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(54) **SYSTEM AND APPARATUS FOR MATERIALS TRANSPORT AND STORAGE**

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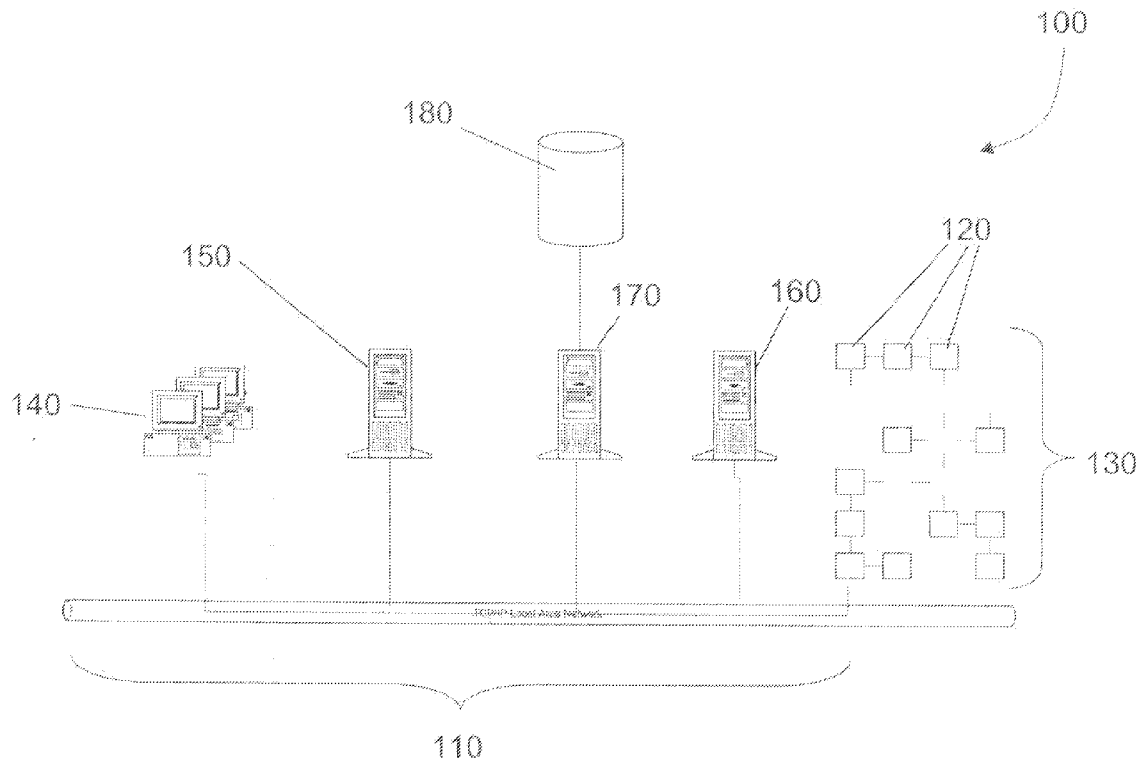Correspondence Address:
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(60) Provisional application No. 60/328,230, filed on Oct. 10, 2001.

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(57) **ABSTRACT**

A system for moving a pallet is provided. The system provides for a pair of pallets each having means for inducing movement in relation to an other pallet. Further, logic is provided for calculating a movement instruction to move the pallets relative to each other. Additionally, the present invention provides for means for communicating the movement instruction to the movement means on the pallets to prompt movement of one of said pair of pallets relative to the other pallet. As no special floor surface or configuration is necessary, the present invention described herein may be readily adaptable for utilization within existing storage and inventory facilities.

100

130

120

160

170

180

150

140

110

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

520

510

520

520

610

520

FIGURE 6A

FIGURE 6B

520

620
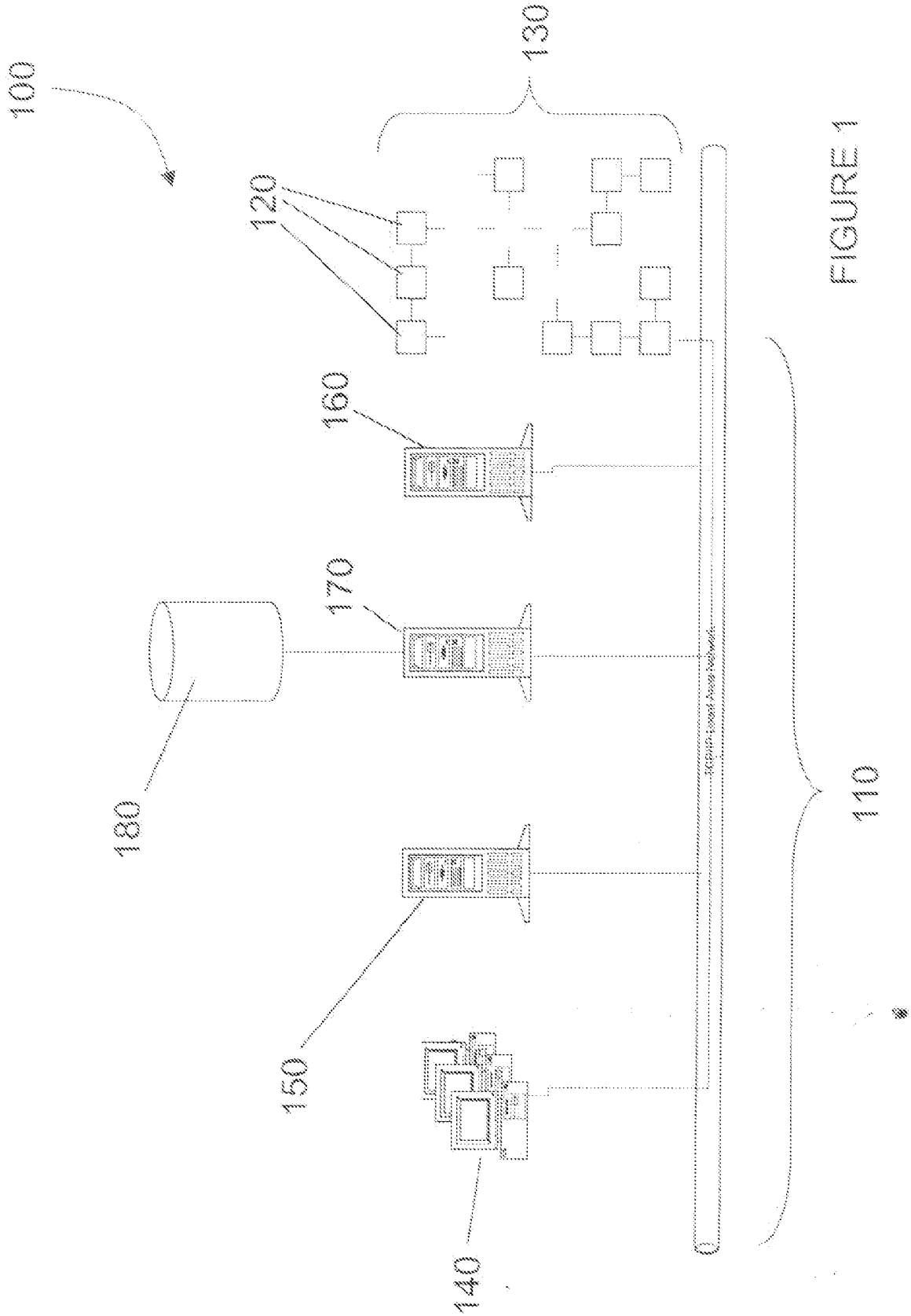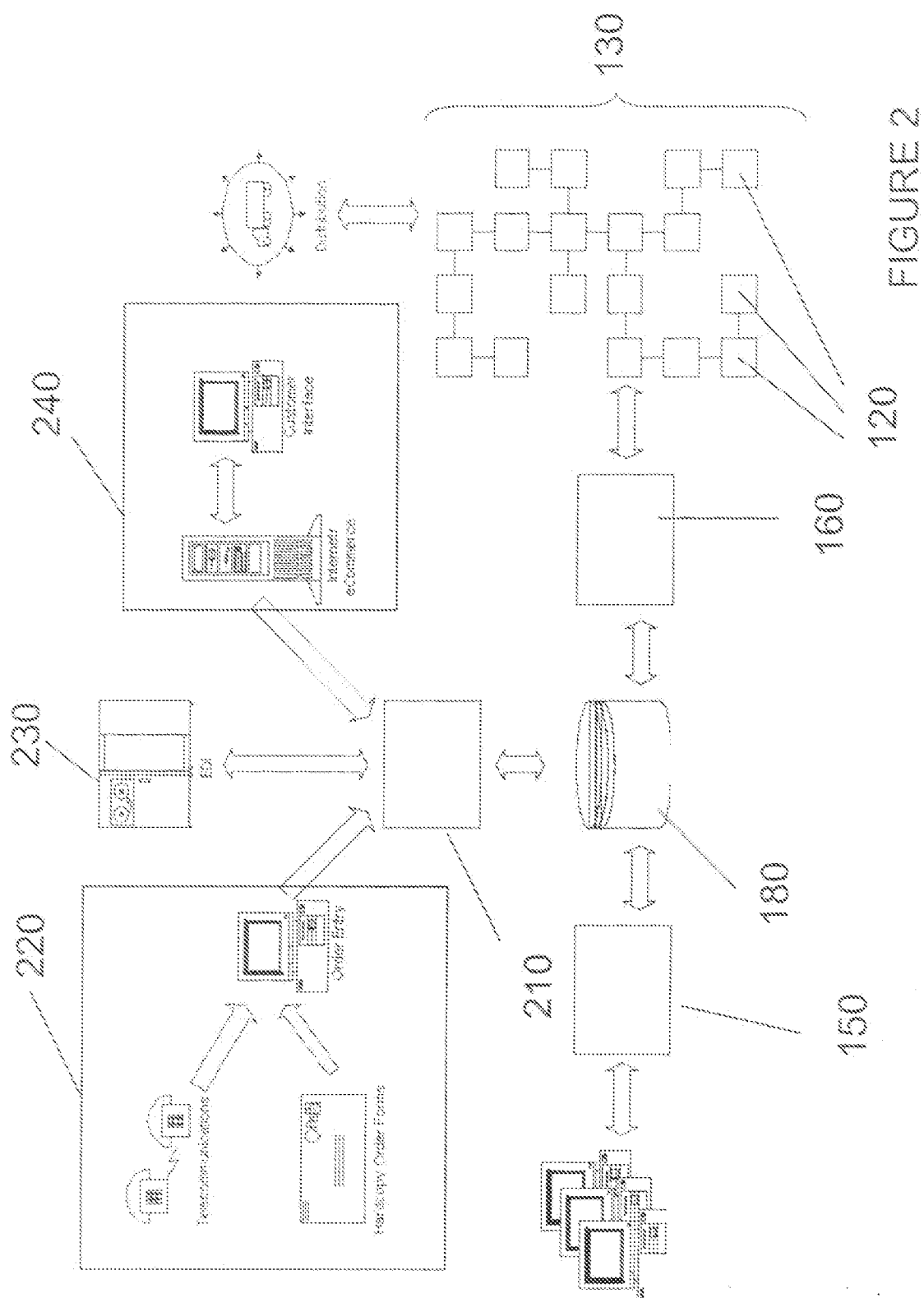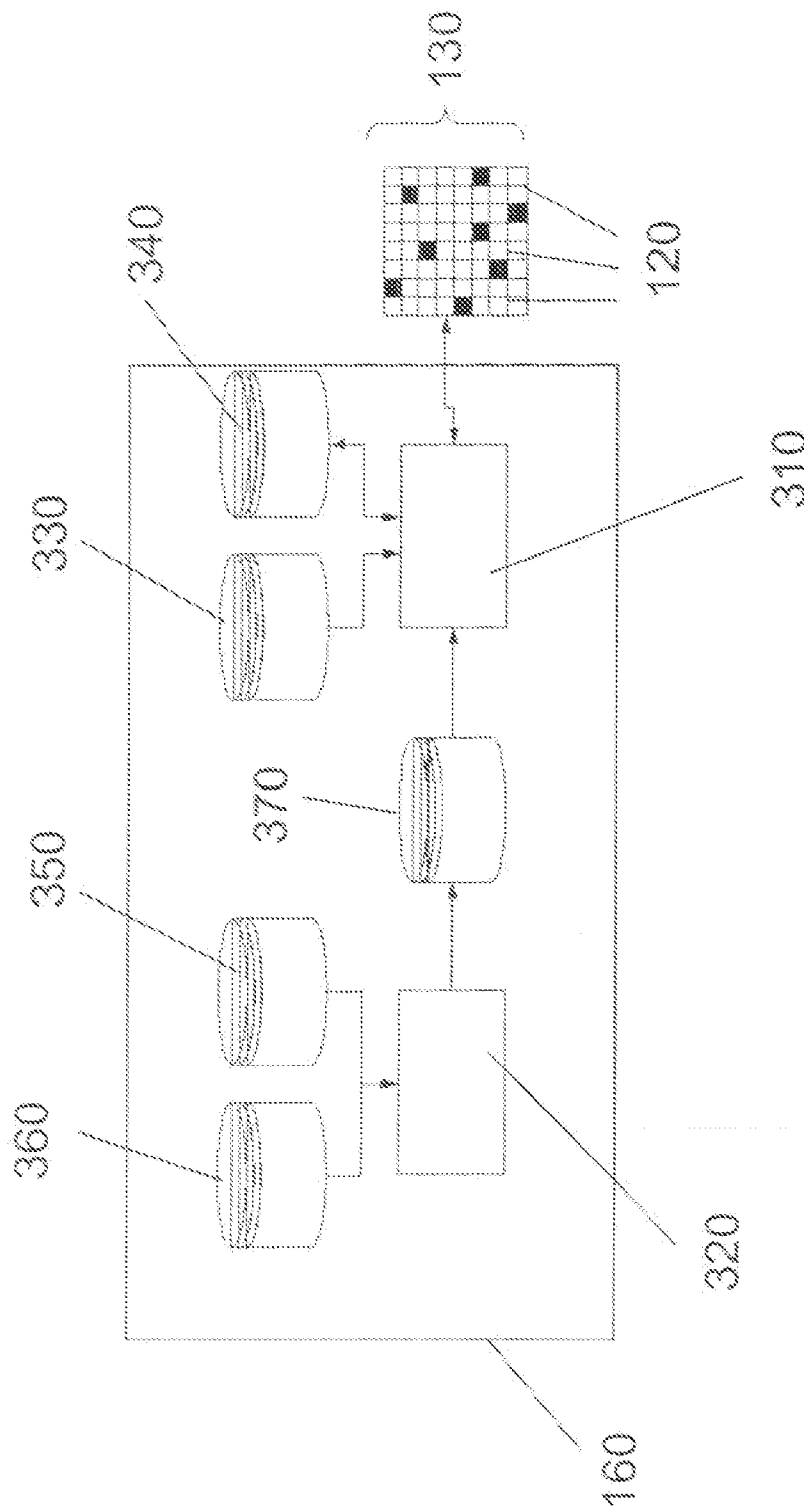
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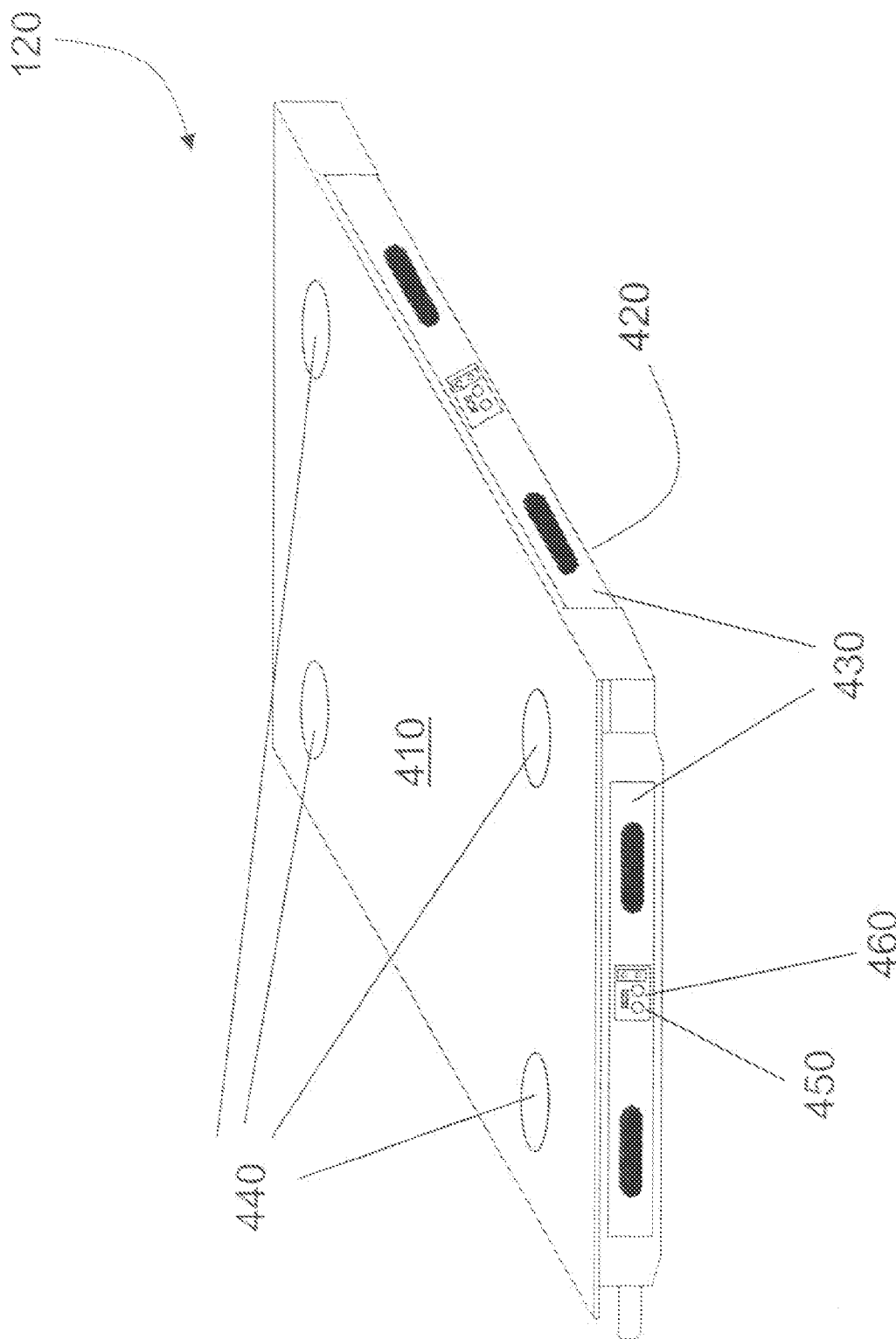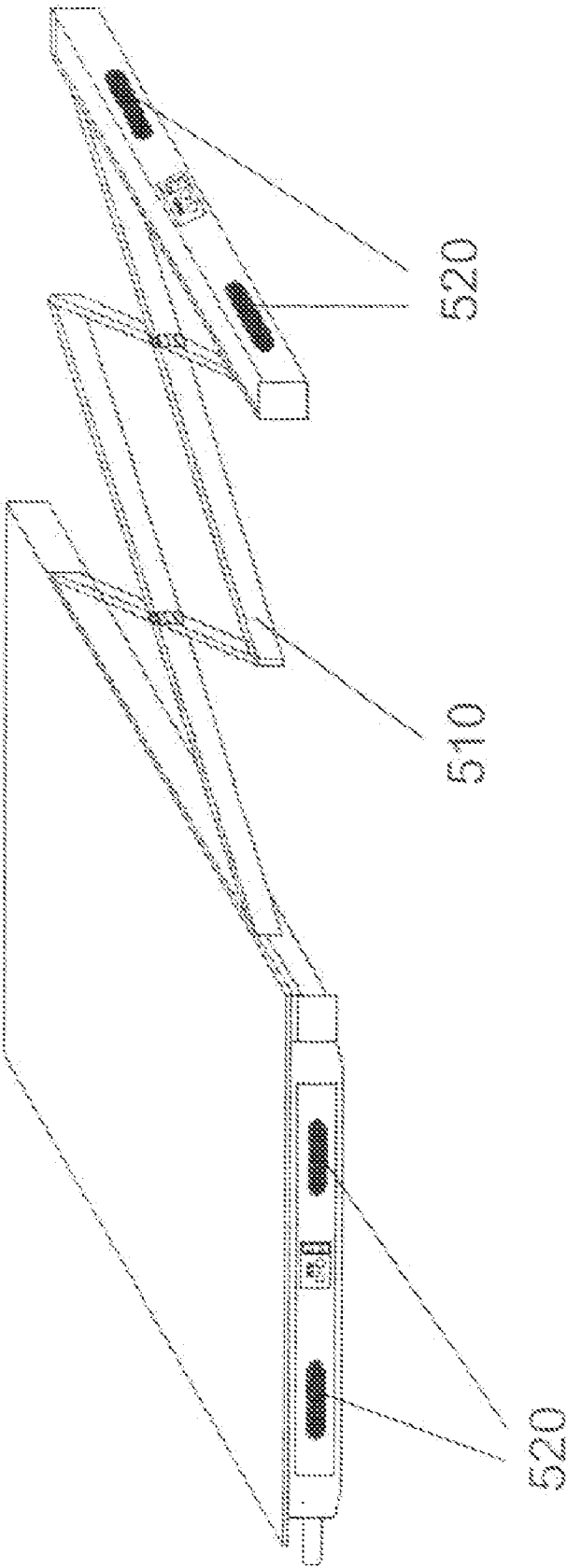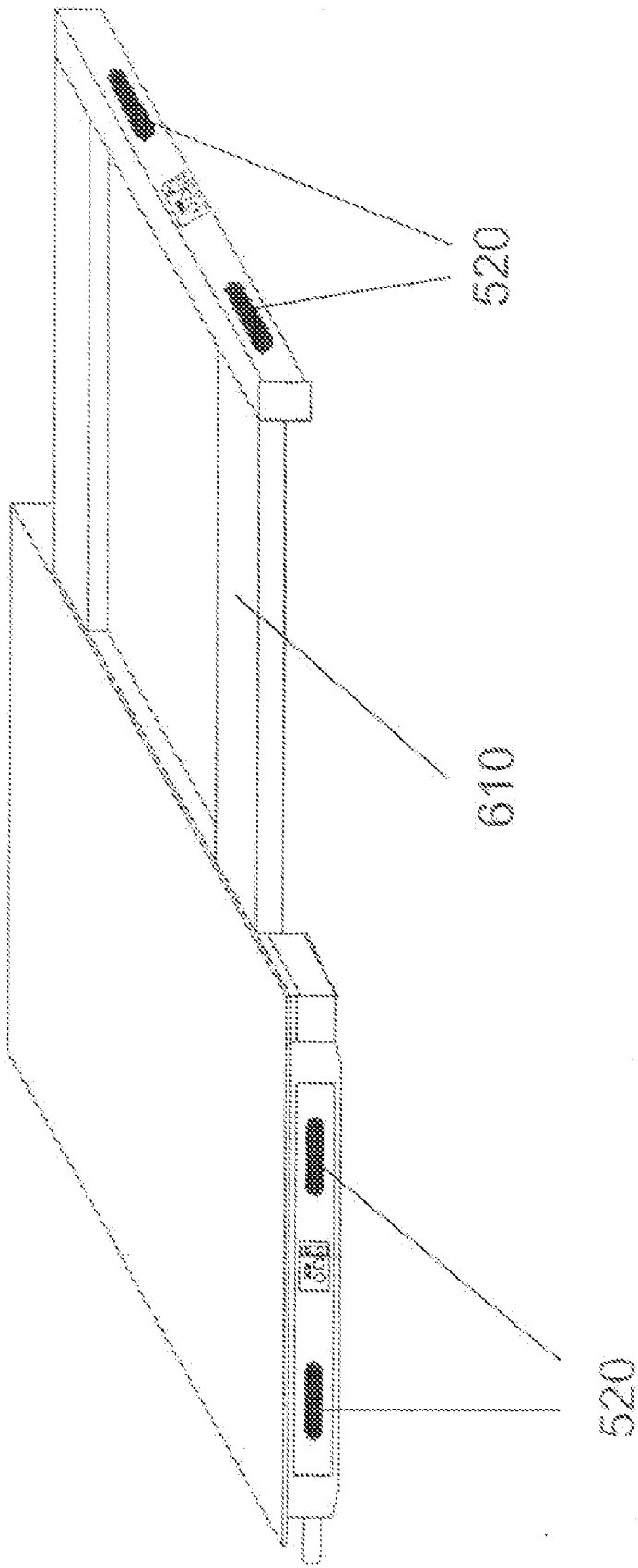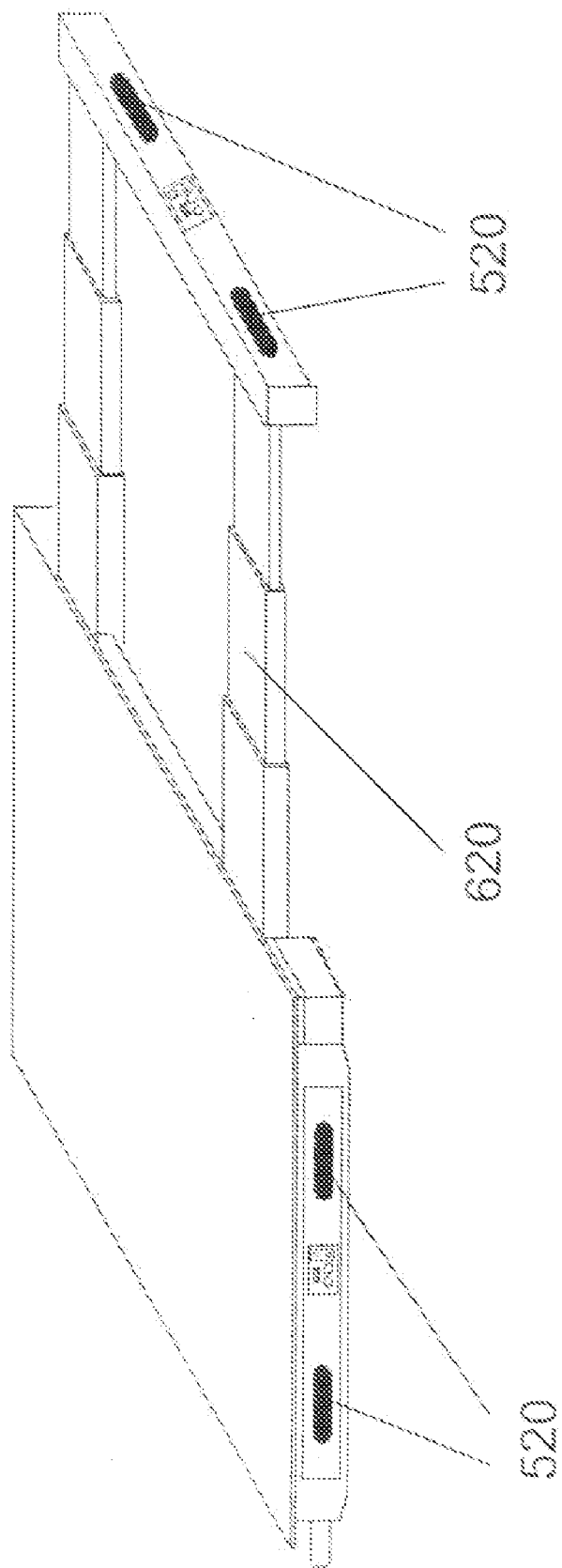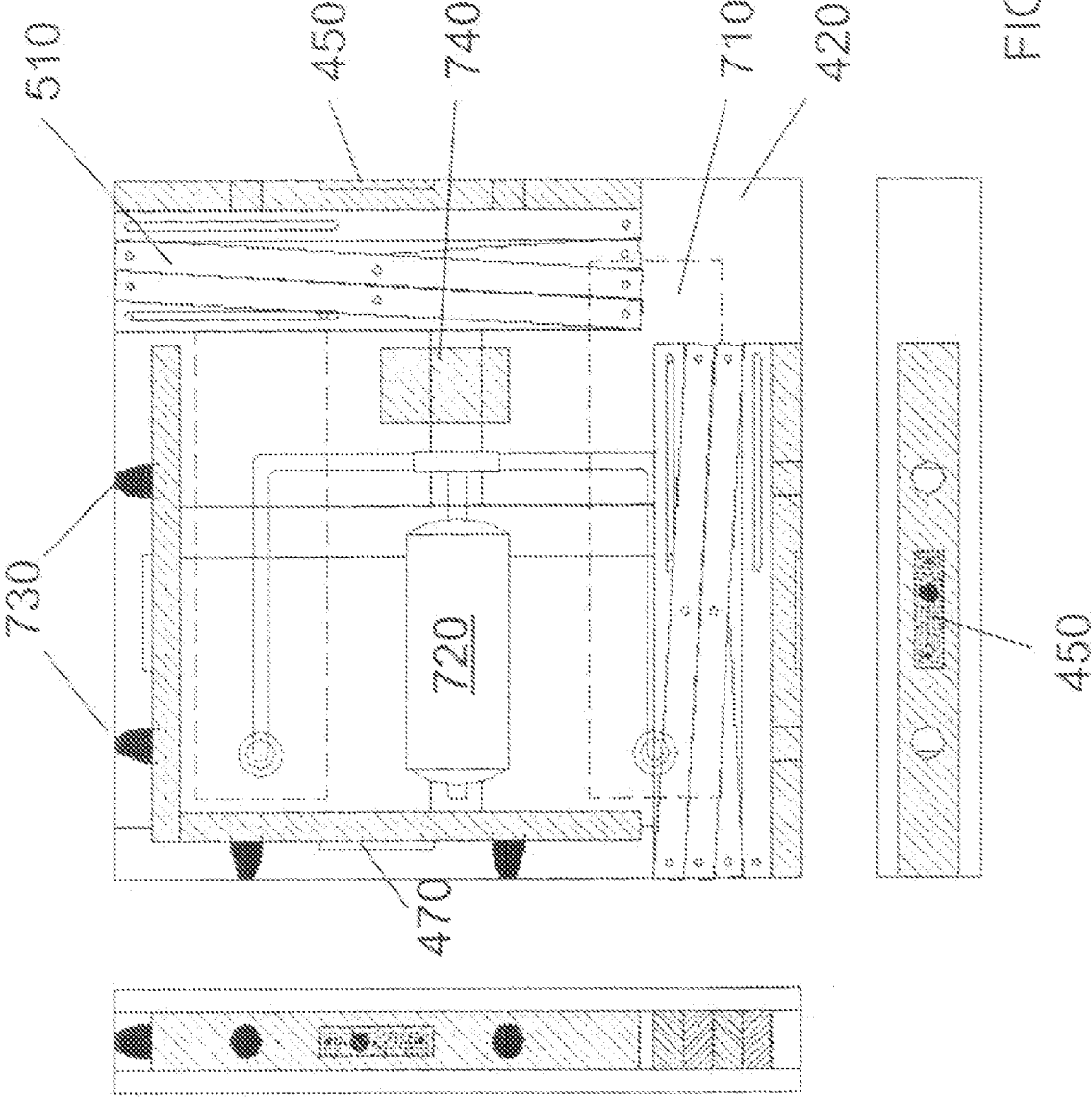
FIGURE 7
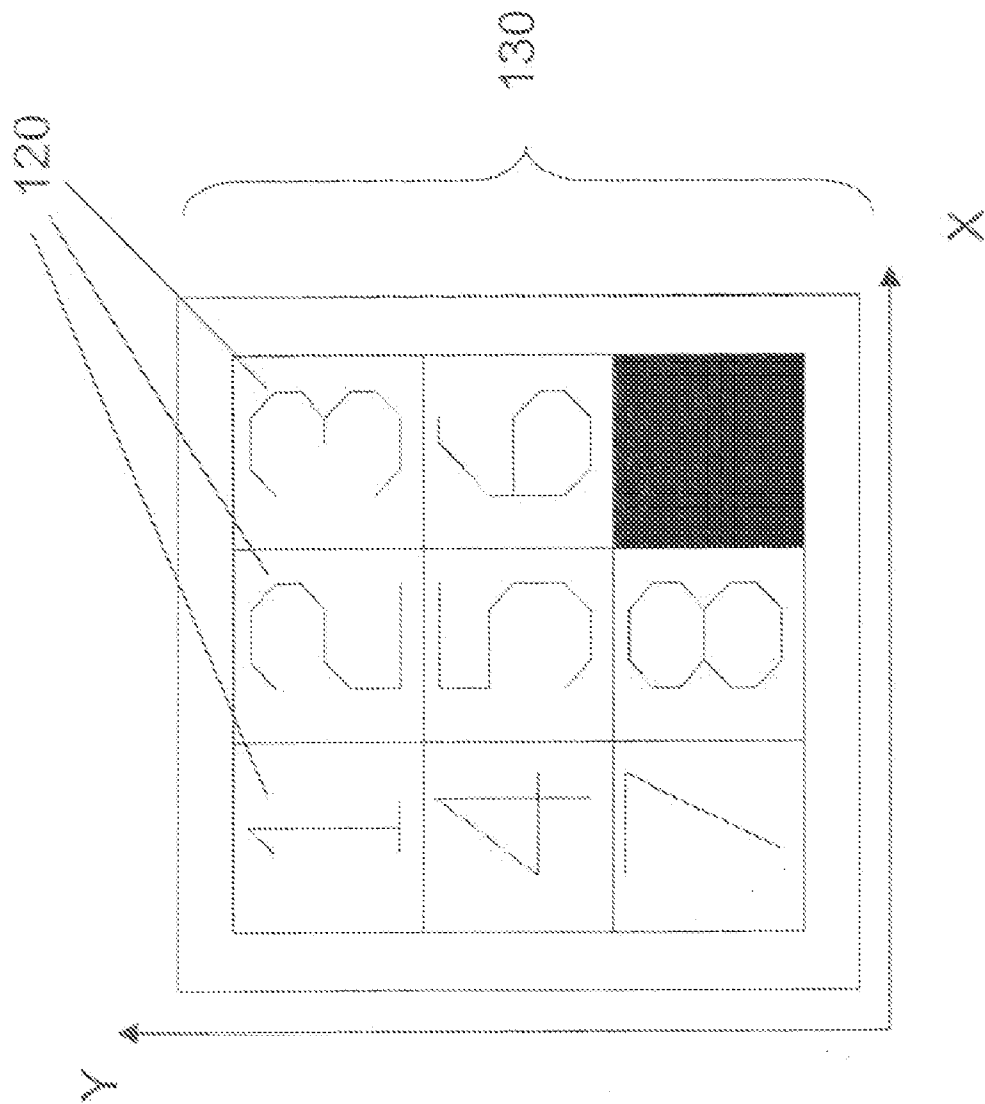
FIGURE 8

FIGURE 9

FIGURE 10

FIGURE 11

FIGURE 12

FIGURE 13

FIGURE 14
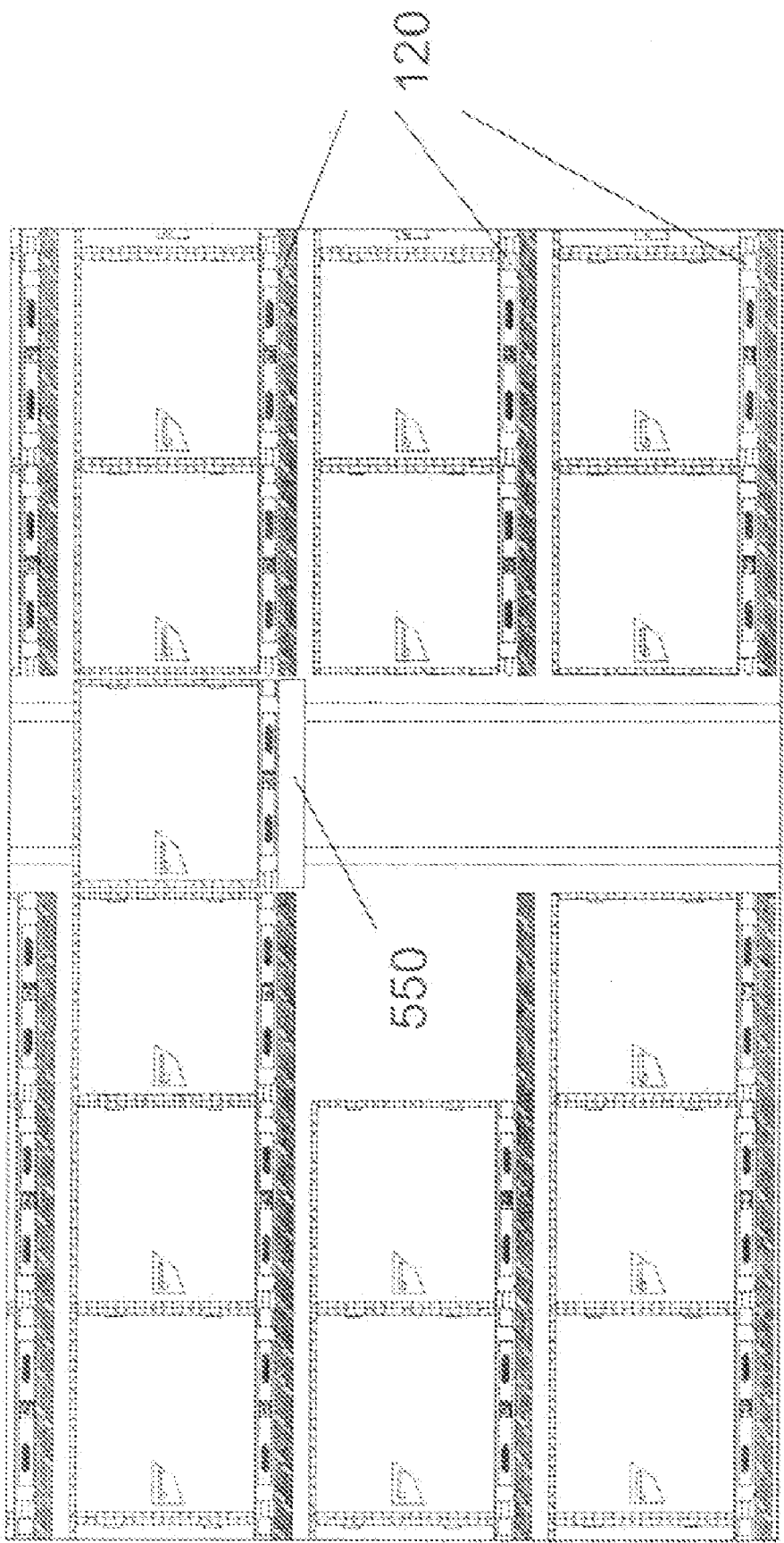
FIGURE 15

FIGURE 16
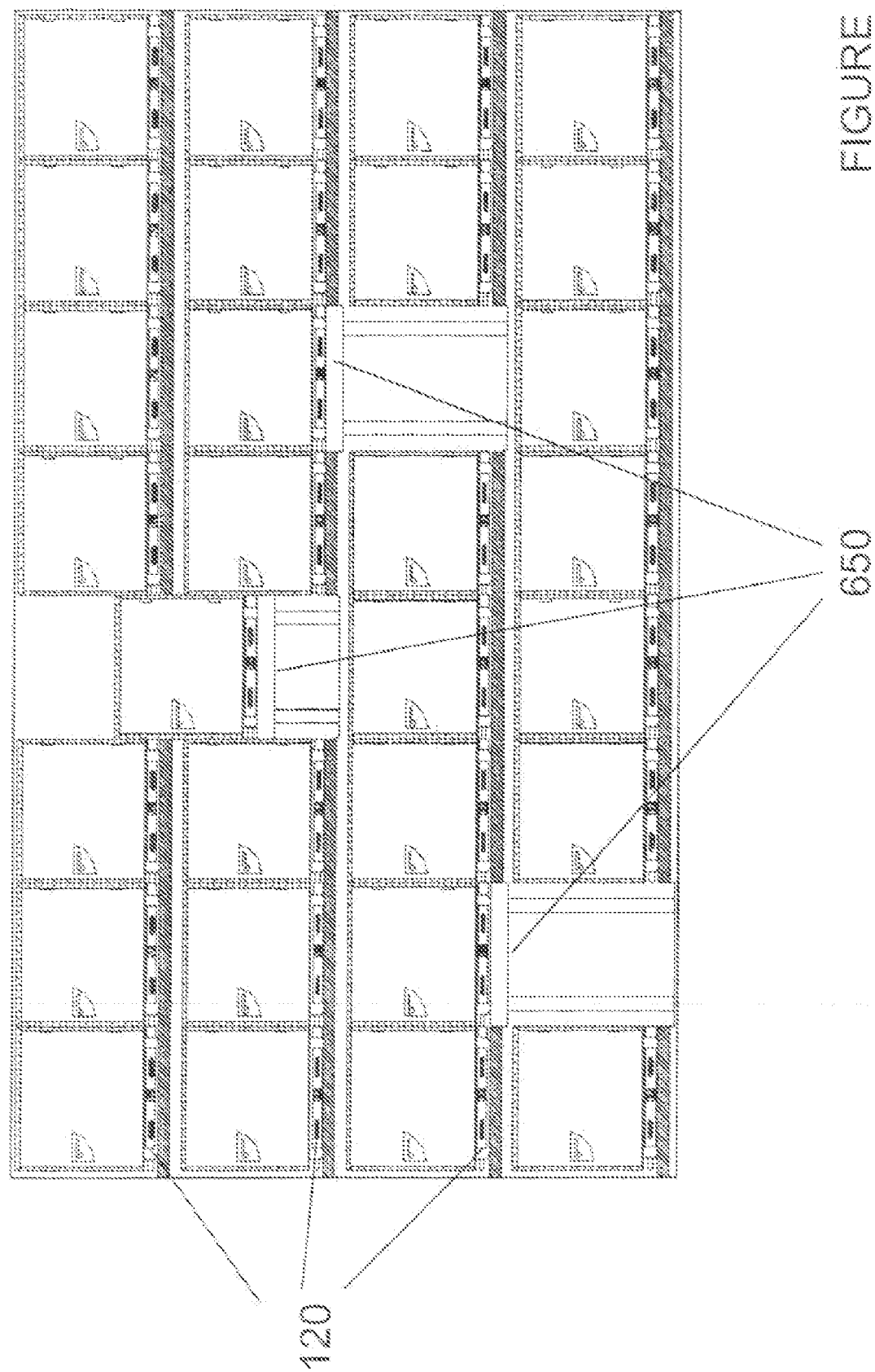
SYSTEM AND APPARATUS FOR MATERIALS TRANSPORT AND STORAGE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. application Ser. No. 10/269,099 filed Oct. 10, 2002 titled "SYSTEM AND APPARATUS FOR MATERIALS TRANSPORT AND STORAGE" and further claims the benefit of U.S. Provisional Application No. 60/328,230 filed on Oct. 10, 2001 titled APPARATUS AND METHOD FOR MATERIALS TRANSPORT AND STORAGE OPTIMIZATION both of which are incorporated herein in their entirety by reference hereto.

FIELD OF THE INVENTION

[0002] The present invention relates to a system for the automated storing, retrieving, and transporting of goods of any shape, size, and configuration utilized in warehouses, ships, airplanes, trains, trucks or other apparatus for storing or transporting goods.

[0003] Generally, it finds application as a system and apparatus related to storage systems and more particularly is directed towards a high-density, modular storage and retrieval system employing a plurality of movable storage units. The present invention also provides for erecting aisle-less warehouses, aisle-less parking buildings, aisle-less parking lots and aisl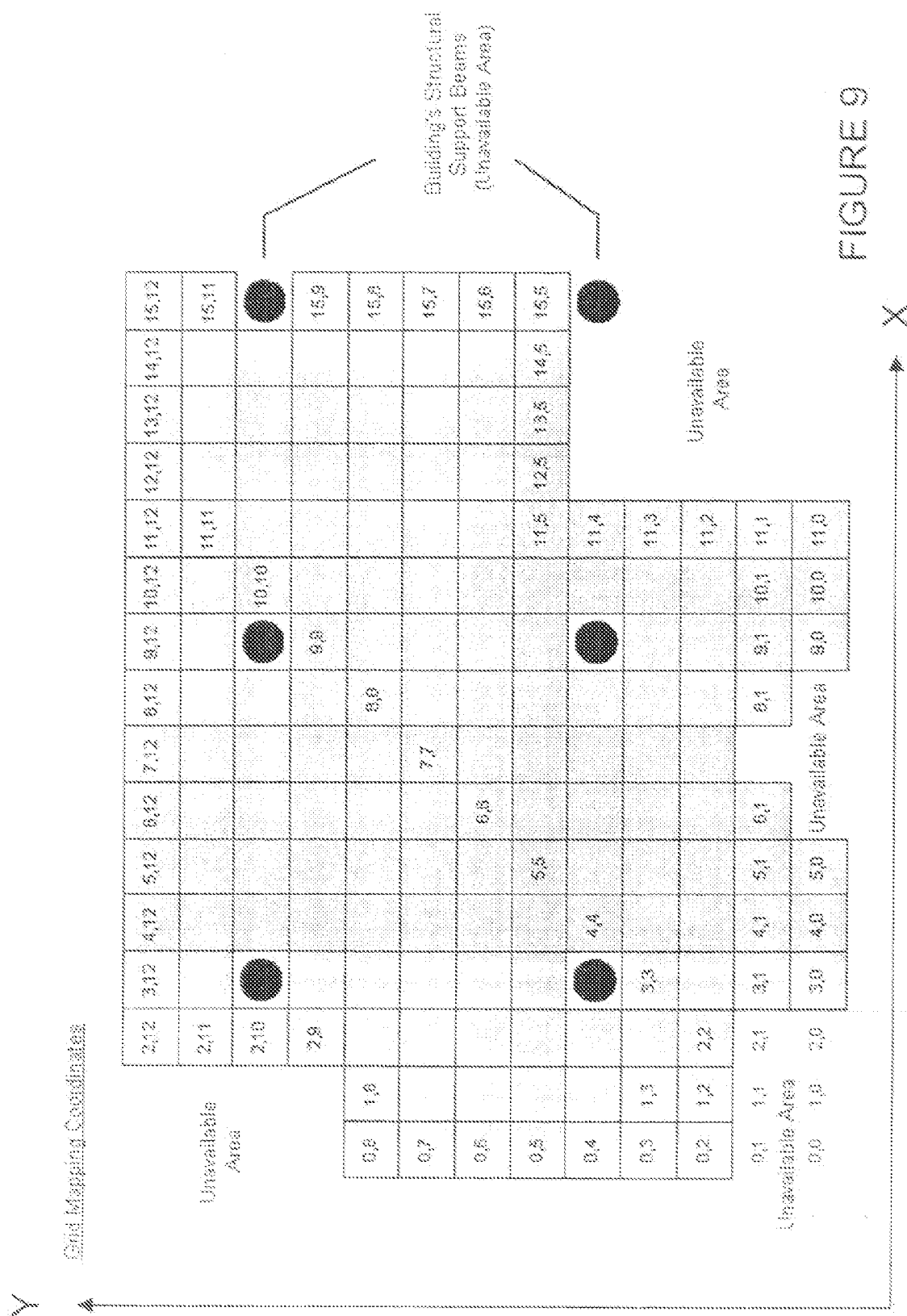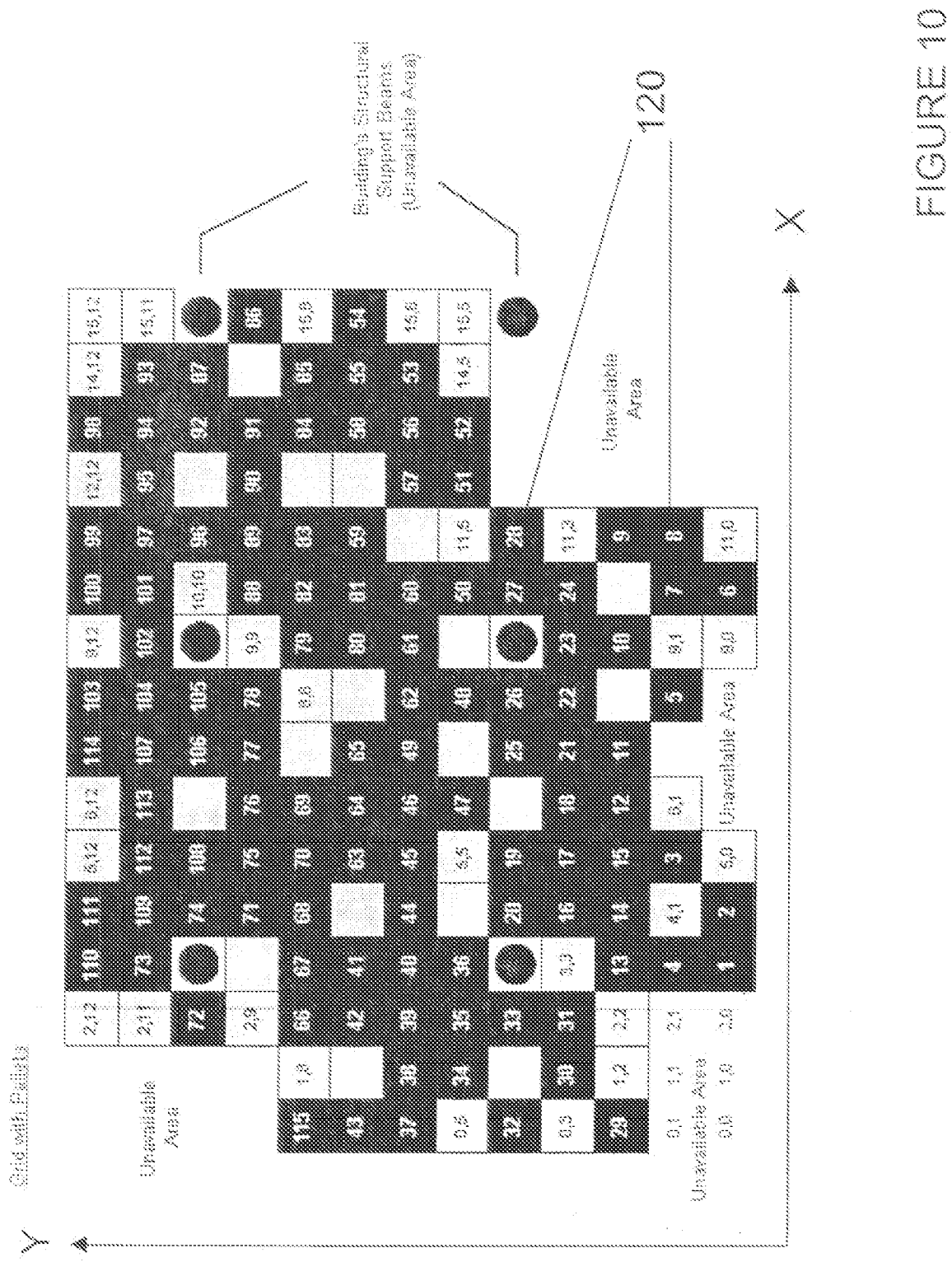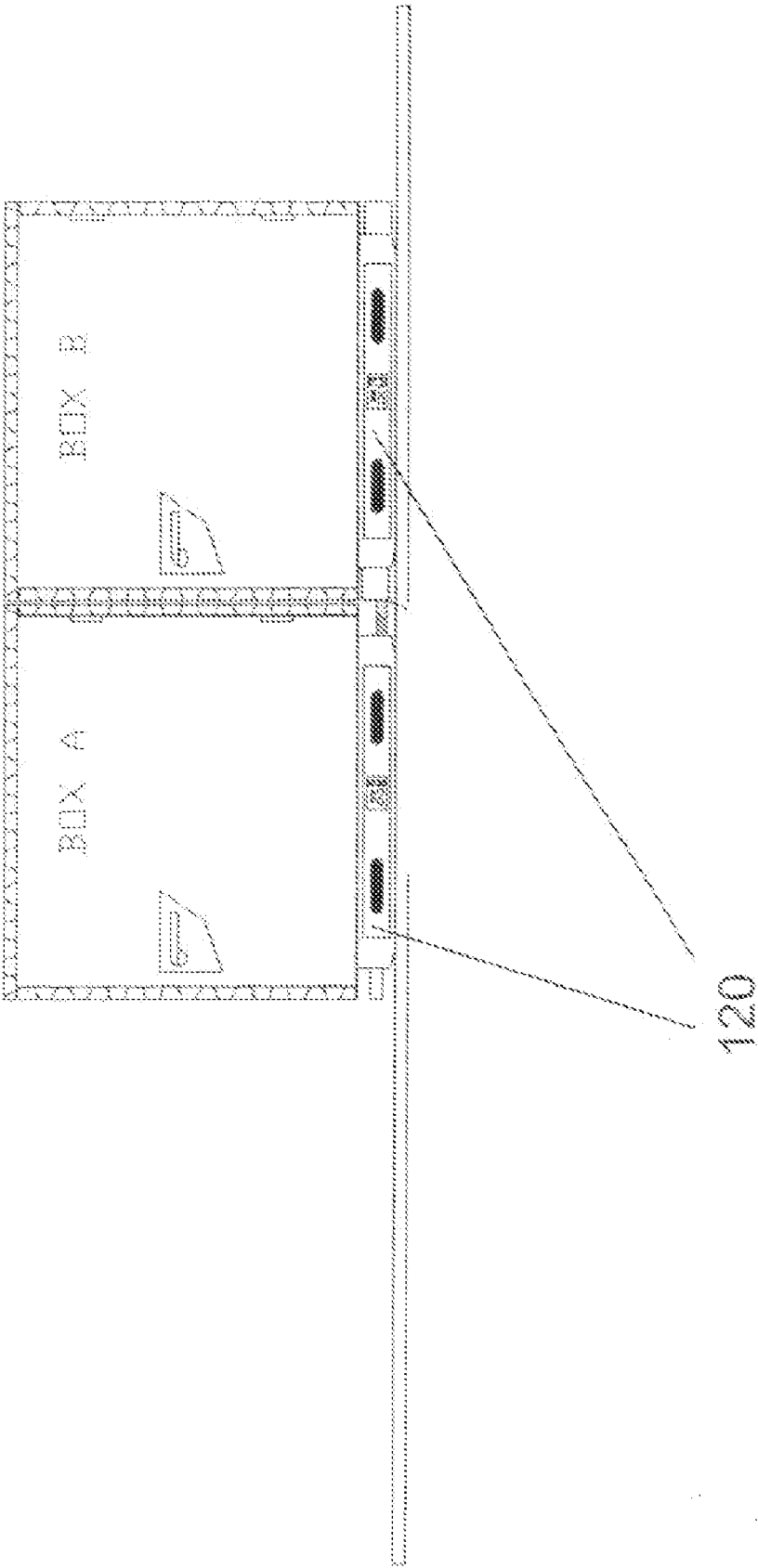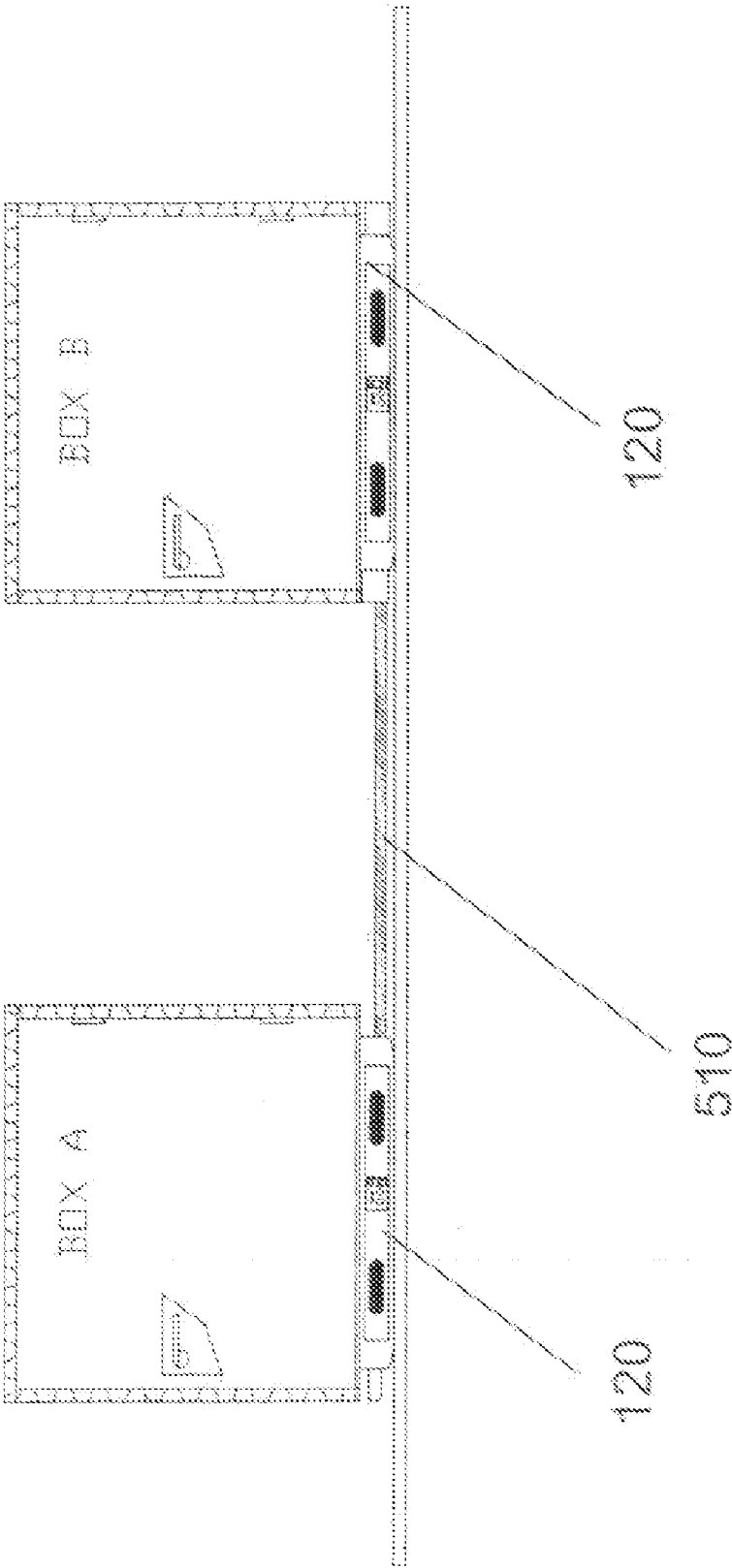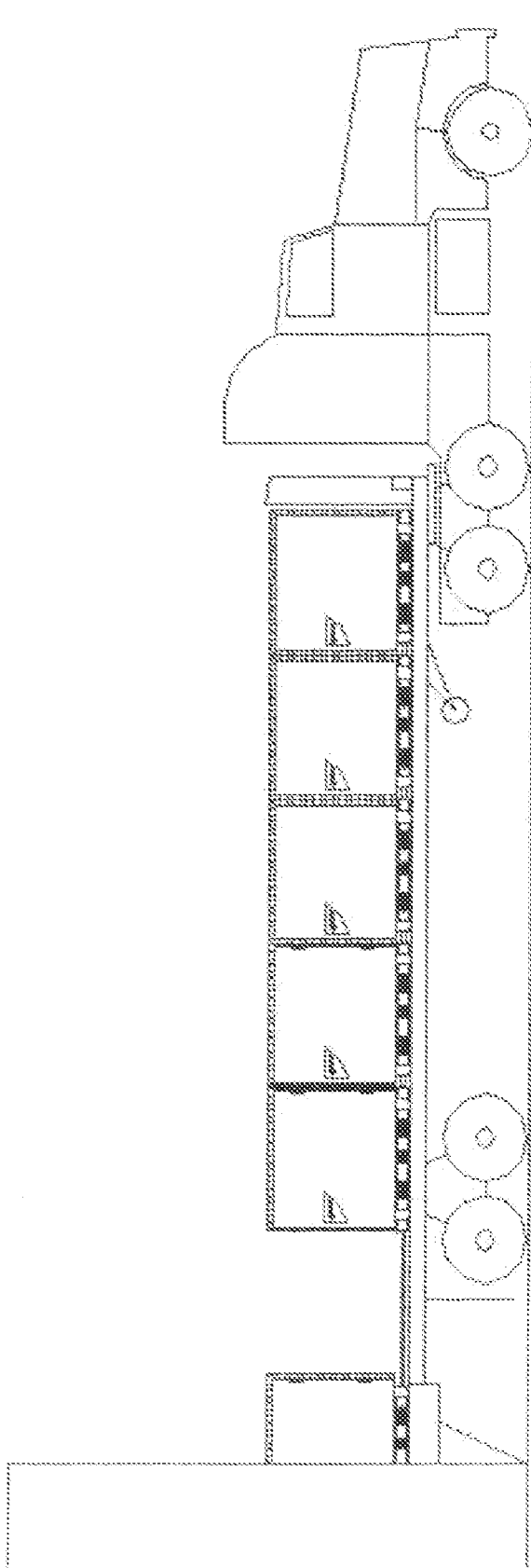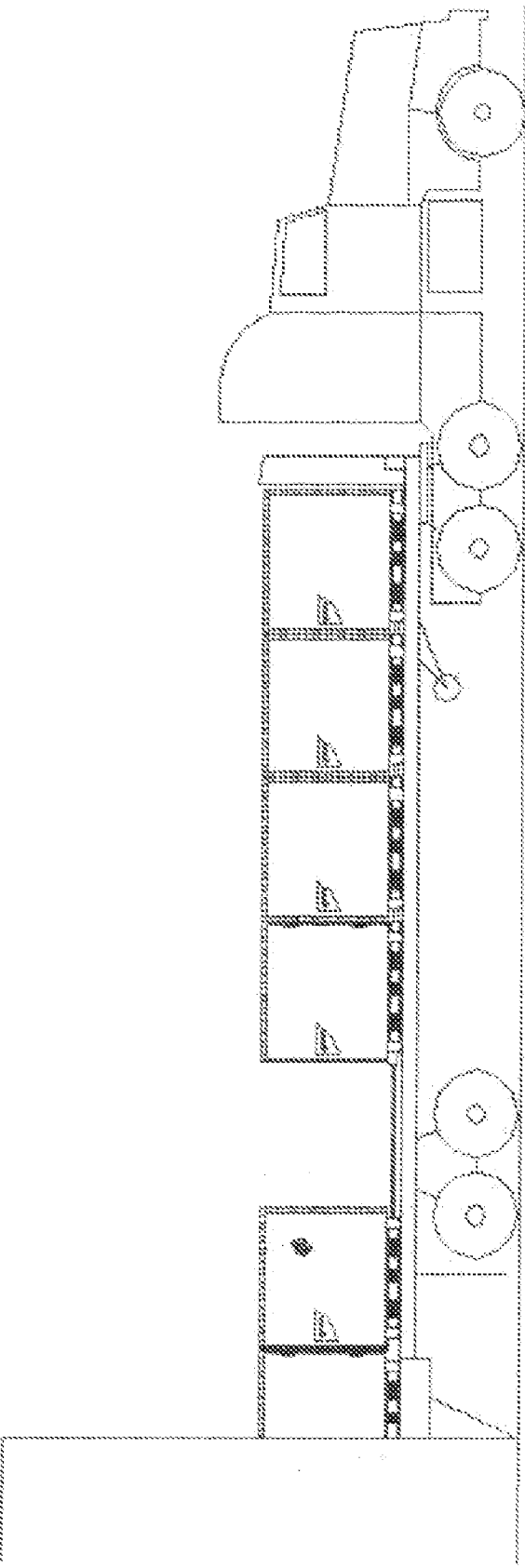e-less storage areas maximizing utilization of available storage space, minimizing human touches and increasing product throughput.

[0004] Although, the invention finds particular application, but not exclusive, to automated storage, retrieval, and transportation of goods stacked on pallets in a matrix or grid format, it is appreciated that other containers and configurations may be utilized without departing from the spirit and scope of the invention.

BACKGROUND OF THE INVENTION

[0005] Traditionally, the storage and transportation of various materials in an inventory warehouse utilized the conventional wooden pallet. These conventional wooden pallets are usually transported by the use of either a hand truck or a conventional forklift. In either case, an operator moves the fork beneath the pallet, lifts the pallet and then physically moves the pallet to the desired location.

[0006] Conventional wooden pallets have many disadvantages. For instance, wooden pallets are subject to breakage, exposing sharp wooden edges, corners and nails, which can cause damage to both materials and to persons.

[0007] Additionally, the conventional pallets themselves are relatively heavy and cumbersome to maneuver even when utilizing the hand truck or forklift. Because of their weight and bulk, pallets are difficult for an individual person to carry from point to point. Pallets must frequently be moved from flatbed trucks onto loading docks, and vice versa. Therefore, when utilizing the conventional pallet, a hand truck or forklift must be present at every location.

[0008] In an effort to address some of the disadvantages previously described, pallets have been designed to incorporate an air bearing, film or cushion between the bottom of the pallet and the floor supporting the pallet. This design feature greatly eliminates friction between the pallet and the underlying floor enabling the pallet, along with its load, to be moved along the floor or other ground surface with relative ease.

[0009] In known warehouses, pallets and their loads are arranged side by side on one or more levels. The displacement of loaded pallets requires bulky, slow-acting and expensive transporting and lifting equipment that requires relatively board access passageways to access the pallets. These access passageways involve a considerably loss of useful space in the warehouse. Furthermore, labor and maintenance are added costs that can be high utilizing traditional storage techniques.

[0010] The current invention provides a system and apparatus that is modular in design and able to automatically store, handle, retrieve and deliver bulk materials inventory. The invention provides for aisle-less warehouses with the ability to automatically deliver palletized or other packaged goods and containers from the cargo bed of trucks, trains, planes, ships and the like directly onto the smooth floor of a warehouse. Additionally the invention can be used to move objects to any designated point in or out of the facility without manual human intervention.

SUMMARY OF THE INVENTION

[0011] According to one embodiment of the present invention, a system for moving a pallet is provided. The system includes a pair of pallets each having means for inducing movement in relation to the other pallet. Additionally, the system utilized a control engine having logic to calculate a movement instruction to move one of the pair of pallets. Finally, means for communicating the movement instruction to the movement means on one of the pair of pallets to prompt movement of one of the pair of pallets is provided.

[0012] In accordance with another embodiment of the present invention, the logic is responsive to an electronic request.

[0013] Another embodiment includes a database for storing coordinate locational data relative to the a pair of pallets. The database is capable of communicating with the control engine to retrieve the data.

[0014] In accordance with yet another embodiment of the invention, the system may utilize a low friction movement means to reduce force required to move the pair of pallets. Such low friction movement means may be an air cushion or the like.

[0015] Still further, another embodiment of the present invention provides for a moveable pallet including a pallet and an arm assembly connected to the pallet that is capable of engaging an other pallet for inducing relative movement between the pallet and the other pallet. The arm assembly in one embodiment may be a scissor-type arm assembly. Further, the arm assembly in another embodiment may be a telescopic-type arm assembly.

[0016] Additionally, in another embodiment of the invention, the pellet may include a transmitter for sending locational data or a receiver for receiving a movement instruction from a control engine.

[0017] Additionally, another embodiment provides for a pallet including a surface for supporting a load, at least one arm assembly means disposed beneath the surface and means for actuating the arm assembly to induce relative movement between the pallet and an other pallet. The actuating means may be an electric motor.

[0018] Still another embodiment of the present invention provides for at least one latching mechanism disposed on the pallet.

[0019] Yet another embodiment of the present invention provides for a system for moving a pallet including a controller capable of identifying available and unavailable locations in a grid and of creating a corresponding grid table. Additionally, the controller is capable of identifying pallet occupied and unoccupied locations in the grid and creating a corresponding pallet table. An alternative embodiment further includes logic for comparing the grid table to the pallet table and determining a movement instruction corresponding to an electronic request. Further, an alternative embodiment provides means for communicating the instruction to the pallet to induce movement of the pallet relative to an other pallet.

[0020] Yet another embodiment of the present invention provides for a method for moving a pallet by identifying available and unavailable locations in a grid, creating a grid table representative of grid coordinate data relative to the available and unavailable locations in the grid, identifying pallet occupied and unoccupied locations in the grid, creating a pallet table representative of pallet coordinate data relative to the occupied and unoccupied locations in the grid, comparing the grid table to the pallet table, determining a movement instruction, communicating the movement instruction to the pallet to induce movement relative to an other pallet, actuating an arm assembly on the pallet to engage an other pallet and inducing relative movement between the pallet and the other pallet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention may take form in various components and arrangements of components. The drawings are only for the purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

[0022] FIG. 1 illustrates an exemplary overall system diagram that suitable practices an embodiment of the invention.

[0023] FIG. 2 illustrates an exemplary system flow diagram that suitably practices an embodiment of the invention.

[0024] FIG. 3 illustrates an exemplary system flow diagram that suitable practices an embodiment of the invention.

[0025] FIG. 4 illustrates a perspective view of a pallet that suitable practices an embodiment of the invention.

[0026] FIG. 5 illustrates a perspective view of a pallet and extended scissor arm assembly that suitable practices an embodiment of the invention.

[0027] FIG. 6A illustrates a perspective view of a pallet and extended slide arm assembly that suitably practices an embodiment of the invention.

[0028] FIG. 6B illustrates a perspective view of a pallet and extended telescopic arm assembly that suitable practices an embodiment of the invention.

[0029] FIG. 7 illustrates a cross-sectional view of a pallet that suitably practices an embodiment of the invention.

[0030] FIG. 8 illustrates an exemplary configuration diagram that suitable practices an embodiment of the invention.

[0031] FIG. 9 illustrates a grid layout in accordance with an embodiment of the invention.

[0032] FIG. 10 illustrates a pallet layout in accordance with an embodiment of the invention.

[0033] FIG. 11 illustrates a side view of two adjacent pallets coupled together in accordance with an embodiment of the invention.

[0034] FIG. 12 illustrates a side view of two pallets coupled together using an extended arm assembly.

[0035] FIG. 13 illustrates a side view of a conveyor application that suitably practices an embodiment of the invention.

[0036] FIG. 14 illustrates a side view of a conveyor application that suitably practices an embodiment of the invention.

[0037] FIG. 15 illustrates a side view of a multiple level application that suitably practices an embodiment of the invention.

[0038] FIG. 16 illustrates a side view of a multiple level application that suitably practices an embodiment of the invention.

DETAILED DESCRIPTION OF THE
ILLUSTRATED EMBODIMENTS

[0039] The following includes definitions of exemplary terms used throughout the disclosure. Both singular and plural forms of all terms fall within each meaning.

[0040] "Software", as used herein, includes but is not limited to one or more computer executable instructions, routines, algorithms, modules or programs including separate applications or ones from dynamically linked libraries for performing functions as described herein. Software may also be implemented in various forms such as a servlet, an applet, a stand-alone program including a server based application and a user based application, a plug-in or other type of application. Software may also be stored on various readable mediums such as disk, CD, tape, memory and can be downloadable.

[0041] "Database", as used herein, includes but is not limited to any means or methods used to organize, store and retrieve data such as relational database management systems (RDBMS), flat file structures, arrays, Random Access Memory (RAM), or the like.

[0042] "Logic", as used herein, includes but is not limited to hardware, software and/or combinations of both to perform one or more functions.

[0043] "Request", as used herein, refers to any identified or scheduled need to move a pallet, whether that need is the result of a manual operator action or the result of intelligent communications or coordination with disparate processing systems such as warehouse management system (WMS), inventory management systems, order processing systems, or the like.

[0044] "Network", as used herein, includes but is not limited to the internet, intranets, Wide Area Networks (WANs), Local Area Networks (LANs), and transducer links such as those using Modulator-Demodulators (modems).

[0045] "Internet", as used herein, includes a wide area communications network, typically accessible by any user having appropriate software.

[0046] "Intranet", as used herein, includes a data communications network similar to an internet but, typically having access restricted to a specific group of individuals, organizations, or computers.

[0047] FIG. 1 is an exemplary system diagram of the system 100 architecture in accordance with the present invention. As shown, the system 100 is configured with both hardware and software 110. In one embodiment, the system 100 is contained within an intranet network such as a TCP/IP local area network.

[0048] The preferred embodiment of the present invention operates under the control of a collection of computer hardware and software applications 110 that monitor, direct and coordinate the movements of automated self-propelled computer controlled pallets 120 arranged in a matrix or grid 130. The pallets 120 when arranged in a plurality or grid 130 on any smooth flat surface in a checkerboard-type fashion create a dynamic floor of shifting squares, each capable of being delivered to any other location in the configuration.

[0049] A variety of graphical user nodes, interfaces (GUI's) or operator desktops 140 in connection with a system manager server 150 provide operators, support and maintenance personnel with the tools needed to initiate, monitor and intervene with the system 100 in a real-time mode. Additionally, comprehensive inventory management software (not shown) interfaces with a system control server 160 to provide a high level of inventory tracking and delivery automation. The system control server 160 communicates with the individual pallets 120 in the grid 130 by providing instructions to effectuate the repositioning of the pallets 120 in accordance with a request. Additionally, a database server 170 and database 180 are provided to store the data pertinent to tracking and moving individual pallets 120 within the grid 130. The database server 170 preferably utilized a RDBMS 180 and is one ordinarily known in the art, for example, Oracle, Microsoft SQL Server, Informix or the like.

[0050] Each of the system components will be more readily understood through a review of the drawings as described below.

[0051] Continued reference to FIG. 1 and briefly describing the operation of the system 100, a request for a specific load is entered by an operator via an operator node 140, or move commonly is scheduled automatically as a result of tight integration with disparate processing systems as mentioned in the definitions above under "request". The system control server 160 processes the request and communicates with the database server 170 to identify the appropriate pallet 120 and further the X-Y coordinate location of the requested pallet 120 within the grid 130. The system control server 160 then calculates the movement instructions necessary to fulfill the request. The system control server 160 then communicates the movement instructions necessary to fulfill the request to the pallets 120 within the grid 130. Each

of the pallets 120 in the grid 130 are capable of receiving the movement instructions from the system control server 160 and of self-repositioning in accordance with the instructions. Finally, the system control server 160 receives updated location and product information from each pallet 120 and communicates with the database server 170 which updates the appropriate data in the database 180 necessary to respond to further requests.

[0052] It is contemplated that FIG. 1 represents a single embodiment of a network hardware configuration, and that each component reflects virtual components that may constitute clusters of servers in some configurations. One ordinarily skilled in the art can appreciate the available alternative designs available to perform any of the functions of the system 100. Furthermore, it is contemplated that the system 100 may be configured using servers that run a variety of operating systems including but, not limited to, Microsoft Windows™. Unix, Linus and the like.

[0053] The pallets 120 are configured in a grid 130 pattern as shown in FIG. 1 and are employed in a network in the same manner as computers are connected to the Internet. As stated earlier, this network of automated pallets 120 receives commands from the system control server 160. These signals are routed through the grid 130 of automated pallets 120 until they reach the target pallet 120. The target pallet 120 receiving the instruction then executes the command and returns an appropriate response signal (i.e. "Acknowledged", "Move Complete", "Errors Encountered", etc.) to the system controller server 160 which updates the database 180.

[0054] As illustrated in FIG. 2, a common database 180 is a central component shared by the three sub-systems; a system control server 160, a system manager server 150 and the inventory manager 210. Information placed or updated in the database 180 by one sub-system triggers events and drives activity in another.

[0055] In operation, orders for goods/materials are entered into the inventory manager 210 through a variety of methods, including, but not limited to, manual entry 220, electronic data interchange (EDI) 230, or other e-commerce channels such as customer entry via the internet 240. Requests entered into the database 180 are processed by the system control server 160, which identifies the location of a target pallet 120 containing the ordered goods.

[0056] Based on the current location of the target pallet 120 and state of the grid 130, the system control server 160 calculates movement instructions pursuant to the coordinates and subsequently communicates with the pallets 120 in the grid 130 to deliver the designated pallet 120 to the desired location. The actions of the system control server 160 effectively moving pallets 120 around the grid 130 are monitored by the system manager server 150, which continually updates the operator node 140 to reflect the current and ever shifting state of the grid 130.

[0057] In another example, as goods (automated pallets 120) are received into the grid 130 for the first time, the system control server 160 recognizes the entry of the new pallets 120 into the grid 130 and captures and downloads the inventory data stored on the automated pallet's internal processor 740 (as shown in FIG. 7). The information captured by the internal processor 740 (as shown in FIG. 7) is

communicated to the system control server **160** via the local area network (LAN) or alternatively via radio frequency (RF) wireless communication. The system control server **160** updates the inventory tables in the database **180**, to make the goods available in the inventory manager **210** during order processing and fulfillment of future requests. Likewise, on the back-end, as an automated pallet **120** is loaded for delivery or otherwise emptied or removed, the system control server **160** updates the inventory management system accordingly in order to alert the inventory manager **210** of the change in inventory status.

[0058] Although the preferred embodiment utilizes hard wired wireless RF technology to enable communications between the system control server **160** and the pallets **120**, one ordinarily skilled in the art can appreciate that other techniques may be used including, but not limited to, wireless RF connections, infrared, Bluetooth™ and the like.

[0059] In addition to the automated updating features as described above, at any time, the data in the database **180** can be manually adjusted by trained operators using the operator node **140** to intervene, override automated processes, adjust schedules, enter ad hoc requests, correct errors, troubleshoot problems, or suspend or shut-down the system **100** either partially or entirely.

[0060] Because of the asynchronous nature of the three control system components, the system control server **160**, the system manager **150** and the inventory manager **210**, each can be managed and maintained separately from the others. Independent operation of these three components **160**, **150**, **210** enables containment of failure. Controlled delays or shutdowns of one component thereby do not affect or interfere with the operations of the other components.

[0061] As indicated herein, the system control server **160** is a collection of processes and logic that monitor, direct and coordinate the movement of automated pallets **120** throughout the grid **130**. Specifically, and as shown in FIG. **3**, the system control server **160** is divided into two sub-components: a control engine **310** and control director **320**.

[0062] FIG. **3** illustrates the interactions between the control engine **310** and the control director **320**.

[0063] Specifically, the control director **320** monitors and/or integrates with order processing systems **360** and inventory management systems **350** and subsequently manages the fulfillment process responsive to a request. Additionally, the control director **320** manages, priorities and coordinates the flow of automated pallets **120** throughout the grid **130** while maintaining a work queue **370** which prompts the control engine **310** to calculate move sequences and sends movement commands to the pallets **120** in the configuration. Finally, the control director **320** updates inventory tables **350** stored in the database **180** as requests are processed and new automated pallets **120** arrive or are introduced into the grid **130**.

[0064] Upon receiving request information via the work queue **370**, the control engine **310** calculates a path for each automated pallet **120** in the grid **130** and sends movement instructions to the individual pallets **120** responsive to a request. Additionally, the control engine **120** is responsible for updating the environment **330** and current state **340** tables in the database **180** to reflect the current location of each pallet **120** in the grid **130** by polling the pallets **120** at startup, manual reset and continually during ongoing operation.

[0065] Furthermore, the control engine **310** detects the introduction of new pallets **120** into the grid **130**, establishes communications, and downloads the inventory data **350** stored on the pallet internal processor **740** (as shown in FIG. **7**), making the information available to the control director **320**.

[0066] Just as the three main components of the controlling software are asynchronous, so too are these sub-components of the system control server **160**. Problems, maintenance or idle time in one sub-system does not necessarily affect the operation of the other.

[0067] In operation, the control engine **310** calculates, at every point in time, the most efficient process to relocate a pallet **120** to a specified target location and accordingly issues a sequence of instructions to the pallets **120** to prompt the reposition pursuant to a request. This asynchronous process constantly checks the work queue **370**, which is automatically filled by the control director **320** and/or manually updated by an operator using an operator node **140**. The control engine **310** then factors these new parameters into the ever-shifting state of the grid **130** in response to future requests. As a result, the pallets **120** in the grid **130** will travel to the target location in accordance with the instructions issued by the control engine **310**.

[0068] The automated pallets **120** are capable of bearing heavy loads and providing the motive means for pushing themselves one pallet-length in either of two directions, preferably, north and west (as a relative reference), and pulling themselves one pallet-length in either of two directions, preferably, east and south. Similarly, using this same motive means, a pallet **120** is capable of pushing or pulling an adjacent pallet **120** in these same four directions. The operative of the motive means will be described in detail below. A pallet **120** as described according to the preferred embodiment of the current invention is capable of pushing or pulling itself one space in two directions, and is capable of being pushed or being pulled by another pallet in the remaining two directions. Although the preferred embodiment moves the pallets one pallet length in any direction, it is contemplated that the system described can be modified to move a pallet any desired distance.

[0069] Illustrated in FIG. **4** is a perspective view of a pallet **120** in accordance with a preferred embodiments of the present invention. As shown, the pallet **120** is preferably rectangular in shape having a top surface **410**, a bottom surface **420**, and four sidewalls **430**. The pallet **120** is preferably constructed of plastic. Although the pallet **120** in the preferred embodiment is constructed of steel, an artisan can appreciate that the pallet **120** may be constructed of other rigid material including but, not limited to aluminum, metal alloy, steel fiberglass, wood and the like.

[0070] The top surface **410** is capable of supporting a load and is equipped with load supporting fasteners **440** to be optionally used to secure a load onto the top surface **410**. Preferably, the fasteners **440** are eye-hooks as shown, however, it is contemplated that alternate methods may be utilized to secure the load to the pallet **120** including but, not limited to straps, hands, notches, channels and the like.

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[0071] The bottom surface **420** is equipped with an air cushion system **710** to facilitate low friction or frictionless movement of the pallet along a smooth surface. Alternatively, the air cushion system **710** can be replaced with wheels, rollers, casters, skids and the like.

[0072] The pallet **120** is equipped with utility junctions **450** on each sidewall. Specifically, the pallet **120** is equipped with male receptacles **470** on the north and west sidewalls and female receptacles **460** on the south and east sidewalls. This arrangement of male and female receptacles **460** enables two adjacent pallets **120** to be in electrical and pneumatic communication with one another. For example, when side by side, the male receptacle **470** on the west sidewall of one pallet **120** is entered into the female receptacle **460** on the east sidewall of the other pallet **120** causing the pallets **120** to establish optional electrical, communications and pneumatic connections with each other.

[0073] FIG. **5** illustrates a scissor arm assembly **510** comprising the utility junction **450** with female receptacle **460** extending from the east sidewall of a pallet **120**. A variety of alternate embodiments of the arm assembly **510** are provided. As illustrated in FIGS. **5**, **6A** and **6B**, a scissor-type arm assembly **510**, a slide-type arm assembly **610** and a telescoping-type arm assembly **620**, respectively, are contemplated. Additionally, a "hinged" arm mechanism (not shown) folded into the pallet that may swing out from a side of the pallet, allowing the pallet to be pushed or pulled. The preferred embodiment utilizes electric motors (not shown) to extend and retract the arm assemblies **510**, **610**, **620**. Although the preferred embodiment of the present invention utilizes electric motors (not shown) to drive the actuator (not shown) controlling the extension and retraction of the arm assembly **510**, **610**, **620**, alternate means of propulsion may be utilized including, but not limited to pneumatic cylinders, gears, pulleys, belts, lead screw propulsion methods, hydraulics, electro-magnetic, electro-mechanical, springs and the like.

[0074] In the preferred embodiment, the north and west faces of each pallet contain locking pins **730** (as shown in FIG. **7**) by which the arm assemblies **510**, **610**, **620** couple and lock into the locking pin ports **520** positioned on the arm assemblies **510**, **610**, **620** that constitute the south and east sidewall of the pallet. Thus, when a plurality of pallets **120** are arranged and oriented accordingly, they create a patchwork of interconnecting pallets **120**. In addition, when locking pins **730** (as shown in FIG. **7**) are engaged the arm assemblies **510**, through the utility junctions **450** provide the coupling means to pass optional electricity, compressed air and computer communications from one pallet **120** to another via receptacles **460**. The preferred embodiment utilizes on-board electric motors (not shown) to drive the extension and retraction of the arm assemblies **510**, **610**, **620**.

[0075] In alternative embodiments of the invention, the pallets **120** may utilize individual facilities such as on-board hydraulic systems, air blowers, batteries, wireless network communications and other mechanisms capable of providing services needed for the operation of the pallets **120**.

[0076] Alternatively, a common bus system to pass power, computer communications and/or compressed air throughout the grid may be provided. In this embodiment, perimeter docking ports (PDP) (not shown) are positioned at multiple locations around the perimeter of the available pallet locations (see FIG. **9**, discussed later). Two embodiments of the PDP are employed, consistant with and identical to the utility junctions **450** discussed previously. Relative to the constant orientation of all pallets **120** in a configuration, and corresponding to the utility junctions **450** on the pallets **120**, PDP's positioned on the north and west perimeter are of the type comprising the female receptacles **460**, and PDP's positioned on the south and east perimeters are of the type comprising male receptacles **470**.

[0077] In embodiments of the entire system where PDP's are utilized, the PDP's are mounted on interior walls or mounted to fixed structures constituting barriers fastened to the floor. In each case, the PDP's are mounted at the level that facilitates the mating with utility junctions **450** on pallets **120**, and each PDP is connected to the network (shown in FIG. **1**) via the optional means defined previously and discussed later.

[0078] In another embodiment of the entire system that employs wireless networking technology in each pallet **120**, PDP's are not used.

[0079] FIG. **7** illustrates a cross-section of the automated pallet **120** and its sub-assemblies.

[0080] As illustrated in FIG. **7**, the preferred embodiment of the current invention employs the application of an air cushion system **710** to provide a thin film of air on which the load-bearing pallet **120** floats. This air cushion system **710** allows a pallet **120** carrying tons of material to easily move from one position to the next with minimal force required. All types of air cushion systems currently commercially available may be applied to the current invention.

[0081] Continued reference to FIG. **7** shows that an onboard canister pump **720** is provided to supply air to the air cushion system **710** embedded in the bottom surface **420** of the pallet **120**. In yet other embodiments, on artisan can appreciate that the pallets **120** may be quipped with wheels, rollers and the like in place of air cushion system **710** without changing the scope or operation of the invention.

[0082] In the preferred embodiment of the present invention, each automated pallet **120** is provided with a computer processor, hardware and software control box **740** to enable the pallet **120** to receive instructions, store data and execute commands. Additionally, as previously described, each individual pallet **120** is capable of sending information to and receiving instructions from the system control server **160** and to her pallets **120**.

[0083] Preferably, the current invention employs common computer networking technology, TCP/IP, to facilitate massaging between the system control server **160** and the pallets **120** in the grid **130**. Common routing software is provided to enable the automated pallets **120** in a configuration to communicate on a network. Each pallet **120** is uniquely identified and is able to distinguish between instructions being sent to itself and instructions intended for other pallets **120** in the grid **130**. Because the system **100** is designed to identify the order of pallets **120** at any given time, messages sent by the system control server **160** are automatically forwarded from pallet **120** to pallet **120** until they reach the intended target pallet **120**. As pallets **120** are constantly being moved, this counting information is constantly updated by the system control server **160** and subsequently

stored in the database **180**. Although the preferred embodiment utilizes a relational database **180** to store data, one ordinarily skilled in the art can appreciate that storing, retrieving and maintaining information can be accomplished using other means including, but not limited to, Random Access Memory (RAM), flat file structures, and the like.

[0084] Although the preferred embodiment utilizes a hardwired TCP/IP communications protocol to facilitate communication between the pallets **120** to each other and to the system control server **160**, an artisan can appreciate that other communication protocols may be utilized to accomplish communication including but, not limited to Ethernet™, X10, Wireless RF, Wireless infrared Bluetooth™, DeviceNet ™, ModBus™, ModBus Plus™ and the like.

[0085] One skilled in the art will contemplate additional components that may be employed to further contend the functionality and capability of the pallets **120**, including, but not limited to, a global positioning satellite (GPS) receiver and transmitter allowing a pallet's **120** exact position on the glove to be tracked, load cells or scales to automatically determine the weight of a pallet **120**, tilt, level and acceleration sensors to monitor load stability, as well as radio frequency identification (RFID), Bar Code readers, ID Matrix readers, or vision systems.

[0086] In operation, the diagram in FIG. **8** illustrates the basic concept of transposition employed by one embodiment of the current invention. In this FIG. **8**, the squares numbered **1** through **8** represent load-bearing pallets **120**. The dark square represents an empty space. Given this configuration, either pallet **6** or pallet **8** could be moved into the empty space, leaving the space previously occupied empty. For example, if pallet **8** slides into the empty space to the right, the space it previously occupied will be left empty, allowing pallet **7** to slide one space to the right or pallet **5** to slide one space down. If pallet **5** slides down, then either pallet **2**, **4** or **6** can slide into the space previously occupied by pallet **5**. In this manner, any pallet **120** in the configuration can be relocated to any position on the grid **130** by simply displacing the empty space in a coordinated fashion.

[0087] In alternate embodiments of the current invention, many more pallets **120** and empty spaces are arranged contiguously in a grid **130**. As previously discussed, as long as at least one empty space exists, any pallet **120** can be relocated to any other position through this method of transposition.

[0088] According to an embodiment of the present invention, FIG. **9** illustrates available floor space in a warehouse divided into a virtual grid **130** with storage spaces delineated by X,Y coordinates as shown.

[0089] As illustrated in FIG. **9**, the grid configuration and X,Y coordinates depicted in FIG. **9** are purely virtual in nature and do not constitute any special demarcation or apparatus on the actual warehouse floor. The X,Y coordinates do however represent the organizational structure. employed by the system **100** of an embodiment of the current invention. The specific controlling methods, logic and processes are described below.

[0090] For illustration, FIG. **10** shows the same warehouse floor as depicted in FIG. **9** superimposed with pallets **120** occupying most of the available storage positions. Accordingly, any pallet **120** in the FIG. **10** configuration can be reheated to any other available space by the transposition means previously described in FIG. **8**.

[0091] The number of unoccupied spaces in any configuration is not required to exceed one. However, an artisan can appreciate that in each installation a balance is struck between the desire to maximize available space utilization and the need to relocate pullets quickly. If the need to maximize space utilization is greater than the requirement to move pallets quickly, then fewer unoccupied spaces are maintained. If the later requirement is greater, then more spaces are left unoccupied.

[0092] In operation, and as previously discussed, the operator programs the system **100** with the coordinates of the layout of the floor and available spaces. A graphical user interface (GUI) (not shown) is provided to facilitate the construction and maintenance of the virtual floor layout. Likewise, a similar GUI is provided (not shown) to facilitate the construction and maintenance of the virtual representation of all pallets **120** and their locations in the configuration.

[0093] The table below represents the basic data structures utilized by the preferred embodiment of the system control server to track and manage the ever-shifting state of the entire system.

Table/Column Name	Type	Prime Index	2nd Index	Description
GRID_TABLE	Table			Contains one row for every available space
X	Integer	1		"X" coordinate of the given space
Y	Integer	2		"Y" coordinate of the given space
ENABLED	Boolean			YES/NO switch
PALLET_TABLE	Table			Contains one row for every Automated pallet
PALLET_ID	Integer	1		Unique identifier
X	Integer		1	Current "X" coordinate of the given pallet
Y	Integer		2	Current "Y" coordinate of the given pallet
DEST_X	Integer			Destination "X" coordinate of the given pallet
DEST_Y	Integer			Destination "Y" coordinate of the given pallet
POWER_STATUS	Integer			Power supply status indicator
COMM_STATUS	Integer			Electronic communications status indicator
AIR_STATUS	Integer			Air supply status indicator
UP_ARM_STATUS	Integer			Upper arm assembly status indicator
RT_ARM_STATUS	Integer			Right arm assembly status indicator
ENABLED	Boolean			YES/NO switch

[0094] Initially, the pallet table (shown above) is populated by optional automatic or manual means. As described herein, the preferred method employs both means. A collection of pallets **120** numbering not less than 8 are placed and positioned contiguously on the designated available floor space with at least one pallet **120** connected to the network via one of the many perimeter docking ports discussed earlier. Upon start-up or optional manual reset, the control engine **310** polls all perimeter docking ports to detect the presence of the (at least one) connected pallets **120**. Because every perimeter docking port is associated with a fixed physical location, a row can be inserted into the pallet table (shown above) comprising the pallet ID and values representing the X,Y coordinates for the location. Additionally, one skilled in the art will recognize that the control engine **310**, through the perimeter docking ports and the previously identified pallet(s) **120** connected to the perimeter docking ports can identify and calculate the X,Y coordinates for adjacent pallet(s) **120**. This process is repeated through all subsequent adjacent pallets **120** until all pallets **120** have been identified and a row has been inserted into the pallet table (shown above) for each pallet **120** in the configuration.

[0095] Upon gathering the necessary data as shown above for each pallet **120** in the configuration, the control engine **310** communicates with the database server **170** to store the data in the database **180**.

[0096] The floor layout as shown in FIG. **9** is converted by the operator into a set of X-Y coordinates. These coordinates are entered into the grid table as shown above. The grid table above is a static collection of data representing the layout of the floor populated during configuration of the entire system and, therefore, is updated only when the collection of available pallet locations is altered. The data in this grid table changes only when the actual layout of the existing floor space changes. As in a standard grid arrangement, the grid table contains a row that corresponds to every square space of floor available to a pallet. As floor space is never perfectly symmetrical or entirely usable, one skilled in the art will recognize that unavailable spaces are designated by the absence of a row for the given unavailable coordinates.

[0097] The available floor space as illustrated in FIG. **9** is mapped out on an X,Y axis. In this example, coordinates 0,0 are assigned to the bottom-left-most corner for any configuration however, because the coordinates are relative, the 0.0 coordinate can be assigned to any location on the floor. As is the case in the example of FIG. **9**, location **0,0** is not always an available space. In accordance with FIG. **9**, the grid table in the database would contain the following rows and values:

X	Y	ENABLED
0	2	Y
0	3	Y
0	4	Y
0	5	Y
0	6	Y
0	7	Y
0	8	Y
1	2	Y
1	3	Y

-continued

X	Y	ENABLED
1	4	Y
1	5	Y
1	6	Y
1	8	Y
2	2	Y
2	3	Y
2	4	Y
. . .	. . .	. . .

[0098] As seen in the grid table above, there is no entry in the table for the space corresponding to the coordinates 0,0-0,1-1,1-2,1 and 2,1. The absence of rows with these values indicates to the control engine **310** that those spaces are not available for population by a pallet **120**.

[0099] Additionally, by using the operator node, the operator is able to designate a space temporarily unavailable. The "Enabled" column is used by system operators to designate a particular grid space as temporarily unavailable. An entry in the grid table with ENABLED="N" is treated the same as a non-existent row for those coordinates.

[0100] Unlike the grid table, the pallet table (shown above) is very much a dynamic table. The values in this pallet table constantly change to affect and reflect the existence, location and movement of automated pallets **120** throughout the grid **130**. The control engine **310** constantly selects data from the pallet table, calculates movement instructions, issues commands to the individual automated pallets **120**, then updates the values in this table at the conclusion of successful movements. This cycle repeats continuously until the system is halted, shut down or the work queue becomes empty.

[0101] FIG. **10** is an illustration of pallets superimposed on the grid as identified in FIG. **9**. Accordingly, the pallet table identifies the current locations of every pallet in the grid. Below is a pallet table corresponding to the location of the pallets as illustrated in FIG. **10**.

PALLET ID	X	Y
1	3	0
2	4	0
3	5	1
4	3	1
5	8	1
6	10	0
7	10	1
8	11	1
9	11	2
10	9	2
11	7	2
12	6	2
13	3	2
14	4	2
15	5	2
16	4	3
. . .	. . .	. . .

[0102] Every automated pallet **120** is assigned a unique pallet identifier that is embedded into the pallet's internal processor (not shown) disposed in the control box **740**. This

unique pallet ID, represented here as a list a contiguous integers starting with 1, are captured by the control engine **310** at startup or reset time and used as the primary key values when populating the pallet table. In practice, the values in the pallet ID field may be "16-digit" hexadecimal values, however, integers are used in this example for the ease of discussion.

[0103] The most fundamental of all of the processes and logic that make up the control engine **310** is the pallet mover logic. This logic is called upon continuously to calculate pallet **120** movements in accordance with requests in the work queue **370**. The logic uses the values in the grid and pallet tables to determine which pallet **120** needs to move in response to a request. Therefore, one call to the pallet mover logic will result in at least one pallet **120** being moved one space in some direction. Additional pallets **120** are moved each time the pallet mover logic is invoked. Each time the logic is invoked the control engine **310** reassesses the current state of the configuration by referring to the current pallet table and subsequently issues instructions to effectuate the most logical move given the entire arrangement of the grid **130** at that particular time.

[0104] For example, again referring to layouts shown in FIGS. **9** and **10**, suppose a request is entered to move pallet ID **115** (at X,Y coordinates 0,8) from the left side of the floor to location (**15,8**) which is on the right side of the floor. Upon assessing the current state of the configuration, the control engine **310** determines that pallet **115** must move laterally to the right by subtracting the origin X,Y coordinates (0.8) from the destination coordinates (15,8). The positive X value from the result (15,0) indicates an east (relative) direction. A negative value for X would indicate the pallet needs to move west. Likewise, a positive value in the Y coordinate result would indicate the pallet must move north, while a negative value in the Y coordinate result would indicate the pallet must move north, while a negative value indicates south. In this example, the Y value of zero means the pallet is currently on the correct lateral row relative to the target location.

[0105] Continuing with the example, the logic then determines if pallet ID **115** is able to move one space east, by determining if the adjacent space to the cast is an available space, and if so, if that available space is vacant. In reaching this determination, the pallet mover logic must fir determine the location of pallet ID **115**. In doing so, the values for X and Y are selected from the pallet table where the pallet ID-**115**. With these coordinates, a query is made by the control engine **310** to the grid table to determine if the location one space to the right of pallet ID **115** (X+1,Y) is an available space in the grid **130**. This determination is accomplished by selecting a column or aggregate value from the grid table where X=the value of X+1 for pallet ID **115** and Y=the value of Y for pallet ID **115** and ENABLED= YES. If a row value is returned from the query, the space is available. Otherwise the space is not available, and the control engine **310** will calculate a movement in another direction before it will be able to move it to the right.

[0106] In this example, the space at location **1.8** (one space to the right) is an available space, therefore the logic must next check to see if the space is occupied. It checks for occupancy of a particular space by querying the pallet table where X=(in this case, 1) and Y=(in this case, 8). In this

example, no row is found that contains these values, therefore, the control engine **310** has determined that the available space to the east is vacant.

[0107] Now, for any configuration oriented in the way previously discussed there are 2 ways a pallet **120** can move in an eastward direction. Because the motive means, that being the arm assemblies **510, 610, 620**, for each pallet **120** are oriented on the south and east sidewalls **430** of the pallet **120**, a pallet **120** can be pushed to the east by an adjacent pallet **120** to the west, or it can extend the arm assembly **510, 610, 620** from the east sidewall **430** across a vacant space and latch onto another pallet **120** or perimeter docking port and then retract the same arm assembly **510, 610, 620** effectively pulling itself one space to the east. Therefore, the logic next looks for a pallet **120** one space to the left to be pushed by. This is done by issuing a query to the pallet table, where X=(in this case, X-1) and Y=(in this case, 8). Now, no row is returned which indicates to the control engine **310** that there is no pallet **120** available to push pallet number **115** to the east.

[0108] Next, the logic checks location **2,8** which is two spaces to the right for a pallet **120** which would enable pallet ID **115** to utilize its east facing arm assembly **510, 610** to pull itself to the east. Upon querying the pallet table where X=2 and Y=8, a row value is returned indicating to the control engine **310** that pallet ID **66** is located in that position. Accordingly, the control engine **310** issues the instructions to pallet ID **115** to extend its right arm assembly **510, 610, 620**, attach to pallet ID **66**, turn on its air cushion, retract its arm assembly **510, 610, 620** (causing it to pull itself one space to the east), then turn off the air. Finally, the control engine **310** updates the pallet table setting X=1 and Y=8 where pallet ID=**115** completing the cycle.

[0109] The control engine **310** continually cycles through this logic until the requested move is complete. Continuing with our example, the logic determines that the location one space to the right of pallet ID **115** (which is now **2,8**) is available but, not empty. This situation dictates that the control engine **310** must either move pallet ID **66** out of the way, or move pallet ID **115** in another direction. Because the requested destination, for pallet ID **115** is on the same Y coordinate, the control engine **310** will make every effort to not move pallet ID **115** off the current Y axis.

[0110] Accordingly, pallet ID **66** now becomes the designated pallet **120** to be moved. The control engine **310**, already knowing that pallet ID **66** is positioned at location **2,8**, checks to see if the location one space north of pallet ID **66** is available. A query to the grid table where X=2 and Y=9 returns a row value indicating to the control engine **310** that the space is available. The pallet table is then queried for a row value with the same coordinates to verify that a pallet **120** is not present in the space. Because there is no pallet **120** in the space, the control engine **310** determines that it can move pallet ID **66** north one space, provided there is a pallet **120** to push against or to be pulled towards. The same logic as identified above is used to make the determination. Instructions are issued by the control engine **310** and communicated to the pallet **120** that cause the pallet **120** to move. Finally, the pallet table is updated accordingly.

[0111] With pallet ID **66** now moved, another loop through the logic of the control engine **310** is concluded. The next invocation of the process will follow the same path as the

first, since there is an empty available space to the east of pallet ID **115**. This cycle repeats itself continuously until pallet ID **115** has been moved to its designated location.

[0112] One skilled in the art will anticipate how this fundamental logic is organized, adjusted, and reapplied to facilitate movement calculations in all four directions (relatively, north, south, east and west).

[0113] While it has been demonstrated pallet movements are calculated and coordinated fundamentally one at a time, in the preferred embodiment it is contemplated, and one skilled in the art will recognize, that multiple movements will occur simultaneously throughout a configuration. Furthermore, in the preferred embodiment, complex and compound move sequences are contemplated involving "strings" of pallets **120** contiguously arranged on a common X or Y coordinate. Examples include, but are not limited to, a string of pallets **120** moving in unison, and a strong of pallets **120** moving in alternate sequences starting with the first pallet **120** in the string, followed by the second, then followed by the first and third simultaneously, then the second and forth simultaneously, then the first, third and fifth simultaneously and so on.

[0114] In accordance with the specific configuration of the floor, and particularly corresponding to the number of vacant spaces on the floor, the amount of shifting of pallets **120** can be minimized or maximated to meet desired performance levels to balance the need for spend with the utilization of available space. In any case, the logic used to achieve the reposition of the pallets **120** is as described above.

[0115] In operation, following a determination of the available grid spaces by the above-described logic, moving instructions are sent to the pallets **120** by the control engine **310** is effectuate the move. FIG. **11** illustrates two pallets **120** carrying cargo boxes (Boxes A and B) attached via the arm assemblies **510,610** of one pallet **120** and the locking pins **730** of the other. As shown, the pallet **120** carrying Box A has its arm assembly **510,610** partially extended and is mechanically locked to the pallet **120** carrying Box B, FIG. **12** further illustrates the pushing and pulling action. To effectuate a move, the pallet **120** carrying Box A would turn on its air cushion system, extend the arm assembly **510,610**, and push itself one pallet-length away. The pallet **120** carrying Box B stays in place because its an cushion is deactivated causing the pallet **120** to act as a push-stop for the pallet **120** carrying Box A.

[0116] The pallet **120** carrying Box A then turns off its air cushion and either disconnects from the other pallet and retracts its arm assembly **510** leaving an unoccupied space between them. Alternatively, the pallet **120** carrying Box B can turn on its air cushion and the pallet **120** carrying Box A can retract its arm assembly **510,610** pulling the pallet **120** carrying Box B next to it leaving an empty space to the right of the pallet **120** carrying Box B.

[0117] In addition to the grid **130** configuration discussed previously, it is contemplated that a minimum of two such automated pallets **120** can be utilized together in an alternating in-line fashion to push and pull each other causing each to be propelled down a straight line creating a virtual conveyor. It is contemplated that this in-line fashion can be used to automate the loading and unloading of cargo from transport vehicles as illustrated in FIGS. **13** and **14**. As illustrated in FIG. **13**, the push-pull technique described above may be utilized to create a virtual conveyor

[0118] Ads the apparatus and method have now been described as deployed on a single floor, deck or other surface, an alternate design is contemplated for use in multiple level applications. The current invention provides for the means to transfer pallets and respective loads to between floors by the use of a variety of elevator and/or lift mechanisms. FIGS. **15** and **16** illustrate varying embodiments of lifting means for use in multiple level applications. One skilled in the art will recognize the a variety of currently available industrial lift and hoist systems can be employed to affect movement of pallets **120** between floors or levels. One skilled in the art will also appreciate that the fundamental configuration on the 2-dimensional plane can easily be repeated and applied to support a complete system comprising multiple levels.

[0119] FIG. **15** illustrates an embodiment of the system that utilizes a central elevator **550** to move pallets **120** between levels. In this embodiment, responsive to a request to move a pallet **120** from one level to another, the system positions the pallet onto the elevator **550**. The elevator **550** would then travel either up or down in accordance with the target location, and upon arrival at the appropriate level, the pallet **120** may pull itself or be pulled by another pallet **120** in the same fashion as previously discussed.

[0120] Alternatively, FIG. **16** illustrates an embodiment that utilizes a lifter assembly **650** that can move a single pallet **120** up or down one level. As shown in FIG. **16**, multiple lifter assemblies **650** may be positioned at many locations throughout the configuration allowing pallets **120** to move freely between levels by positioning the pallet **120** over the lifter assembly **650** location and moving up or down one level.

[0121] There have been described and illustrated herein embodiments of the apparatus and methods of using the same to automate storage, retrieval and transportation of goods while maximizing efficiencies and likewise optimizing physical space. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto. It is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. For example, those skilled in the art will appreciate that certain features of one embodiment may be combined with features of another embodiment to provide yet additional embodiments. It will therefore be appreciated by those skilled in the art that other modifications could be made to the provided invention without deviating from its spirit and scope as so claimed and described.

We claim:

1. A system for moving a pallet, the system comprising:

a pair of pallets each having means for inducing movement in relation to an another pallet;

a control engine having logic for calculating a movement instruction to move one of said pair of pallets; and

means for communicating said instruction to said movement means on one of said pair of pallets to prompt movement of one of said pair of pallets.

2. The system as set forth in claim 1, wherein said logic is responsive to an electronic request.

3. The system as set forth in claim 1, further comprising a database for storing coordinate locational data relative to said pair of pallets.

4. The system as set forth in claim 3, wherein said control engine is capable of communicating with said database to retrieve said data.

5. The system as set forth in claim 1 further comprising low friction movement means to reduce energy required to move said pair of pallets.

6. The system as set forth in claim 5 wherein said low friction movement means is an air cushion.

* * * * *