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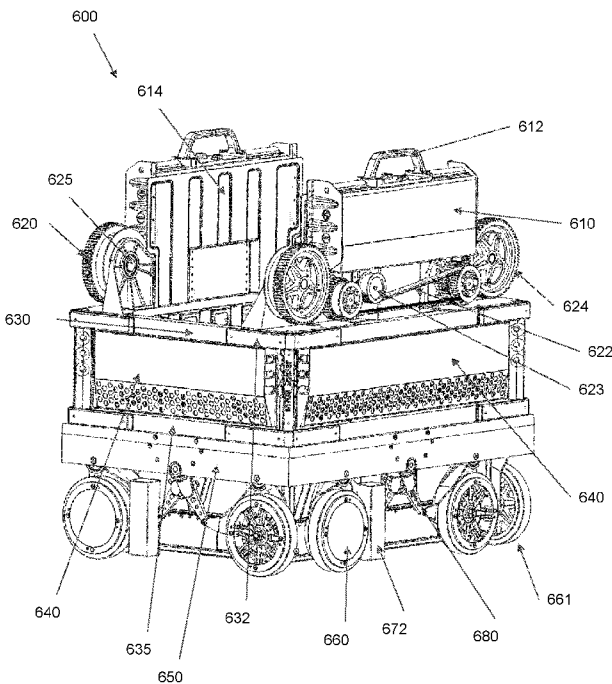


Figure 6

(57) Abstract: A load handling device (600) designed to operate on the top of a cubic automated storage and retrieval system (ASRS). The components which control the operation of the load handling device (600), for example, moving the load handling device on top of the ASRS, changing direction, lifting a container, etc are received in component modules (640). The component modules (640) are received on one or more of the exterior faces of the load handling device (600). The modular format allows component modules (640) to be replaced easily in the event of component failure.

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LOAD HANDLING DEVICE

The disclosure relates to a load handling device, and in particular to a robotic load handling device
5 which can be operated on a grid within a fulfilment centre.

Background

Grid-based automatic storage and retrieval systems are well known in the art. In such systems a
10 plurality of robotic load handlers operate on a horizontal grid structure, underneath which is
received a plurality of containers, arranged in a plurality of stacks. The containers are used to
hold products and the load handlers are adapted to retrieve containers from one of the plurality
of stacks and to deposit a container within one of the stacks. The load handlers may be routed
15 in an autonomous manner (or a semi-autonomous manner) on the grid but a wireless
communications system is required to transmit instructions to load handlers and to enable each
of the load handlers to communicate with a management system. The claimed apparatus,
methods, systems and computer programs are intended to provide improvements relating to
communications systems for use in an automated retrieval and storage system which uses a fleet
20 of robotic load handlers.

Summary

According to a first aspect of the present disclosure, there is provided a load handling device for
use in a storage system, the storage system comprising a first set of parallel tracks extending in
25 an X-direction, a second set of parallel tracks extending in a Y-direction transverse to the first set
in a substantially horizontal plane to form a grid pattern comprising a plurality of grid spaces and
a plurality of stacks of storage containers located beneath the tracks, and arranged such that
each stack is located within a footprint of a single grid space; the load handling device comprising:
one or more component modules, the component modules being releasably connected to an
30 exterior face of the load handling device.

Such an arrangement simplifies the maintenance of a load handling device. In the event of a
component failure then the component module housing that component can be disconnected and
removed from the bot. A replacement component module can then be fitted to the bot.

The one or more component modules may comprise at least one of: one or more processor circuits, one or more communications interfaces, one or more volatile data storage units or one or more non-volatile data storage units.

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In one example, the load handling device comprises four component modules, with one component module being received on each exterior face of the load handling device. The load handling device may comprise a plurality of component modules, each of the plurality of component modules being configured such that they are in communication with the other

10 component modules.

The load handling device may further comprise one or more power sources such that the or each component module receives power from the one or more power sources. The or each component module may comprise a power storage unit, the or each power storage unit being configured to

15 receive charge from the one or more power sources of the load handling device.

The load handling device may further comprise one or more antennae such that one or more component module is connected to an antenna such that the load handling device can communicate with a communications network

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According to a second aspect of the present disclosure, there is provided a storage system comprising: a first set of parallel tracks extending in an X-direction, and a second set of parallel tracks extending in a Y-direction transverse to the first set in a substantially horizontal plane to form a grid pattern comprising a plurality of grid spaces; a plurality of stacks of storage containers

25 located beneath the tracks, and arranged such that each stack is located within a footprint of a single grid space; at least one load handling device as described above, the at least one transporting device being arranged to selectively move in the X and/or Y directions, above the stacks on the tracks and arranged to transport a storage container. The storage system may further comprise a picking station arranged to receive a storage container transported by the at

30 least one transporting device and to transfer an item from the storage container into a delivery container.

Brief description of the drawings

The communication system will now be described in detail with reference to examples, in which:

- 5 Figure 1 schematically illustrates a storage structure and containers;
 Figure 2 schematically illustrates track on top of the storage structure illustrated in Figure 1;
 Figure 3 schematically illustrates load-handling devices on top of the storage structure illustrated in Figure 1;
10 Figure 4 schematically illustrates a single load-handling device with container-lifting means in a lowered configuration;
 Figure 5 schematically illustrates cutaway views of a single load-handling device with container-lifting means in a raised and a lowered configuration;
 Figures 6 to 10 shows a schematic depiction of a load handling device according to the
15 present disclosure;
 Figures 11 to 13 show schematic depictions of different examples of the structure(s) that form the frame of the bot;
 Figure 14 shows schematic depictions of an integrated drive module;
 Figure 15 shows a depiction of a flowchart showing the operation of a load handling device
20 according to the present disclosure; and
 Figure 16 shows a schematic depiction of the components which are received within a component module of the bot.

Detailed description of the drawings

- 25 The following examples represent the applicant's preferred examples of how to implement a communications system for use with robots in a warehouse but they are not necessarily the only examples of how that could be achieved.

- 30 Figure 1 illustrates a storage structure 1 comprising upright members 3 and horizontal members 5, 7 which are supported by the upright members 3. The horizontal members 5 extend parallel to one another and the illustrated x-axis. The horizontal members 7 extend parallel to one another and the illustrated y-axis, and transversely to the horizontal members 5. The upright members 3 extend parallel to one another and the illustrated z-axis, and transversely to the horizontal

members 5, 7. The horizontal members 5, 7 form a grid pattern defining a plurality of grid cells. In the illustrated example, containers 9 are arranged in stacks 11 beneath the grid cells defined by the grid pattern, one stack 11 of containers 9 per grid cell.

5 Figure 2 shows a large-scale plan view of a section of track structure 13 forming part of the storage structure 1 illustrated in Figure 1 and located on top of the horizontal members 5, 7 of the storage structure 1 illustrated in Figure 1. The track structure 13 may be provided by the horizontal members 5, 7 themselves (e.g. formed in or on the surfaces of the horizontal members 5, 7) or by one or more additional components mounted on top of the horizontal members 5, 7. The
10 illustrated track structure 13 comprises x-direction tracks 17 and y-direction tracks 19, i.e. a first set of tracks 17 which extend in the x-direction and a second set of tracks 19 which extend in the y-direction, transverse to the tracks 17 in the first set of tracks 17. The tracks 17, 19 define apertures 15 at the centres of the grid cells. The apertures 15 are sized to allow containers 9 located beneath the grid cells to be lifted and lowered through the apertures 15. The x-direction
15 tracks 17 are provided in pairs separated by channels 21, and the y-direction tracks 19 are provided in pairs separated by channels 23. Other arrangements of track structure may also be possible.

Figure 3 shows a plurality of load-handling devices 31 moving on top of the storage structure 1
20 illustrated in Figure 1. The load-handling devices 31, which may also be referred to as robots 31 or bots 31, are provided with sets of wheels to engage with corresponding x- or y-direction tracks 17, 19 to enable the bots 31 to travel across the track structure 13 and reach specific grid cells. The illustrated pairs of tracks 17, 19 separated by channels 21, 23 allow bots 31 to occupy (or pass one another on) neighbouring grid cells without colliding with one another.

25 As illustrated in detail in Figure 4, a bot 31 comprises a body 33 in or on which are mounted one or more components which enable the bot 31 to perform its intended functions. These functions may include moving across the storage structure 1 on the track structure 13 and raising or lowering containers 9 (e.g. from or to stacks 11) so that the bot 31 can retrieve or deposit
30 containers 9 in specific locations defined by the grid pattern.

The illustrated bot 31 comprises first and second sets of wheels 35, 37 which are mounted on the body 33 of the bot 31 and enable the bot 31 to move in the x- and y-directions along the tracks 17 and 19, respectively. In particular, two wheels 35 are provided on the shorter side of the bot

31 visible in Figure 4, and a further two wheels 35 are provided on the opposite shorter side of the bot 31 (side and further two wheels 35 not visible in Figure 4). The wheels 35 engage with tracks 17 and are rotatably mounted on the body 33 of the bot 31 to allow the bot 31 to move along the tracks 17. Analogously, two wheels 37 are provided on the longer side of the bot 31 visible in Figure 4, and a further two wheels 37 are provided on the opposite longer side of the bot 31 (side and further two wheels 37 not visible in Figure 4). The wheels 37 engage with tracks 19 and are rotatably mounted on the body 33 of the bot 31 to allow the bot 31 to move along the tracks 19.

The bot 31 also comprises container-lifting means 39 configured to raise and lower containers 9. The illustrated container-lifting means 39 comprises four tapes or reels 41 which are connected at their lower ends to a container-engaging assembly 43. The container-engaging assembly 43 comprises engaging means (which may, for example, be provided at the corners of the assembly 43, in the vicinity of the tapes 41) configured to engage with features of the containers 9. For instance, the containers 9 may be provided with one or more apertures in their upper sides with which the engaging means can engage. Alternatively or additionally, the engaging means may be configured to hook under the rims or lips of the containers 9, and/or to clamp or grasp the containers 9. The tapes 41 may be wound up or down to raise or lower the container-engaging assembly, as required. One or more motors or other means may be provided to effect or control the winding up or down of the tapes 41.

As can be seen in Figure 5, the body 33 of the illustrated bot 31 has an upper portion 45 and a lower portion 47. The upper portion 45 is configured to house one or more operation components (not shown). The lower portion 47 is arranged beneath the upper portion 45. The lower portion 47 comprises a container-receiving space or cavity for accommodating at least part of a container 9 that has been raised by the container-lifting means 39. The container-receiving space is sized such that enough of a container 9 can fit inside the cavity to enable the bot 31 to move across the track structure 13 on top of storage structure 1 without the underside of the container 9 catching on the track structure 13 or another part of the storage structure 1. When the bot 31 has reached its intended destination, the container-lifting means 39 controls the tapes 41 to lower the container-gripping assembly 43 and the corresponding container 9 out of the cavity in the lower portion 47 and into the intended position. The intended position may be a stack 11 of containers 9 or an egress point of the storage structure 1 (or an ingress point of the storage structure 1 if the bot 31 has moved to collect a container 9 for storage in the storage structure 1). Although in the

illustrated example the upper and lower portions 45, 47 are separated by a physical divider, the upper and lower portions 45, 47 may not be physically divided by a specific component or part of the body 33 of the bot 31.

5 To enable the bot 31 to move on the different wheels 35, 37 in the first and second directions, the bot 31 includes a wheel-positioning mechanism for selectively engaging either the first set of wheels 35 with the first set of tracks 17 or the second set of wheels 37 with the second set of tracks 19. The wheel-positioning mechanism is configured to raise and lower the first set of wheels 35 and/or the second set of wheels 37 relative to the body 33, thereby enabling the load-handling
10 device 31 to selectively move in either the first direction or the second direction across the tracks 17, 19 of the storage structure 1.

The wheel-positioning mechanism may include one or more linear actuators, rotary components or other means for raising and lowering at least one set of wheels 35, 37 relative to the body 33
15 of the bot 31 to bring the at least one set of wheels 35, 37 out of and into contact with the tracks 17, 19. In some examples, only one set of wheels is configured to be raised and lowered, and the act of lowering the one set of wheels may effectively lift the other set of wheels clear of the corresponding tracks while the act of raising the one set of wheels may effectively lower the other set of wheels into contact with the corresponding tracks. In other examples, both sets of wheels
20 may be raised and lowered, advantageously meaning that the body 33 of the bot 31 stays substantially at the same height and therefore the weight of the body 33 and the components mounted thereon does not need to be lifted and lowered by the wheel-positioning mechanism.

To remove a container 9 from the top of a stack 11, the bot 31 is moved as necessary in the X
25 and Y directions so that the container-gripping assembly 43 is positioned above the stack 11. The container-gripping assembly 43 is then lowered vertically in the Z direction to engage with the container 9 on the top of the stack 11. The container-gripping assembly 43 grips the container 9, and is then pulled upwards on the tapes 41, with the container 9 attached. At the top of its vertical travel, the container 9 is accommodated within the vehicle body and is held above the level of the
30 tracks. In this way, the load handling device 30 can be moved to a different position in the X-Y plane, carrying the container 9 along with it, to transport the container 9 to another location. The tapes 41 are long enough to allow the load handling device 30 to retrieve and place containers from any level of a stack 11, including the floor level. The weight of the vehicle may be comprised in part of batteries that are used to power the drive mechanism for the wheels 35, 37.

As shown in Figure 3, a plurality of load handling devices 31 are provided, so that each bot 31 can operate simultaneously to increase the throughput of the system. The system illustrated in Figure 3 may include specific locations, known as ports, at which containers 9 can be transferred into or out of the system. An additional conveyor system (not shown) is associated with each port, so that containers 9 transported to a port by a bot 31 can be transferred to another location by the conveyor system, for example to a picking station (not shown). Similarly, containers 9 can be moved by the conveyor system to a port from an external location, for example to a container-filling station (not shown), and transported to a stack 11 by the bots 31 to replenish the stock in the system.

Each bot 31 can lift and move one container 9 at a time. If it is necessary to retrieve a container ("target container") that is not located on the top of a stack 11, then the overlying containers ("non-target containers") must first be moved to allow access to the target container. This is achieved in an operation referred to hereafter as "digging". During a digging operation, one of the bots 31 sequentially lifts each non-target container 9a from the stack 11 containing the target container 9b and places it in a vacant position within another stack 11. The target container 9b can then be accessed by the bot 31 and moved to a port for further transportation.

Each of the bots 31 is under the control of a grid controller. Each individual container 9 in the system is tracked, so that the appropriate containers 9 can be retrieved, transported and replaced as necessary. For example, during a digging operation, the locations of each of the non-target containers is logged, so that the non-target containers can be tracked.

The system described with reference to Figures 1 to 5 has many advantages and is suitable for a wide range of storage and retrieval operations. In particular, it allows very dense storage of product, and it provides a very economical way of storing a huge range of different items in the containers 9, while allowing reasonably economical access to all of the containers 9 when required for picking.

It should be understood that it is necessary for messages to be transmitted to the bots. These may be short messages, for example an instruction to move a container from a first location to a second location, or the messages may be larger, for example an update to the computer code which is used to operate the bot or a component of the bot. Similarly, it may be necessary for the

bot to send messages to a central management system, for example to report operating parameter values, operating state reports etc. An example of a communications system which can be used is disclosed in the Applicant's international patent application WO 2015/185726.

5 Figures 6 to 10 show schematic depictions of a load handling device 600 according to the present disclosure: Figure 6 shows a perspective view of the load handling device; Figure 7 shows a side view of the load handling device on its long side; Figure 8 shows a side view of the load handling device on one of its short sides; Figure 9 shows a side view of the load handling device on the other short side; and Figure 10 shows a top view of the load handling device.

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The load handling device, or bot, 600 has a rectangular profile such that the footprint of the bot fits within a single grid cell of a storage cell on which it will be in operation. Thus, a bot in the central grid cell of a 3 x 3 grid cell array can be surrounded by a bot in each of the neighbouring eight grid cells without there being any interference between any of the adjacent bots.

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The bot comprises two batteries 610. Each of the batteries 610 are releasably received on a battery holder 614. The battery holders 614 (and thus a battery 610 attached thereto) are preferably located on the long edges of the bots. Each of the batteries may comprise a handle 612. The battery handle may enable the replacement of a discharged (or partially discharged) battery with a recharged battery. Such a battery replacement process may be performed manually or using an automated process, for example by the use of a device having a movable manipulator. Examples of battery exchange methods are disclosed in the Applicant's co-pending applications WO2023/017184 and PCT/EP2023/051832, the contents of which are herein incorporated by reference.

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It should be understood that the bot may operate using only a single battery, although this will reduce the time in between battery exchange. Alternatively, the bot may be provided with more than two batteries.

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As discussed above, the bot comprises a container lifting device. The container lifting device comprises hoist drive motor 627, first hoist drive wheel set 620 and second hoist drive wheel set 624. The second hoist drive wheel set 624 is connected by a drive belt 622. The first hoist drive wheel set 620 and second hoist drive wheel set 624 are mounted to the bot on the first hoist drive wheel set mount 625 and the second hoist drive wheel set mount 626 respectively. The hoist drive

motor is arranged to drive one or both wheels of the first hoist drive wheel set using a drive shaft (not shown), the effect of which is to cause the container lifting device to be lowered or raised, as appropriate, through the movement of the first and second hoist wheel sets and the drive belt.

- 5 Referring to Figure 10, the container lifting device further comprises gripper activators 692. When the container lifting device is lowered such that it is adjacent to the top of a container stored in a stack beneath the grid then the gripper activators 692 can be actuated such that a container can be acquired by the container lifting device. The hoist drive motor can then be activated such that the container is lifted such that the container is received within the interior of the bot. In this position, the bottom of the container is located above the surface of the grid such that bot is free to move across the grid. It should be appreciated that the container lifting device may be implemented in a different manner using different components in order to achieve the same effect. The interior of a container received within a bot in this manner may be accessed via aperture 690.
- 10
- 15 The bot comprises first and second haloes 630 635 which extend around the periphery of the bot. Located in between the first halo 630 and the second halo 635 are one or more component modules 640. In one example, each face of the bot comprises a component module but it should be understood that a bot may comprise fewer than four component modules. The component module(s) hold the electronic circuitry that is used to control the operation of the bot, send and receive messages to and from the central management system of the fulfilment centre, etc. The component module(s) may comprise additional components, for example a backup battery to retain operating and configuration data that might otherwise be lost during an exchange of the batteries 610. Each of the component modules may comprise connectors and/or cabling that enables them to be connected to a further component module. The cabling may be routed through the corners between adjacent component modules.
- 20
- 25

The outer faces of the component modules may comprise a region in which are formed a plurality of ventilation apertures 642. The ventilation apertures are provided to allow airflow through the interior volume of the component module(s), such that heat generated by the components received therein can be dissipated outside of the module(s). The inside faces of the component module(s) (not shown in Figures 6 to 9) may also comprise a region in which a further plurality of ventilation apertures are formed. The ventilation apertures formed in the inner and outer faces may be configured to facilitate the flow of air from the interior of the bot to the exterior, through

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the component module(s) such that heat can be vented away from the interior of the bot. The interior structure may be configured to facilitate such an airflow.

By providing the components in a modular form a defective bot may be repaired by the replacement of the appropriate module. In an alternative, a component module which comprises a defective component (or components) may be disconnected from the other modules, opened up and the defective component(s) replaced. The repaired module could then be re-connected to the other modules such that the bot can be recommissioned. This aspect of the bot design avoids the need to open the bot to access a defective component and then replace it. This allows a bot to be repaired more simply within a fulfilment centre.

Halo bumpers 632 may be located on each corner of the first and second haloes 630, 635. The halo bumpers extend the footprint of the bot beyond that defined by the direction control mount 650 and the wheels 660 661 such that the halo bumpers define the greatest extent of the bot footprint. In the event that a bot overshoots the target grid cell then it may collide with another bot present in the adjacent grid cell. The bot-to-bot contact will be the contact between the respective halo bumpers. This should reduce the forces that will act on the bot structure and components. The presence of the bot haloes may prevent damage from occurring to the bot, or reduce the extent of any damage. The halo bumper(s) may be formed from a deformable material, which may deform permanently or elastically. In an alternative, the halo bumper(s) may be formed from a material that shatters on impact. The halo bumper(s) may be replaceable without needing to remove any other part of the bot.

Each face of the bot comprises a drive set, with each of the drive sets comprising a drive wheel 660, passive wheel 661 and drive wheel controller 672. The drive set is further connected to a direction connection mechanism 680. Each drive wheel 660 comprises a hub motor 662. In operation, the drive wheel controller 672 causes the hub motor to be selectively actuated, such that the drive wheel is rotated in a selected direction. Each wheel preferably comprises a tyre 666 received around the wheel. The tyre may be secured on the wheel using a retaining member, which may take the form of an annular ring. The retaining member may be secured to the wheel using one or more securing mechanisms, for example a threaded bolt. Thus, when a tyre has exceeded its service life, the retaining member may be removed from the wheel, such that the tyre can be removed and replaced.

As discussed above with reference to Figures 3 to 5, the bot needs to be able to move across the top surface of the grid in both the X and Y directions, and to be able to change between the X direction and the Y direction, and *vice versa*. When the bot is configured to move in a first direction then the direction change mechanism 680 will be configured such that the drive sets on two
5 opposed faces of the bot are in contact with the rails of the grid and the drive sets on the other two opposed faces of the bot are raised such they are clear of the grid rails. The bot can then move in the first direction, through the application of appropriate signals from the drive wheel controller 672 to the hub motors of the drive wheels 660. When it is required that the bot changes direction, i.e. that the bot moves in the second direction at right-angles to the first direction then
10 the direction change mechanism is activated such that the raised opposed drive sets are lowered onto the grid rails and the other opposed drive sets are lifted from the grid rails. In one example, the direction change mechanism may be that as described in the Applicant's co-pending application, WO2022/058550 A1, the contents of which are herein incorporated by reference.

15 The direction change mechanism is connected to a direction change mount 650, which is connected to the frame 700 of the bot. The direction change mount may take the form of an inverted U-shape, such that the inner arm of the U-shape is connected to the frame of the bot and the outer arm covers a portion of the direction change mechanism above the level of the wheels. The direction change mechanism 672 is received within the channel formed by the inner and outer
20 arms of the direction change mount. As can be seen in Figures 7 to 9, the wheels may extend beyond the footprint of the direction change mount 650.

Figures 6 to 8 show that each face of the bot has an associated drive wheel controller. In an alternative example, the bot may comprise two drive wheel controllers, such that, for example,
25 the first drive wheel controller is associated with the two opposed longer faces of the bot and the second drive wheel controller is associated with the two opposed shorter faces of the bot. In a further alternative, the drive wheel controller functionality may be provided using components received within one or more of the component modules 640.

30 It will be understood that it is necessary for the position of the bot relative to the grid to be determined accurately and repeatedly. It is known in similar bots that a 'fifth wheel' may be installed, the rotations of which can be used to determine the movement of the bot in a given direction (see the Applicant's co-pending application WO 2022/136454, the contents of which are herein incorporated by reference). In the present disclosure, one or more of the passive wheels

may be used in a similar manner, with a suitable sensor (for example, a rotary encoder or similar sensor) used to measure the rotation of the passive wheel as the respective drive wheels move the bot on the grid. If the passive wheels on two opposed bot faces are used in such a manner an average value may be used to determine the displacement of the bot. Alternatively, if the displacement determined from one of the passive wheels is greater than the displacement determined from the opposed passive wheel then this may mean that the bot is becoming misaligned with the grid, potentially leading to the bot becoming derailed.

Other techniques for determining the location of a bot are known and may be used in conjunction with, or instead of, the sensing of the movement of the passive wheels. For example, the bot may comprise sensors to determine the location of barcodes, or other indicia, which are located on the track (see the Applicant's co-pending application, WO 2019/170805 A1, the contents of which are herein incorporated by reference). Furthermore, the bot may comprise sensors to determine the location of RFID sensors embedded within the grid (see the Applicant's co-pending application, WO 2020/148315 A1, the contents of which are herein incorporated by reference). A further technique is disclosed in the Applicant's co-pending application, WO2019/122080 A1, the contents of which are herein incorporated by reference, in which timing data derived from signals received from multiple base stations can be used to determine the location of a bot. It should be understood that one or more of these additional techniques may be used in conjunction with the determination of the position of the bot based on the data derived from the passive wheels.

In operation, the central management system will send an instruction to a bot to retrieve a container from the storage system and then move to a predetermined position adjacent, or near to, a picking station such that a robotic picking arm may pick one or more product items from the container. The picking station may be static or mobile, and examples of such picking stations are disclosed in the Applicant's co-pending application WO 2017/081275. The required product items may be retrieved from the container and transferred to a further container for subsequent storage or delivery. The bot may then take the container to a further picking station for a further picking operation to be performed or the bot may be returned to a predetermined location such that it is stored within the storage system.

Figures 6 to 9 show that the long sides of the bot comprise the battery and the hoist mechanisms. It can be seen that these features would complicate the picking process as a robotic picking arm would need to reach over them to access the internal volume of the container. Thus, it is preferred

if the robotic picking arm can be configured such that it can access the internal volume of the container via one of the shorter sides of the bot.

Figures 11 to 13 show schematic depictions of different examples of the structure(s) that form the frame of the bot. Figure 11a shows a schematic depiction of a halo 630 and Figure 11b shows a schematic depiction of a first frame panel 637. It can be seen that the frame panel 637 is configured to be attached to one of the long sides of the bot and as such comprises a battery holder 614. Figure 12 shows a schematic depiction of a frame 700 for a bot which comprises first halo 630, second halo 635 and two first frame panels 637, which are connected to the long sides of the first and second halos. The frame further comprises two second frame panels which are connected to the short sides of the first and second halos. The two first and second frame panels ensure that the first and second halos are appropriately spaced apart (for example, such that the component modules can be received in the space between the first and second halos. The first and second frame panels also provide the strength and rigidity of the frame such that the bot is able to lift containers from the grid, move on the grid, deposit containers etc., in a repeatable, reliable manner. It should be understood that if the frame is sufficiently robust based on the use of just the two first frame panels then one or both of the second frame panels may be omitted. It should be understood in such a case that the drive set and the component module for the shorter side of the bot (and any other related components) will need to be connected to the halo in the absence of a second frame panel.

The frame may additionally comprise one or more panel connectors 639, which are mounted at a corner of the frame, such that a first frame panel may be connected to a second frame panel. The halos, the first frame panels and/or the second frame panels may be provided with holes at pre-determined positions in order to allow components to be connected to the frame, such as a drive set, a component module, etc. The frame provides a sufficiently robust support for the other bot components whilst being relatively light and easy to manufacture. Having identical first frame panels (and also identical second frame panels) reduces the number of unique parts required to build a bot and simplifies the associated manufacturing and maintenance processes.

The halos may be formed by welding together appropriate lengths of extruded aluminium. The halos may have a cross-section of 30 mm x 30 mm. The first frame panels, the second frame panels and the panel connectors may be pressed from sheet metal. In one example, the first frame panels, the second frame panels and the panel connectors may be formed from 1.5 mm

thick aluminium sheet. The battery holder of each first frame panel may also be formed in the pressing of the first frame panel. Whilst it will be understood that other metals could be used to form the halos and panels that form the frame, the use of aluminium provides a weight saving, which in turn enables the use of smaller and lighter motors and batteries. In a specific example, the halos may be formed from 6061 aluminium alloy and the sheet pressed from 6082 T6 aluminium alloy.

The halos and the panels can be connected together to construct the frame using any suitable technique for the material(s) used to form the halo and the panels, for example riveting, friction-stir welding, delta spot resistance spot welding, etc. It should be understood that the two first frame panels and the two second frame panels may be pressed as a single integrated panel, which is then formed into a rectangular shape and welded (or otherwise connected) to the first and second halos to form the frame. A panel connector 639 may then be used to connect the two ends of the integrated panel.

Figure 13 shows a schematic depiction of an alternative structure for the frame of the bot. Figure 13a shows a schematic depiction of two complementary frame portions 700a 700b and Figure 13b shows a schematic depiction of a frame 700'. Referring to Figure 12, each of the frame portions 700a 700b comprises a first halo portion 630', second halo portion 635', corner supports 705, vertical bracing element 706, diagonal bracing elements 708, flanges 702 and flange apertures 704.

The two complementary frame portions 700a 700b may be joined together to form frame 700'. It can be seen that the two first halo portions 630' then co-operate to form the first halo 630. Similarly, the two second halo portions 635' co-operate to form the second halo 635. The respective drive sets may be connected to each face of the frame, with the drive sets being connected using the flange apertures of the flanges. The component modules may be connected to the frame in the volumes defined by the first halo, the second halo and the corner supports on each side of the bot. It should be understood that additional support elements will need to be connected to both of the long sides of the frame 700 to receive the respective battery holders. For example, such additional support elements may be similar to the upper portion of the first frame panels 637 described above in relation to Figures 11 & 12.

In an alternative, the frame 700' of Figure 13b may be cast as a unitary structure. The complementary frame portions of Figure 13a and/or the frame 700' of Figure 13b may be die cast from aluminium due to the above-discussed advantages relating to weight. Other materials could be used but have weight and/or cost penalties

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Figure 14a & 14b show respective schematic depictions of an integrated drive module 750 which comprises a drive set and a direction change mechanism 800. Figure 14a shows the drive module when the direction change mechanism is actuated such that the wheels are in the lowered position and Figure 14b shows the drive set when the direction change mechanism is actuated such that

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Referring to Figure 14a, the integrated drive module 750 comprises a frame 756, which can be removably connected to one side of the frame of a bot. It should be understood that it is preferable for integrated drive modules to be provided in two different sizes, one sized to fit on the long side of the bot frame, and one sized to fit on the short side of the bot frame. The integrated drive module comprises a drive set, which comprises a drive wheel 660, a passive wheel 661 and a drive wheel controller 672. The drive wheel 660 and the drive wheel controller 672 are received on a drive wheel mount 663. The drive wheel mount is pivotably connected to the integrated drive module frame via drive wheel mount connection 752. Similarly, the passive wheel 661 is received on a passive wheel mount 664 and the passive wheel mount is pivotably connected to the integrated drive module frame via passive wheel mount connection 754.

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Figure 14b shows a view of the integrated drive module 750 without the frame 756 being present. The a direction change mechanism 800 comprises a motor 802, direction change toothed wheels 804, crankshaft 805, direction change mechanism housing 806, first conrod 808 and second conrod 810. The first end of the first conrod 808 is connected to the drive wheel mount 663 and the second end of the first conrod is connected to the crankshaft within the direction change mechanism housing. Similarly, the first end of the second conrod 810 is connected to the passive wheel mount 664 and the second end of the second conrod is connected to the crankshaft within the direction change mechanism housing. The motor 802 is connected to the toothed wheels such that the motor can be actuated to cause the toothed wheels to rotate. The rotation of the toothed wheels will cause the second end of the first conrod and the second end of the second conrod to move accordingly. The direction change mechanism housing 806 is connected to the frame of the integrated drive module. The toothed wheels may be configured to provide a step

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down ratio, such that the toothed wheel connected to the crankshaft rotates at a slower speed than the motor does, but applies an increased torque to the crankshaft. It will be understood that the motor may drive the crankshaft using alternative mechanisms, such as a belt, etc.

5 Figure 14a shows an integrated drive module when the motor has been actuated such that the first and second conrods are in a lowered position, causing the drive wheel and the passive wheel to be in a lowered position. In such a lowered position, the wheels are in contact with the tracks of the grid such that the weight of the bot is supported by the wheels. In operation, the bot may be placed into a 'park' mode, in which the wheels are in the lowered position on all four sides of the bot, preventing the bot from moving on the grid. For the bot to be able to move, the wheels on two opposite sides of the bot need to be in the lowered position and the wheels on the other two opposite sides of the bot need to be in the raised position.

Figure 14b shows an integrated drive module when the motor has been actuated such that the first and second conrods are in a raised position. The movement of the first conrod causes the drive wheel mount 663 to rotate about the drive wheel mount connection 752, lifting the drive wheel such that it is raised above the level of the grid. Similarly, the movement of the second conrod causes the passive wheel mount 664 to rotate about the passive wheel mount connection 754, lifting the passive wheel such that it is raised above the level of the grid. The integrated drive modules on opposed sides of the bot may be co-ordinated such that the wheels are raised or lowered at substantially the same time. Furthermore, when a bot needs to change direction then the two sets of raised wheels should be lowered onto the grid before the other two sets of wheels are raised off the grid.

25 The direction change mechanism 800 may additionally comprise a locking mechanism (not shown in Figure 14), which acts to lock the wheels in position. In one example, the locking mechanism may comprise a solenoid which can be energised once the wheels have been lowered into position on the rails, to lock the wheels into the lowered position. The solenoid will then need to be de-energised before the motor is actuated such that the wheels are moved from the lowered position to the raised position. Once the wheels are in the raised position then the solenoid can be re-energised such that the wheels are locked in the raised position. This means that the direction change mechanism motor does not need to continually apply a torque to the crankshaft in order to hold the wheels in the raised position. It should be understood that the a locking

mechanism may be implemented in an alternative manner, for example using mechanical or electromechanical components, etc.

In one example, when the wheels are in the lowered position then the wheels are arranged such that the centre of the drive wheel is substantially vertically aligned beneath the drive wheel mount connection 752. Similarly, the centre of the passive wheel is substantially vertically aligned beneath the drive wheel mount connection passive wheel mount connection 754. Such an arrangement significantly reduces any forces that are passed into the motor or the body of the bot.

An integrated drive module can be connected to the frame of the bot and data and power connections (not shown in Figure 14) made to the bot such that the direction change mechanism and the drive set can be controlled in order that the bot can move on the grid. In the event that a fault occurs within the integrated drive module then the module can be replaced with another integrated drive module. This simplifies the maintenance and repair processes that can be carried out within a fulfilment centre where the bots are active. A defective integrated drive module may be shipped to a centralised repair facility for repair. The first and second conrods may be identical, reducing the number of replacement parts that need to be held.

In one example, the integrated drive modules can be arranged such that the drive wheels for the opposed long sides of the bot are both located at the same face of the bot and that the drive wheels for the opposed short sides of the bot are both located at the same face of the bot. If the drive wheels were not arranged in this manner (i.e. the drive wheels were located at diagonally opposite corners of the bot) then the steering of the bot would be complicated due to the torque that would be applied to the bot when the two drive wheels were activated.

Although the integrated drive module described above with reference to Figures 6-9 & 14 have shown that the integrated drive module comprises the direction change mechanism 800 it should be understood that in an alternative a drive set which does not have a direction change mechanism could be used. Such a drive set would comprise a drive wheel, a passive wheel and a drive controller. These components would operate as described above. The wheels would be controlled by a known direction change mechanism such as, for example, the direction change mechanism disclosed in WO2022/058550.

The operation of a bot according to the present disclosure will now be described with reference to the flowchart shown in Figure 15. In operation a bot will receive a message (S1500) from the central management system of the fulfilment centre, the message comprising a location within the storage system and a route to take to move to that location. The bot will then move to the specified location (S1510). Once the bot has reached that location, the bot will retrieve the storage container (S1520) which is at the top of the stack of containers at the location. The bot will lower the container lifting device until it makes contact with the storage container. The gripper activators can then be actuated so that the container lifting device secures the storage container such that the storage container can be lifted into the interior of the bot. In this position, the storage container is lifted clear of the level of the grid such that the bot is able to move across the grid.

The bot will send a message to the central management system to confirm that the storage container has been retrieved. In response, the central management system will send a further message to the bot, the further message comprising a picking location, that is a location within the storage system which is adjacent to a picking station and a route to take to navigate to that location. The bot will then move to that picking location (S1530) such that one or more product items can be picked from the bot during a picking operation (S1540). The picking operation is undertaken by the robotic arm of the picking station reaching into the interior of the storage container received within the bot and picking the required product items.

After the picking operation is complete, the central management system may send a message which comprises a second storage location. The bot will then, in response, move to the second storage location and return the storage container to the storage system (S1550). The second storage location may be the same location that the storage container was retrieved from in step S1520. Alternatively, it may be a different location elsewhere in the storage system. Alternatively, the message sent by the central management system after the completion of the picking operation may comprise a further picking location, such that the bot moves to a position adjacent to a further picking station, such that one or more product items may be picked from the storage container through the top of the bot. Examples of picking stations which are suitable for use with a bot according to the present disclosure are disclosed in the applicant's co-pending applications WO2017/081275 and WO2023/285487.

Figure 16 shows a further schematic depiction of a bot 600 according to the present disclosure comprising one or more component modules 640. In particular, Figure 16 shows a schematic

depiction of the components which are received within the one or more component modules 640 of the bot. The component module may comprise processor 643, communications interface 644, non-volatile data storage 645, volatile data storage 647 and back-up power supply 648. The non-volatile data storage stores one or more computer programs such that the processor can execute
5 the program(s) to control one or more functions of the bot, for example, causing the bot to move on the grid, to change direction on the grid, to raise or lower the container lifting device, to communicate with the central management system of the fulfilment centre, etc. The volatile data storage 647 is used to store data that is being processed by the processor. Some data, for example system logs, will be stored in the non-volatile data storage such that it can be reported
10 to the central management system on a periodic basis or when an unexpected event occurs.

Data can be transmitted to, and received from the central management system via the communications interface 644, which is connected to one or more antennae (not shown in Figure 16). The processor in one component module may be directly connected to the processor(s)
15 present in one or more other component modules. Alternatively, the communications interface 644 may be used to route data between component modules. The component module is connected to the one or more batteries 610 such that that the component module is able to operate. The back-up power supply 648 may be charged from the bot batteries and can provide power to the component module for a brief period in the event that both bot batteries are removed
20 at the same time, such that the data, parameters etc. held in the volatile data storage is not lost. The back-up power supply 648 may comprise a rechargeable battery or a high capacity capacitor.

It should be understood that the one or more component modules are capable of operating all of the functionality of the bot. Some of the bot functions may be distributed between different
25 component modules. Each component module may have different functionality. Each of the one or more component modules may comprise more than one of the components discussed above with reference to Figure 16, for example multiple processors, for multiple non-volatile data storage. One or more of the processors may comprise a CPU which executes code. Alternatively, one or more of the processors may comprise an FPGA, or similar device, which is configured to
30 perform one or more bot functions. Data related to specific functions may be stored in dedicated non-volatile data storage. Duplicate components may be provided across multiple component modules to provide a degree of redundancy. It will be understood that the functionality of the component modules may be implemented in different ways, using a combination of hardware, software and middleware. The volatile data storage may comprise some form of RAM. The non-

volatile data storage may comprise a hard disk, solid state disk, flash memory or similar. The communications interface may comprise a WiFi interface or an interface for a 3G/4G/5G style network.

- 5 While the bot described above with reference to Figures 6 to 16 enables items to be picked directly from a container received within the bot via aperture 690, it will be understood that some of the features described above may be used in conjunction with bots such as those described in WO 2015/019055, WO 2021/148612 or WO 2023/025418 or other similar bots which do not comprise such an aperture and where it is not possible to pick from a container that is received within the
- 10 bot. In such a case, the batteries 610 may be provided in a horizontal orientation, as opposed to the vertical orientation shown in Figures 6 to 9. Similarly, the components that comprise the container lifting device such that it is received above the position that a container would be received at within the bot. Furthermore, the panels 637 which comprise the long edges of the bot may take a different form. The two opposed panels 637 may be configured such that they meet together,
- 15 or can be connected together.

In one regard, the present disclosure provides a load handling device designed to operate on the top of a cubic automated storage and retrieval system (ASRS). The components which control the operation of the load handling device, for example, moving the load handling device on top of

20 the ASRS, changing direction, lifting a container, etc are received in component modules. The component modules are received on one or more of the exterior faces of the load handling device. The modular format allows component modules to be replaced easily in the event of component failure

CLAIMS

1. A load handling device for use in a storage system, the storage system comprising a first set of parallel tracks extending in an X-direction, a second set of parallel tracks extending in a Y-direction transverse to the first set in a substantially horizontal plane to form a grid pattern comprising a plurality of grid spaces and a plurality of stacks of storage containers located beneath the tracks, and arranged such that each stack is located within a footprint of a single grid space; the load handling device comprising:
- one or more component modules, the component modules being releasably connected to an exterior face of the load handling device.
2. A load handling device according to claim 1, wherein the one or more component modules comprise at least one of: one or more processor circuits, one or more communications interfaces, one or more volatile data storage units or one or more non-volatile data storage units.
3. A load handling device according to claim 1 or claim 2, wherein the load handling device comprises four component modules, one component module being received on each exterior face of the load handling device.
4. A load handling device according to any of claims 1 to 3, wherein the load handling device comprises a plurality of component modules, each of the plurality of component modules being configured such that they are in communication with the other component modules.
5. A load handling device according to any of claims 1 to 3, wherein the load handling device further comprises one or more power sources such that the or each component module receives power from the one or more power sources.
6. A load handling device according to claim 5, wherein the or each component module comprises a power storage unit, the or each power storage unit being configured to receive charge from the one or more power sources of the load handling device.
7. A load handling device according to any of claims 1 to 6, wherein the load handling device further comprises one or more antennae such that one or more component module is connected

to an antenna such that the load handling device can communicate with a communications network.

8. A load handling device according to any of claims 1 to 7, wherein the load handling device further comprises a container lifting device arranged, in use, to lift a container from one of the plurality of stacks into the interior of the load handling device.

9. A load handling device according to any of claims 1 to 8, wherein the load handling device further comprises a direction change mechanism configured, in use, such that the load handling device can change movement between the X-direction and the Y-direction.

10. A storage system comprising:

a first set of parallel tracks extending in an X-direction, and a second set of parallel tracks extending in a Y-direction transverse to the first set in a substantially horizontal plane to form a grid pattern comprising a plurality of grid spaces;

a plurality of stacks of storage containers located beneath the tracks, and arranged such that each stack is located within a footprint of a single grid space;

at least one transporting device according to any of claims 1 to 9, the at least one transporting device being arranged to selectively move in the X and/or Y directions, above the stacks on the tracks and arranged to transport a storage container.

11. A storage system according to claim 10, further comprising a picking station arranged to receive a storage container transported by the at least one transporting device and to transfer an item from the storage container into a delivery container.

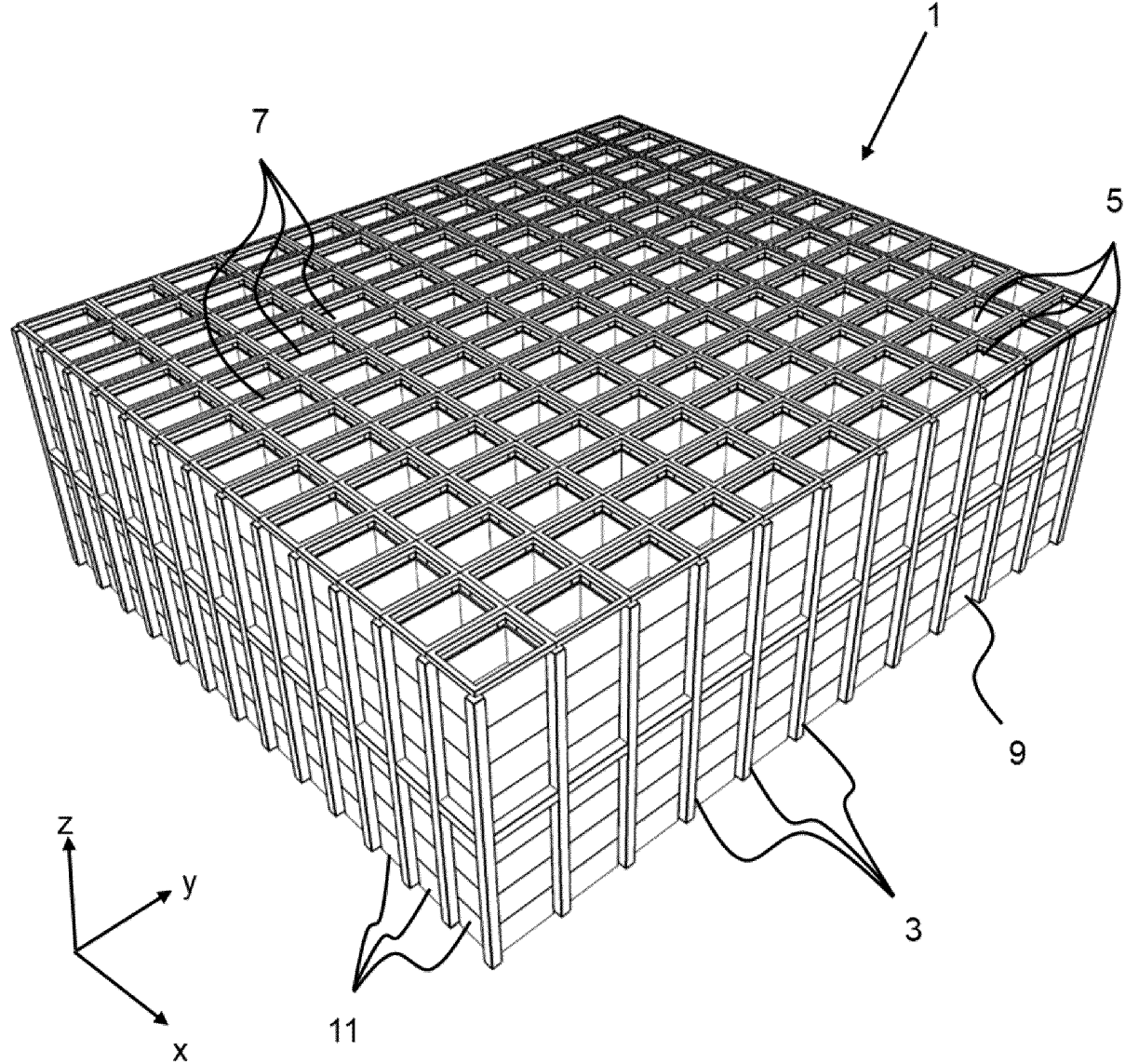


Figure 1
(PRIOR ART)

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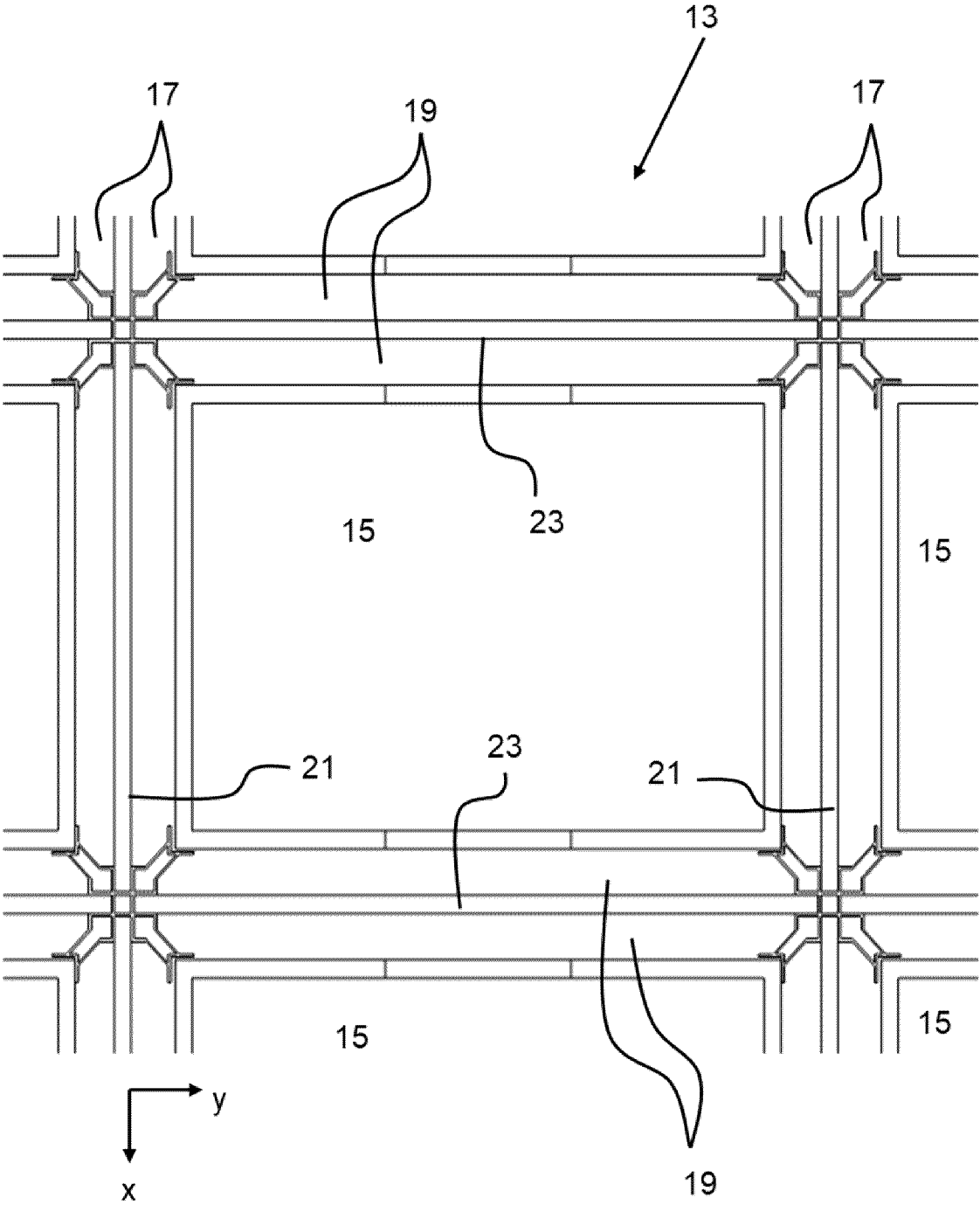


Figure 2
(PRIOR ART)

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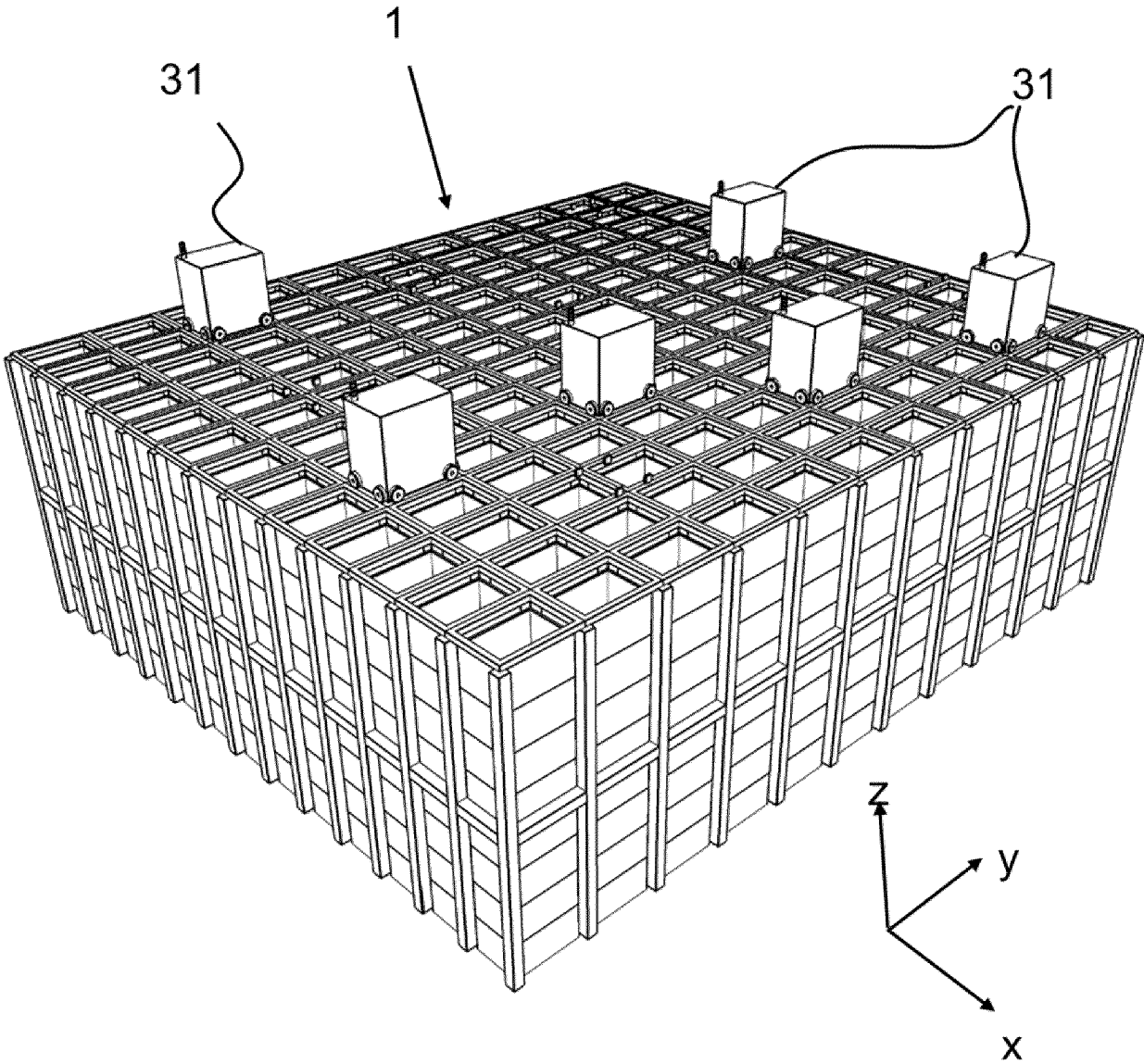


Figure 3
(PRIOR ART)

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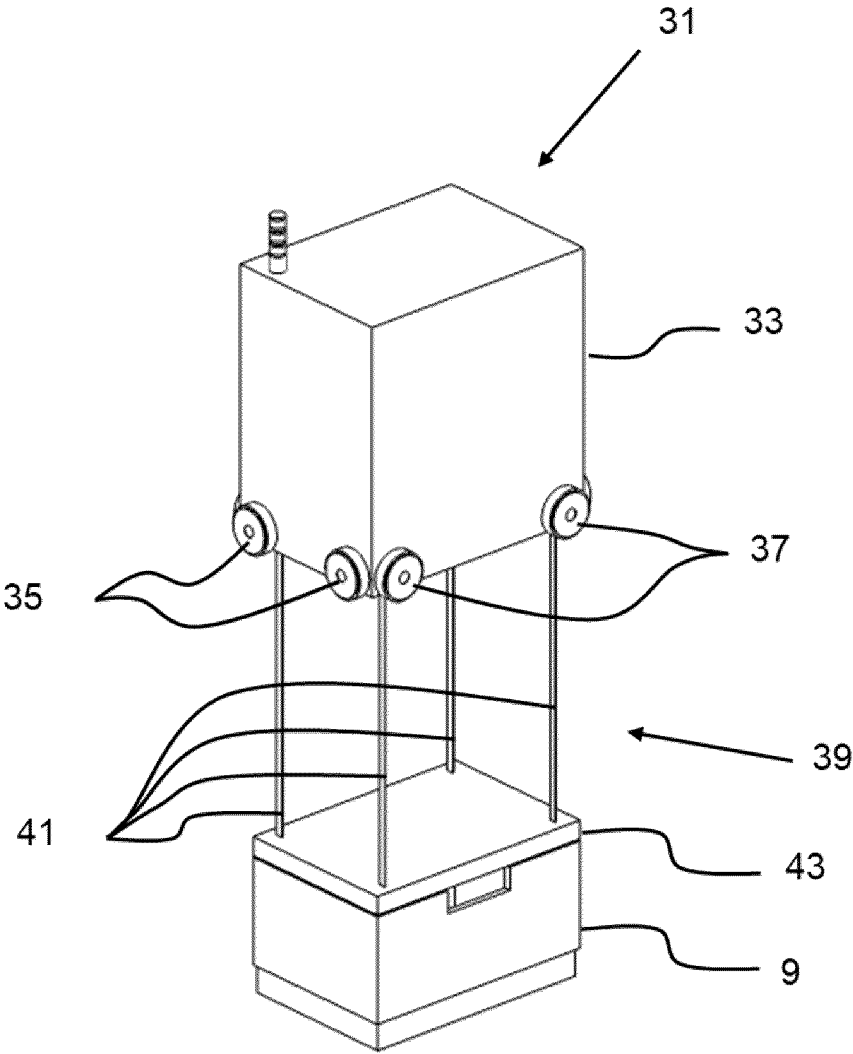


Figure 4
(PRIOR ART)

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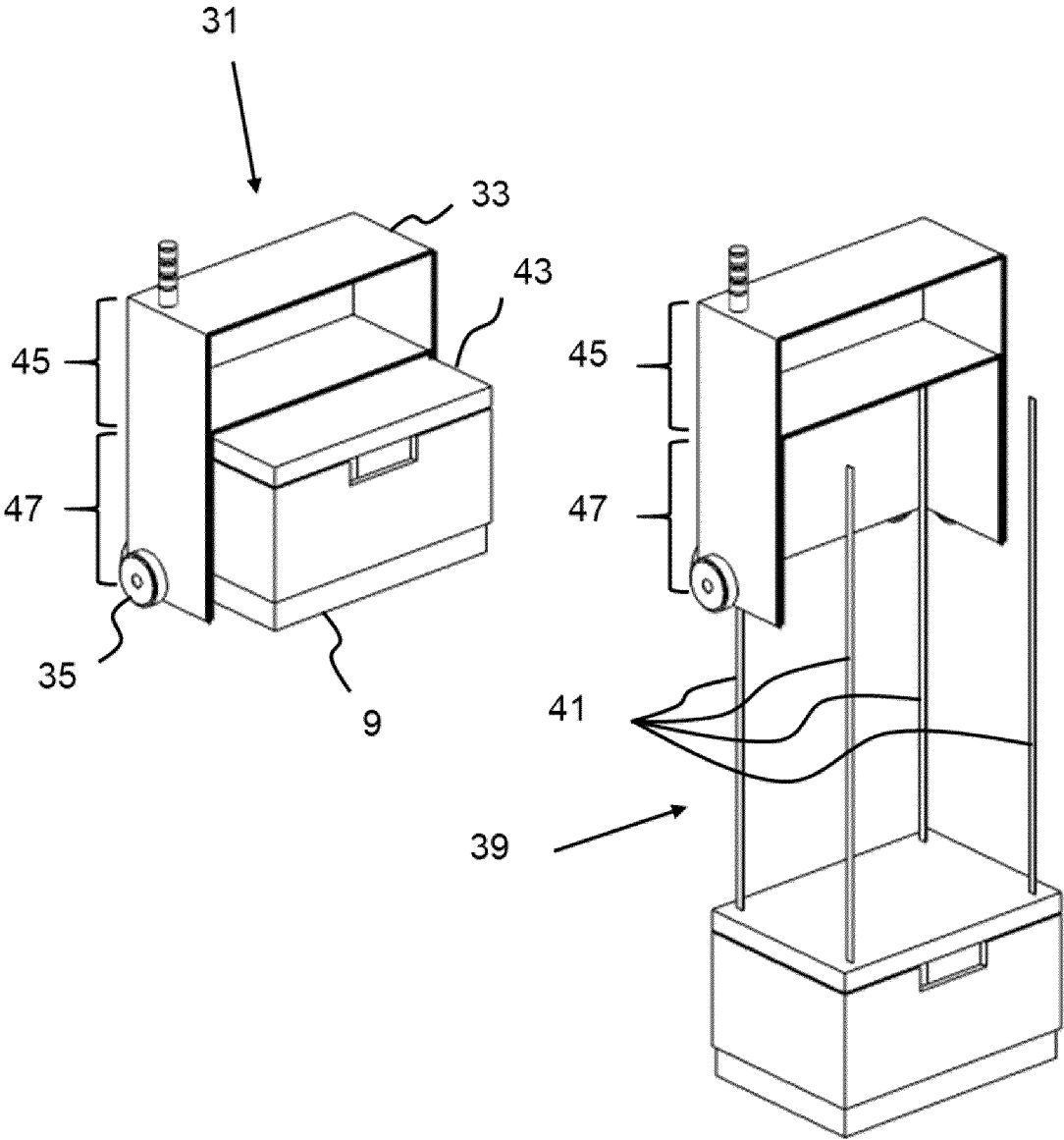


Figure 5
(PRIOR ART)

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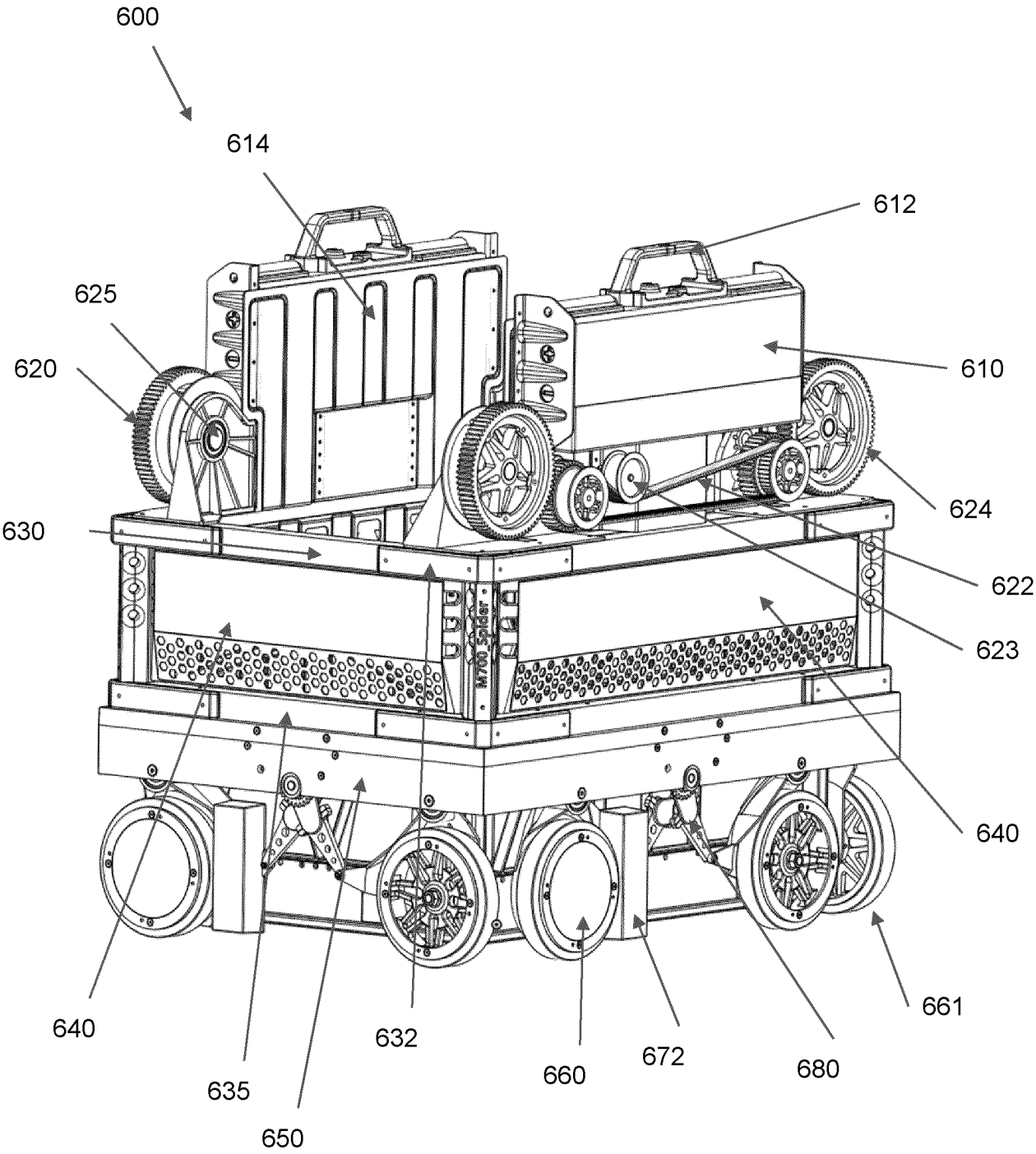


Figure 6

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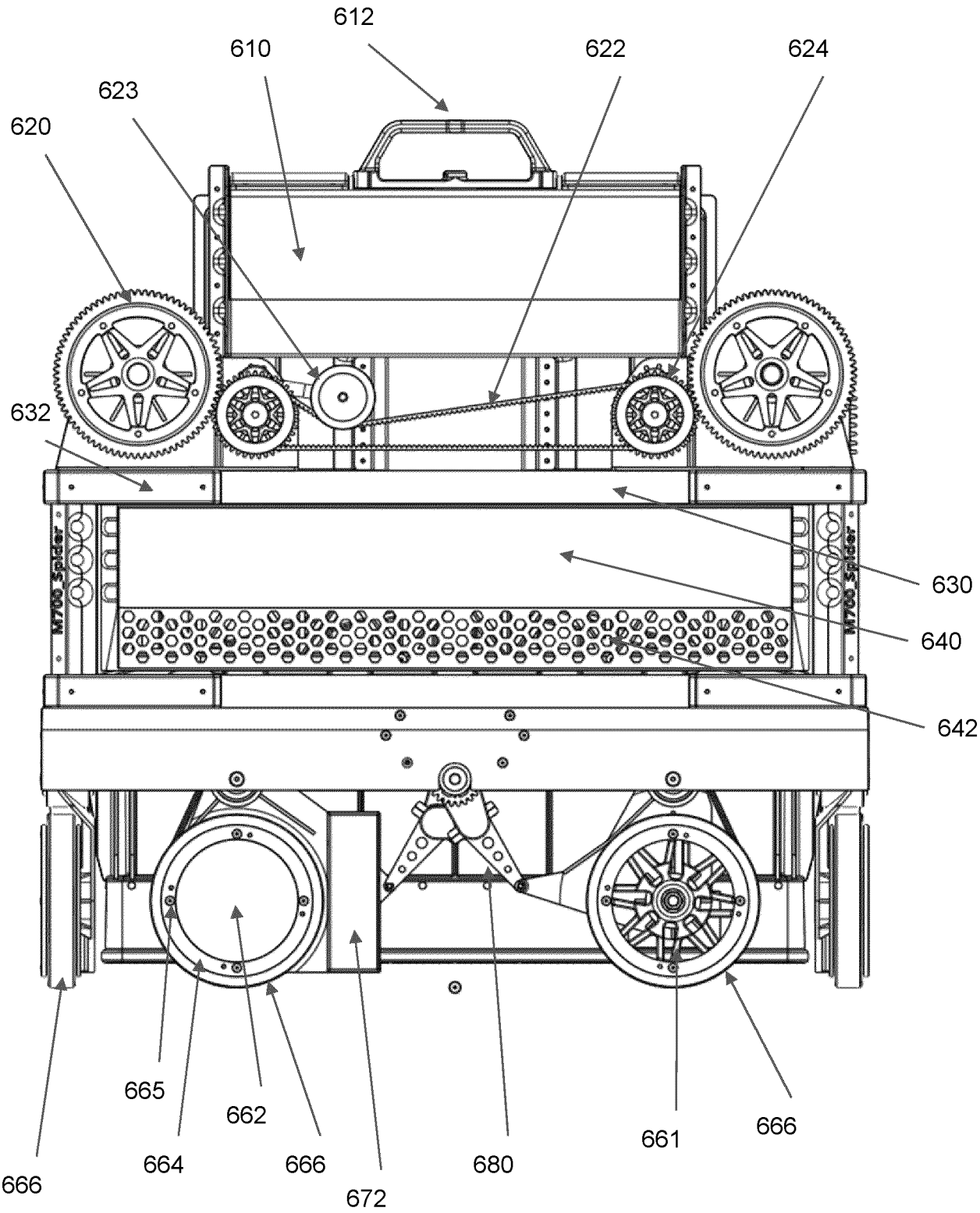


Figure 7

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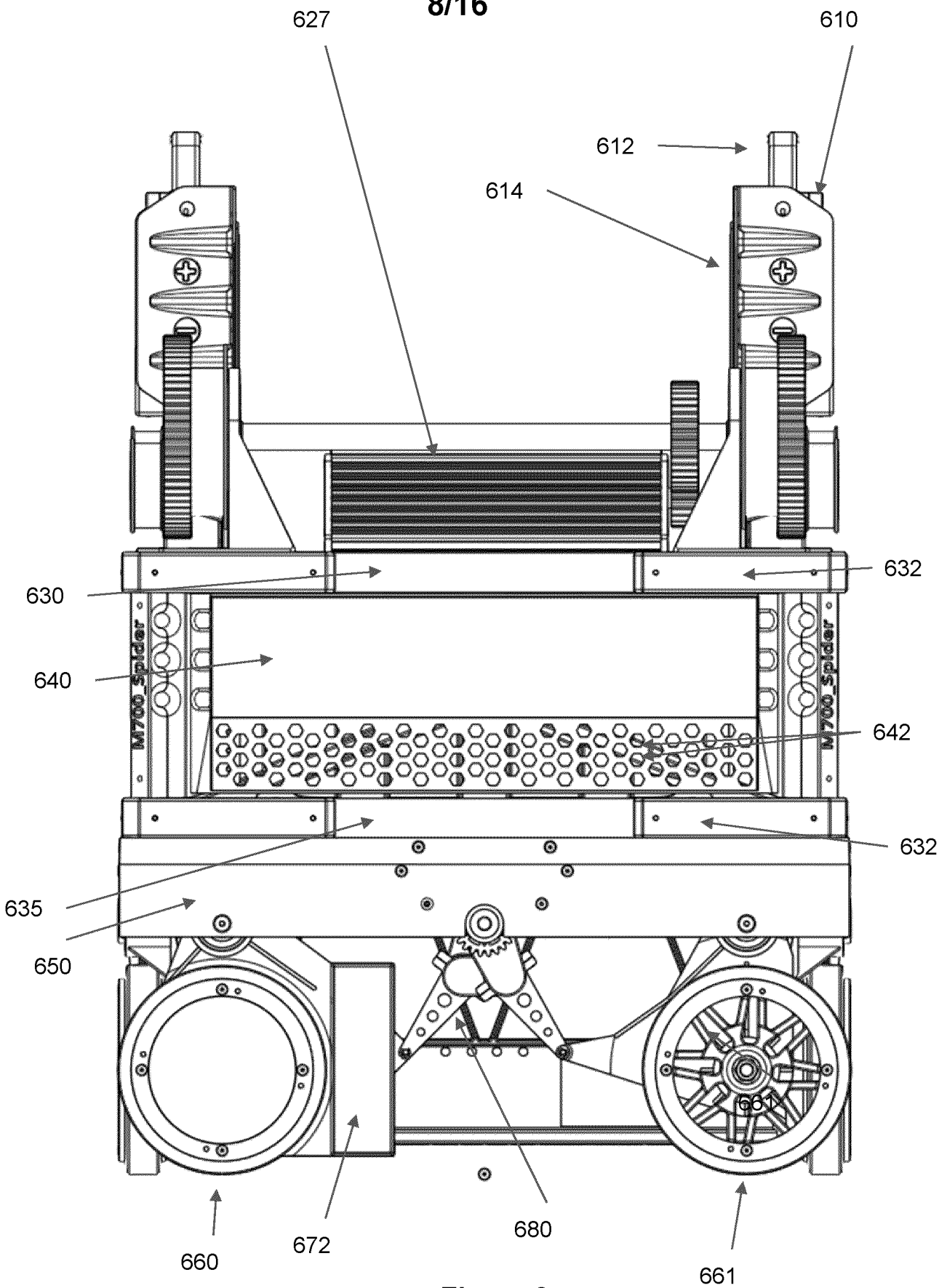


Figure 8

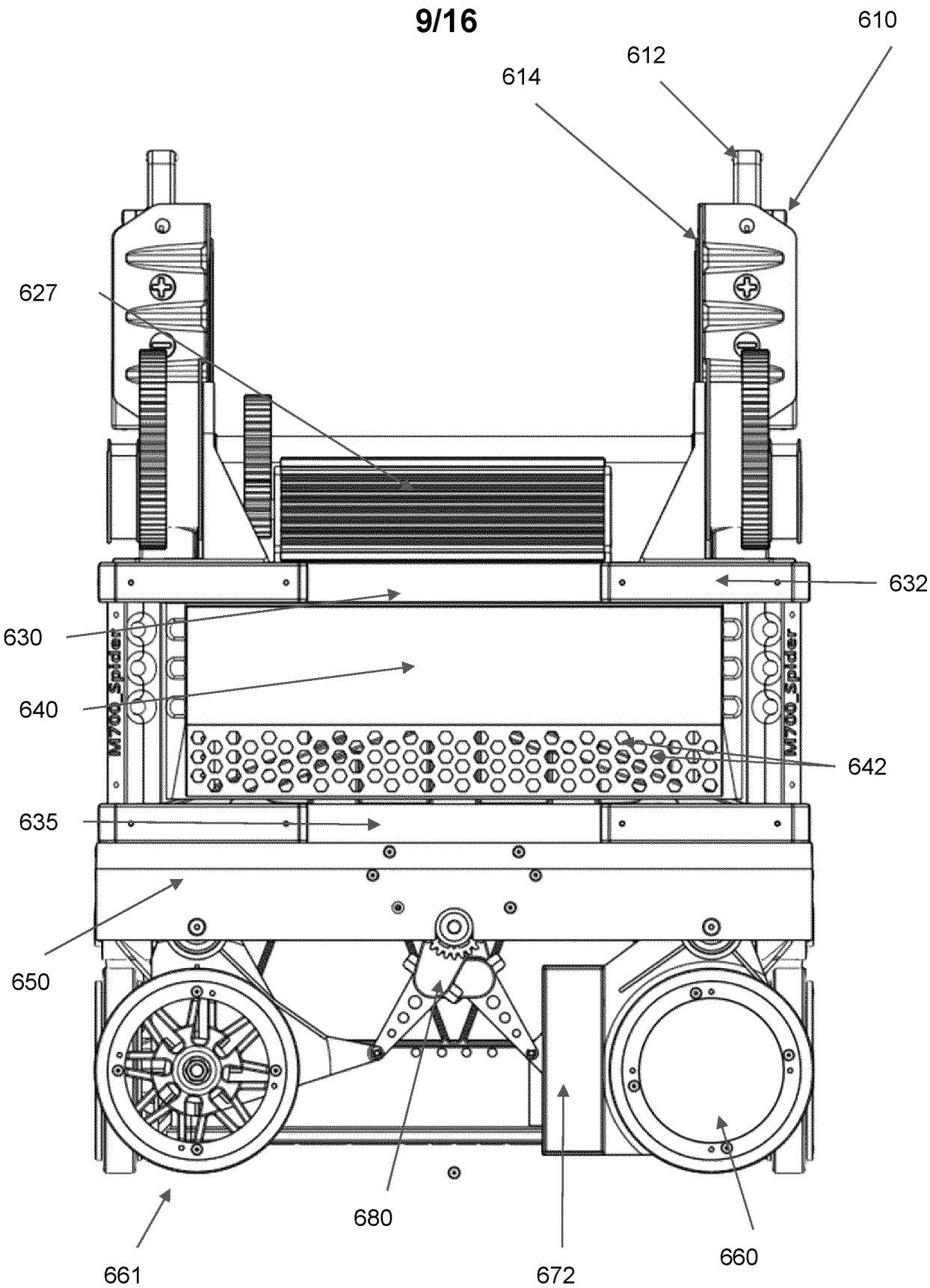


Figure 9

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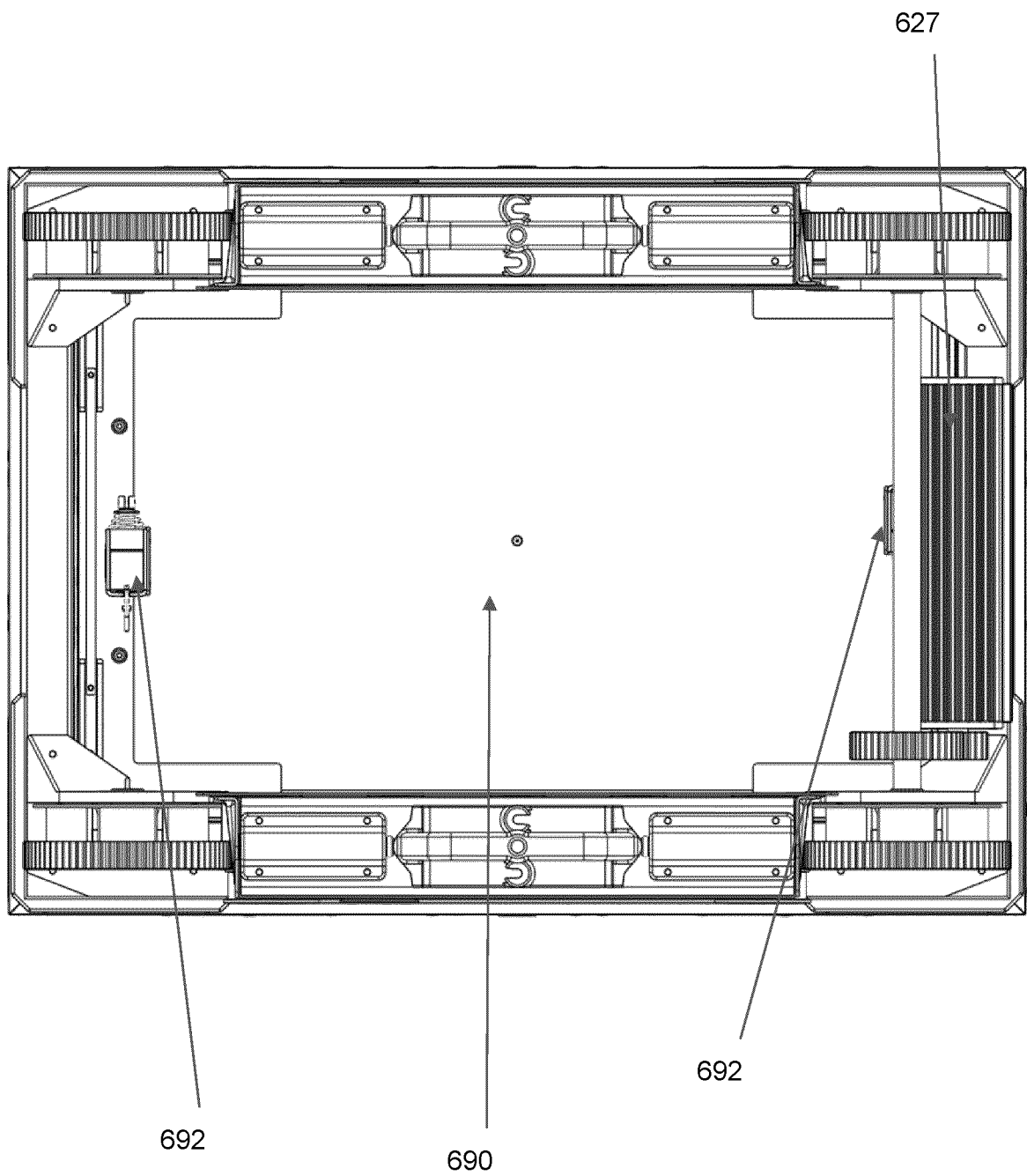


Figure 10

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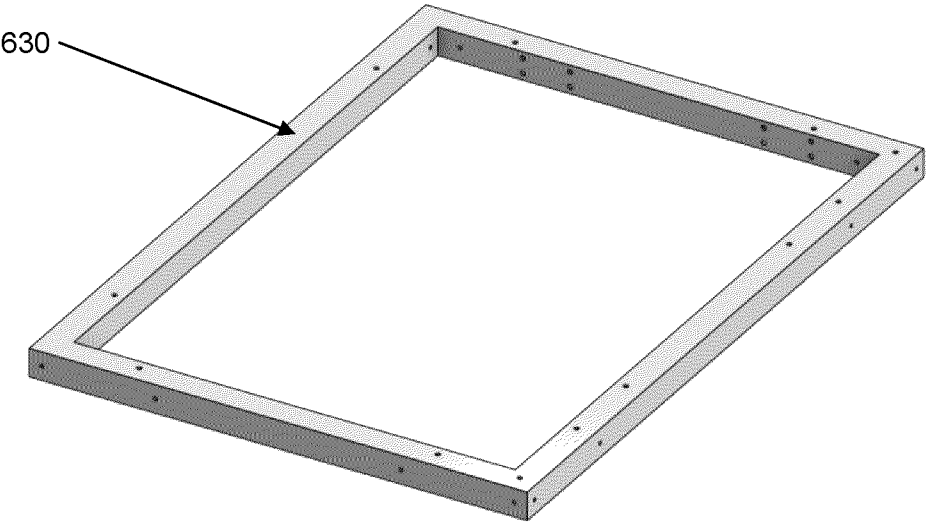


Figure 11a

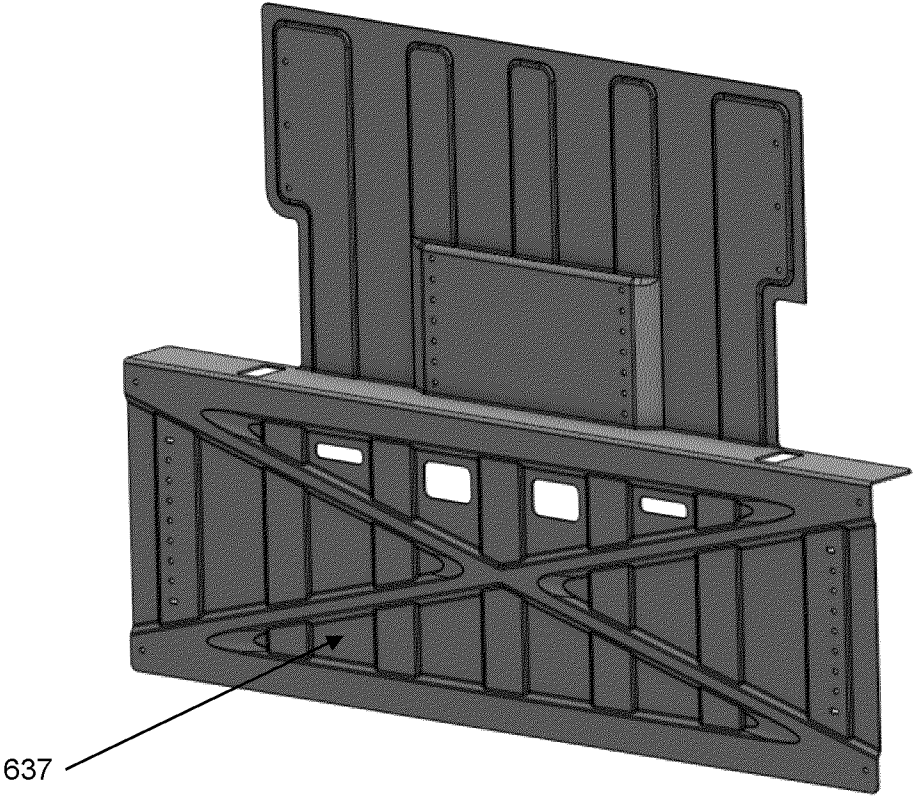


Figure 11b

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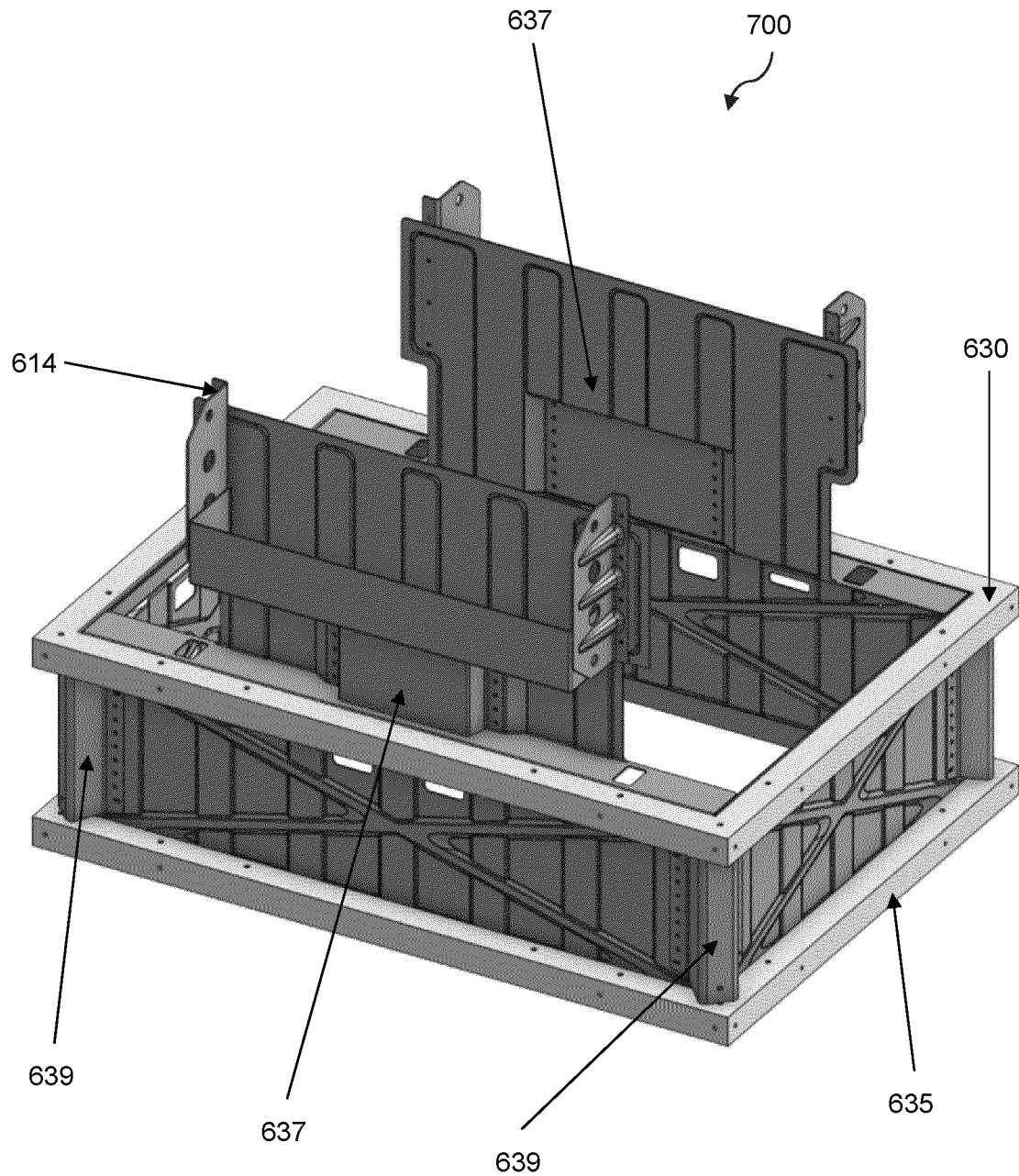


Figure 12

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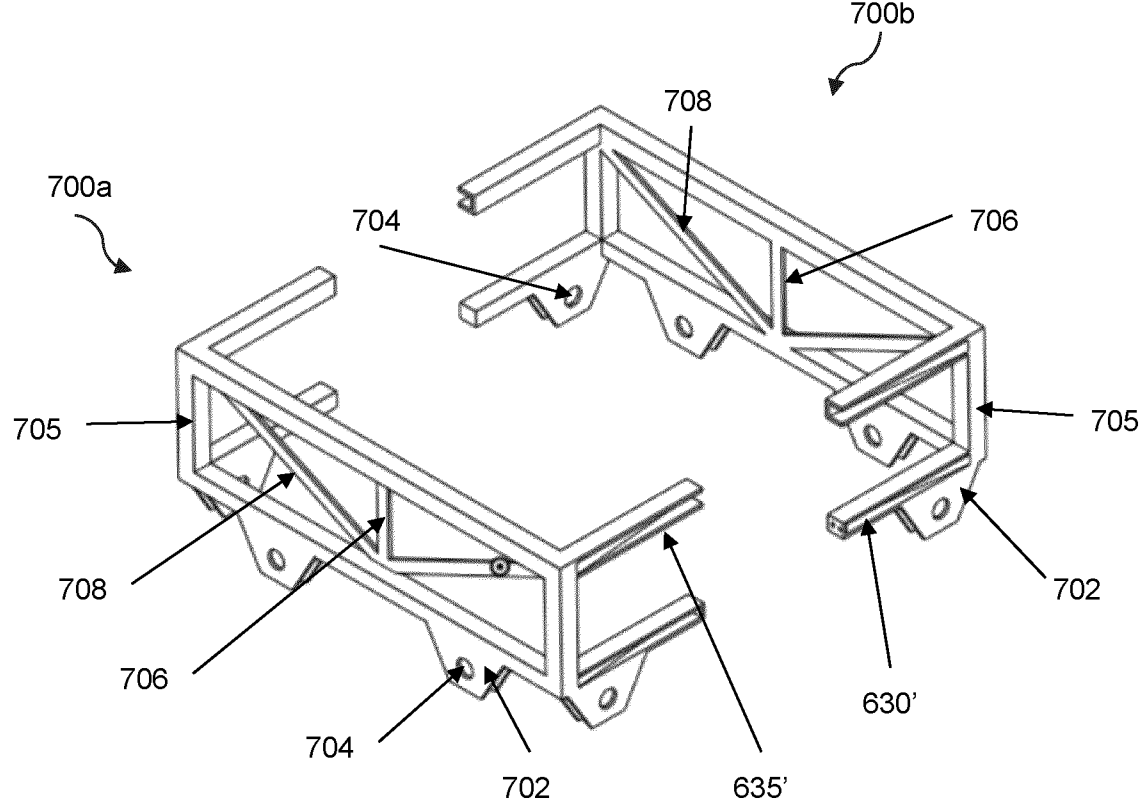


Figure 13a

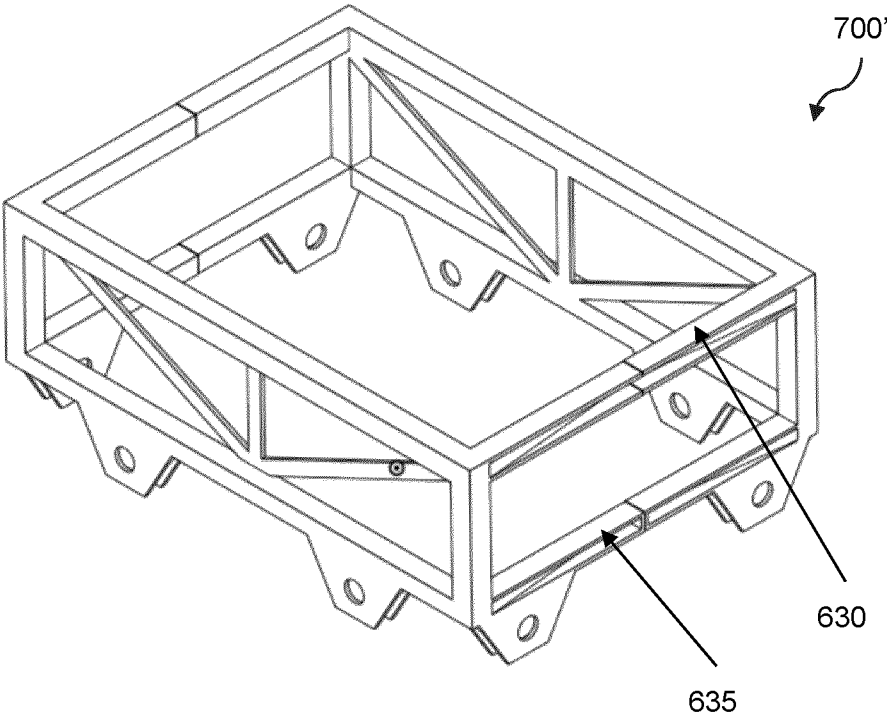


Figure 13b

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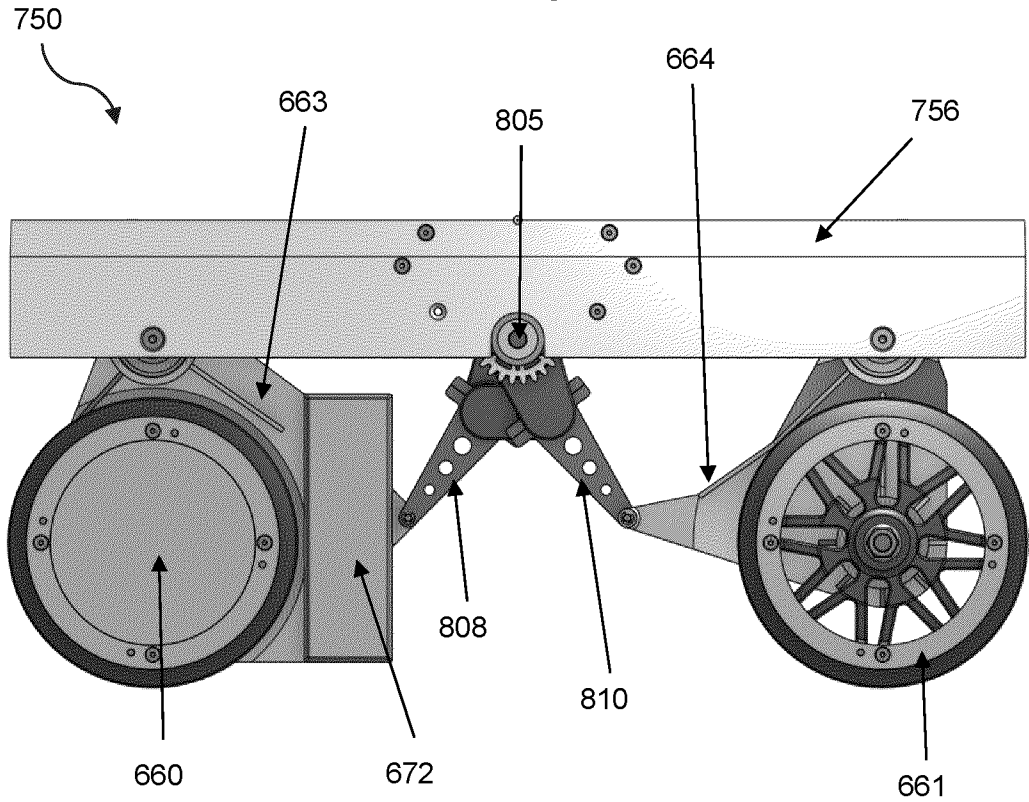


Figure 14a

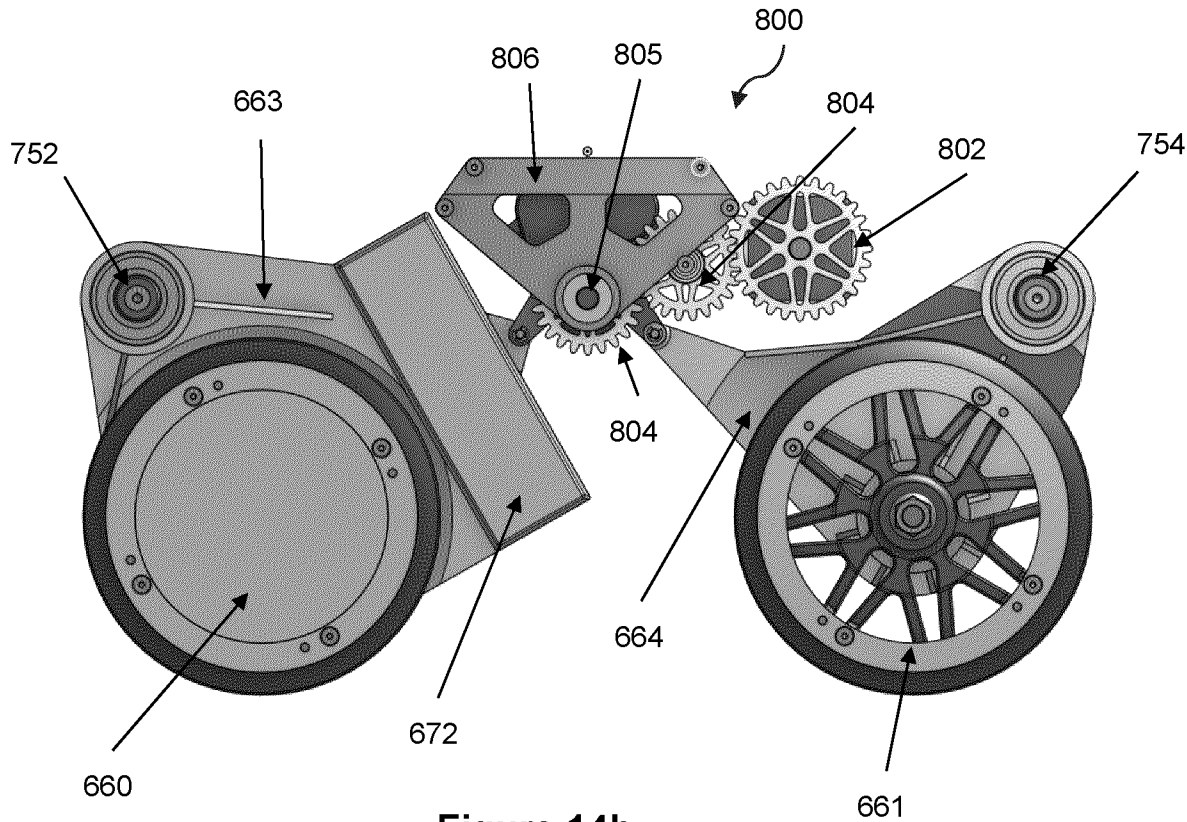


Figure 14b

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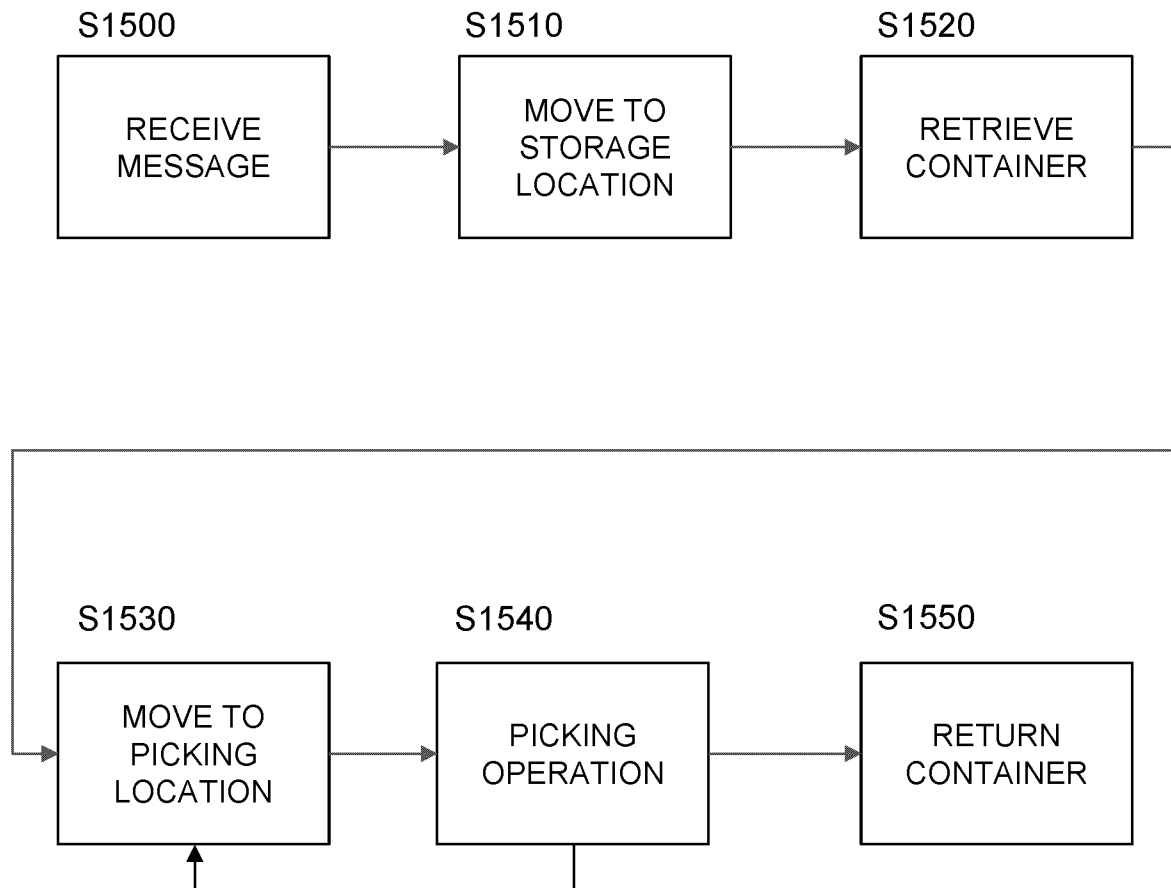


Figure 15

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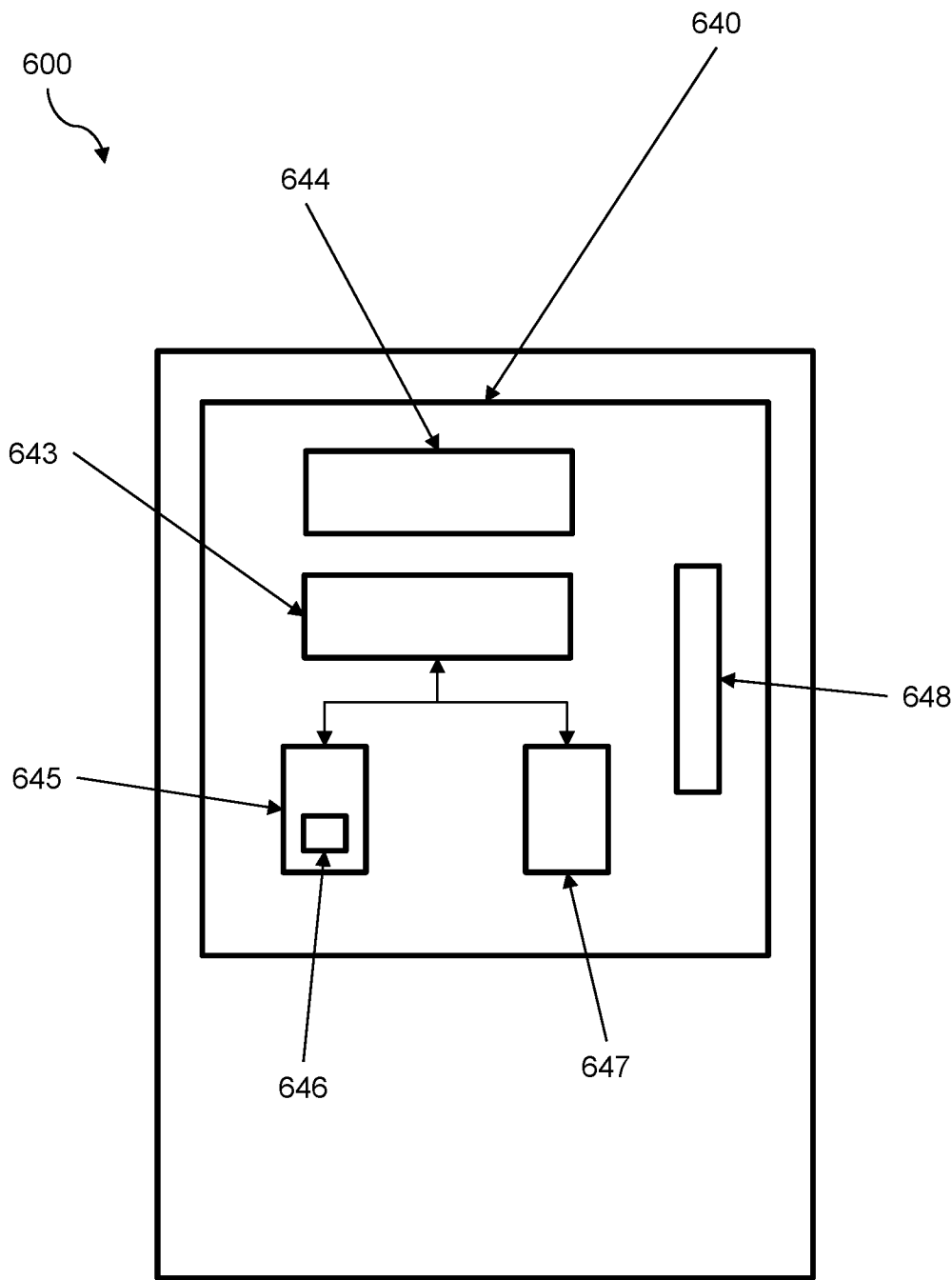


Figure 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/062001

A. CLASSIFICATION OF SUBJECT MATTER

INV. B65G1/04 B65G1/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B65G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/161273 A1 (INGRAM-TEDD ANDREW JOHN [GB] ET AL) 30 May 2019 (2019-05-30) figures 9-12 paragraphs [0021], [0064], [0076] -----	1,2,5-11
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 July 2024

Date of mailing of the international search report

22/07/2024

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Authorized officer

Moreno Rey, Marcos

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/062001

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

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