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(54) **AUTOMATED LOCKER SYSTEM FOR DELIVERY AND COLLECTION OF INVENTORY ITEMS**

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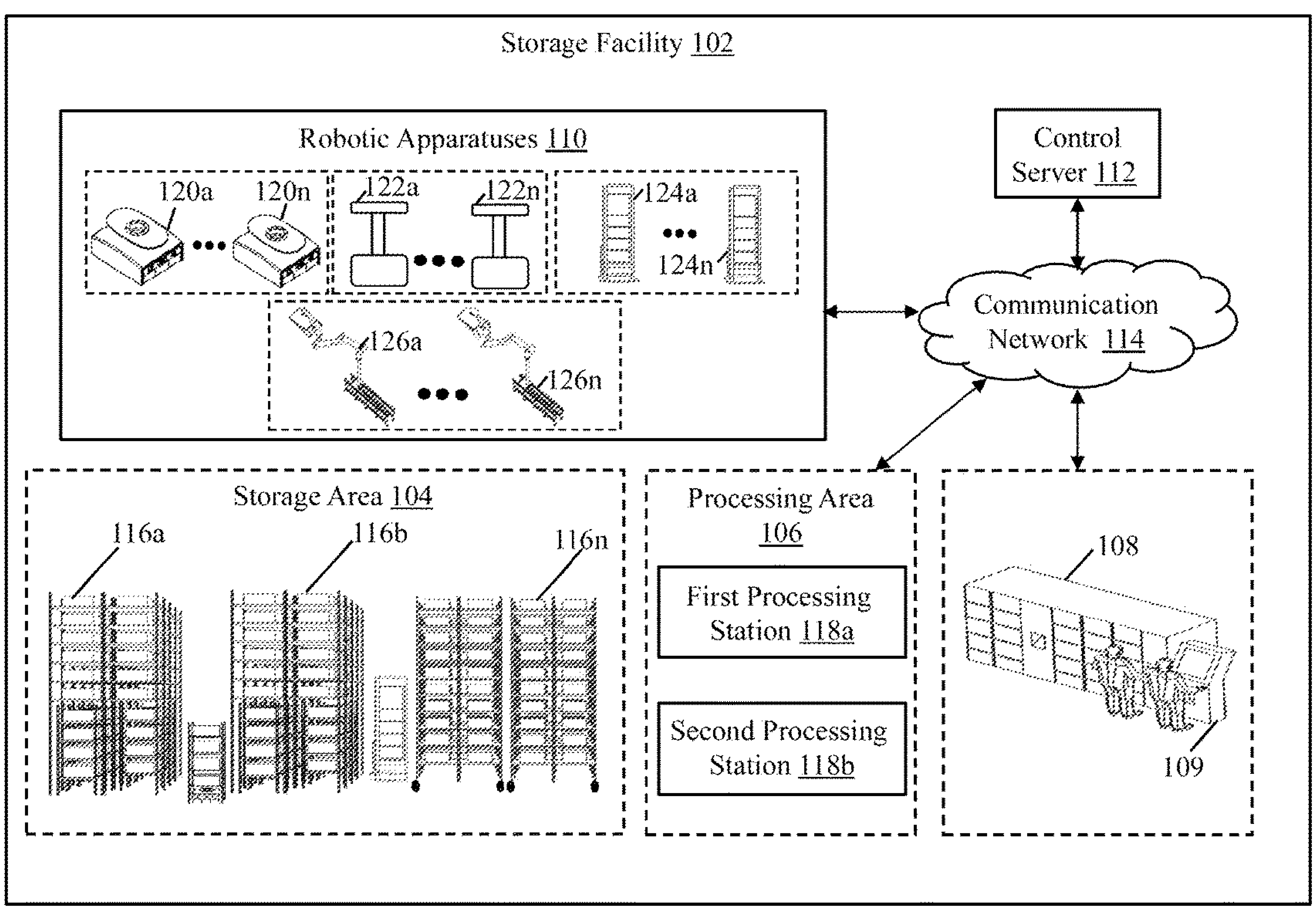
(57) **ABSTRACT**

Provided is a locker system that includes a plurality of lockable doors, a security lock mechanism, and a plurality of compartments. Opening of each lockable door is controlled based on a corresponding security parameter. The security lock mechanism controls opening and closing of each lockable door based on the corresponding security parameter. Each compartment is accessible from a front side and a rear side of the locker system. An access to each compartment from the front side is controlled by a corresponding lockable door. Each compartment is open from the rear side. When a robotic apparatus, transporting one or more items associated with a process at a storage facility, aligns with the locker system from the rear side, the one or more items are accessible from the front side based on opening of one or more corresponding lockable doors of one or more compartments of the plurality of compartments.

100



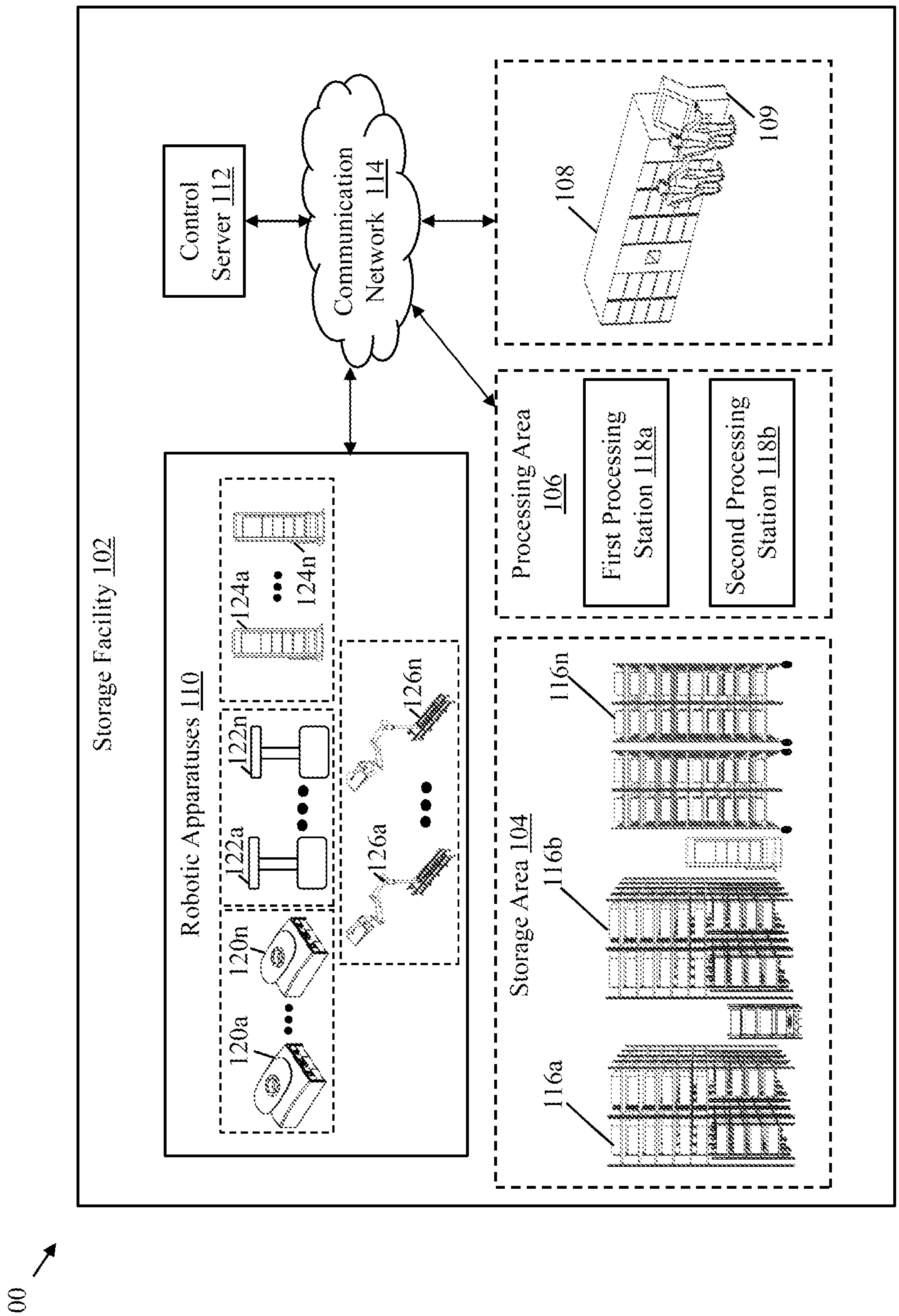

100
Storage Facility 102
Control Server 112
Communication Network 114
108
109
Robotic Apparatuses 110
120a
120n
122a
122n
124a
124n
126a
126n
Processing Area 106
First Processing Station 118a
Second Processing Station 118b
Storage Area 104
116a
116b
116n

FIG. 1

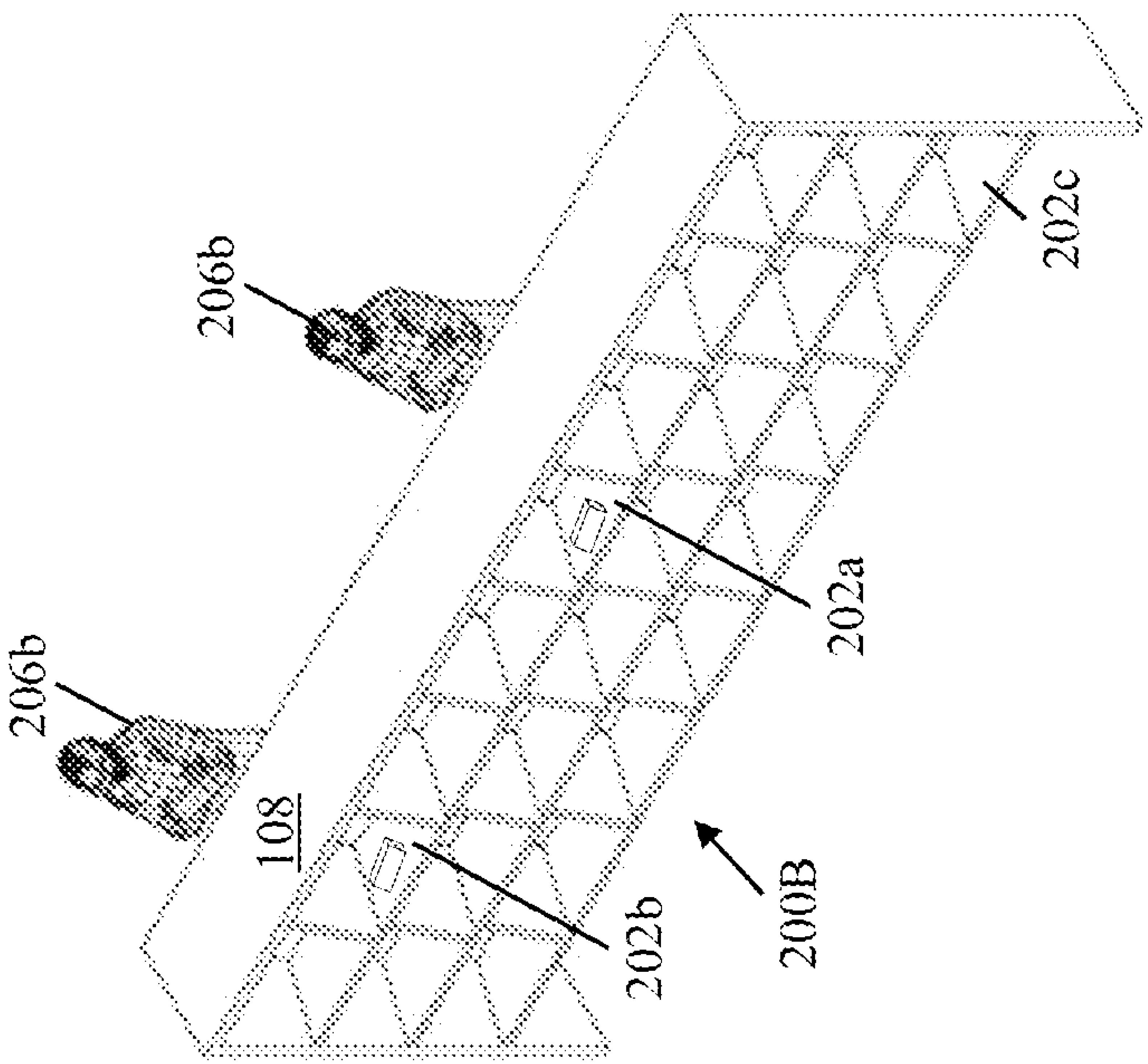
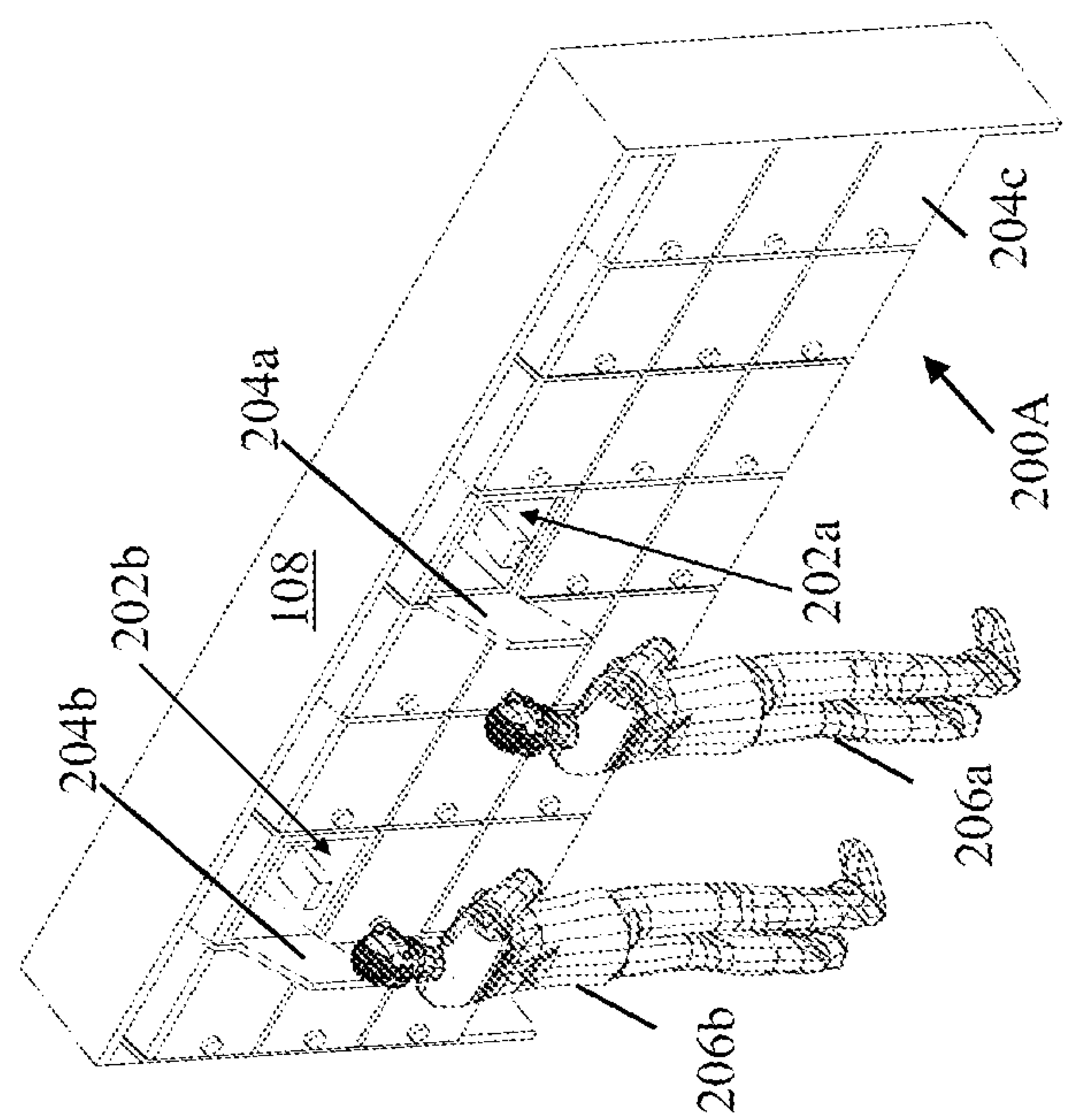

206b
206b
108
202b
202a
200B
202c

FIG. 2B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204a
202a
200A
204c
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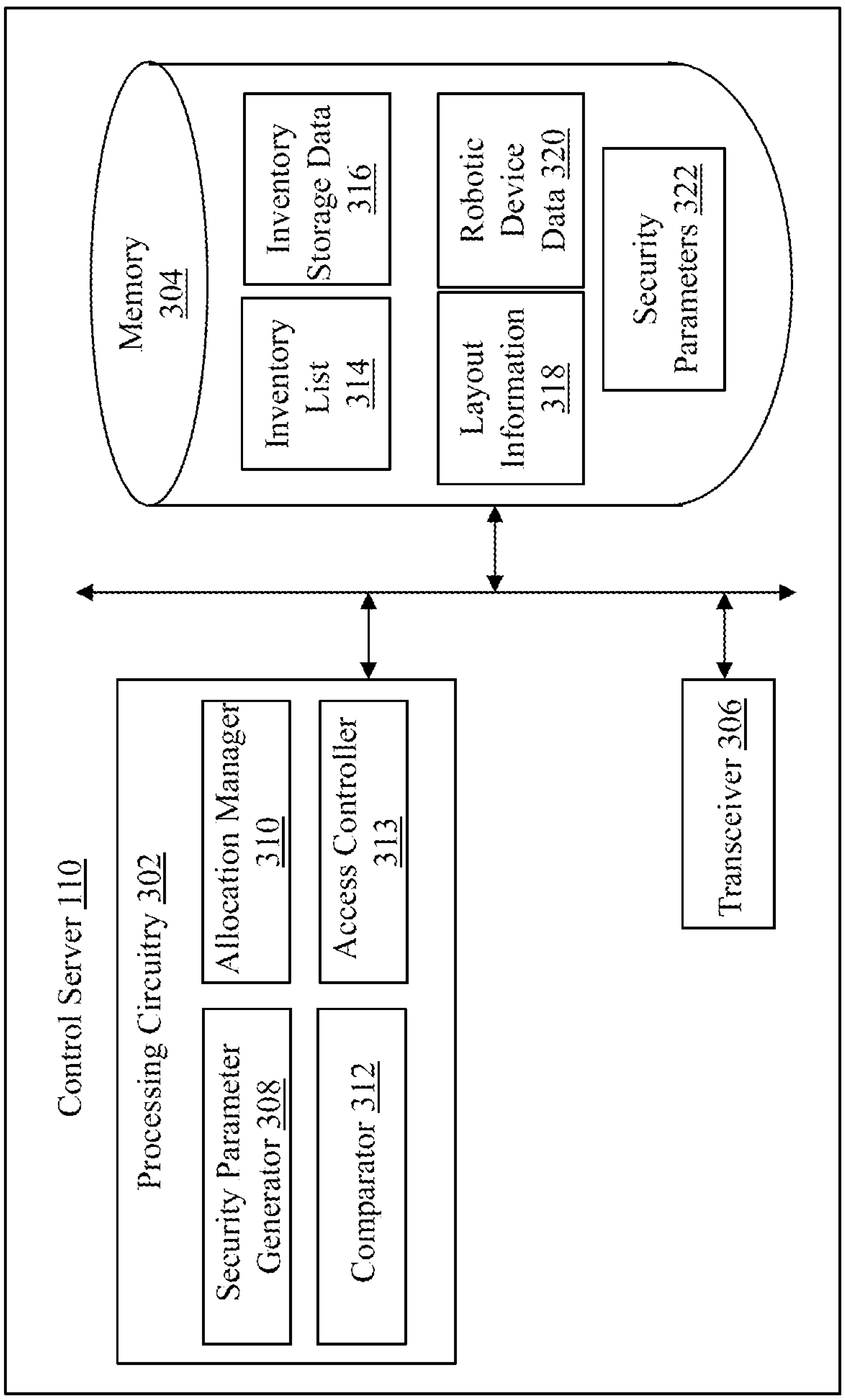
206b

FIG. 2A



Control Server 110
Processing Circuitry 302
Security Parameter Generator 308
Allocation Manager 310
Comparator 312
Access Controller 313
Transceiver 306
Memory 304
Inventory List 314
Inventory Storage Data 316
Layout Information 318
Robotic Device Data 320
Security Parameters 322

FIG. 3

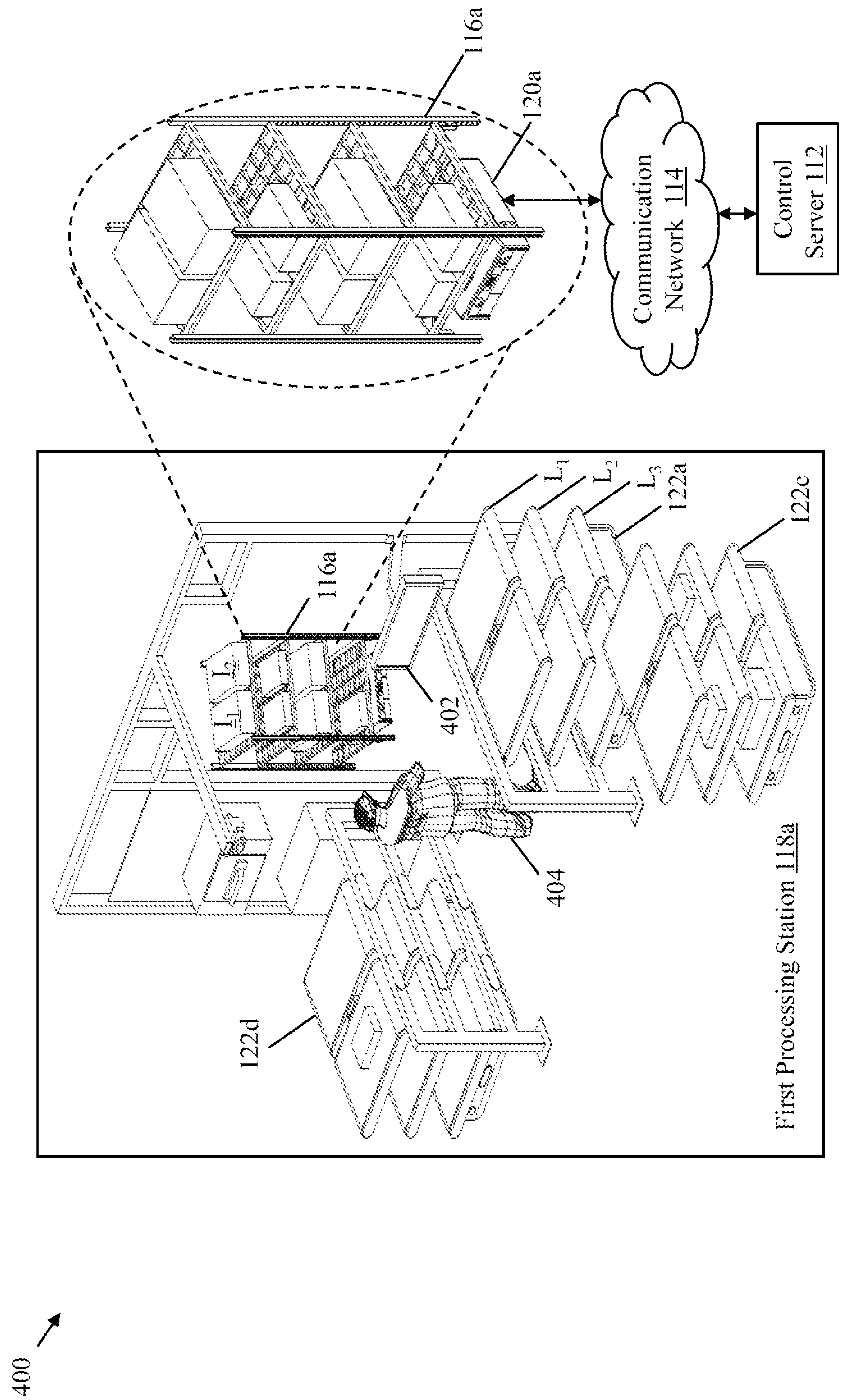
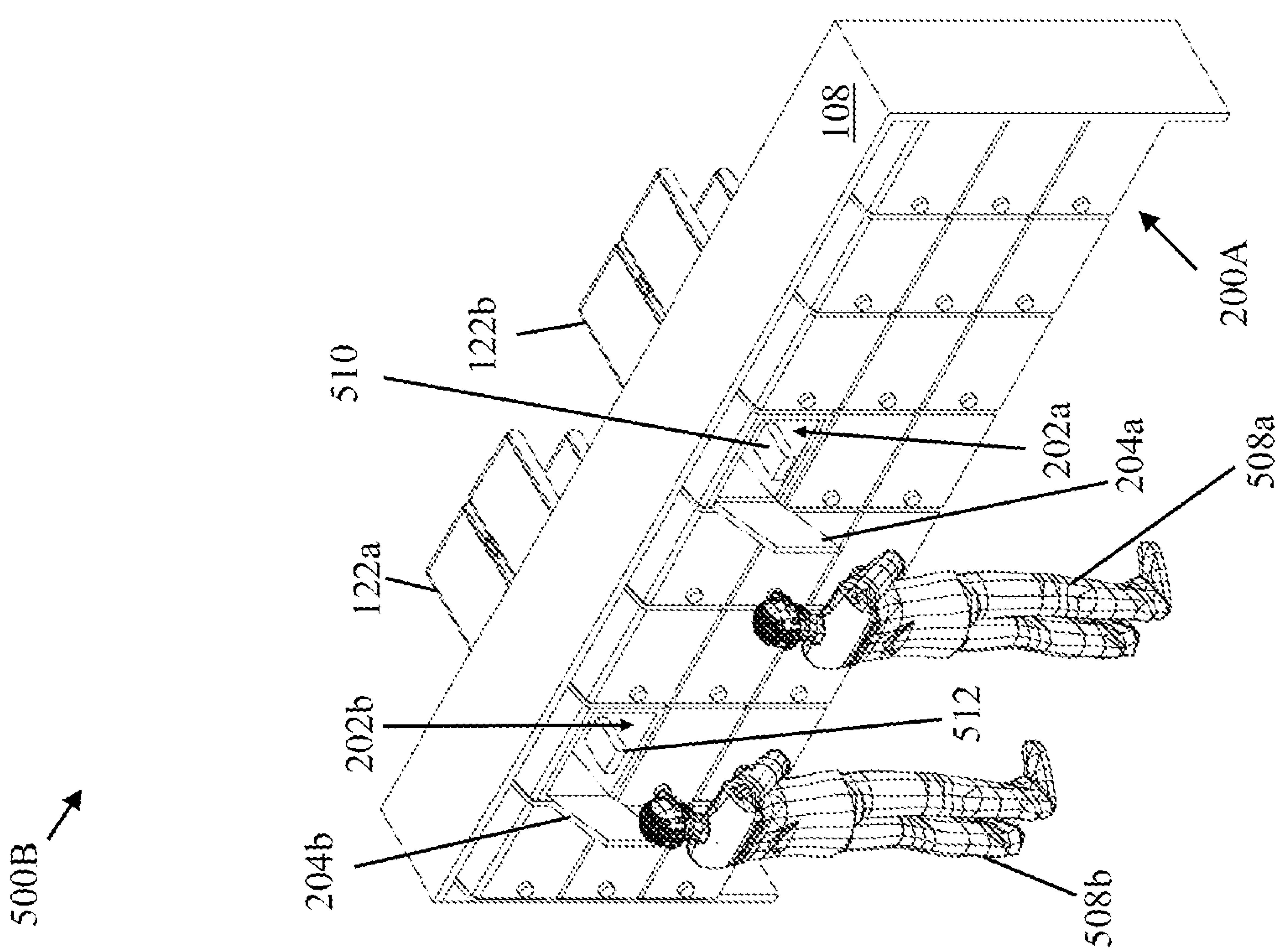

116a
120a
Communication Network 114
Control Server 112
L1
L2
L3
122a
122c
116a
L2
L1
402
404
122d
First Processing Station 118a
400

FIG. 4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204b
202b
122a
512
510
202a
204a
122b
508a
508b
108
200A

FIG. 5B

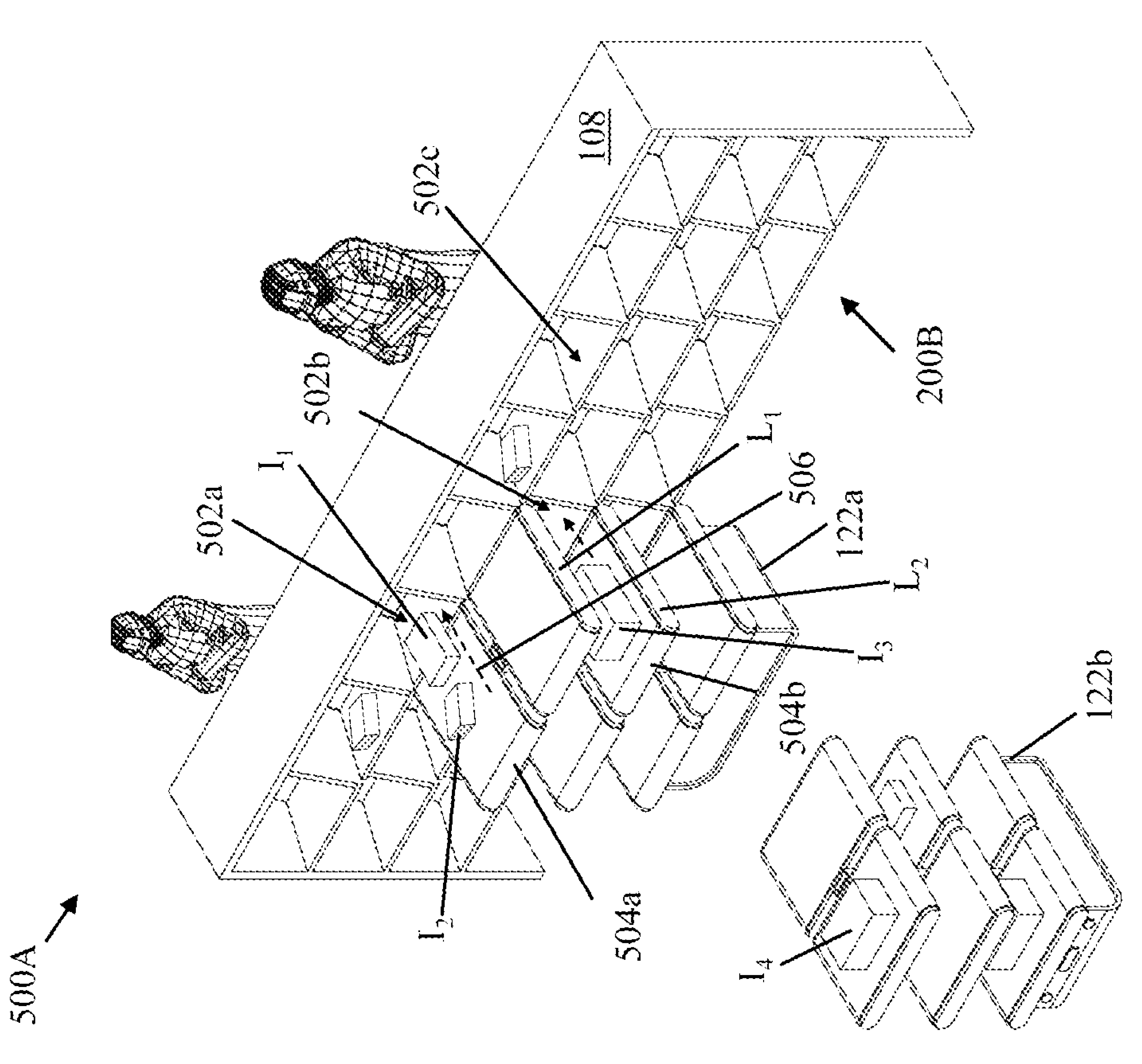
500A
502a
I_1
I_2
504a
502b
502c
L_1
506
122a
L_2
I_3
504b
122b
I_4
108
200B

FIG. 5A

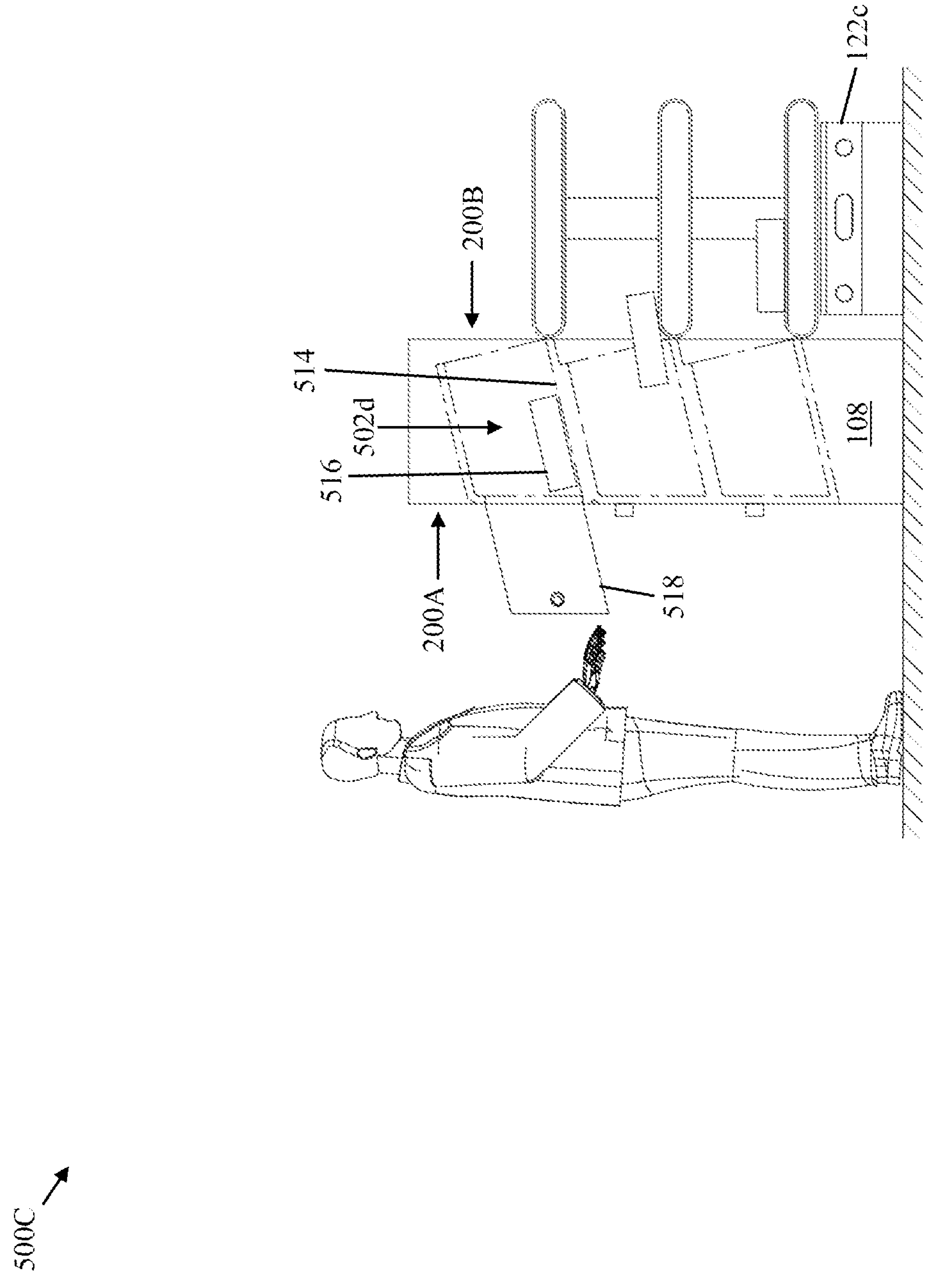

FIG. 5C

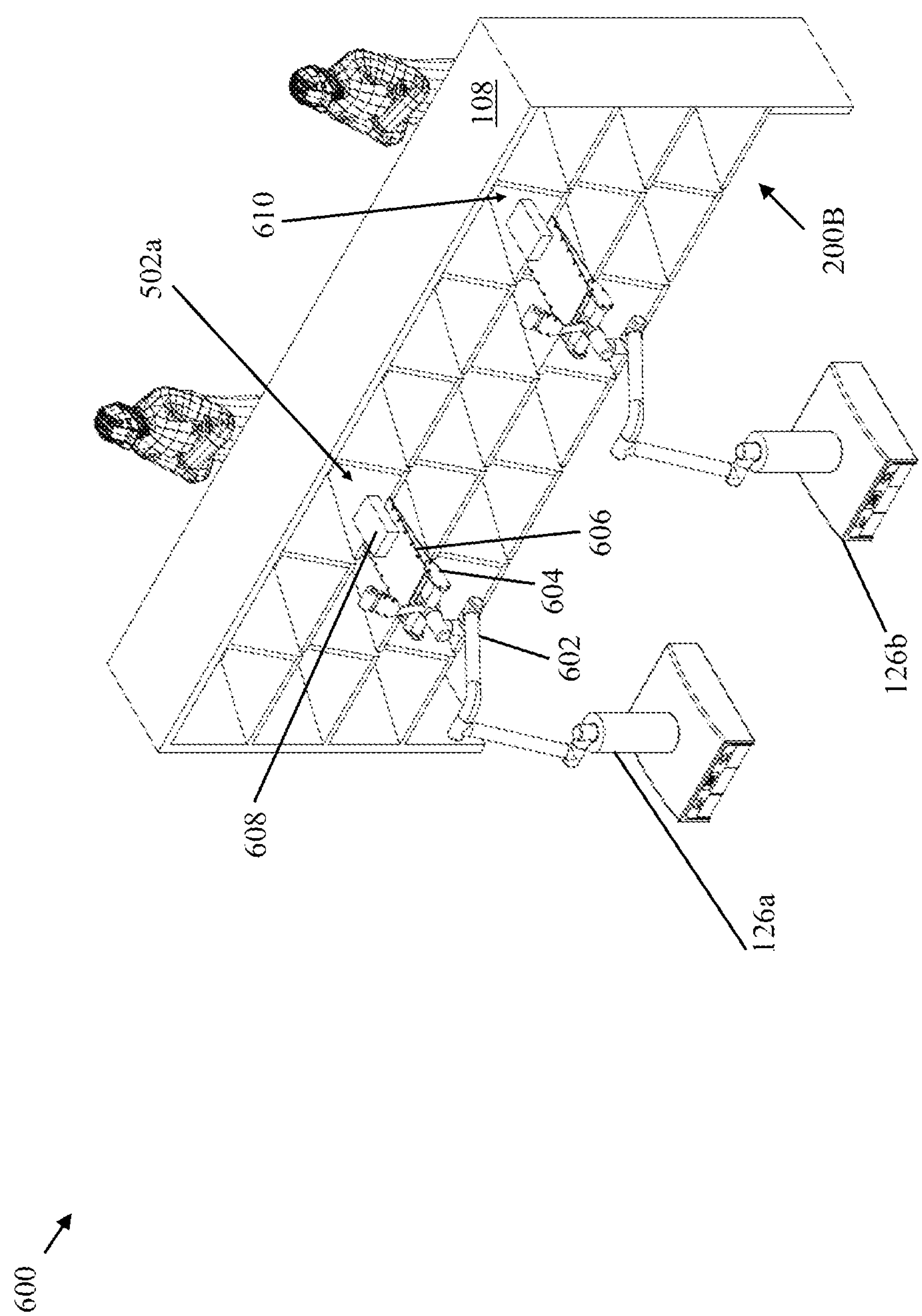

FIG. 6

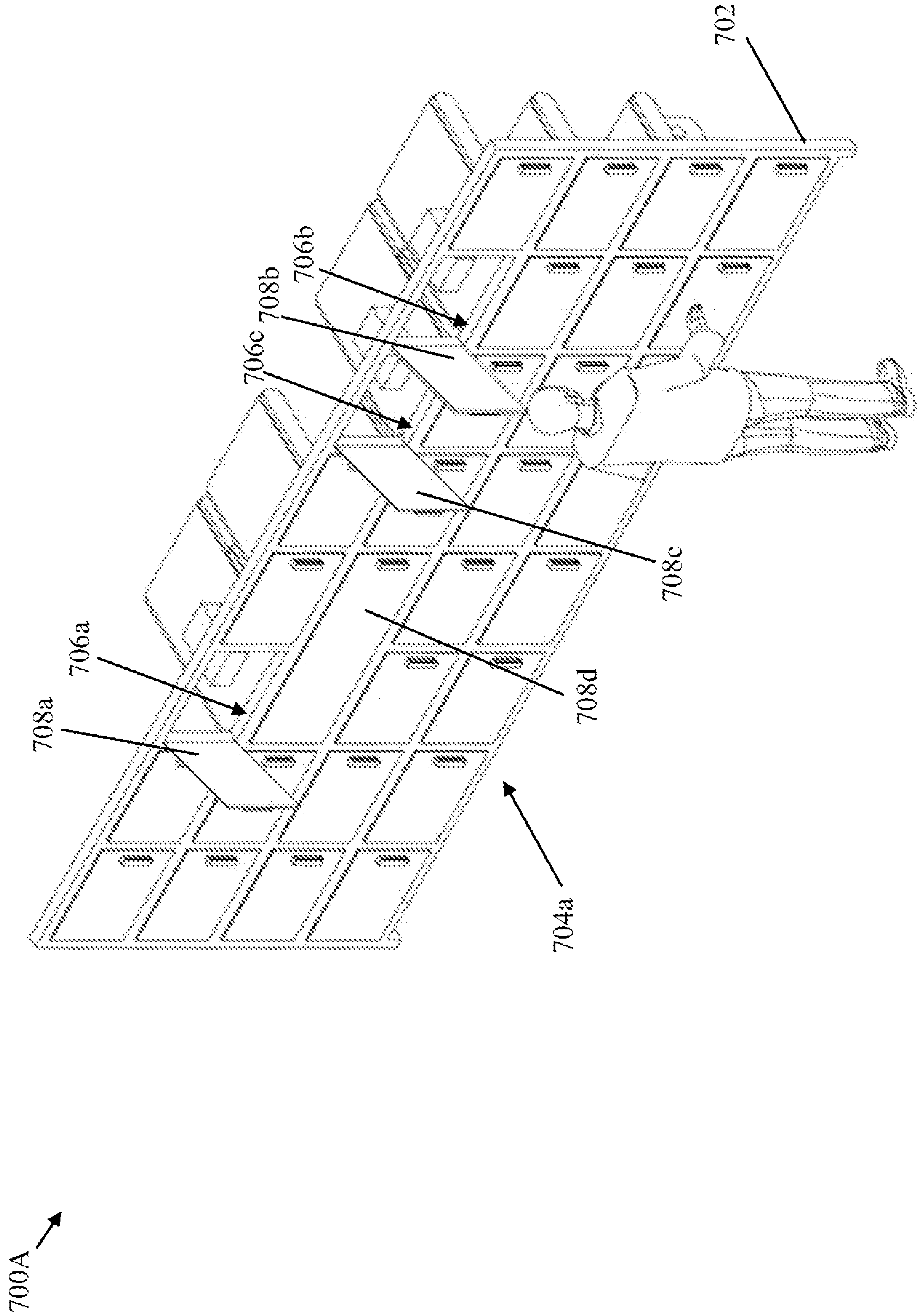

FIG. 7A

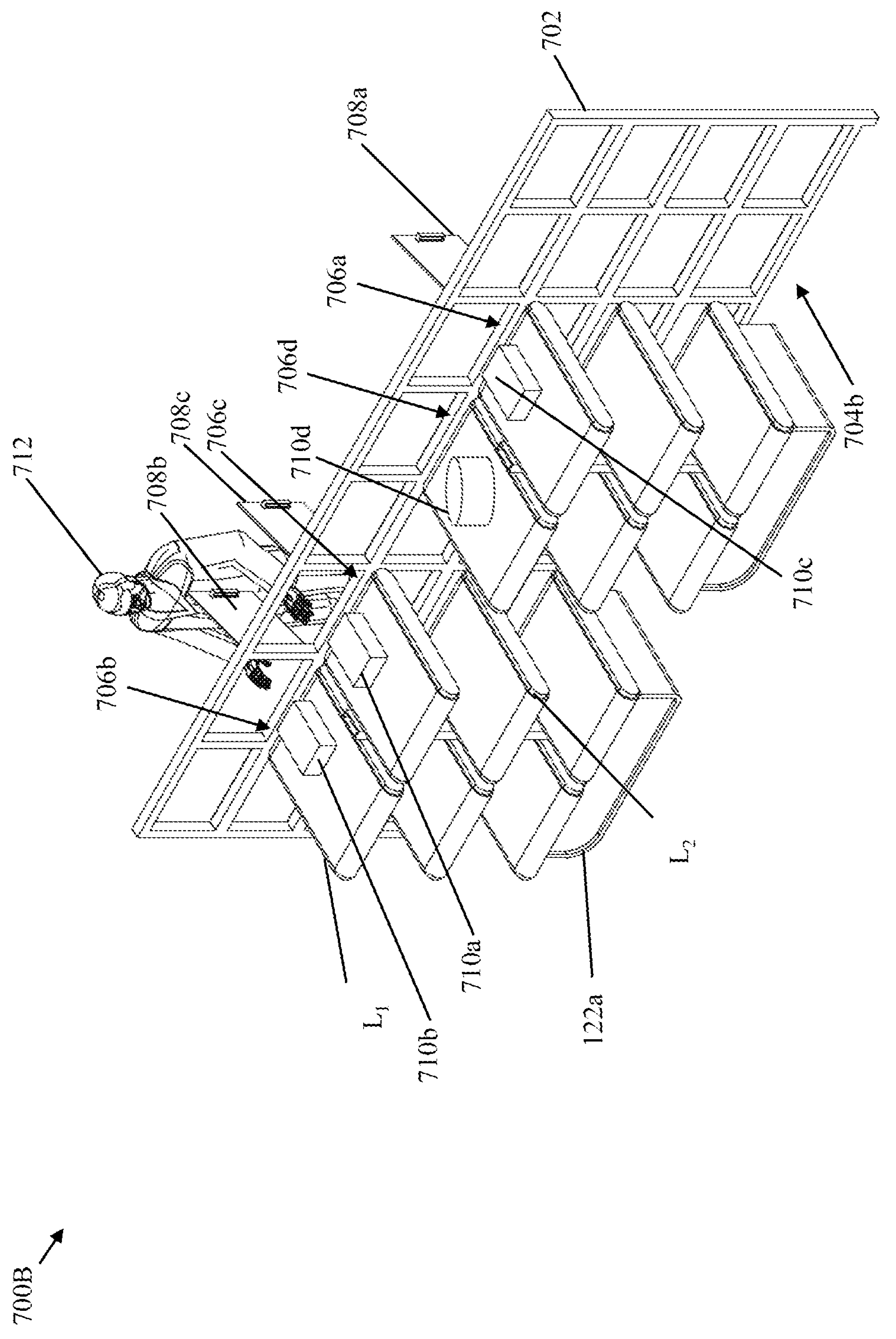
700B
702
708a
706a
706d
708c
706c
710d
712
708b
706b
704b
710c
L1
710b
710a
122a
L2

FIG. 7B

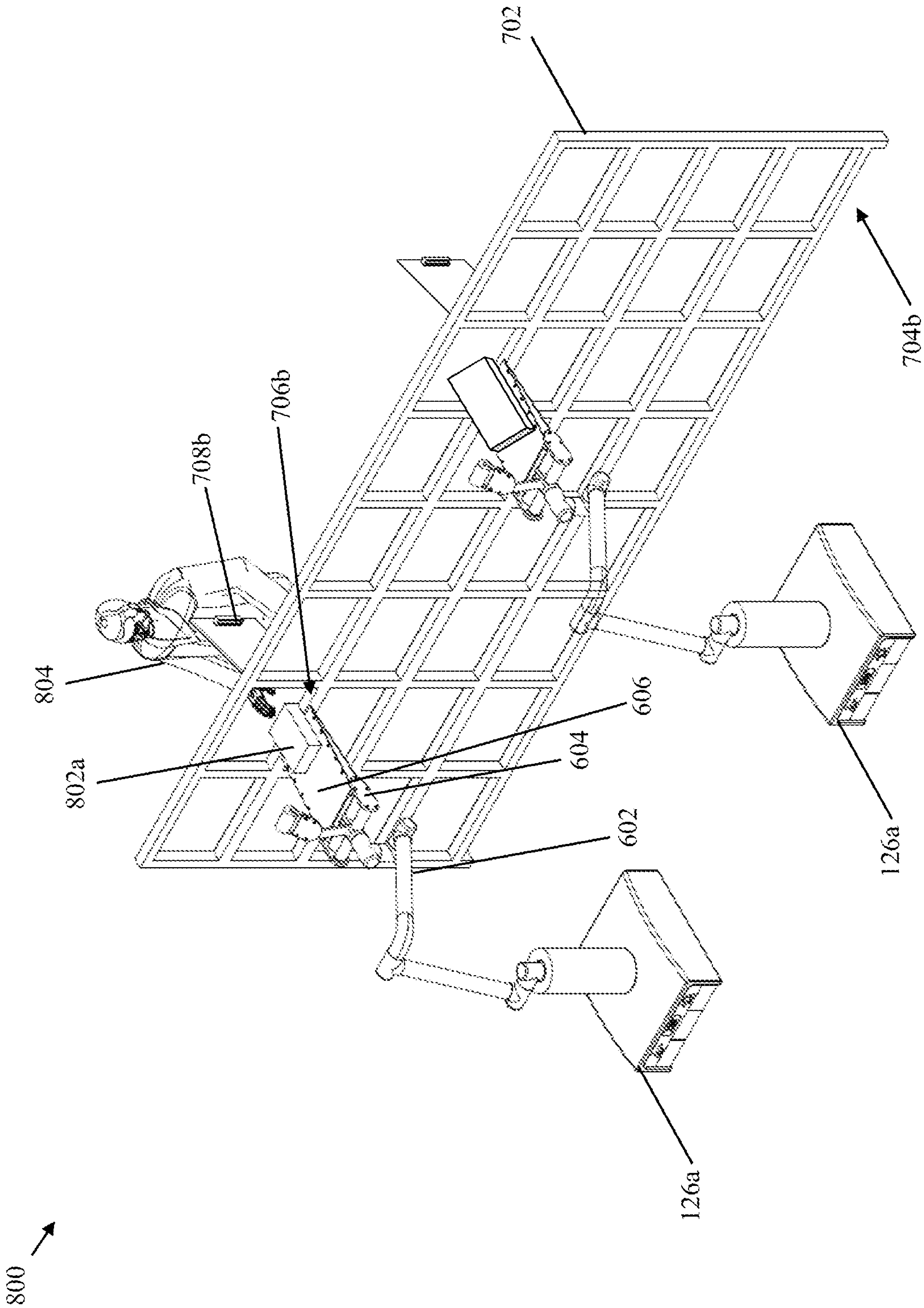

FIG. 8

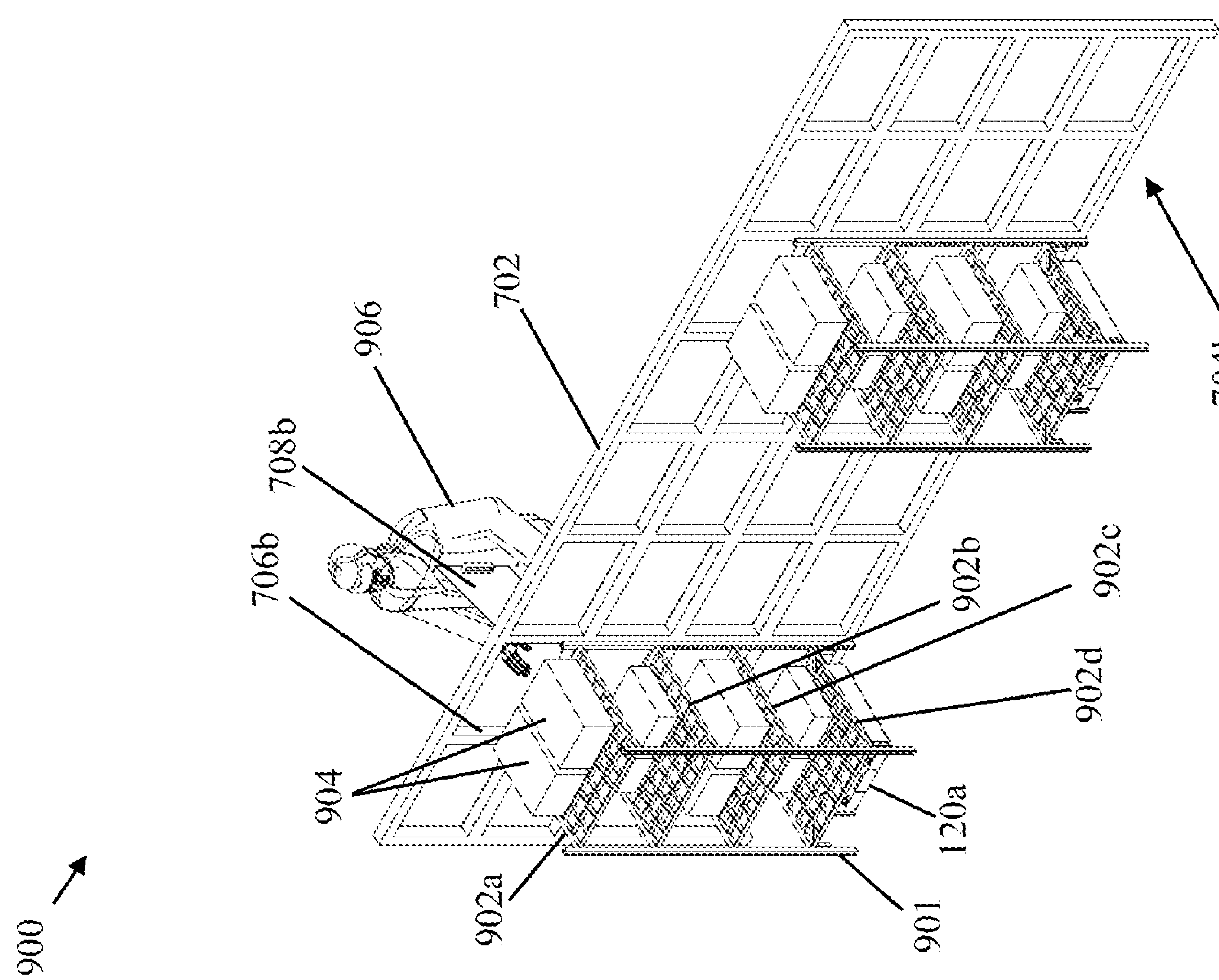
900
902a
904
706b
708b
906
702
902b
902c
902d
120a
901
704b

FIG. 9A

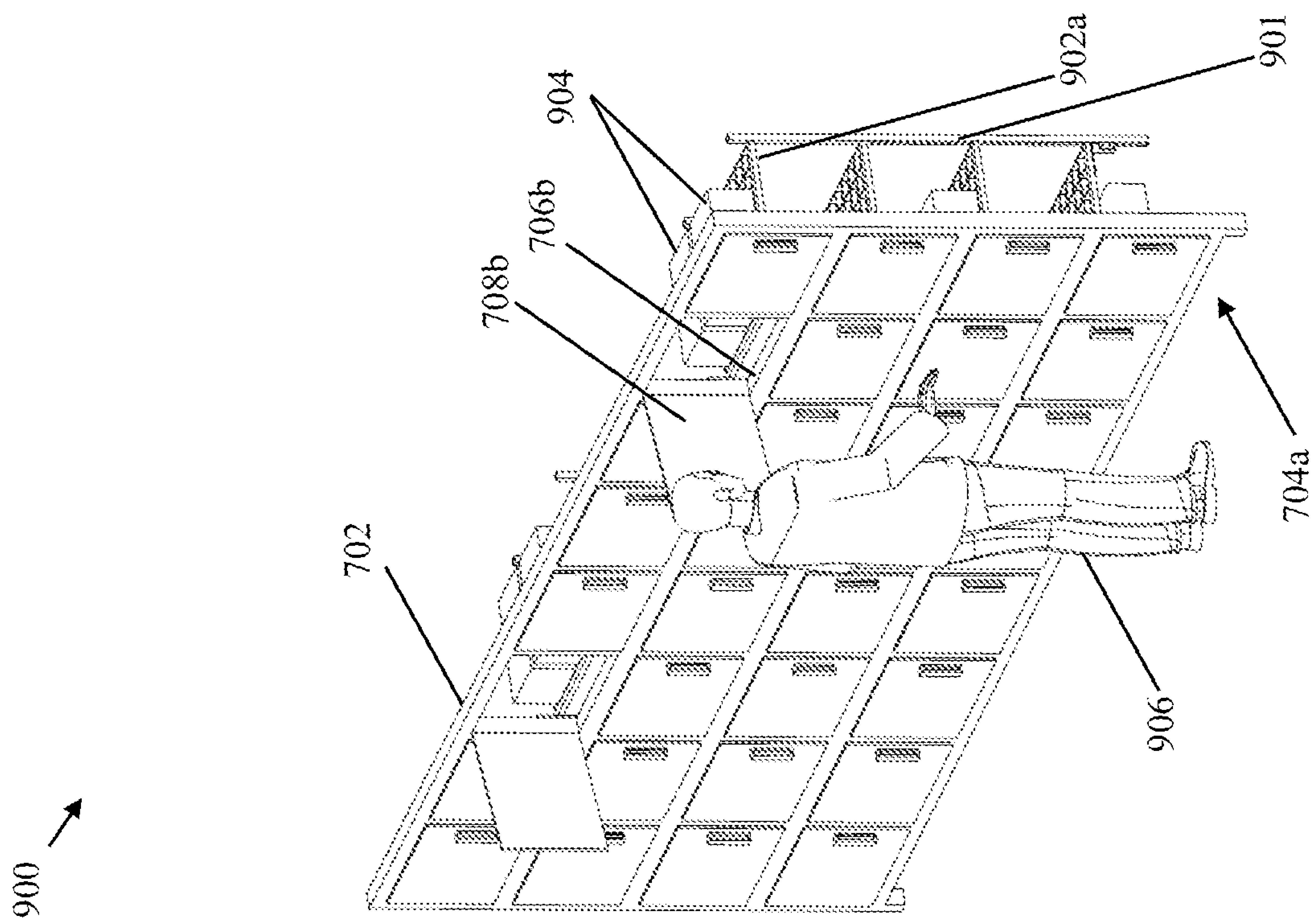
900
702
708b
706b
904
902a
901
906
704a

FIG. 9B

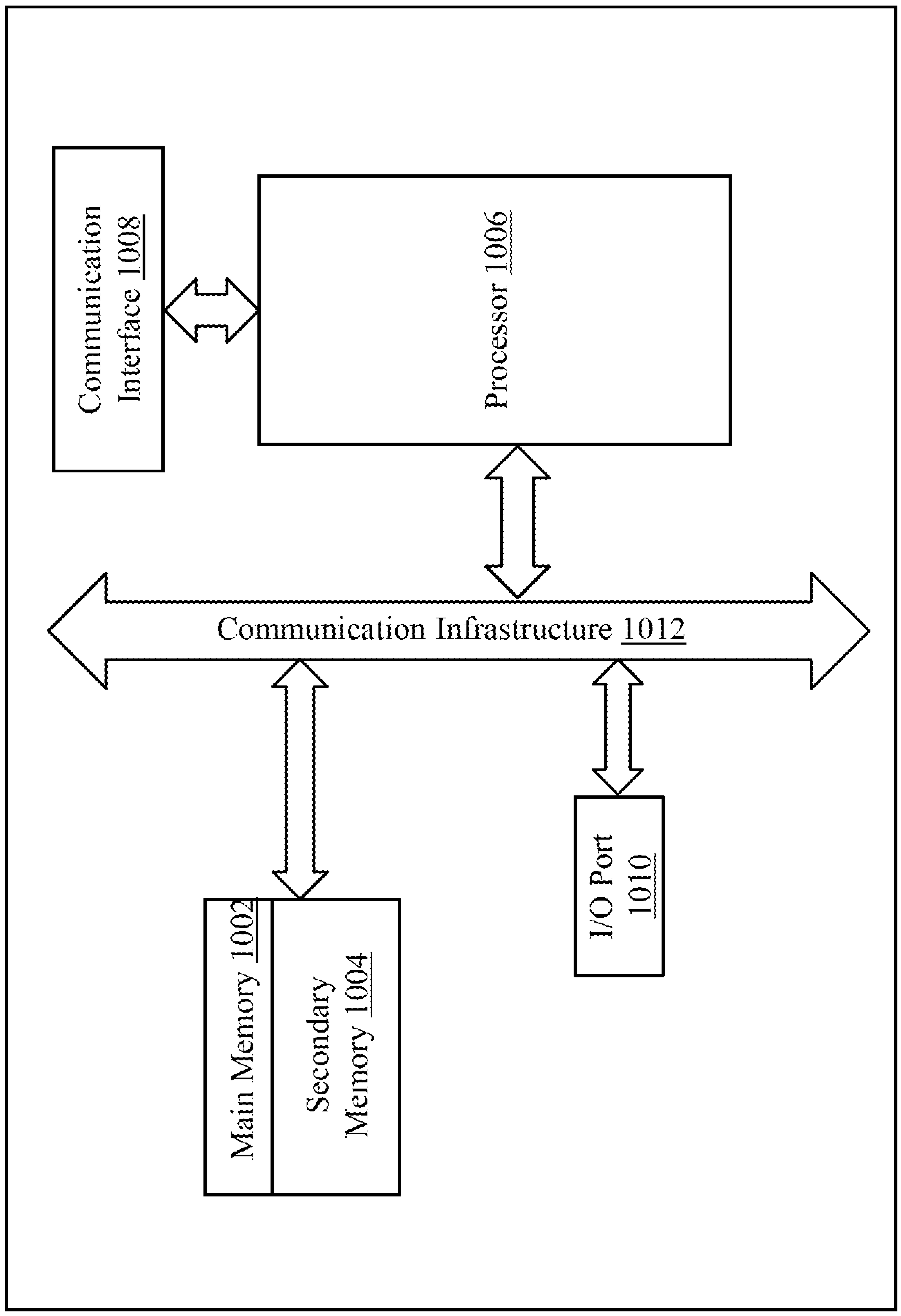
Communication Interface 1008
Processor 1006
Communication Infrastructure 1012
Main Memory 1002
Secondary Memory 1004
I/O Port 1010

FIG. 10

1000

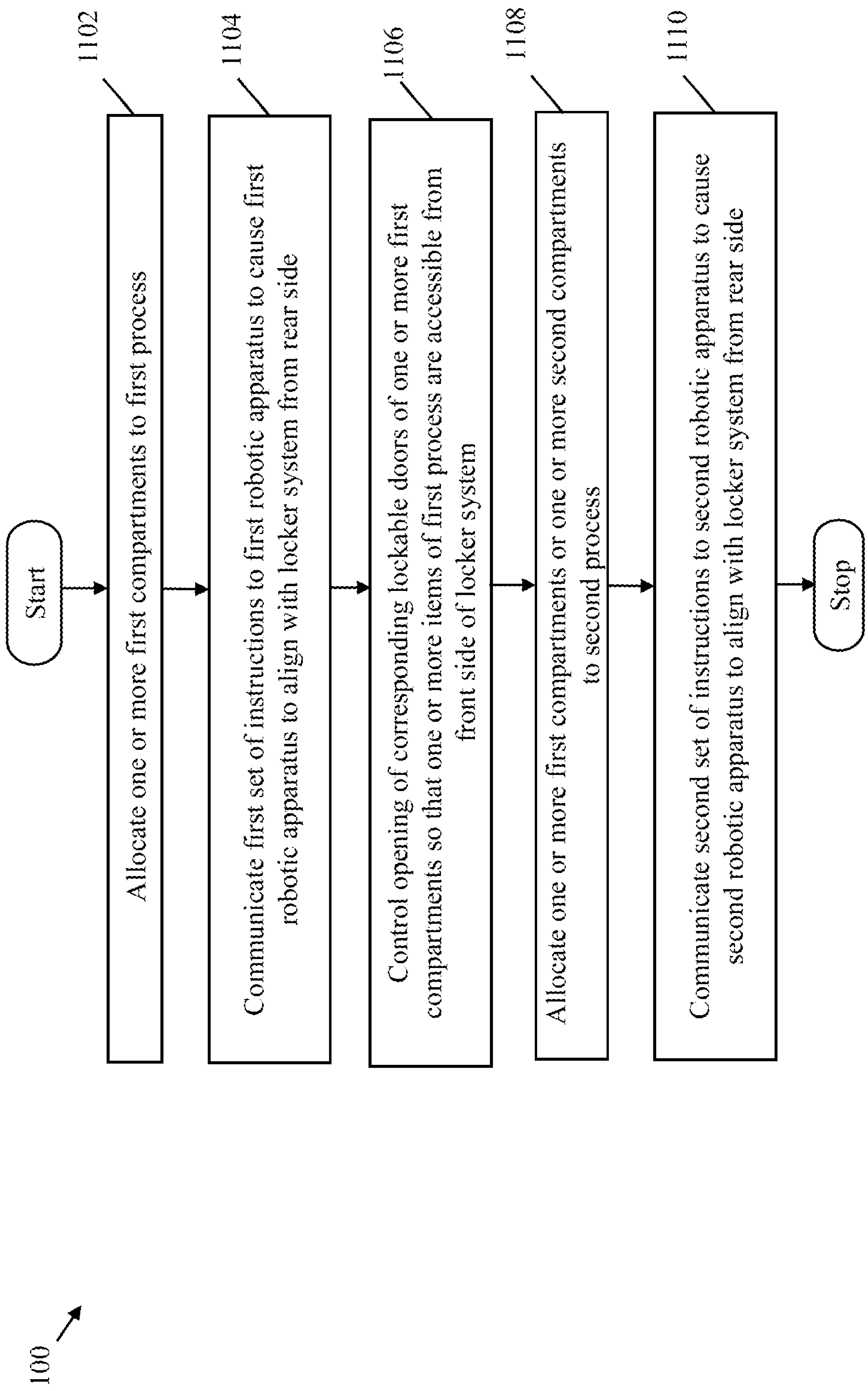
1100
Start
1102
Allocate one or more first compartments to first process
1104
Communicate first set of instructions to first robotic apparatus to cause first robotic apparatus to align with locker system from rear side
1106
Control opening of corresponding lockable doors of one or more first compartments so that one or more items of first process are accessible from front side of locker system
1108
Allocate one or more first compartments or one or more second compartments to second process
1110
Communicate second set of instructions to second robotic apparatus to cause second robotic apparatus to align with locker system from rear side
Stop

FIG. 11

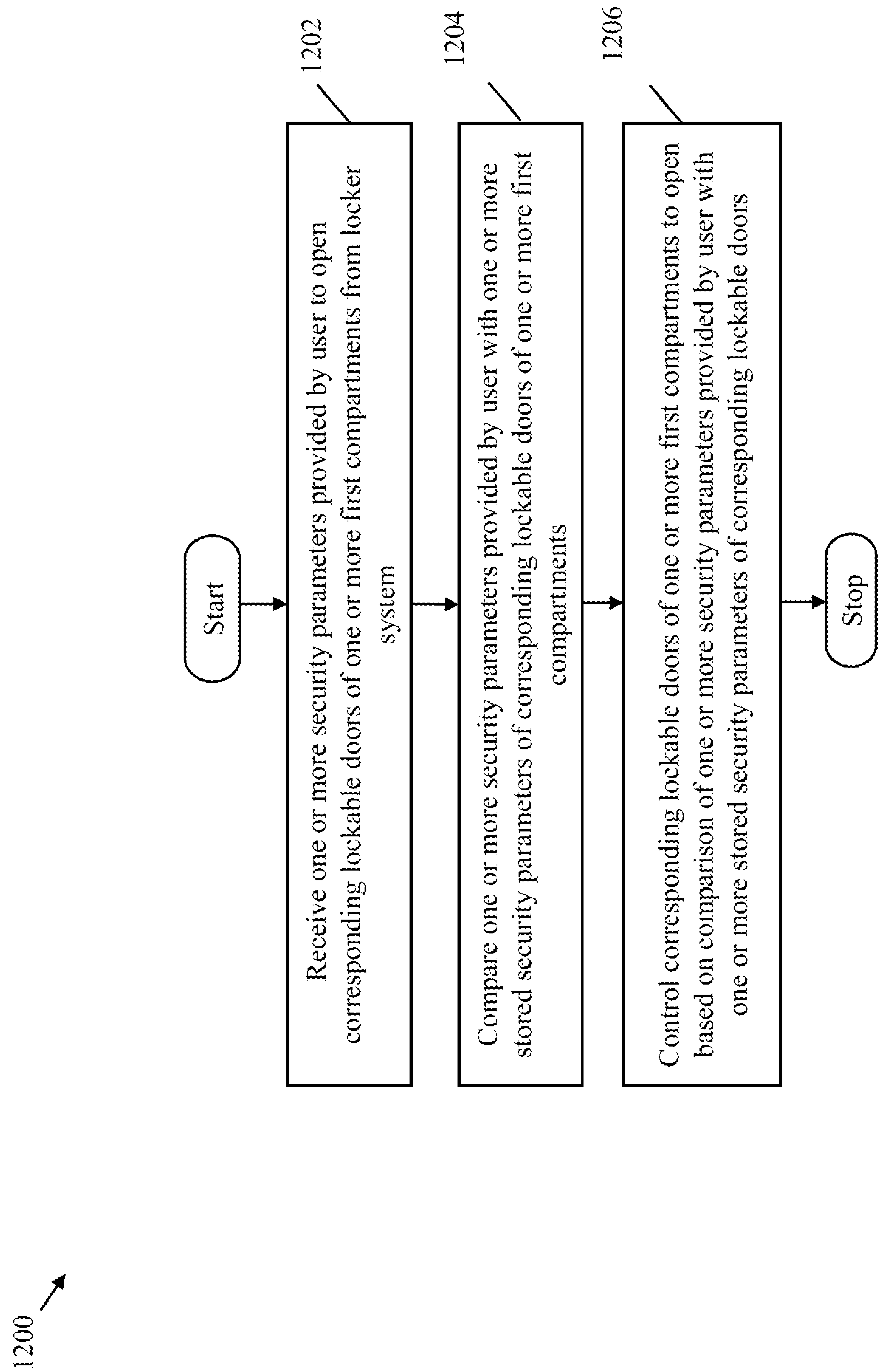
1200
Start
1202
Receive one or more security parameters provided by user to open corresponding lockable doors of one or more first compartments from locker system
1204
Compare one or more security parameters provided by user with one or more stored security parameters of corresponding lockable doors of one or more first compartments
1206
Control corresponding lockable doors of one or more first compartments to open based on comparison of one or more security parameters provided by user with one or more stored security parameters of corresponding lockable doors
Stop

FIG. 12

AUTOMATED LOCKER SYSTEM FOR DELIVERY AND COLLECTION OF INVENTORY ITEMS

CROSS-RELATED APPLICATIONS

[0001] This application claims priority of Indian Provisional Application No. 202111015301, filed Mar. 31, 2021, the contents of which are incorporated herein by reference.

FIELD

[0002] The present disclosure relates generally to a locker management system, and more particularly, to a system and a method for an automated locker system for delivery and collection of inventory items.

BACKGROUND

[0003] Modern storage facilities handle a large number of inventory items on a daily basis. The inventory items are handled within the storage facility for the fulfilment of an order or brought inside the storage facility for replenishment of inventory stock. Throughputs of such storage facilities have a direct bearing on various business metrics such as time taken to complete orders, the total number of orders completed within a time duration, customer satisfaction, or the like.

[0004] In certain scenarios, such storage facilities include locker systems having multiple compartments where consolidated orders are stored to be collected by delivery personnel or customers. In order to store consolidated orders in the locker system, operators at the storage facility open compartment doors of the locker system, place the consolidated orders in the compartments and then close the compartment doors. The compartment doors are then operated by the delivery personnel or customers for collecting their orders. As for a single order, the compartment door is required to be operated twice; first—for storing the order, and second—for collecting the order. Thus, such locker systems are inefficient and decrease the throughput of order deliveries, resulting in the order collection being suboptimal.

[0005] In light of the foregoing, there exists a need for a technical solution that overcomes the abovementioned problems.

[0006] Limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of described systems with some aspects of the present disclosure, as set forth in the remainder of the present application and with reference to the drawings.

SUMMARY

[0007] Embodiments of the present disclosure provide an automated locker management system. The system includes a locker system including a plurality of compartments and a plurality of lockable doors. Each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system. An access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of the plurality of lockable doors. Each compartment of the plurality of compartments is open from the rear side. The system further includes a plurality of robotic apparatuses. A first robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more first items associated with a first process at a storage facility. The system further includes a control server. The control server is configured to allocate one or more first compartments of the plurality of compartments to the first process. Further, the control server is configured to communicate a first set of instructions to the first robotic apparatus to cause the first robotic apparatus to align with the locker system from the rear side. Based on the alignment of the first robotic apparatus with the locker system at the rear side, the one or more first items transported by the first robotic apparatus may be accessible from the front side of the one or more first compartments based on opening of corresponding lockable doors of the one or more first compartments.

[0008] Embodiments of the present disclosure provide an automated locker system. The system includes a plurality of lockable doors. Opening of each lockable door of the plurality of lockable doors is controlled based on a corresponding security parameter of each lockable door. The system further includes a security lock mechanism configured to control opening and closing of each lockable door based on the corresponding security parameter. The system further includes a plurality of compartments. Each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system. An access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of the plurality of lockable doors. Each compartment of the plurality of compartments is open from the rear side. When a robotic apparatus, transporting one or more items associated with a process at a storage facility, aligns with the locker system from the rear side, the one or more items are accessible from the front side of the locker system based on the opening of one or more corresponding lockable doors of one or more compartments of the plurality of compartments.

[0009] In some embodiments, a second robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more second items associated with a second process at the storage facility. The control server may be further configured to allocate the one or more first compartments to the second process. Further, the control server is configured to communicate a second set of instructions to the second robotic apparatus to cause the second robotic apparatus to align with the locker system from the rear side. The second robotic apparatus is configured to align with the locker system from the rear side based on the second set of instructions when the one or more first items are successfully collected from the one or more first compartments. Based on the alignment of the second robotic apparatus with the locker system at the rear side, the one or more second items transported by the second robotic apparatus are accessible from the front side of the one or more first compartments based on opening of the corresponding lockable doors of the one or more first compartments.

[0010] In some embodiments, a second robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more second items associated with a second process at the storage facility. The control server may be configured to allocate one or more second compartments of the plurality of compartments to the second process. The one or more second compartments are different from the one or more first compartments. The control server is configured to communicate a second set of instructions to the second robotic apparatus to cause the second robotic apparatus to align with the locker system from the rear side concurrently with the first robotic apparatus. Based on the alignment of the second robotic apparatus with the locker system at the rear side, the one or more second items transported by the second robotic apparatus are accessible from the front side of the one or more second compartments based on opening of corresponding lockable doors of the one or more second compartments.

[0011] In some embodiments, the control server is further configured to control opening of each lockable door of the plurality of lockable doors based on a corresponding security parameter.

[0012] In some embodiments, the corresponding security parameter is at least one of a password, a machine-readable optical code, or biometric information of a user.

[0013] In some embodiments, the control server is further configured to control the corresponding lockable doors of the one or more first compartments to open concurrently based on one security parameter.

[0014] In some embodiments, the control server is further configured to receive, from the locker system, the one or more security parameters provided by a user to open the corresponding lockable doors of the one or more first compartments. Further, the control server is configured to compare the one or more security parameters provided by the user with one or more stored security parameters of the corresponding lockable doors of the one or more first compartments. Further, the control server is configured to control the corresponding lockable doors of the one or more first compartments to open based on the comparison of the one or more security parameters provided by the user with the one or more stored security parameters of the corresponding lockable doors.

[0015] In some embodiments, the system may include a set of storage systems such that a first storage system of the set of storage systems is configured to store the one or more first items on one or more shelves thereof. The first robotic apparatus is configured to transport the one or more first items by lifting and transporting the first storage system.

[0016] In some embodiments, when the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more shelves storing the one or more first items are aligned with the one or more first compartments.

[0017] In some embodiments, the first robotic apparatus may include one or more conveyors such that the one or more first items are placed on the one or more conveyers. When the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more conveyors, having the one or more first items thereon, are aligned with the one or more first compartments.

[0018] In some embodiments, the first robotic apparatus is further configured to actuate the one or more conveyors based on the first set of instructions to transfer the one or more first items from the one or more conveyers to the one or more first compartments.

[0019] In some embodiments, the first robotic apparatus includes one or more levels such that the one or more first items are placed on the one or more levels. When the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more levels of the first robotic apparatus are aligned with the one or more first compartments.

[0020] These and other features and advantages of the present disclosure may be appreciated from a review of the following detailed description of the present disclosure, along with the accompanying figures in which like reference numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings illustrate the various embodiments of systems, methods, and other aspects of the disclosure. It will be apparent to a person skilled in the art that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. In some examples, one element may be designed as multiple elements, or multiple elements may be designed as one element. In some examples, an element shown as an internal component of one element may be implemented as an external component in another, and vice versa.

[0022] Various embodiments of the present disclosure are illustrated by way of example, and not limited by the appended figures, in which like references indicate similar elements:

[0023] FIG. **1** is a diagram that illustrates an exemplary environment of a storage facility, in accordance with an exemplary embodiment of the present disclosure;

[0024] FIG. **2**A is a diagram that illustrates a front side of a locker system, in accordance with an exemplary embodiment of the disclosure;

[0025] FIG. **2**B is a diagram that illustrates a rear side of the locker system, in accordance with an exemplary embodiment of the present disclosure;

[0026] FIG. **3** is a block diagram that illustrates a control server, in accordance with an exemplary embodiment of the present disclosure;

[0027] FIG. **4** is a diagram that illustrates an implementation of a processing station in the storage facility, in accordance with an exemplary embodiment of the disclosure;

[0028] FIGS. **5**A-**5**C are diagrams that illustrate exemplary scenarios for operating the locker system, in accordance with an exemplary embodiment of the disclosure;

[0029] FIG. **6** is a diagram that illustrates transfer of inventory items to the locker system using a robotic apparatus, in accordance with an exemplary embodiment of the present disclosure;

[0030] FIGS. **7**A and **7**B are diagrams that illustrates an alignment of one of the fourth robotic apparatus with the rear side of the locker system, in accordance with another embodiment of the present disclosure;

[0031] FIG. **8** is a diagram that illustrates collection of inventory items from the locker system, in accordance with another embodiment of the present disclosure;

[0032] FIGS. **9**A and **9**B are diagrams that illustrate an exemplary scenario for collection of inventory items from the locker system, in accordance with another embodiment of the present disclosure;

[0033] FIG. **10** is a block diagram that illustrates a system architecture of a computer system for inventory management in a storage facility, in accordance with the embodiments of the present disclosure;

[0034] FIG. **11** is a flow chart that illustrates an automated locker management method for delivery and collection of inventory items using the automated locker system, in accordance with an exemplary embodiment of the disclosure; and

[0035] FIG. **12** is a flow chart that illustrates a method for controlling opening of lockable doors of one or more compartments of the automated locker system, in accordance with an exemplary embodiment of the disclosure.

[0036] Further areas of applicability of the present disclosure will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description of exemplary embodiments is intended for illustration purposes only and is, therefore, not intended to necessarily limit the scope of the disclosure.

DETAILED DESCRIPTION

[0037] The present disclosure is best understood with reference to the detailed figures and description set forth herein. Various embodiments are discussed below with reference to the figures. However, those skilled in the art will readily appreciate that the detailed descriptions given herein with respect to the figures are simply for explanatory purposes as the methods and systems may extend beyond the described embodiments. In one example, the teachings presented and the needs of a particular application may yield multiple alternate and suitable approaches to implement the functionality of any detail described herein. Therefore, any approach may extend beyond the particular implementation choices in the following embodiments that are described and shown.

[0038] References to "an embodiment", "another embodiment", "yet another embodiment", "one example", "another example", "yet another example", "for example", and so on, indicate that the embodiment(s) or example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment or example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase "in an embodiment" does not necessarily refer to the same embodiment.

[0039] Certain embodiments of the disclosure may be found in disclosed systems and methods for an automated locker system for delivery and collection of inventory items. Exemplary aspects of the disclosure provide methods and systems for the automated locker systems. The systems and methods of the disclosure provide a solution for automated handling of inventory items within the storage facility. Specifically, the disclosed systems and methods include an automated locker system that allows for consolidated orders to be made accessible for collection without requiring various doors of the locker system to be opened and closed for storing the consolidated orders.

[0040] FIG. **1** is a diagram that illustrates an exemplary environment of a storage facility **102**, in accordance with an exemplary embodiment of the present disclosure. The storage facility **102** includes a storage area **104**, a processing area **106**, a locker system **108**, an access control interface **109**, robotic apparatuses **110**, a control server **112**, and a communication network **114**. The storage area **104** includes a plurality of storage systems **116***a*-**116***n*. The processing area **106** includes a plurality of processing stations (for example, a first processing station **118***a* and a second processing station **118***b*). The robotic apparatuses **110** may include multiple robotic apparatuses of different architecture, operating principles, or the like. For example, the robotic apparatuses **110** may include a plurality of first robotic apparatuses **120***a*-**120***n*, a plurality of second robotic apparatuses **122***a*-**122***n*, a plurality of third robotic apparatuses **124***a*-**124***n*, and a plurality of fourth robotic apparatuses **126***a*-**126***n*. The plurality of first robotic apparatuses **120***a*-**120***n* may be configured to transport the plurality of storage systems **116***a*-**116***n* within the storage facility **102**. The plurality of second robotic apparatuses **122***a*-**122***n* may have multiple level conveyors and may be configured to transport one or more inventory items or consolidated orders within the storage facility **102**. The plurality of third robotic apparatuses **124***a*-**124***n* may include storage shelves and movable trays, and may be configured to transport the inventory items or consolidated orders within the storage facility **102**. The plurality of fourth robotic apparatuses **126***a*-**126***n* may have one or more robotic arms and may be configured to pick the inventory items or consolidated orders from a first location and may put the inventory items or consolidated orders at a second location within the storage facility **102**. The robotic apparatuses **110** may receive one or more instructions from the control server **112** for their operation. The control server **112** may communicate with the robotic apparatuses **110** by way of the communication network **114**. The locker system **108**, the access control interface **109**, the robotic apparatuses **110**, the control server **112**, the communication network **114**, and the plurality of storage systems **116***a*-**116***n* may collectively form an automated locker management system for the storage facility **102**.

[0041] The storage facility **102** is a facility where inventory items or packages of inventory items are stored for order fulfillment and/or selling. Examples of the storage facility **102** may include, but are not limited to, a forward warehouse, a backward warehouse, a fulfillment center, or a retail store (e.g., a supermarket, an apparel store, a departmental store, a grocery store, or the like). Examples of the inventory items may include, but are not limited to, groceries, apparel, electronic goods, mechanical goods, or the like. The storage facility **102** has the storage area **104** where the plurality of storage systems **116***a*-**116***n* (hereinafter, collectively referred to and designated as "the storage systems **116**") are placed for storing the inventory items or the packages. In an embodiment, the storage area **104** may further serve as a resting place for the robotic apparatuses **110**. The storage systems **116** may be arranged in the storage area **104** in any arrangement that may be optimal for storage and retrieval of the storage systems **116** as well as the inventory items stored in the storage systems **116**. Various plans for arrangement of the storage systems **116** within the storage area **104** may be known in the art. Arrangement of the storage systems **116** in the storage area **104** may be automatic, semi-automatic, or manual. Storage of the inventory items in the storage systems **116** may be automatic, semi-automatic, or manual.

[0042] The storage systems **116** may be movable storage systems that store various inventory items and/or various packages, e.g., totes of different dimensions, types, shapes, materials, and capacity. In an embodiment, the storage systems **116** may further store therein various packages of consolidated orders. Each of the storage systems **116** may include multiple shelves, which enable the storage systems **116** to store multiple inventory items or packages. Each of the storage systems **116** may further include a reference marker associated therewith for uniquely identifying a corresponding storage system. Examples of the reference marker may include, but are not limited to, a barcode, a quick response (QR) code, a radio frequency identification device (RFID) tag, or the like. It will be apparent to those of skill in the art that the storage systems **116** may further include additional structural features that aid in transporting the storage systems **116**, without deviating from the scope of the disclosure.

[0043] The storage facility **102** may further include the processing area **106**. The processing area **106** may refer to a portion of the storage facility **102** where one or more pick/put operations are performed for handling the inventory items. The processing area **106** may have a plurality of processing stations (hereinafter, collectively referred to and designated as "the processing stations **118**") for executing one or more pick/put operations on the inventory items. The processing stations **118** may be associated with corresponding operators assigned to perform the pick/put operations on the inventory items. In an embodiment, the processing stations **118** may also utilize the plurality of fourth robotic apparatuses **126***a*-**126***n* for performing the pick/put operations on the inventory items along with the human operators. The pick/put operations may be performed at the processing stations **118** for various processes such as, item replenishment in the storage systems **116**, item retrieval from the storage systems **116** for order fulfillment, order consolidation, performing one or more value-added services on the inventory items, performing quality check on the inventory items, or the like. Each of the processing stations **118** may have a user interface for presenting one or more instructions to assigned operators for handling the inventory items. The processing stations **118** may further include one or more optical sensors that may be configured to capture one or more images or videos to monitor the pick/put operations, alignment and positioning of the inventory items being handled, state of the inventory items, or the like. In an embodiment, the processing area **106** or the processing stations **118** may serve as resting locations for the robotic apparatuses **110**.

[0044] The storage facility **102** may further include various locker systems and access control interfaces, such as the locker system **108** and the access control interface **109**. In an embodiment, the locker system **108** and the access control interface **109** may be utilized for order collection and delivery. For example, the locker system **108** may serve as a curbside locker where consolidated orders are stored for delivery and collection by delivery personnel or customers. The access control interface **109** may serve as a curbside kiosk including an interactive interface. The access control interface **109** may be used by the delivery personnel or the customers for collecting their order from the locker system **108**. In other words, the access control interface **109** may enable the delivery personnel or the customers to access the locker system **108** for collecting their consolidated orders. In another embodiment, the locker system **108** and the access control interface **109** may be utilized in the storage facility **102** for providing controlled access to inventory items. For example, the locker system **108** may serve as a locker where inventory items are stored for collection by operators. In such a scenario, the access control interface **109** may be used by the operator for collecting the requisite inventory items from the locker system **108**.

[0045] The locker system **108** includes a plurality of compartments and a plurality of lockable doors that control access to the plurality of compartments, respectively. Each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system **108**. An access to each compartment from the front side is controlled by a corresponding lockable door positioned at the front side of the corresponding compartment whereas each compartment is open from the rear side. The rear side of the locker system **108** serves as an access point for storing inventory items in the plurality of compartments and the front side of the locker system **108** serves as an access point for collecting the stored inventory items from the plurality of compartments. Since the plurality of compartments are open from the rear side, inventory items may be stored in the locker system **108** without the need of opening any compartment door. In other words, the plurality of lockable doors are only opened for collecting inventory items from the locker system **108**, thereby improving the throughput of various processes in the storage facility **102**.

[0046] The inventory items may be stored in the plurality of compartments by the robotic apparatuses **110** under the control of the control server **112**. For example, the robotic apparatuses **110** may access the locker system **108** from the rear side and store the inventory items in the plurality of compartments. Various embodiments where the robotic apparatuses **110** are used to store the inventory items in the locker system **108** from the rear side of the locker system **108** are described later in conjunction with FIGS. **5**A-**5**C and **6**-**9**.

[0047] In some embodiments, two or more lockable doors of the plurality of lockable doors may be opened concurrently (for example, at the same time) to provide simultaneous access to respective compartments. In an embodiment, each of the plurality of lockable doors may be associated with a unique security parameter that controls the opening of the respective lockable door. For example, a first lockable door may be associated with a first security parameter and a second lockable door may be associated with a second security parameter. In such a scenario, when the first security parameter is inputted to the access control interface **109**, the first lockable door is automatically opened and when the second security parameter is inputted to the access control interface **109**, the second lockable door is automatically opened. In a scenario, if an incorrect security parameter is inputted to the access control interface **109**, no lockable door is opened. In other words, opening of the plurality of lockable doors may be controlled based on corresponding security parameters.

[0048] In some embodiments, two or more lockable doors of the locker system **108** may be associated with the same security parameter. For example, the first and second lockable doors may be associated with the same security parameter. In such a scenario, when the security parameter is inputted to the access control interface **109**, the first and second lockable doors are automatically opened concurrently or at the same time.

[0049] In some embodiments, the security parameters of the plurality of lockable doors may be dynamic parameters that are updated periodically by the control server **112**. Examples of the dynamic parameters may include, but are not limited to, a one-time password (OTP), barcodes, and quick response (QR) codes. In another embodiment, the security parameters of the plurality of lockable doors may be static parameters that do not change with time. Examples of the static parameters may include, but are not limited to, personal identification numbers (PINs), machine-readable optical codes such as barcodes or QR codes, or biometric information of a user.

[0050] The locker system **108** may further include a plurality of security lock mechanisms for the respective plurality of lockable doors. The plurality of security lock mechanisms may be configured to open or close the respective plurality of lockable doors. In other words, a security lock mechanism is configured to secure a corresponding lockable door in a closed position until a correct security parameter is inputted at the access control interface **109** for opening the lockable door. In some embodiments, the plurality of security lock mechanisms may receive instructions to lock or unlock the respective plurality of lockable doors from the control server **112** and/or the access control interface **109**. The security lock mechanisms may be implemented by way of electromagnetic locks such as solenoid and/or actuators.

[0051] In some embodiments, the plurality of compartments and the plurality of lockable doors of the locker system **108** may have same size, shape, dimensions, and weight bearing capacity. In some embodiments, the plurality of compartments and the plurality of lockable doors of the locker system **108** may have different sizes, shapes, dimensions, and weight bearing capacities.

[0052] The locker system **108** may further include a plurality of sensors such as weight sensors, infrared sensors, ultrasonic sensors, or the like for each of the plurality of compartments. The weight sensors in a compartment may be configured to generate sensor data that indicates weight of items placed in the compartment. Hereinafter, the terms "inventory items" and "items" are used interchangeably. For example, when no inventory item is placed in the first compartment of the plurality of compartments, the sensor data generated by the weight sensors of the first compartment indicate that the weight is zero. The infrared sensors or the ultrasonic sensors may be coupled to the rear side and the front side of each of the plurality of compartments and may be configured to generate sensor data that indicates whether the plurality of compartments are being accessed from the front side or whether any of the robotic apparatuses **110** is aligned with the compartments from the rear side. For example, when a user attempts to access the first compartment from the front side, the infrared sensors or the ultrasonic sensors coupled to the front side of the first compartment generate sensor data that indicates that a hand of the user is inside the first compartment. Similarly, when one of the robotic apparatuses **110** is aligned with the first compartment from the rear side, the infrared sensors or the ultrasonic sensors coupled to the rear side of the first compartment generate sensor data that indicates that one of the robotic apparatuses **110** is aligned with the first compartment from the rear side. In some embodiments, the sensor data generated by the infrared sensors or the ultrasonic sensors coupled to the rear side of the first compartment may further indicate whether the robotic apparatus is incorrectly or correctly aligned with the first compartment.

[0053] The locker system **108** may have a fixed or a dynamic location within the storage facility **102**. For the sake of brevity, the storage facility **102** is shown to include a single locker system **108** and a single access control interface **109**. In other embodiments, the storage facility **102** may include any number of locker systems having a similar or different architecture. The locker system **108** is described in detail in conjunction with FIGS. **2**A and **2**B.

[0054] Examples of the access control interface **109** may be an electronic kiosk or any user interaction entity (e.g., a human machine interface, HMI). The electronic kiosk refers to a computer-based information delivery system generally accessible to some segment of the public for retrieving information or initiating some processes. The access control interface **109** may include a display screen for presenting information to the customer and some form of computer input device for the customer such as a touch screen or keypad, although a full keyboard or mouse may also be provided. The type of kiosk system of interest here may be an interactive system that may have multiple kiosk sites (for example, the access control interface **109**) accessible by customers. The access control interface **109** may present multiple selectable options to a user (e.g., a customer or an operator), for example, a first option for placing a new order, a second option to search information regarding a previously placed order, a third option for viewing an inventory item catalog of the storage facility **102**, a fourth option for collecting the inventory items for a previously placed order or for executing a process in the storage facility **102**, or the like. Upon selection of the fourth option by the user, the access control interface **109** may be configured to prompt the customer to enter the security parameter associated with the previously placed order. If the security parameter provided by the customer is correct, lockable doors corresponding to the inputted security parameter are opened for item or order collection.

[0055] Although the access control interface **109** and the locker system **108** are shown as separate entities, in some embodiments, the access control interface **109** may be integrated with the locker system **108** without deviating from the scope of the disclosure.

[0056] Transportation of the inventory items or consolidated orders within the storage facility **102** may be performed by the robotic apparatuses **110**. The robotic apparatuses **110** may be configured to receive one or more instructions from the control server **112**. Based on the received one or more instructions, the robotic apparatuses **110** may be configured to transport the inventory items or the consolidated orders within the storage facility **102**, for example, from the processing area **106** to the locker system **108**.

[0057] The control server **112** may include suitable logic, circuitry, interfaces, and/or code, executable by the circuitry, to facilitate various inventory management operations in the storage facility **102**. Examples of the control server **112** may include, but are not limited to, personal computers, laptops, mini-computers, mainframe computers, any non-transient and tangible machine that can execute a machine-readable code, cloud-based servers, distributed server networks, or a network of computer systems. The control server **112** may be realized through various web-based technologies such as, but not limited to, a Java web-framework, a .NET framework, a personal home page (PHP) framework, or any other web-application framework. The control server **112** may be maintained by a storage facility management authority or a third-party entity that facilitates inventory management and handling operations for the storage facility **102**. It will be understood by a person having ordinary skill in the art that the control server **112** may execute other storage facility management operations as well along with the inventory management operations.

[0058] The control server **112** may be configured to communicate with the locker system **108**, the access control interface **109**, and the robotic apparatuses **110** by way of the communication network **114**. The control server **112** may be further configured to remotely control the robotic apparatuses **110** and the locker system **108**. The control server **112** may be further configured to store, in a memory of the control server **112**, a virtual map of the storage facility **102** and inventory storage data of inventory stock. The virtual map is indicative of current locations of the robotic apparatuses **110**, entry and exit points of the storage facility **102**, various reference markers in the storage facility **102**, a current location of each inventory item, a current location of each storage system **116**, locations of the first and second processing stations **118***a* and **118***b*, location of the locker system **108**, or the like. The inventory storage data is indicative of associations between the inventory items stored in the storage facility **102** and the storage systems **116** in the storage facility **102**. The inventory storage data may further include historic storage locations of each inventory item. The inventory storage data may further include parameters (for example, weight, shape, size, color, dimensions, or the like) associated with each inventory item. The control server **112** may be further configured to manage allocation of the plurality of compartments to various processes in the storage facility and allocation of the robotic apparatuses **110** for transporting the inventory items associated with the processes. The control server **112** may be further configured to generate and store therein the security parameters of the plurality of lockable doors of the locker system **108** so as to control the opening of the plurality of lockable doors. The control server **112** may be configured to receive security parameters inputted by a user (e.g., a customer, delivery personnel, or an operator of the storage facility **102**) from the access control interface **109** and match the received security parameters with stored security parameters. When the inputted security parameters match any of the stored security parameters, the control server **112** may be configured to control unlocking of one or more lockable doors of one or more compartments corresponding to the matched security parameters.

[0059] The communication network **114** is a medium through which instructions and messages are transmitted between the control server **112**, the robotic apparatuses **110**, the locker system **108**, and the access control interface **109**. Examples of the communication network **114** may include, but are not limited to, a wireless fidelity (Wi-Fi) network, a light fidelity (Li-Fi) network, a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), a satellite network, the Internet, a fiber optic network, a coaxial cable network, an infrared (IR) network, a radio frequency (RF) network, and a combination thereof. Various entities (such as the robotic apparatuses **110**, the locker system **108**, the access control interface **109**, and the control server **112**) in the storage facility **102** may be coupled to the communication network **114** in accordance with various wired and wireless communication protocols, such as Transmission Control Protocol and Internet Protocol (TCP/IP), User Datagram Protocol (UDP), Long Term Evolution (LTE) communication protocols, or any combination thereof.

[0060] In operation, the control server **112** may be configured to receive a process request for executing a first process. The first process may be associated with one or more first inventory items of the plurality of inventory items stored in the storage facility **102** and may require the first inventory items to be made accessible to a delivery personnel, a customer, or an operator in the storage facility **102**. In one example, the first process may correspond to providing an access to a consolidated order via the locker system **108** so that the delivery personnel or the customer may be able to collect the consolidated order. In another example, the first process may correspond to an internal process of the storage facility **102** where the first inventory items are to be made accessible to a specific operator via the locker system **108**. Here, the internal process may refer to any process (for example, quality check process, item replenishment process, order fulfilment process, or the like) that is executed within the storage facility **102** for carrying out one or more operations in the storage facility **102**.

[0061] Based on the received process request, the control server **112** may be configured to allocate one or more first compartments of the plurality of compartments of the locker system **108** to the first process. The control server **112** may further communicate instructions to a robotic apparatus of the robotic apparatuses **110** to transport the first inventory items from a current storage location to the locker system **108**. The robotic apparatus may be any of the plurality of first robotic apparatuses **120***a*-**120***n*, the plurality of second robotic apparatuses **122***a*-**122***n*, the plurality of third robotic apparatuses **124***a*-**124***n*, and the plurality of fourth robotic apparatuses **126***a*-**126***n*. The control server **112** may be configured to select the robotic apparatus from the robotic apparatuses **110** based on an availability of the robotic apparatus, a type of the first process, compatibility of the robotic apparatus with the first process, or the like. Based on the instructions from the control server **112**, the robotic apparatus may be configured to transport the first inventory items associated with the first process to the locker system **108**. The control server **112** may be further configured to communicate a set of instructions to the robotic apparatus to cause the robotic apparatus to align with the locker system **108** from the rear side. In an embodiment, the set of instructions may include path information of a first path that the robotic apparatus is to travel in the storage facility **102** to reach the location of the locker system **108** to align with the one or more first compartments. The first set of instructions may further include unique identifiers of the one or more first compartments that enable the robotic apparatus to identify the one or more first compartments from the plurality of compartments.

[0062] Based on the received set of instructions, the robotic apparatus may travel along the first path and align with the one or more first compartments from the rear side of the locker system **108**. The first inventory items transported by the robotic apparatus are accessible from the front side of the one or more first compartments upon opening of corresponding lockable doors of the one or more first compartments.

[0063] In some embodiments, the robotic apparatus may transfer the first inventory items to the one or more first compartments after successfully aligning with the one or more first compartments and once the transfer is complete, the robotic apparatus may become available for executing one or more other operations in the storage facility **102**.

[0064] In other embodiments, the robotic apparatus may not transfer the first inventory items to the one or more first compartments and may remain aligned with the one or more first compartments until the first inventory items are collected from the robotic apparatus by a designated entity by opening the corresponding lockable doors of the one or more first compartments from the front side of the locker system **108**. In such an embodiment, the robotic apparatus may become available for executing one or more other operations in the storage facility **102** after the first inventory items are successfully collected by the designated entity.

[0065] The control server **112** may be further configured to store therein security parameters of the plurality of lockable doors. In a first exemplary scenario where the first inventory items correspond to a consolidated order of a customer, the control server **112** may be configured to communicate security parameters of the one or more first compartments, that provide access to the first inventory items, to a customer device (for example, a smartphone, a laptop, a wearable device, a mobile phone, or the like) of the customer or a delivery personnel. The customer or the delivery personnel may then input the security parameters into the access control interface **109** at the storage facility **102**. The access control interface **109** may communicate the inputted security parameters to the control server **112**. The control server **112** may compare the received security parameters with the stored security parameters and when the received security parameters match any of the stored security parameters, the control server **112** may communicate an unlock signal to the locker system **108** or the access control interface **109**.

[0066] In some embodiments, the control server **112** may communicate the unlock signal to the locker system **108** or the access control interface **109** when the sensor data generated by the infrared sensors or the ultrasonic sensors coupled to the rear side of the one or more first compartments indicate that the robotic apparatus is correctly aligned with the one or more first compartments from the rear side. However, if the sensor data generated by the infrared sensors or the ultrasonic sensors coupled to the rear side of the one or more first compartments indicates that the robotic apparatus is incorrectly aligned with the one or more first compartments, the control server **112** may communicate an instruction to the robotic apparatus to correct the alignment with the one or more first compartments. Here, the instruction communicated to the robotic apparatus may include distance, rotation, or height adjustment information. The robotic apparatus may move as per the instruction and may get correctly aligned with the one or more first compartments. Since the infrared sensors or the ultrasonic sensors generate sensor data periodically, new sensor data generated by the infrared sensors or the ultrasonic sensors may indicate that the robotic apparatus is now correctly aligned with the one or more first compartments from the rear side.

[0067] In some embodiments, the control server **112** may communicate the unlock signal to the access control interface **109** and the access control interface **109** may actuate the security lock mechanism of the one or more first compartments to open the lockable doors of the one or more first compartments. In other embodiments, the control server **112** may communicate the unlock signal directly to the locker system **108** to actuate the security lock mechanism of the one or more first compartments for opening the lockable doors of the one or more first compartments. In other words, the control server **112** may control the opening of the lockable doors of the one or more first compartments based on the comparison of the received security parameters with the stored security parameters. Upon opening of the lockable doors of the one or more first compartments, the customer or the delivery personnel may collect the consolidated order from the one or more first compartments and the security lock mechanism may then close the opened lockable doors.

[0068] In some embodiments, the security lock mechanism may close the opened lockable doors when sensor data generated by the weight sensors of the one or more first compartments indicate that the weight of items placed in the one or more first compartments has changed to zero due to retrieval of the first inventory items by the customer or the delivery personnel.

[0069] In some embodiments, the security lock mechanism may not close the opened lockable doors until the sensor data generated by the infrared sensors or the ultrasonic sensors at the front side of the one or more first compartments indicate that a human hand is present inside the one or more first compartments.

[0070] In some embodiments, the control server **112** may change or update the security parameters associated with the one or more first compartments once the order is collected, to enhance the security of the locker system **108**.

[0071] In a second exemplary scenario where the first inventory items correspond to an internal process of the storage facility **102**, the control server **112** may be configured to communicate security parameters of the one or more first compartments from where the first inventory items could be collected, to an operator device of the operator executing the internal process. The first inventory items are collected by the operator from the one or more first compartments in the same manner as described above in the first exemplary scenario.

[0072] FIG. **2**A is a diagram that illustrates a front side **200**A of the locker system **108**, in accordance with an exemplary embodiment of the disclosure. In FIG. **2**A, two of the compartments **202*a*** and **202*b*** of the locker system **108** are labelled and three of the lockable doors **204*a***, **204*b***, and **204*c*** of the locker system **108** are labelled. Labelling of other compartments and lockable doors is omitted for the sake of brevity. In an embodiment, the locker system **108** includes a plurality of shelves that are spaced in a vertical direction and a plurality of walls that are disposed on each of the plurality of shelves to define the plurality of compartments on each shelf. The walls and the shelves, in combination, define the plurality of compartments of the locker system **108**.

[0073] As shown in FIG. **2**A, the lockable doors **204*a*** and **204*b*** are open at the same time. The compartments **202*a*** and **202*b*** and items stored in the compartments **202*a*** and **202*b*** are accessible to users **206*a*** and **206*b*** from the front side **200**A. Here, the users **206*a*** and **206*b*** may be operators, delivery personnel, or customers. Further, the lockable door **204*c*** is closed, and hence a compartment **202*c*** (shown in FIG. **2**B) of the lockable door **204*c*** is not accessible from the front side **200**A. The users **206*a*** and **206*b*** may have provided the security parameters to the access control interface **109** (shown in FIG. **1**) for requesting access to the compartments **202*a*** and **202*b***, respectively.

[0074] FIG. **2**B is a diagram that illustrates a rear side **200**B of the locker system **108**, in accordance with an exemplary embodiment of the present disclosure. As shown in FIG. **2**B, the plurality of compartments (e.g., the compartments **202*a***, **202*b***, and **202*c***) remain open at the rear side **200**B.

[0075] It will be apparent to a person skilled in the art that the exemplary usage of locker system **108** is for illustration purposes and does not limit the scope of the disclosure. As shown in FIGS. **2**A and **2**B, the plurality of compartments of the locker system **108** have dedicated shelves; however, the scope of the disclosure is not limited to it. In other embodiments, the plurality of compartments of the locker system **108** may not have dedicated shelves (as described in FIGS. **7**A-**9**), and therefore may only serve as access points instead of access and storage points.

[0076] FIG. **3** is a block diagram that illustrates the control server **112**, in accordance with an exemplary embodiment of the present disclosure. The control server **112** may include processing circuitry **302**, a memory **304**, and a transceiver **306**. The processing circuitry **302** may include a security parameter generator **308**, an allocation manager **310**, a comparator **312**, and an access controller **313**. It will be apparent to a person having ordinary skill in the art that the control server **112** is for illustrative purposes and not limited to any specific combination of hardware circuitry and/or software.

[0077] The processing circuitry **302** may execute and manage various operations (such as allotting compartments to processes, generating and updating security parameters, remotely controlling opening and closing of the plurality of lockable doors, inventory management, or the like) in the storage facility **102**. The processing circuitry **302** may execute the operations using the security parameter generator **308**, the allocation manager **310**, the comparator **312**, and the access controller **313**.

[0078] The security parameter generator **308** may include suitable logic, instructions, circuitry, interfaces, and/or code for generating unique security parameters for the plurality of lockable doors (e.g., the lockable doors **204***a*, **204***b*, and **204***c*) of the locker system **108**. In an embodiment, the generated security parameters for the plurality of lockable doors may be static. In another embodiment, the generated security parameters for the plurality of lockable doors may be dynamic. In an example, the dynamic security parameters may be time-limited parameters which the security parameter generator **308** updates after a specific time period. In another example, the dynamic security parameters may be process-based which the security parameter generator **308** updates after completion of the process. The opening of the plurality of lockable doors is controlled based on the unique security parameters. In some embodiments, the security parameter generator **308** may generate a single security parameter for multiple lockable doors. For example, when two or more compartments of the plurality of compartments are allocated to a single process, the security parameter generator **308** may generate a single security parameter for the two or more compartments. Thus, the security parameter generator **308** may be configured to generate the security parameters for the plurality of lockable doors based on allotment of the plurality of compartments to various processes. The security parameter generator **308** may be configured to store the generated security parameters in the memory **304**.

[0079] The allocation manager **310** may include suitable logic, instructions, circuitry, interfaces, and/or code for dynamically and continuously allocating and re-allocating the robotic apparatuses **110** for inventory item transportation. The allocation manager **310** may be further configured to manage the allocation of the plurality of compartments to various processes. The allocation manager **310** may allocate one or more compartments of the locker system **108** to a process based on the availability of the one or more compartments and compatibility between the one or more compartments and one or more inventory items associated with the process. For example, different compartments of the locker system **108** may have different sizes. In such a scenario, the allocation manager **310** may allocate those compartments to a process that have sufficient size to accommodate the inventory items of the process. For example, for a large size order, the allocation manager **310** may either allocate a single compartment of the locker system **108** that matches a size of the order or may split the consolidated order into two or more sub-orders and allocate two or more compartments that match the size of the two or more sub-orders, respectively. The allocation manager **310** may manage allocation of the robotic apparatuses **110** to transport inventory items based on a compatibility between the robotic apparatuses **110** and the inventory items. In one example, the allocation manager **310** may allocate the first robotic apparatus **120***a* to transport a batch of inventory items when a weight handling capacity, a size, dimensions, or the like of the first robotic apparatus **120***a* are sufficient to transport the batch of inventory items. However, if the weight handling capacity, the size, the dimensions, or the like of the first robotic apparatus **120***a* are not sufficient to transport the batch of inventory items, the allocation manager **310** may select another robotic apparatus for the task.

[0080] The comparator **312** may include suitable logic, instructions, circuitry, interfaces, and/or code for comparing security parameters received from the access control interface **109** with the security parameters stored in the memory **304**. Opening of the plurality of lockable doors of the locker system **108** is controlled based on comparison results generated by the comparator **312**. The comparator **312** may be further configured to provide the comparison results to the access controller **313**.

[0081] The access controller **313** may include suitable logic, instructions, circuitry, interfaces, and/or code for controlling opening of the plurality of lockable doors of the locker system **108**. The access controller **313** may be configured to receive the comparison results generated by the comparator **312**. In an example, when a comparison result generated by the comparator **312** indicates that a received security parameter does not match any of the stored security parameters, the access controller **313** generates an error notification and communicates the error notification to the access control interface **109**. In another example, when a comparison result generated by the comparator **312** indicates that a received security parameter matches any of the stored security parameters, the access controller **313** generates an unlock signal and communicates the unlock signal to the access control interface **109** or the security lock mechanism of the locker system **108**. The unlock signal may indicate which lockable doors of the plurality of lockable doors are to be opened. For example, if the received security parameter matches the stored security parameter of the lockable door **204***a*, the access controller **313** generates an unlock signal that indicates that the lockable door **204***a* is to be opened. In another example, if the received security parameter matches the stored security parameter of the two or more lockable doors, the access controller **313** generates an unlock signal that indicates that the two or more lockable doors are to be opened concurrently.

[0082] Examples of the security parameter generator **308**, the allocation manager **310**, the comparator **312**, and the access controller **313** may include, but are not limited to, an application-specific integrated circuit (ASIC) processor, a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a field-programmable gate array (FPGA), a microcontroller, a combination of a central processing unit (CPU) and a graphics processing unit (GPU), or the like.

[0083] The memory **304** may include suitable logic, instructions, circuitry, interfaces to store one or more instructions that are executed by entities such as the security parameter generator **308**, the allocation manager **310**, the comparator **312**, and the access controller **313** for performing one or more operations. Additionally, the memory **304** may be configured to store therein an inventory list **314**, inventory storage data **316**, layout information **318**, robotic apparatus data **320**, and security parameters **322**. Examples of the memory **304** may include a random access memory (RAM), a read only memory (ROM), a removable storage drive, a hard disk drive (HDD), a flash memory, a solid-state memory, and the like.

[0084] The inventory list **314** may include a list of inventory items and packages stored in the storage facility **102** and a number of units of each inventory item stored in the storage facility **102**. The layout information **318** may include information regarding the layout of the storage facility **102**, such as location data of the storage systems **116**, the first and second processing stations **118***a* and **118***b*, the locker system **108**, or the like. The layout information **318** may further include real-time path availability information of various paths in the storage facility **102**. For example, a first path in the storage facility **102** may be under maintenance, and hence may be unavailable for traversing.

[0085] The inventory storage data **316** is indicative of storage locations of the inventory items stored in the storage systems **116**. The inventory storage data **316** may further include the reference markers of the storage systems **116**. The reference identifiers are unique codes assigned to each of the storage systems **116**. In one example, the reference markers are radio frequency identification (RFID) tags that are readable by the robotic apparatuses **110**. Thus, based on the inventory storage data **316**, the control server **112** is aware of the locations of all inventory items stored in the storage facility **102**.

[0086] The security parameters **322** may act as a repository of security parameters associated with the plurality of lockable doors of the locker system **108**. The comparator **312** may refer to the security parameters **322** for generating comparison results. The security parameters **322** may be dynamically updated by the security parameter generator **308**. In one example, the security parameters **322** may be a look-up table that stores security parameters generated by the security parameter generator **308** in association with identifiers of the plurality of compartments and/or the plurality of lockable doors of the locker system **108**. The unlock signal generated by the access controller **313** may include identifiers of those compartments and/or lockable doors whose security parameters matched the security parameters provided by a user.

[0087] The transceiver **306** may include suitable logic, instructions, circuitry, interfaces to transmit and receive data over the communication network **114** using one or more communication network protocols. The transceiver **306** may transmit various messages and commands to the robotic apparatuses **110**, the locker system **108**, and the access control interface **109** and receive data from the one or more optical sensors deployed in the storage facility **102**, the robotic apparatuses **110**, the locker system **108**, and the access control interface **109**. Examples of the transceiver **306** may include, but are not limited to, an antenna, a radio frequency transceiver, a wireless transceiver, a Bluetooth transceiver, an ethernet-based transceiver, a universal serial bus (USB) transceiver, or any other device configured to transmit and receive data.

[0088] Though the processing circuitry **302** is depicted as a hardware component in FIG. **3**, a person skilled in the art will appreciate that the scope of the disclosure is not limited to realizing the processing circuitry **302** as the hardware component. In another embodiment, the functionality of the processing circuitry **302** may be implemented by way of a computer-executable code or a set of computer-readable instructions stored in the memory **304**, without deviating from the scope of the disclosure.

[0089] FIG. **4** is a diagram **400** that illustrates an implementation of the first processing station **118***a* in the storage facility **102**, in accordance with an exemplary embodiment of the disclosure. The control server **112** may receive a first process request for executing a first process. In a non-limiting example, it is assumed that the first process corresponds to an order collection process and is associated with one or more first inventory items (e.g., items I_1 and I_2). The first inventory items I_1 and I_2 may be stored in the storage system **116***a* in the storage area **104** and may need to be transported to the first processing station **118***a* in the processing area **106** for order consolidation. The control server **112** may be configured to select one of the plurality of first robotic apparatuses **120***a*-**120***n* (for example, the first robotic apparatus **120***a*) that is available and compatible for transporting the storage system **116***a* from the storage area **104** to the first processing station **118***a*. The control server **112** may be further configured to communicate a first instruction to the first robotic apparatus **120***a*. The first instruction may be indicative of the storage system **116***a* that stores the first inventory items I_1 and I_2, a path to reach a location of the storage system **116***a* in the storage area **104**, and a path to be followed by the first robotic apparatus **120***a* to reach the first processing station **118***a* where the first inventory items I_1 and I_2—are to be handled. Based on the first instruction, the first robotic apparatus **120***a* may transport the storage system **116***a* from the storage area **104** to the first processing station **118***a*. As shown in FIG. **4**, the first robotic apparatus **120***a* has successfully transported the storage system **116***a* to the first processing station **118***a*.

[0090] The control server **112** may be further configured to allocate one or more first compartments of the plurality of compartments of the locker system **108** to the first process based on the first process request. The allocation of the one or more first compartments to the first process may be based on compatibility of the first inventory items I_1 and I_2 with the plurality of compartments, for example, size, weight, and dimension compatibility, and availability of the one or more first compartments.

[0091] In an exemplary scenario, each of the plurality of compartments may have a weight-bearing capacity of 20 kilograms and the first inventory items I_1 and I_2 may have a collective weight of 15 kilograms. In such a scenario, the control server **112** may allocate any of the plurality of compartments that is currently unoccupied or is available, to the first process. In another exemplary scenario, the plurality of compartments may have different weight-bearing capacities and only two compartments may have a weight-bearing capacity greater than 15 kilograms. In such a scenario, the control server **112** may allocate one of the two compartments that is available and has a weight-bearing capacity greater than 15 kilograms, to the first process. In another exemplary scenario, none of the plurality of compartments may have a weight-bearing capacity greater than or equal to 15 kilograms. In such a scenario, the control server **112** may allocate two different compartments that are available to the first inventory items I_1 and I_2 such that each compartment has a weight bearing capacity greater than or equal to a weight of the corresponding item. In another exemplary scenario, none of the plurality of compartments may have a size that is sufficient to collectively hold the first inventory items I_1 and I_2. In such a scenario, the control server **112** may allocate two different compartments that are available to the first inventory items I_1 and I_2 such that each compartment has a size that is compatible with a size of the corresponding item.

[0092] The control server **112** may be further configured to select one of the robotic apparatuses **110** that is available and compatible for collecting the first inventory items I_1 and I_2 from the first processing station **118***a* and transporting the collected first inventory items I_1 and I_2 to the locker system **108**. In an exemplary scenario, the control server **112** may select one of the plurality of second robotic apparatuses **122***a*-**122***n* (e.g., the second robotic apparatus **122***a*) to collect and transport the first inventory items I_1 and I_2 to the locker system **108**.

[0093] The second robotic apparatus **122***a* may have a plurality of levels L_1, L_2, and L_3. Each level of the plurality of levels L_1, L_2, and L_3 may have one or more conveyors for receiving inventory items. In an exemplary illustration, each level L_1, L_2, and L_3 is shown to include two conveyors that are rotatable in clockwise or anti-clockwise directions. Further, each level of the plurality of levels L_1, L_2, and L_3 may have same or different physical attributes. The physical attributes of each level of the plurality of levels L_1, L_2, and L_3 may include a weight-bearing capacity, a size, one or more dimensions, a height, and a count of conveyors. The conveyors of each level may be actuated independent of each other.

[0094] The control server **112** may then communicate a second set of instructions to the second robotic apparatus **122***a*. The second set of instructions may be indicative of a path to be followed by the second robotic apparatus **122***a* to reach a location of the first processing station **118***a* for the collection of the first inventory items I_1 and I_2 and a subsequent path to be followed by the second robotic apparatus **122***a* to reach the locker system **108** from the first processing station **118***a*. Based on the second set of instructions, the second robotic apparatus **122***a* may reach the first processing station **118***a* for collection of the first inventory items I_1 and I_2. As shown in FIG. **4**, the second robotic apparatus **122***a* has successfully reached the first processing station **118***a* and is waiting to receive the first inventory items I_1 and I_2.

[0095] The control server **112** may be further configured to render, via a user interface **402**, information (for example, a position, a shape, a size, a weight, or the like) of the first inventory items I_1 and I_2 that are to be handled at the first processing station **118***a*. The rendered information may further indicate a shelf of the storage system **116***a* on which the first inventory items I_1 and I_2 are stored. Based on the rendered information, a first set of pick/put operations may be performed by an operator **404** present at the first processing station **118***a* for handling the first inventory items I_1 and I_2. The first set of pick/put operations may include picking of the first inventory items I_1 and I_2 from the storage system **116***a* and putting the first inventory items I_1 and I_2 on a target level (for example, the level L_1) of the second robotic apparatus **122***a*. In an embodiment, the target level may be indicated to the operator **404** via the user interface **402**. In an embodiment, the first processing station **118***a* may further include a pick/put to light (PPTL) device or a projector for providing visual cues to indicate the target level and/or the shelf of the storage system **116***a* storing the first inventory items I_1 and I_2 to the operator **404**.

[0096] The first inventory items I_1 and I_2 and the target level of the second robotic apparatus **122***a* may be identified by the operator **404** based on the information rendered via the user interface **402** and/or the visual cues. Subsequently, the first inventory items I_1 and I_2 may be placed on the target level (for example, the level L_1) of the second robotic apparatus **122***a* by the operator **404**.

[0097] In some embodiments, the second robotic apparatus **122***a* and/or the control server **112** may be configured to determine a correct placement of the first inventory items I_1 and I_2 on the target level. The second robotic apparatus **122***a* and/or the control server **112** may determine the correct placement based on one of one or more images or videos captured by one or more optical sensors deployed at the first processing station **118***a*, a weight of the first inventory items I_1 and I_2, or the like.

[0098] In an exemplary scenario, the one or more images or videos captured by the optical sensors deployed at the first processing station **118***a* may indicate that the first inventory items I_1 and I_2 are only partially placed on the target level of the second robotic apparatus **122***a*. In such a scenario, the control server **112** may instruct the operator **404** via the user interface **402** to adjust the placement of the first inventory items I_1 and I_2 so as to ensure that the first inventory items I_1 and I_2 are completely placed on the target level. In another exemplary scenario, one or more weight sensors placed on or beneath the conveyors of the target level may detect that the weight of the first inventory items I_1 and I_2 is not evenly distributed on the target level. In such a scenario, the second robotic apparatus **122***a* may either generate an audio/visual or haptic signal to alert the operator **404** regarding the incorrect placement of the first inventory items I_1 and I_2 or communicate an error signal to the control server **112** to indicate the incorrect placement of the first inventory items I_1 and I_2 on the target level. The second robotic apparatus **122***a* may not follow the subsequent path indicated in the second set of instructions until the first inventory items I_1 and I_2 are correctly placed on the target level by the operator **404**.

[0099] Based on the determination that the first inventory items I_1 and I_2 are placed correctly on the target level, the second robotic apparatus **122***a* may start following the subsequent path indicated in the second set of instructions to reach the locker system **108**. As shown in FIG. **4**, the second robotic apparatuses **122***c* and **122***d* are also present at the first processing station **118***a* for other operations.

[0100] Although FIG. **4** is described in conjunction with the control server **112** selecting one of the plurality of first robotic apparatuses **120***a*-**120***n* to transport the storage system **116***a* storing the first inventory items I_1 and I_2, the scope of the disclosure is not limited to it. In another embodiment, the control server **112** may select any of the plurality of third robotic apparatuses **124***a*-**124***n* or any of the plurality of fourth robotic apparatuses **126***a*-**126***n* to transport the first inventory items I_1 and I_2 from the storage area **104** to the first processing station **118***a*.

[0101] Although FIG. **4** is described in conjunction with the control server **112** selecting one of the plurality of second robotic apparatuses **122***a*-**122***n* to transport the first inventory items I_1 and I_2, the scope of the disclosure is not limited to it. In another embodiment, the control server **112** may select any of the plurality of third robotic apparatuses **124***a*-**124***n* or any of the plurality of fourth robotic apparatuses **126***a*-**126***n* to transport the first inventory items I_1 and I_2 from the first processing station **118***a* to the locker system **108**. The transfer of the first inventory items I_1 and I_2 to the locker system **108** by the second robotic apparatus **122***a* is described in conjunction with FIGS. **5**A-**5**C.

[0102] In some embodiments, the control server **112** may instruct the operator **404** to put the first inventory items I_1 and I_2 picked from the storage system **116***a* onto a shelf of another storage system carried by one of the plurality of first robotic apparatuses **120***b*-**120***n*. In some embodiments, the control server **112** may instruct the first robotic apparatus **120***a* to directly transport the storage system **116***a* from the storage area **104** to the location of the locker system **108**.

[0103] FIGS. **5**A-**5**C are diagrams that illustrate exemplary scenarios **500**A-**500**C for operating the locker system **108**, in accordance with an exemplary embodiment of the disclosure. Referring now to FIG. **5**A, the second robotic apparatus **122***a* is shown to have reached the location of the locker system **108**. Further, based on the second set of instructions, the second robotic apparatus **122***a* may be configured to identify the one or more first compartments (for example, a compartment **502***a*) that are allocated to the first process. Upon identification of the compartment **502***a*, the second robotic apparatus **122***a* may align with the compartment **502***a*.

[0104] Alignment of the second robotic apparatus **122***a* with the compartment **502***a* may include alignment of a conveyor **504***a* of the level L_1 on which the first inventory items I_1 and I_2 are placed with a shelf of the compartment **502***a* from the rear side **200**B of the locker system **108**. In other words, when the second robotic apparatus **122***a* aligns with the locker system **108** based on the second set of instructions, the level L_1 of the second robotic apparatus **122***a* is also aligned with the compartment **502***a*.

[0105] The infrared sensors or the ultrasonic sensors coupled to the rear side **200**B of the compartment **502***a* may generate sensor data indicating the alignment of the second robotic apparatus **122***a* with the compartment **502***a* and may communicate the sensor data to the control server **112**.

[0106] The control server **112** may receive the sensor data from the infrared sensors or the ultrasonic sensors coupled to the rear side **200**B of the compartment **502***a* and/or one or more images or videos captured by one or more image sensors deployed on at least one of the locker system **108** and the second robotic apparatus **122***a*. Based on the received sensor data and/or the one or more images, the control server **112** may be configured to determine whether the second robotic apparatus **122***a* is correctly aligned with the compartment **502***a*.

[0107] In an exemplary scenario, based on the received sensor data, the control server **112** may determine that the second robotic apparatus **122***a* is incorrectly aligned with the compartment **502***a*. The incorrect alignment may be due to an incorrect height of the level L_1 (for example, the level L_1 may not be at the same height as the shelf of the compartment **502***a*), a gap between the level L_1 and the shelf of the compartment **502***a*, or a left or right offset between the conveyor **504***a* of the level L_1 and the shelf of the compartment **502***a*. In such a scenario, the control server **112** may be configured to instruct the second robotic apparatus **122***a* to adjust the alignment with the compartment **502***a* by lowering or raising the level L_1, eliminating the gap between the level L_1 and the shelf of the compartment **502***a*, or eliminating the left or right offset between the conveyor **504***a* of the level L_1 and the shelf of the compartment **502***a*. In another exemplary scenario, based on the received sensor data, the control server **112** may determine that the second robotic apparatus **122***a* is correctly aligned with the compartment **502***a*. In such a scenario, the control server **112** may be configured to instruct the second robotic apparatus **122***a* to transfer the first inventory items I_1 and I_2 to the compartment **502***a*.

[0108] For transferring the first inventory items I_1 and I_2 to the compartment **502***a*, the second robotic apparatus **122***a* may be configured to actuate (for example, rotate) the conveyor **504***a* at the level L_1 in a clockwise direction (as shown by arrow **506**) so that the first inventory items I_1 and I_2 are transferred onto the shelf of the compartment **502***a*. In an embodiment, while the first inventory items I_1 and I_2 are being transferred from the conveyor **504***a* to the compartment **502***a*, another item I_3 placed at a conveyor **504***b* of the level L_2 may also be transferred to another compartment **502***b* that is allocated to another process associated with the item I_3. In other words, same robotic apparatus may be utilized by the control server **112** to transfer inventory items of different processes to different compartments of the locker system **108** concurrently.

[0109] In some embodiments, the control server **112** may be further configured to determine whether a correct item has been transferred into the compartment **502***a*. In an example, the weight sensor placed on or beneath the shelf of the compartment **502***a* may be able to sense the weight of the first inventory items I_1 and I_2. The sensor data of the weight sensor may be communicated to the control server **112**, which compares the sensed weight with the actual weight of the first inventory items I_1 and I_2. Further, a code scanner (for example, a barcode scanner, a QR code scanner, or a radio frequency identifier (RFID) reader) present at the compartment **502***a* may be configured to scan identifiers of the first inventory items I_1 and I_2 and communicate the scanned identifiers to the control server **112**. Based on the weight data and/or the scanned identifiers, the control server **112** may determine whether the items transferred to the compartment **502***a* are correct. In other words, the control server **112** may determine whether the transfer of the first inventory items I_1 and I_2 is a success or a failure. In an event of a failure of transfer, the control server **112** may determine a cause of the operational failure and generate correction-based instructions to correct the operational failure. In an example, the failure may have occurred due to a placement of an incorrect item in the compartment **502***a*. In such a scenario, the control server **112** may generate correction-based instructions for the second robotic apparatus **122***a* to transfer the correct first inventory items I_1 and I_2 to the compartment **502***a* and may instruct an operator to remove the incorrect item from the compartment **502***a*. In an event of success, the control server **112** may communicate a transfer success signal to the second robotic apparatus **122***a* to indicate the successful transfer of the first inventory items I_1 and I_2.

[0110] Upon successful transfer of the first inventory items I_1 and I_2 and other inventory items carried by the second robotic apparatus **122***a* into the locker system **108**, the control server **112** may further provide instructions to the second robotic apparatus **122***a* to pick-up other inventory items from the first or second processing stations **118***a* or **118***b* for transfer.

[0111] The first inventory items I_1 and I_2 transported by the second robotic apparatus **122***a* are accessible from the front side **200**A of the compartment **502***a* upon opening of a corresponding lockable door of the compartment **502***a*.

[0112] In FIG. **5**A, another second robotic apparatus **122***b* is shown to be transporting one or more second inventory items I_4 associated with a second process that is different from the first process. In an embodiment, the control server **112** may have allocated the compartment **502***a* to the second process and may have communicated a third set of instructions to the second robotic apparatus **122***b* to facilitate collection and transport of the second inventory items I_4 by the second robotic apparatus **122***b*. In a scenario where the same compartment **502***a* is allocated to both the first and second processes, the second robotic apparatus **122***b* may only align with the locker system **108** from the rear side **200**B based on the third set of instructions, when the first inventory items I_1 and I_2 are successfully collected from the compartment **502***a* and the second robotic apparatus **122***a* has moved away from the locker system **108**. The second robotic apparatus **122***b* may align with the compartment **502***a* from the rear side **200**B of the locker system **108** in a similar manner as the second robotic apparatus **122***a* had aligned with the compartment **502***a*. Based on the alignment of the second robotic apparatus **122***b* with the locker system **108** at the rear side **200**B, the second inventory items I_4 transported by the second robotic apparatus **122***b* are accessible from the front side **200**A of the compartment **502***a* based on opening of the corresponding lockable door of the compartment **502***a*.

[0113] In another embodiment, the control server **112** may allocate another compartment **502***c* that is different from the compartment **502***a* to the second process. In such a scenario, where different compartments **502***a* and **502***c* are allocated to the first and second processes, the second robotic apparatus **122***b* may align with the locker system **108** from the rear side **200**B concurrently with the second robotic apparatus **122***a*. Based on the alignment of the second robotic apparatus **122***b* with the locker system **108** at the rear side **200**B, the second inventory items I_4 transported by the second robotic apparatus **122***b* are accessible from the front side **200**A of the compartment **502***c* based on opening of a corresponding lockable door of the compartment **502***c*.

[0114] Collection of an inventory item from a compartment of the locker system **108** is described in conjunction with FIG. **5**B.

[0115] Referring now to FIG. **5**B, a schematic diagram for collection of an item from the front side **200**A of the locker system **108**, in accordance with an exemplary embodiment of the present disclosure, is shown. A user (for example, an operator, a delivery personnel, or a customer) is able to collect inventory items associated with a process from the front side **200**A of the locker system **108**.

[0116] For the sake of brevity, the ongoing exemplary scenario is described for a user **508***a* who has placed an order (for example, a process request) and now wants to collect ordered inventory items **510**. To collect the ordered inventory items **510**, the user **508***a* may input a security parameter at the access control interface **109** (shown in FIG. **1**). The security parameter may have been communicated to a user device of the user **508***a* by the control server **112** when the user **508***a* had placed the order. The security parameter communicated to the user device is associated with a compartment (for example, the compartment **202***a*) in which the inventory items **510** ordered by the user **508***a* are transferred for collection by the user **508***a*. In other words, the control server **112** may communicate the security parameter of the compartment **202***a* that is allocated to the order of the user **508***a* to the user device. In an embodiment, the security parameter may be a barcode and the user **508***a* may scan the barcode using a barcode scanner of the access control interface **109**. In another embodiment, the security parameter may be a QR code and the user **508***a* may scan the QR code using a QR code scanner of the access control interface **109**. In another embodiment, the security parameter may be an OTP and the user **508***a* may input the OTP using a keypad of the access control interface **109**.

[0117] The access control interface **109** may communicate the inputted security parameter to the control server **112** over the communication network **114**. The control server **112** may determine whether the received security parameter matches any of the security parameters stored in the memory **304**. Based on a match of the received security parameter with at least one of the stored security parameters, the control server **112** may be configured to provide an unlock signal to the locker system **108** or the access control interface **109**. The unlock signal may include an identifier of a compartment (for example, the compartment **202***a*) whose stored security parameter matched the received security parameter. The unlock signal is then communicated to the security lock mechanism of the compartment **202***a*. Upon receiving the unlock signal, the security lock mechanism of the compartment **202***a* opens the lockable door **204***a* of the compartment **202***a* such that the inventory items **510** placed in the compartment **202***a* become accessible to the user **508***a* from the front side **200**A of the locker system **108**. The user **508***a* is thus able to collect the inventory items **510** from the compartment **202***a*. Upon successful collection of the inventory items **510** from the compartment **202***a*, the security lock mechanism of the compartment **202***a* locks or closes the lockable door **204***a*. After the lockable door **204***a* is closed, new inventory items may be stored in the compartment **202***a* by the robotic apparatuses **110**.

[0118] In an embodiment, the security parameter provided by the user **508***a* may be associated with multiple compartments due to the ordered inventory items being stored in multiple compartments. In such a scenario, the unlock signal generated by the control server **112** is capable of concurrently (e.g., at the same time) unlocking lockable doors of all the compartments that are allocated to the order of the user **508***a*. In an embodiment, when the security parameter is inputted to the access control interface **109** by the user **508***a*, the access control interface **109** may present an identifier of the compartment **202***a* to the user **508***a*. The identifier of the compartment **202***a* may be included in the unlock signal communicated by the control server **112** to the access control interface **109**.

[0119] Further, as shown in FIG. **5**B, multiple robotic apparatuses (for example, the second robotic apparatuses **122***a* and **122***b*) may be configured to store inventory items in different compartments of the locker system **108** concurrently.

[0120] Further, as shown in FIG. **5**B, multiple users (for example, the user **508***a* and another user **508***b*) may concurrently collect corresponding inventory items from the locker system **108**. For example, as shown, the lockable doors **204***a* and **204***b* are open at the same time so that the users **508***a* and **508***b* may concurrently collect their ordered inventory items **510** and **512** from the locker system **108**.

[0121] Referring to FIG. **5**C, a schematic diagram that illustrates a side view of the locker system **108**, in accordance with an embodiment of the present disclosure, is shown. In FIG. **5**C, the plurality of compartments of the locker system **108** are shown to have slanting shelves. For example, as shown, a compartment **502***d* of the locker system **108** has a slanting shelf **514** such that an elevated side of the slanting shelf **514** is positioned towards the rear side **200**B of the locker system **108**, whereas a slanting side of the slanting shelf **514** is positioned towards the front side **200**A of the locker system **108**. Once an inventory item **516** is transferred to the compartment **502***d* by the second robotic apparatus **122***c*, the slanting shelf **514** may cause the inventory item **516** to slide towards the front side **200**A of the compartment **502***d* from the rear side **200**B. Further, the compartment **502***d* may have a mechanical stopper and/or a plate coupled to the front side **200**A of the compartment **502***d* that prevents the inventory item **516** from falling off the compartment **502***d* when a lockable door **518** of the compartment **502***d* is opened. It will be apparent to a person skilled in art that the scope of the disclosure is not limited to the slanting shelf **514**, but any other form of mechanism that may assist in the movement of the inventory items from the rear side **200**B to the front side **200**A may be implemented, without deviating from the scope of the disclosure.

[0122] FIG. **6** is a diagram **600** that illustrates transfer of inventory items to the locker system **108** using a robotic apparatus, in accordance with an embodiment of the present disclosure. As shown in FIG. **6**, the fourth robotic apparatus **126***a* has a robotic arm **602** with multiple degrees of freedom and a spatula-shaped end effector **604** coupled to the robotic arm **602**. The spatula-shaped end effector **604** may include a conveyor **606** that could be rotated (e.g., actuated) in clockwise or anti-clockwise direction. In an example, the fourth robotic apparatus **126***a* may be selected by the control server **112** to transfer inventory items **608** associated with a process to an allocated compartment (e.g., the compartment **502***a*) of the locker system **108**. The control server **112** may communicate instructions to the fourth robotic apparatus **126***a* to place the inventory item **608** in the compartment **502***a*. Based on the instructions, the fourth robotic apparatus **126***a* carrying the inventory items **608** may align with the compartment **502***a* at the rear side **200**B after identifying the compartment **502***a*. The instructions may further include position and identifier of the compartment **502***a* and a degree of movement required for the robotic arm **602** to move the spatula-shaped end effector **604** from an original position to a desired height to place the inventory item **608** in the compartment **502***a*. Once the spatula-shaped end effector **604** has attained the desired position, the fourth robotic apparatus **126***a* actuates the conveyor **606** to transfer the inventory item **608** into the compartment **502***a*.

[0123] As shown in FIG. **6**, while the fourth robotic apparatus **126***a* is transferring the inventory item **608** into the compartment **502***a*, another fourth robotic apparatus **126***b* may concurrently transfer another inventory item into a different compartment **610** of the locker system **108**.

[0124] Although FIG. **6** shows two fourth robotic apparatuses **126***a* and **126***b* concurrently transferring the inventory items to different compartments **502***a* and **610** of the locker system **108**, the scope of the disclosure is not limited to it. In other embodiments, different types of robotic apparatuses **110** may concurrently transfer inventory items into different compartments of the locker system **108**, without deviating from the scope of the disclosure.

[0125] FIGS. **7**A and **7**B are diagrams **700**A and **700**B that illustrate a locker system **702** to be used in the storage facility **102** for delivery and collection of inventory items, in accordance with another embodiment of the present disclosure.

[0126] Referring now to FIG. **7**A, the locker system **702** is operationally similar to the locker system **108** shown in FIGS. **2**A and **2**B but differs in structure, for example, the locker system **702** includes a plurality of compartments that do not have any shelves and a plurality of lockable doors that control access to the plurality of compartments, respectively. Each compartment of the plurality of compartments is accessible from a front side **704***a* and a rear side (shown in FIG. **7**B) of the locker system **702**. An access to each compartment from the front side **704***a* is controlled by a corresponding lockable door positioned at the front side **704***a*, and each compartment is open from the rear side. In other words, the locker system **702** is a frame-like structure that has a plurality of openings that are formed in longitudinal axis and vertical axis where each opening defines a compartment without shelf and the compartment is secured at the front side **704***a* with a lockable door. For the sake of brevity, three of the compartments **706***a*, **706***b*, and **706***c* of the plurality of compartments and four of the lockable doors **708***a*, **708***b*, **708***c*, and **708***d* of the plurality of lockable doors, are labelled.

[0127] As shown in FIG. **7**A, access to the compartments **706***a*, **706***b*, and **706***c* is controlled by the lockable doors **708***a*, **708***b*, and **708***c*, respectively. Since the lockable doors **708***a*, **708***b*, and **708***c* are open, the respective compartments **706***a*, **706***b*, and **706***c* are accessible from the front side **704***a*; however, the lockable door **708***d* is closed and as a result, a corresponding compartment is not accessible from the front side **704***a*.

[0128] In an embodiment, the plurality of compartments may have same size and dimensions. In another embodiment, the plurality of compartments may have different sizes and dimensions. For example, as shown in FIG. **7**A, the compartments **706***a*, **706***b*, and **706***c* are of the same size; however, the compartment of the lockable door **708***d* is larger in size and dimensions as compared to the compartments **706***a*, **706***b*, and **706***c*.

[0129] Referring now to FIG. **7**B, the rear side **704***b* of the locker system **702**, in accordance with an embodiment of the present disclosure, is shown. The rear side **704***b* of the locker system **702** serves as an access point for the robotic apparatuses **110** whereas the front side **704***a* serves as an access point for collecting the inventory items from the plurality of compartments.

[0130] The robotic apparatuses **110** may collect the inventory items associated with different processes from the first and second processing stations **118***a* and **118***b* and transport the collected inventory items to the locker system **702** under the control of the control server **112** (as described in the foregoing description of FIGS. **1-6**). Upon reaching a location of the locker system **702**, the robotic apparatuses **110** may align with those compartments that are allocated to the respective processes by the control server **112**. As the plurality of compartments of the locker system **702** do not have any storage shelves, the robotic apparatuses **110** remain aligned with the respective compartments until the inventory items are collected by corresponding users from the front side **704***a* upon opening of the lockable doors of the respective compartments.

[0131] For example, as shown in FIG. **7**B, the second robotic apparatus **122***a* is aligned with the compartments **706***b* and **706***c* so that inventory items **710***a* and **710***b* placed on the level L_1 of the second robotic apparatus **122***a* could be accessed from the front side **704***a* of the locker system **702** when the lockable doors **708***b* and **708***c* are opened. In FIG. **7**B, the lockable doors **708***b* and **708***c* are shown to be open and a user **712** is collecting the inventory items **710***a* and **710***b* from the level L_1 of the second robotic apparatus **122***a* via the compartments **706***a* and **706***b*, respectively. Opening and closing of the plurality of lockable doors of the locker system **702** are controlled by the control server **112** in a similar manner as the plurality of lockable doors of the locker system **108** (as described in the foregoing description of the FIGS. **1-6**). In the exemplary scenario of FIG. **7**B, the inventory items **710***a* and **710***b* of the user **712** are made accessible concurrently by concurrent opening of the lockable doors **708***b* and **708***c*. Thus, the user **712** may collect both the inventory items **710***a* and **710***b* from the second robotic apparatus **122***a* at the same time. Similarly, FIG. **7**B shows another second robotic apparatus **122***b*, carrying inventory items **710***c* and **710***d*, aligned with the compartments **706***a* and **706***d*. The inventory item **710***c* may be collected from the front side **704***a* of the compartment **706***a* and the inventory item **710***d* may be collected from the front side **704***a* of the compartment **706***d*. At a current time-instance, the lockable door **708***a* of the compartment **706***a* is open, and hence the inventory item **710***c* may be collected from the second robotic apparatus **122***b* by a corresponding user (not shown) via the compartment **706***a*. However, the lockable door of the compartment **706***d* is closed, and hence the inventory item **710***d* is inaccessible from the front side **704***a*. Such controlled opening and closing of the plurality of lockable doors of the locker system **702** prevents unauthorized access to the inventory items.

[0132] In an embodiment, based on a size of a compartment, multiple conveyors on a level of a second robotic apparatus (e.g., any of the plurality of second robotic apparatuses **122***a*-**122***n*) could be aligned with a single compartment of the locker system **702**. For example, two conveyors at the level L_2 of the second robotic apparatus **122***a* may concurrently align with a compartment corresponding to the lockable door **708***d* (shown in FIG. **7**A). Therefore, any inventory items placed on the two conveyors of the level L_2 of the second robotic apparatus **122***a* may be accessed concurrently from the same compartment upon opening of the lockable door **708***d* (shown in FIG. **7**A).

[0133] FIG. **8** is a diagram **800** that illustrates collection of inventory items from the locker system **702**, in accordance with another embodiment of the present disclosure. As shown in FIG. **8**, the fourth robotic apparatus **126***a* may be selected by the control server **112** to make an inventory item **802***a* associated with a process accessible from an allocated compartment (e.g., the compartment **706***b*) of the locker system **702**. The control server **112** may communicate instructions to the fourth robotic apparatus **126***a* to align with the compartment **706***b* at the rear side **704***b* of the locker system **702**. The instructions may further include a position and an identifier of the compartment **706***b* and a degree of movement required for the robotic arm **602** to move the spatula-shaped end effector **604** from an original position to a desired height of the compartment **706***b*. Once the spatula-shaped end effector **604** has attained the desired position, the fourth robotic apparatus **126***a* remains aligned with the compartment **706***b* until the inventory item **802***a* is collected by a corresponding user **804**. As shown in FIG. **8**, the lockable door **708***b* of the compartment **706***b* is open and the user **804** is stretching their hand to collect the inventory item **802***a*. Upon successful collection of the inventory item **802***a* by the user **804**, the lockable door **708***b* closes and the fourth robotic apparatus **126***a* becomes available for executing a next operation.

[0134] FIGS. **9**A and **9**B are diagrams that illustrate an exemplary scenario **900** for collection of inventory items from the locker system **702**, in accordance with another embodiment of the present disclosure.

[0135] Referring now to FIG. **9**A, the first robotic apparatus **120***a* is shown to have transported a storage system **901** to a location of the locker system **702**. The storage system **901** is structurally and functionally similar to the storage systems **116** shown in FIG. **1**. The storage system **901** may have a plurality of shelves **902***a*-**902***d* each storing inventory items corresponding to a unique process. For example, the shelf **902***a* may store thereon inventory items **904** associated with an order of a customer **906**. The control server **112** may have instructed the first robotic apparatus **120***a* to transport the inventory items **904** to the location of the locker system **702** by lifting and transporting the storage system **901**, and aligning with the locker system **702** from the rear side **704***b*. When the first robotic apparatus **120***a* aligns with the locker system **702** from the rear side **704***b*, the shelf **902***a* storing the inventory items **904** is aligned with the compartment **706***b* which is allocated to the process associated with the inventory items **904**. The first robotic apparatus **120***a* may be configured to adjust a height of the storage system **901** such that the shelf **902***a* is aligned with the compartment **706***b* from the rear side **704***b* of the locker system **702**. The first robotic apparatus **120***a* may remain aligned with the locker system **702** until the inventory items **904** are collected by the customer **906** via the compartment **706***b*.

[0136] Referring now to FIG. **9**B, the front side **704***a* of the locker system **702** is shown while the first robotic apparatus **120***a* carrying the storage system **901** is aligned with the locker system **702** from the rear side **704***b*. In FIG. **9**B, the lockable door **708***b* is shown to be open and the customer **906** is attempting to collect the inventory items **904** from the shelf **902***a* via the compartment **706***b*. Upon successful collection of the inventory items **904** by the customer **906**, the lockable door **708***b* is closed and the first robotic apparatus **120***a* transports the storage system **901** to another location for executing a next operation. Opening and closing of the plurality of lockable doors of the locker system **702** are controlled by the control server **112** in a similar manner as the plurality of lockable doors of the locker system **108** (as described in the foregoing description of the FIGS. **1-6**).

[0137] FIG. **10** is a block diagram that illustrates a system architecture of a computer system **1000** for inventory management in the storage facility **102**, in accordance with an exemplary embodiment of the disclosure. An embodiment of the disclosure, or portions thereof, may be implemented as computer readable code on the computer system **1000**. In one example, the control server **112** of FIG. **1** may be implemented in the computer system **1000** using hardware, software, firmware, non-transitory computer-readable media having instructions stored thereon, or a combination thereof and may be implemented in one or more computer systems or other processing systems. Hardware, software, or any combination thereof may embody modules and components used to implement the methods of FIGS. **11** and **12**. The computer system **1000** may include a main memory **1002**, a secondary memory **1004**, a processor **1006**, a communication interface **1008**, an input/output (I/O) port **1010**, and a communication infrastructure **1012**.

[0138] Examples of the main memory **1002** may include random access memory (RAM), read-only memory (ROM), and the like. The secondary memory **1004** may include a hard disk drive or a removable storage drive (not shown), such as a floppy disk drive, a magnetic tape drive, a compact disc, an optical disk drive, a flash memory, or the like. Further, the removable storage drive may read from and/or write to a removable storage device in a manner known in the art. In an embodiment, the removable storage system may be a non-transitory computer-readable recording media.

[0139] The processor **1006** may be a special purpose or a general-purpose processing device. The processor **1006** may be a single processor or multiple processors. The processor **1006** may have one or more processor "cores." Further, the processor **1006** may be coupled to the communication interface **1008** such as a bus, a bridge, a message queue, the communication network **114**, multi-core message-passing scheme, or the like.

[0140] The I/O port **1010** may include various input and output devices that are configured to communicate with the processor **1006**. Examples of the input devices may include a keyboard, a mouse, a joystick, a touchscreen, a microphone, and the like. Examples of the output devices may include a display screen, a speaker, headphones, and the like. The communication infrastructure **1012** may be configured to allow data to be transferred between the computer system **1000** and various devices that are communicatively coupled to the computer system **1000**. Examples of the communication infrastructure **1012** may include a modem, a network interface, i.e., an Ethernet card, a communication port, and the like. Data transferred via the communication infrastructure **1012** may be signals, such as electronic, electromagnetic, optical, or other signals as will be apparent to a person skilled in the art. The signals may travel via a communications channel, such as the communication network **114**, which may be configured to transmit the signals to the various devices that are communicatively coupled to the computer system **1000**. Examples of the communication channel may include a wired, wireless, and/or optical medium such as cable, fiber optics, a phone line, a cellular phone link, a radio frequency link, and the like. The main memory **1002** and the secondary memory **1004** may refer to non-transitory computer-readable mediums that may provide data that enables the computer system **1000** to implement the method illustrated in FIGS. **11** and **12**.

[0141] FIG. **11** is a flow chart **1100** that illustrates an automated locker management method for delivery and collection of inventory items using the locker system **108** or the locker system **702** in the storage facility **102**, in accordance with an exemplary embodiment of the disclosure. At **1102**, one or more first compartments of a plurality of compartments in the locker system **108** or the locker system **702** are allocated to a first process in the storage facility **102**. The control server **112** may be configured to allocate the one or more first compartments of the plurality of compartments in the locker system **108** or the locker system **702** to the first process in the storage facility **102**. Allocation of the one or more first compartments of the locker system **108** or the locker system **702** to the first process by the control server **112** is described in the foregoing description of FIGS. **1-9**. Each compartment of the plurality of compartments may be accessible from a front side and a rear side of the locker system **108** or the locker system **702**. An access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of a plurality of lockable doors of the locker system **108** or the locker system **702**. Each compartment of the plurality of compartments is open from the rear side.

[0142] At **1104**, a first set of instructions is communicated to a robotic apparatus (e.g., any of the robotic apparatuses **110**) to cause the robotic apparatus to align with the locker system **108** or the locker system **702** from the rear side. The control server **112** may be configured to communicate the first set of instructions to the robotic apparatus (e.g., any of the robotic apparatuses **110**) to cause the robotic apparatus to align with the locker system **108** or the locker system **702** from the rear side. Based on the alignment of the robotic apparatus with the locker system **108** or the locker system **702** from the rear side, one or more first items transported by the robotic apparatus are accessible from the front side of the one or more first compartments based on opening of corresponding lockable doors of the one or more first compartments. The one or more first items are associated with the first process allocated to the one or more first compartments.

[0143] At **1106**, opening of corresponding lockable doors of the one or more first compartments of the locker system **108** or the locker system **702** is controlled, so that the one or more first items of the first process are accessible from the front side of the locker system **108** or the locker system **702**. The control server **112** may be configured to control opening of the corresponding lockable doors of the one or more first compartments, so that the one or more first items of the first process are accessible from the front side of the locker system **108** or the locker system **702**. A method for controlling the opening of the corresponding lockable doors by the control server **112** is described later in conjunction with FIG. **12**.

[0144] At **1108**, the one or more first compartments or one or more second compartments are allocated to a second process. The control server **112** may be further configured to allocate the one or more first compartments or the one or more second compartments to the second process.

[0145] At **1110**, a second set of instructions are communicated to another robotic apparatus (any of the remaining robotic apparatuses **110**) to cause the other robotic apparatus to align with the locker system **108** or the locker system **702** from the rear side. The control server **112** may be configured to communicate the second set of instructions to the other robotic apparatus (e.g., any of the robotic apparatuses **110**) to cause the other robotic apparatus to align with the locker system **108** or the locker system **702** from the rear side. Based on the second set of instructions, the other robotic apparatus aligns with the locker system **108** or the locker system **702** from the rear side. Based on the alignment of the other robotic apparatus with the locker system **108** or the locker system **702** from the rear side, one or more second items transported by the other robotic apparatus are accessible from the front side of the one or more first compartments or the one or more second compartments based on opening of corresponding lockable doors of the one or more first compartments or the one or more second compartments, respectively.

[0146] FIG. **12** is a flow chart **1200** that illustrates a method for controlling opening of lockable doors of one or more compartments of the automated locker system **108** or **702**, in accordance with an exemplary embodiment of the disclosure. At **1202**, one or more security parameters provided by a user is received by the control server **112**. The control server **112** may be configured to receive the security parameters provided by the user from the access control interface **109** over the communication network **114**.

[0147] At **1204**, the one or more security parameters provided by the user are compared with one or more stored security parameters of the plurality of lockable doors of the locker system **108** or **702**. The control server **112** may be configured to compare the one or more security parameters provided by the user with the one or more security parameters stored in the memory **304** (as shown in FIG. **3**).

[0148] At **1206**, corresponding lockable doors of the one or more first compartments are controlled to open based on the comparison of the one or more security parameters provided by the user with the one or more stored security parameters of the corresponding lockable doors. The control server **112** may be further configured to control opening of the corresponding lockable doors of the one or more first compartments based on the comparison of the one or more security parameters provided by the user with the one or more stored security parameters of the corresponding lockable doors.

[0149] The disclosed embodiments encompass numerous advantages. Exemplary advantages of the disclosed methods include, but are not limited to, an automated locker system management for delivery and collection of inventory items. The disclosed methods and systems significantly reduce manual labor requirement (e.g., conventionally a compartment needs to be opened twice, one for transporting item into the compartment and then to retrieve the item) during handling of the inventory items in the storage facilities. For example, the disclosed methods and systems offer a no-walk solution for the storage facility **102** where operators are not required to move from one location to another for any operation. Therefore, the disclosed methods and systems significantly reduce a time required for processing an order. Consequently, the disclosed methods and systems increase the throughput of the storage facility **102**. Further, the disclosed methods and systems significantly reduce inconvenience caused to operators and users in the storage facility **102** during collection of inventory items associated with a process. The locker system **108** or the locker system **702** enables a physical partition between a non-man zone (e.g., an area in a storage facility where the robotic apparatuses **110** are deployed) and a manned zone (e.g., an area where human presence is allowed) for delivery and collection of inventory items. The disclosed methods and systems significantly reduce chances of human errors during transportation and delivery of orders. Since the delivery and collection of inventory items is automated by the control server **112**, a likelihood of an incorrect order or items being presented to a user is eliminated. The disclosed methods and systems enable automated handling of inventory items without having to make any significant change to existing infrastructure of the storage facility **102**. Hence, the disclosed methods and systems are cost-efficient and provide an optimal solution for hassle-free handling of the inventory items.

[0150] Further, the locker system **108** or the locker system **702** is portable and can be moved from one location to another location by any of the plurality of first robotic apparatuses **120***a*-**120***n*. The portability feature of the locker system **108** or the locker system **702** enables easy and convenient set up of a delivery and collection area in the storage facility **102**.

[0151] A person of ordinary skill in the art will appreciate that embodiments and exemplary scenarios of the disclosed subject matter may be practiced with various computer system configurations, including multi-core multiprocessor systems, minicomputers, mainframe computers, computers linked or clustered with distributed functions, as well as pervasive or miniature computers that may be embedded into virtually any device. Further, the operations may be described as a sequential process, however some of the operations may in fact be performed in parallel, concurrently, and/or in a distributed environment, and with program code stored locally or remotely for access by single or multiprocessor machines. In addition, in some embodiments, the order of operations may be rearranged without departing from the scope of the disclosed subject matter.

[0152] Techniques consistent with the disclosure provide, among other features, systems and methods for automated delivery and collection of inventory items in a storage facility. While various exemplary embodiments of the disclosed systems and methods have been described above, it should be understood that they have been presented for purposes of example only, and not limitations. It is not exhaustive and does not limit the disclosure to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practicing the disclosure, without departing from the breadth or scope.

[0153] While various embodiments of the disclosure have been illustrated and described, it will be clear that the disclosure is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions, and equivalents will be apparent to those skilled in the art, without departing from the scope of the disclosure, as described in the claims.

1. An automated locker management system, comprising:

a locker system including a plurality of compartments and a plurality of lockable doors, wherein each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system, wherein an access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of the plurality of lockable doors, and wherein each compartment of the plurality of compartments is open from the rear side;

a plurality of robotic apparatuses, wherein a first robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more first items associated with a first process at a storage facility; and

a control server configured to:

allocate one or more first compartments of the plurality of compartments to the first process; and

communicate a first set of instructions to the first robotic apparatus to cause the first robotic apparatus to align with the locker system from the rear side, wherein based on the alignment of the first robotic apparatus with the locker system at the rear side, the one or more first items transported by the first robotic apparatus are accessible from the front side of the one or more first compartments upon opening of corresponding lockable doors of the one or more first compartments.

2. The automated locker management system of claim **1**, wherein a second robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more second items associated with a second process at the storage facility, and wherein the control server is further configured to:

allocate the one or more first compartments to the second process; and

communicate a second set of instructions to the second robotic apparatus to cause the second robotic apparatus to align with the locker system from the rear side, wherein the second robotic apparatus is configured to align with the locker system from the rear side based on the second set of instructions when the one or more first items are successfully collected from the one or more first compartments, and wherein based on the alignment of the second robotic apparatus with the locker system at the rear side, the one or more second items transported by the second robotic apparatus are accessible from the front side of the one or more first compartments based on opening of the corresponding lockable doors of the one or more first compartments.

3. The automated locker management system of claim **1**, wherein a second robotic apparatus of the plurality of robotic apparatuses is configured to transport one or more second items associated with a second process at the storage facility, and wherein the control server is further configured to:

allocate one or more second compartments of the plurality of compartments to the second process, wherein the one or more second compartments are different from the one or more first compartments; and

communicate a second set of instructions to the second robotic apparatus to cause the second robotic apparatus to align with the locker system from the rear side concurrently with the first robotic apparatus, wherein based on the alignment of the second robotic apparatus with the locker system at the rear side, the one or more second items transported by the second robotic apparatus are accessible from the front side of the one or more second compartments based on opening of corresponding lockable doors of the one or more second compartments.

4. The automated locker management system of claim **1**, wherein the control server is further configured to control opening of each lockable door of the plurality of lockable doors based on a corresponding security parameter.

5. The automated locker management system of claim **4**, wherein the corresponding security parameter is at least one of a password, a machine-readable optical code, or biometric information of a user.

6. The automated locker management system of claim **1**, wherein the control server is further configured to control the corresponding lockable doors of the one or more first compartments to open concurrently based on one security parameter.

7. The automated locker management system of claim **1**, wherein the control server is further configured to:

receive, from the locker system, one or more security parameters provided by a user to open the corresponding lockable doors of the one or more first compartments;

compare the one or more security parameters provided by the user with one or more stored security parameters of the corresponding lockable doors of the one or more first compartments; and

control the corresponding lockable doors of the one or more first compartments to open based on the comparison of the one or more security parameters provided by the user with the one or more stored security parameters of the corresponding lockable doors.

8. The automated locker management system of claim **1**, further comprising a set of storage systems such that a first storage system of the set of storage systems is configured to store the one or more first items on one or more shelves thereof, and wherein the first robotic apparatus is configured to transport the one or more first items by lifting and transporting the first storage system.

9. The automated locker management system of claim **8**, wherein when the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more shelves storing the one or more first items are aligned with the one or more first compartments.

10. The automated locker management system of claim **1**, wherein the first robotic apparatus includes one or more conveyors such that the one or more first items are placed on the one or more conveyers, and wherein when the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more conveyors having the one or more first items thereon are aligned with the one or more first compartments.

11. The automated locker management system of claim **10**, wherein the first robotic apparatus is further configured to actuate the one or more conveyors based on the first set of instructions to transfer the one or more first items from the one or more conveyers to the one or more first compartments.

12. The automated locker management system of claim **1**, wherein the first robotic apparatus includes one or more levels such that the one or more first items are placed on the one or more levels, and wherein when the first robotic apparatus aligns with the locker system based on the first set of instructions, the one or more levels of the first robotic apparatus are aligned with the one or more first compartments.

13. An automated locker management method, comprising:

allocating, by a control server, one or more first compartments of a plurality of compartments in a locker system to a first process in a storage facility, wherein each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system, wherein an access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of a plurality of lockable doors of the locker system, and wherein each compartment of the plurality of compartments is open from the rear side; and

communicating, by the control server, a first set of instructions to a first robotic apparatus to cause the first robotic apparatus to align with the locker system from the rear side, wherein based on the alignment of the first robotic apparatus with the locker system at the rear side, one or more first items transported by the first robotic apparatus are accessible from the front side of the one or more first compartments based on opening of corresponding lockable doors of the one or more first compartments; and wherein the one or more first items are associated with the first process allocated to the one or more first compartments.

14. The automated locker management method of claim **13**, further comprising:

allocating, by the control server, one or more first compartments to a second process; and

communicating, by the control server, a second set of instructions to a second robotic apparatus configured to transport one or more second items associated with the second process at the storage facility, wherein the second set of instructions cause the second robotic apparatus to align with the locker system from the rear side, and wherein the second robotic apparatus aligns with the locker system from the rear side based on the second set of instructions when the one or more first items are successfully collected from the one or more first compartments, and wherein based on the alignment of the second robotic apparatus with the locker system at the rear side, the one or more second items transported by the second robotic apparatus are accessible from the front side of the one or more first compartments based on opening of the corresponding lockable doors of the one or more first compartments.

15. The automated locker management method of claim **13**, further comprising controlling, by the control server, opening of each lockable door of the plurality of lockable doors based on a corresponding security parameter.

16. The automated locker management method of claim **15**, wherein the corresponding security parameter is at least one of a password, a machine-readable optical code, or biometric information of a user.

17. The automated locker management method of claim **13**, further comprising controlling, by the control server, the corresponding lockable doors of the one or more first compartments to open concurrently based on one security parameter.

18. The automated locker management method of claim **13**, further comprising:

receiving, by the control server, from the locker system, one or more security parameters provided by a user to open the corresponding lockable doors of the one or more first compartments;

comparing, by the control server, the one or more security parameters provided by the user with one or more stored security parameters of the corresponding lockable doors of the one or more first compartments; and

controlling, by the control server, corresponding lockable doors of the one or more first compartments to open based on the comparison of the one or more security parameters provided by the user with the one or more stored security parameters of the corresponding lockable doors.

19. An automated locker system, comprising:

a plurality of lockable doors, wherein opening of each lockable door of the plurality of lockable doors is controlled based on a corresponding security parameter of each lockable door;

a security lock mechanism configured to control opening and closing of each lockable door based on the corresponding security parameter; and

a plurality of compartments, wherein each compartment of the plurality of compartments is accessible from a front side and a rear side of the locker system, wherein an access to each compartment of the plurality of compartments from the front side is controlled by a corresponding lockable door of the plurality of lockable doors, wherein each compartment of the plurality of compartments is open from the rear side, wherein when a robotic apparatus, transporting one or more items associated with a process at a storage facility, aligns with the locker system from the rear side, the one or more items are accessible from the front side of the locker system based on opening of one or more corresponding lockable doors of one or more compartments of the plurality of compartments.

20. The automated locker system of claim **19**, further comprising:

an input/output interface configured to receive one or more security parameters provided by a user to open the corresponding lockable doors of the one or more compartments, wherein the security lock mechanism is further configured to open the corresponding lockable doors of the one or more compartments when the one or more security parameters provided by the user matches one or more stored security parameters of the corresponding lockable doors.

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