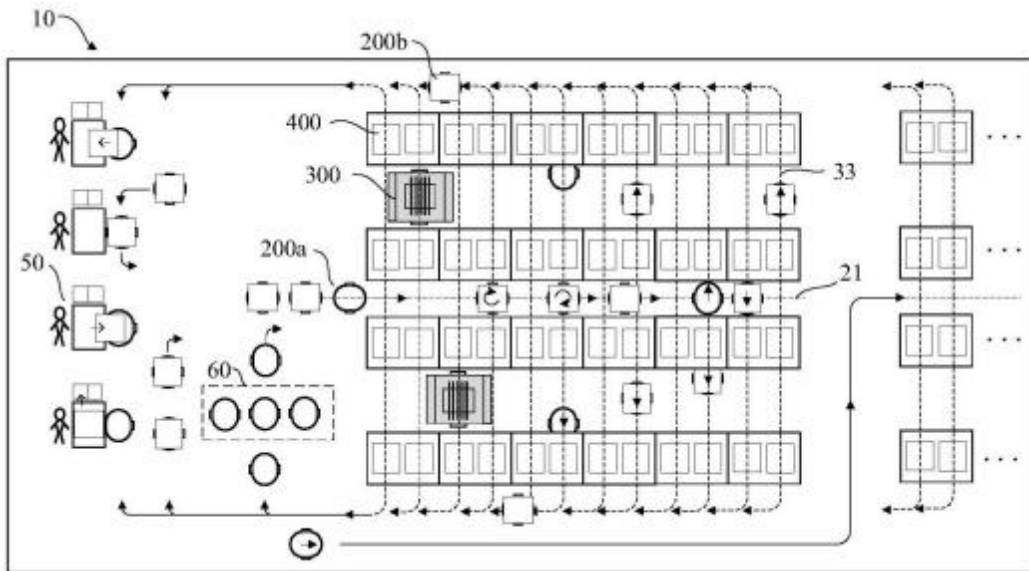


FIG. 9

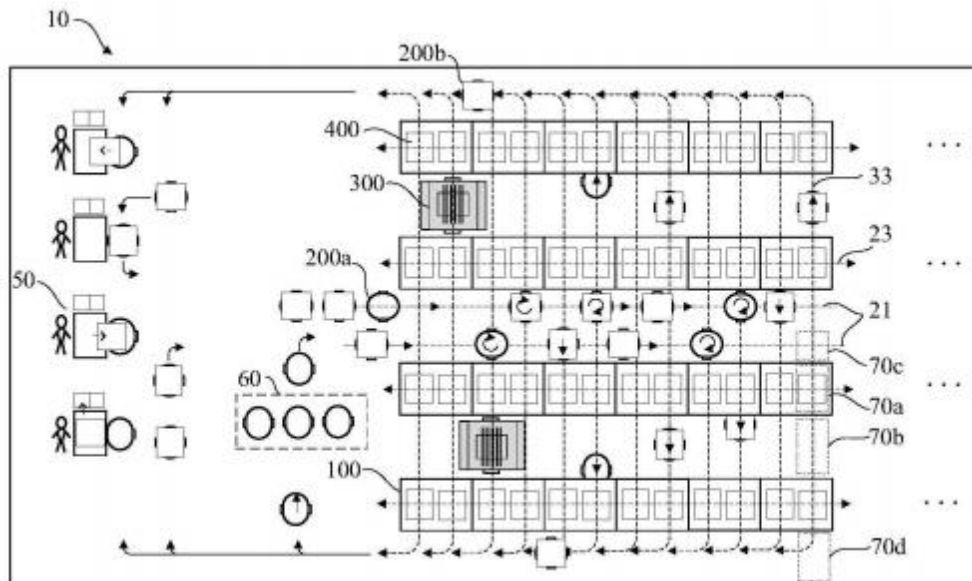


FIG. 10

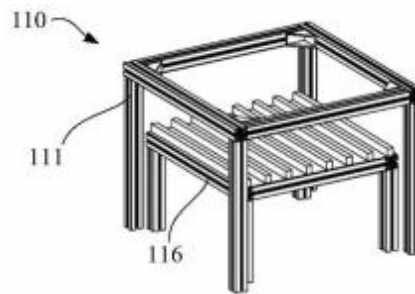


FIG. 11

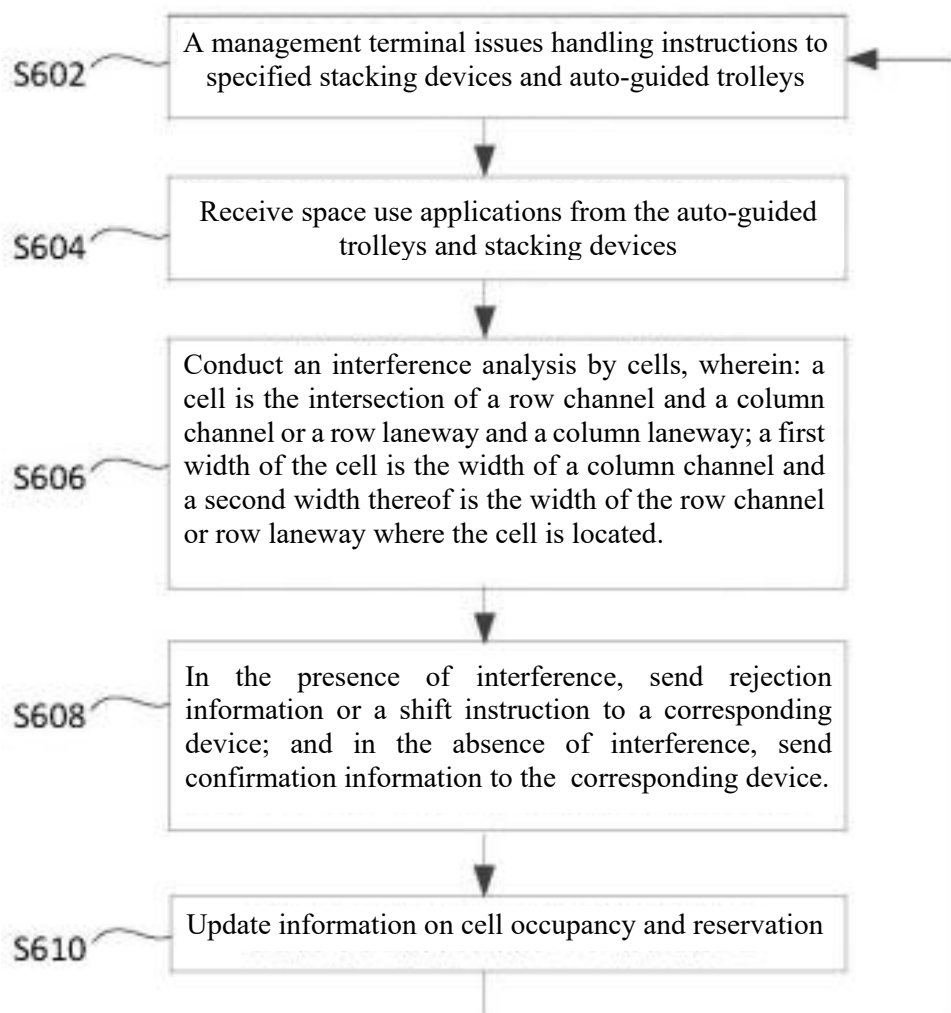


FIG. 12

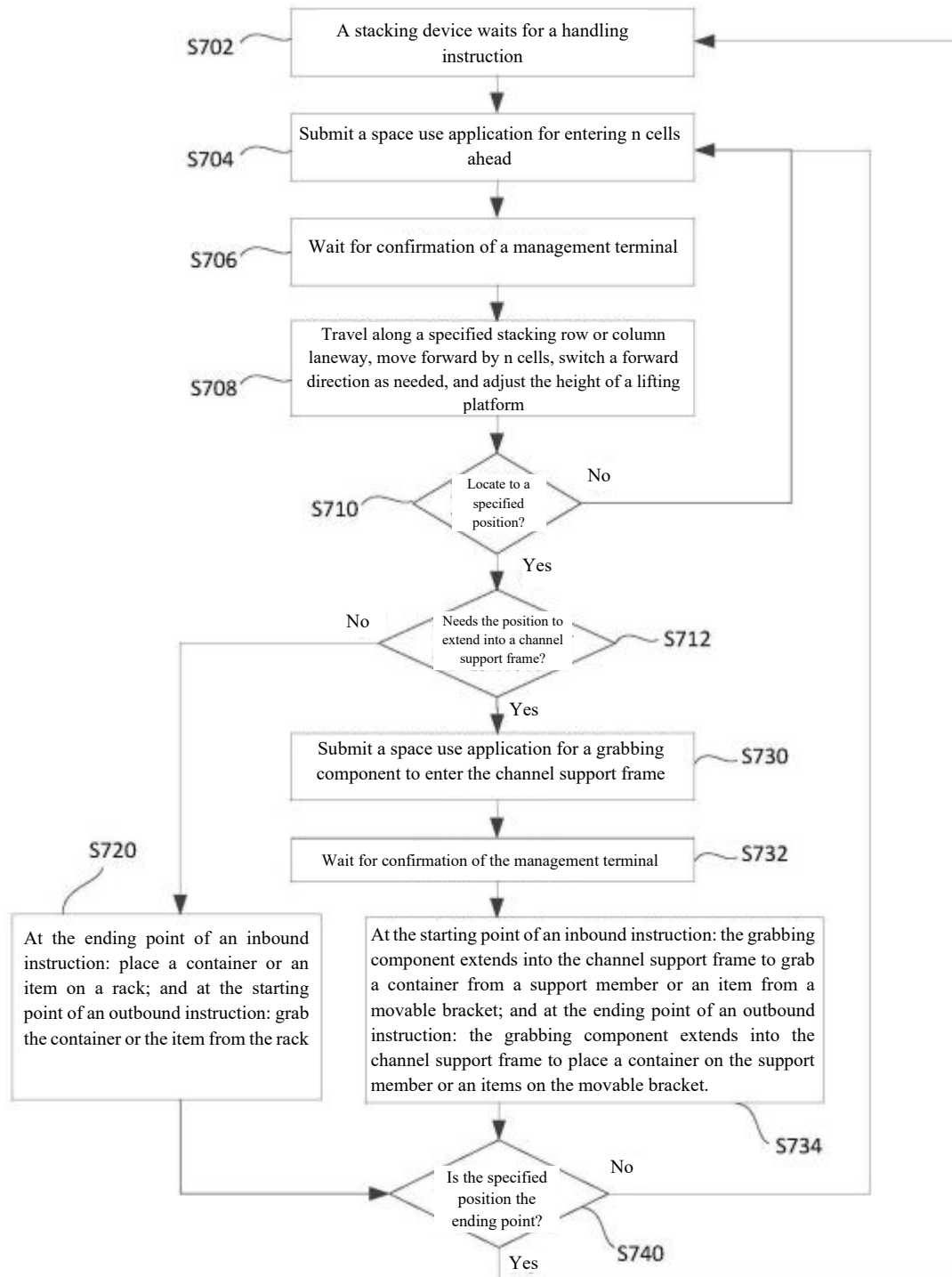


FIG. 13

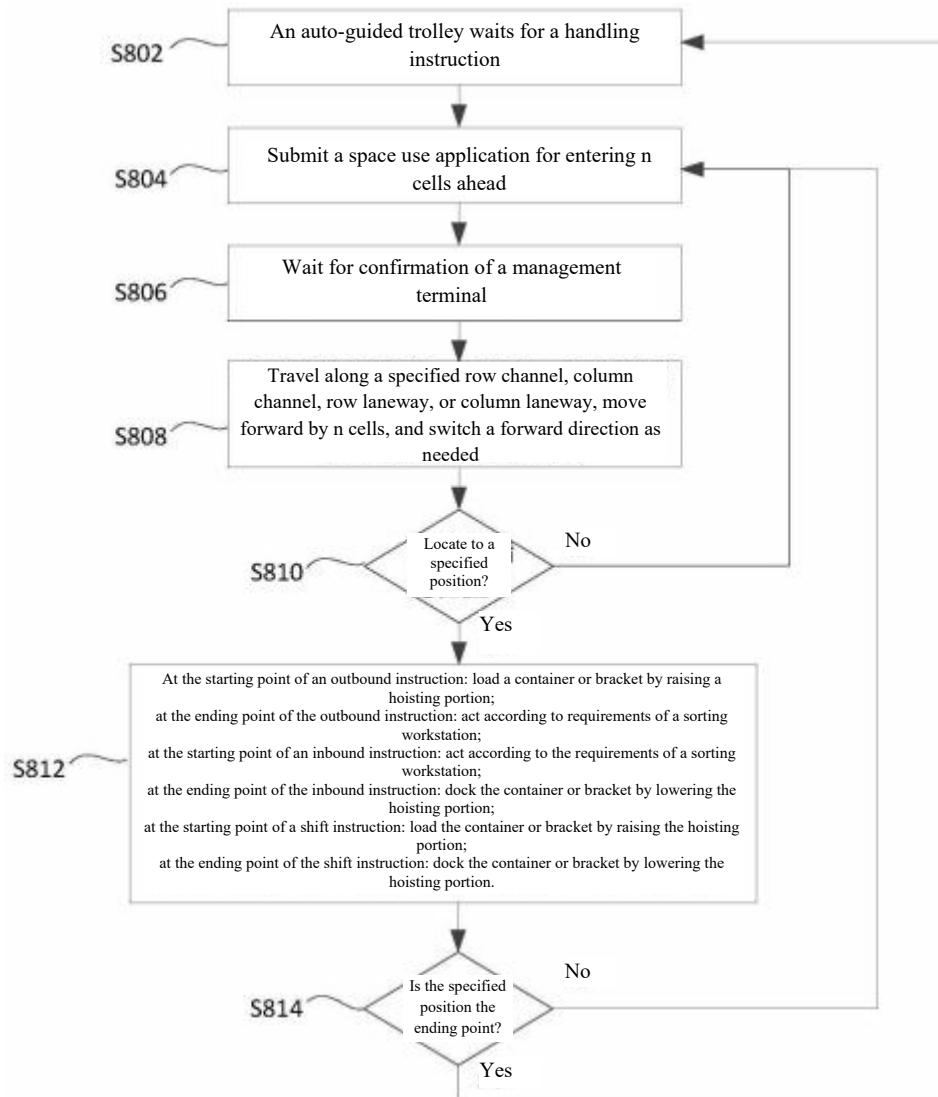


FIG. 14

TRANSLATOR DECLARATION

Date: April 27, 2024

To whom it may concern:

I, FANG CHEN, hereby declare as follows:

1. I personally prepare the attached translation from Chinese into English of the patent that is entitled "CN109987366A_Original_document_20240425202044."
2. The attached translation is, to the best of my knowledge, a true, full, and accurate translation of the attached Chinese document.
3. I am competent to perform this translation, because I have more than 19 years of experience as a professional Chinese-to-English patent translator.
4. I declare under the penalty of perjury under the laws of the United States that the foregoing is true and correct; and further declare that I am aware that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 1001 of Title 18 of the United States Code.



Signature

FANG CHEN

Print