MATERIAL HANDLING SYSTEM

PRIORITY CLAIM

[0001] This application claims priority under 35 U.S.C. §119 to U.S. Provisional Patent Application No. 62/886,602 filed on August 14, 2019. The entire disclosure of U.S. Appl. No. 62/886,602 is hereby incorporated herein by reference.

FIELD OF THE INVENTION

[0002] Embodiments of the present invention generally relate to automated material and article handling systems which can be used in warehouse, storage and/or distribution environments.

BACKGROUND

[0003] Modern material handling systems, such as those used in mail-order warehouses, supply chain distribution centers, and custom-order manufacturing facilities, face significant challenges in responding to requests for inventory articles. In their incipiency, enterprises will generally invest in a level of automation that is at least adequate for current needs. As the scale of an inventory management system expands to accommodate a greater number and variety of articles, however, so too does the cost and complexity of operating it to simultaneously complete the packing, storing, replenishment, and other inventory management tasks for which it is intended.

[0004] Failure to efficiently utilize resources such as space, equipment, and manpower in an inventory management facility results in lower throughput, longer response times, and a growing backlog of unfinished tasks. Greater efficiency may often be achieved, for a time, by incrementally expanding the capacity of the facility's existing automation infrastructure, particularly when that expansion follows a well-conceived plan for growth. Sooner or later, however, a point of diminishing returns is encountered. That is, the achievement of further gains in capacity and/or functionality eventually becomes cost prohibitive as compared to available alternatives, if such gains can be realized at all. When that point of diminishing returns is reached, a facility operator may be forced to abandon pre-existing material handling infrastructure and to replace that infrastructure with a completely new automation platform.

SUMMARY ~~OF THE INVENTION~~

[0005] The present ~~invention~~ disclosure provides a number of inventive aspects that relate to material handling and/or storage and retrieval processes.

[0005a] According to an aspect, the present disclosure refers to a method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of: providing a plurality of storage racks spaced apart from one another forming a plurality of aisles, wherein each storage rack comprises a plurality of columns and each column comprises a plurality of storage locations; providing a plurality of delivery vehicles wherein each vehicle comprises a horizontal drive system operable to drive the vehicle along a horizontal surface, a vertical drive operable to drive the vehicle vertically and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations; driving a first one of the vehicles to drive the first vehicle to the storage racks; driving the first vehicle along a first path under a first one of the racks wherein the first rack is adjacent a first one of the aisles and wherein the first path extends in a direction parallel to the first aisle and spaced apart from the first aisle; turning the first vehicle while the first vehicle is under the first rack; driving the vehicle into the first aisle; driving the first vehicle upwardly in the aisle to a first of the storage locations; transferring an item between the first vehicle and the first storage location; driving the first vehicle downwardly in the aisle until the vehicle is on a horizontal surface; driving the first vehicle across the first aisle after the step of driving the first vehicle downwardly; and driving the vehicle out from under the storage racks after the step of driving the first vehicle across the first aisle.

[0005b] According to another aspect, the present disclosure refers to a material handling system for delivering items to storage locations and retrieving items from storage locations, comprising: a first storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the first storage rack is longitudinally elongated; a second storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the second storage rack is longitudinally elongated, wherein the second storage rack is spaced apart from the first storage rack to provide an aisle between the first and second storage racks; a plurality of delivery vehicles wherein each vehicle has a length and a width and each vehicle comprises: a horizontal drive system operable to drive the vehicle along a horizontal surface; a vertical drive operable to drive the vehicle vertically; and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations; a track positioned in the aisle wherein the vertical drive is configured to cooperate with the track to drive the vehicle vertically upwardly; a first horizontal path that extends under the first rack in a direction parallel to the aisle; a second horizontal path that extends under the first rack in a direction parallel to the aisle; wherein the horizontal drive is configured to turn the vehicle under the first rack by rotating the vehicle about

a vertical axis that extends through the vehicle; wherein the storage rack comprises a plurality of vertical posts and the first and second horizontal paths are each spaced apart from the vertical posts a distance greater the one half the length of the vehicles; wherein the first horizontal path under the path is spaced apart from the first horizontal path a distance greater than the width of the vehicles.

[0005c] According to another aspect, the present disclosure refers to a method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of: providing a vehicle having a horizontal drive and a vertical drive comprising a forward rotatable element adjacent a front end of the vehicle and a rearward rotatable element adjacent a rear end of the vehicle; providing a first vertical track on a first side of a first column wherein the first vertical track has drive elements configured to cooperate with the forward rotatable element to drive the vehicle upwardly; providing a second vertical track on a second side of the first column wherein the second vertical track has drive elements configured to cooperate with rearward rotatable element to drive the vehicle upwardly, wherein the vertical drive and the first and second vertical tracks are configured so that the vertical track impedes displacement of the vehicle along a horizontal path when the vertical drive is rotated into a position of misalignment; aligning the vertical drive, wherein the step of aligning comprises the steps of: rotating the forward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the forward rotatable element with gaps in the first and second vertical tracks; and rotating the rearward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the rearward rotatable element with gaps in the first and second vertical tracks; after the step of aligning, driving the vehicle along the horizontal path toward the first vertical track, wherein the step of driving comprises driving the vehicle so that the forward rotatable element passes through the gaps in the second vertical track; continuing to drive the vehicle along the horizontal path to position the forward rotatable element in operative engagement with first track and the rearward rotatable element in operative engagement with the second track; rotating the forward and rearward rotatable elements to drive the vehicle upwardly toward a first storage location; transferring a first item from the first storage location to the vehicle; driving the vehicle down with the first item; driving the vehicle with the first item along the horizontal path so that the rearward rotatable element passes through gaps in the first vertical track.

[0005d] According to another aspect, the present disclosure refers to a method for delivering items to storage locations and retrieving items from storage locations, comprising the steps of: providing a plurality of storage racks spaced apart from one another forming a plurality of aisles, wherein

each storage rack comprises a plurality of columns and each column comprises a plurality of storage locations; providing a plurality of delivery vehicles wherein each vehicle comprises a horizontal drive system operable to drive the vehicle along a horizontal surface, a vertical drive operable to drive the vehicle vertically and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations; driving a first of the vehicle under one or more of the storage racks along a path that crosses one or more aisle, wherein the step of driving the first vehicle includes driving the first vehicle into a first of the columns in a first of the aisles; driving the first vehicle vertically upwardly within the first aisle until the first vehicle is adjacent a first of the storage locations; transferring an item from the first storage location to the first vehicle; driving the first vehicle vertically downwardly within the first aisle; driving the vehicle out of the first aisle via a path that extends under at least one of the storage racks.

[0006] According to one ~~aspect~~example, the present ~~invention~~ disclosure provides a method for delivering items to storage locations and retrieving items from storage locations. The method may include the step of providing a plurality of storage racks spaced apart from one another forming a plurality of aisles. Each storage rack may include a plurality of columns and each column may include a plurality of storage locations. The method may also include the step of providing a plurality of delivery vehicles wherein each vehicle includes a horizontal drive system operable to drive the vehicle along a horizontal surface. The vehicles may also include a vertical drive operable to drive the vehicle vertically and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations. The method may also include the step of driving a first one of the vehicles to drive the first vehicle to the storage racks. Optionally, the method includes the step of driving the first vehicle along a first path under a first one of the racks wherein the first rack is adjacent a first one of the aisles and wherein the first path extends in a direction parallel to the first aisle and spaced apart from the first aisle. The method may also include the step of turning the first vehicle while the first vehicle is under the first rack. Additionally, the method includes the step of driving the vehicle into the first aisle and driving the first vehicle upwardly in the aisle to a first of the storage locations. An item may be transferred between the first vehicle and the first storage location. The first vehicle may then be driven downwardly in the aisle until the vehicle is on a horizontal surface. The first vehicle may then driven across the first aisle and then out from under the storage racks after the step of driving the first vehicle across the first aisle.

[0007] According to another example ~~aspect~~ a method for delivering items may include a storage rack having a plurality of vertical posts form a first column of the first storage rack and a

first vehicle having a first width extending from a first side of the first vehicle to a second side of the first vehicle. The first vehicle may also include a vertical drive that projects outwardly from the first side and the second side so that the vehicle has a second width corresponding to the distance between outer edges of the vertical drive so that the second width is greater than the first width and wherein the vertical posts of the first column are spaced apart a distance greater than the first width and less than the second width.

[0008] According to yet another exampleaspect, a method for delivering items may include a plurality of vertical tracks segments attached to vertical posts of a first column and the method may include the step of aligning the vertical drive of the first vehicle with the vertical track segments.

[0009] According to another exampleaspect, the present invention may provide a method for delivering items that includes the step of driving a first portion of a vertical drive of a vehicle through a

vertical track segment and driving a second part of the vertical drive into operative engagement with the vertical track segment.

[0010] According to a further exampleaspect, a method for delivering items may include the step of driving a first vehicle along a first path by driving the vehicle along a path spaced apart from the vertical posts by a distance greater the half the length of the vehicle.

[0011] According to yet another exampleaspect, a method for delivering items may include the step of driving a first vehicle to a workstation to present an item to an operator after driving the first vehicle out from under storage racks.

[0012] According to a further exampleaspect, a method for delivering items may include the step of driving the first vehicle across the aisle by driving the first vehicle under a second of the storage racks.

[0013] According to another exampleaspect, a method for delivering items may include the step of turning a vehicle by rotating the vehicle about a vertical axis that extends through the vehicle. Optionally, the vertical axis may extend through the first path.

[0014] According to a further exampleaspect, a method for delivering items may include the step of driving a second vehicles under a first rack along a second path parallel to a first path so that a second vehicle passes the first vehicle as the first vehicle travels along the first path.

[0015] According to a further exampleaspect, a material handling system for delivering items to storage locations and retrieving items from storage locations is provided. The system may include a first storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the first storage rack is longitudinally elongated and a second storage rack having a plurality of columns each of which comprises a plurality of storage locations wherein the second storage rack is longitudinally elongated. The first storage rack may be spaced apart from the first storage rack to provide an aisle between the first and second storage racks. Additionally, the system may include a plurality of delivery vehicles. Optionally, each vehicle may have a length and a width and each vehicle include a horizontal drive system operable to drive the vehicle along a horizontal surface, a vertical drive operable to drive the vehicle vertically, and a transfer mechanism operable to transfer an item between the vehicle and one of the storage locations. The system may also include a track positioned in the aisle. Additionally, the vertical drive may be configured to cooperate with the track to drive the vehicle vertically upwardly. The system may also include a first horizontal path that extends under the first rack in a direction parallel to the aisle and a second horizontal path that extends under the

first rack in a direction parallel to the aisle. Optionally, the horizontal drive is configured to turn the vehicle under the first rack by rotating the vehicle about a vertical axis that extends through the vehicle. Additionally, the storage rack may include a plurality of vertical posts and the first and second horizontal paths may each be spaced apart from the vertical posts a distance greater the one half the length of the vehicles. Further, the first horizontal path under the path may be spaced apart from the first horizontal path a distance greater than the width of the vehicles.

[0016] According to a further example ~~aspect~~ a system for delivering items may include a vertical drive having a plurality of rotatable elements that each rotate about a horizontal axis. Additionally, the system may include a horizontal drive that includes a plurality of rotatable elements that each rotate about a horizontal axis transverse the axes of rotation of the vertical drive elements.

[0017] According to yet another example~~aspect~~, the present ~~invention~~ disclosure may provide a system for delivering items that includes a plurality of vertical posts that form a first column of a first storage rack and vehicles that have a first width extending from a first side of the vehicle to a second side of the vehicle. The vertical drive of the vehicle may project outwardly from the first side and the second side so that the vehicle has a second width corresponding to the distance between outer edges of the vertical drive so that the second width is greater than the first width. Optionally, the vertical posts of the first column are spaced apart a distance greater than the first width and less than the second width.

[0018] According to a further example~~aspect~~, a system for delivering items may include a track that includes drive elements configured to cooperate with a vertical drive so that rotating the vertical drive about a horizontal axis operates to drive the vehicle upwardly along the track. Optionally, the track includes a lower section and an upper section wherein the drive elements are spaced apart further in the lower section then the upper section to provide gaps in the lower section.

[0019] ~~The system of claim 15 wherein t~~In an example, the gaps are configured to facilitate the vertical drive passing through the gaps without contacting the lower section when the vehicle is driven past the lower section.

[0020] According to an additional example~~aspect~~, the present ~~invention~~ disclosure may provide a method for delivering items to storage locations and retrieving items from storage locations. The method may include the steps of providing a vehicle having a horizontal drive and a vertical drive having a forward rotatable element adjacent a front end of the vehicle and a rearward rotatable element adjacent a rear end of the vehicle and providing a first vertical track on a first side of a first

column. The first vertical track may have drive elements configured to cooperate with the forward rotatable element to drive the vehicle upwardly. The method may also include the step of providing a second vertical track on second side of the first column wherein the second vertical track has drive elements configured to cooperate with rearward rotatable element to drive the vehicle upwardly. The vertical drive and the first and second vertical tracks may be configured so that the vertical track impedes displacement of the vehicle along a horizontal path when the vertical drive is rotated into a position of misalignment. Additionally, the method may aligning the vertical drive that may include the steps of rotating the forward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the forward rotatable element with gaps in the first and second vertical tracks and rotating the rearward rotatable element about a horizontal axis substantially parallel with the horizontal path to align the rearward rotatable element with gaps in the first and second vertical tracks. After the step of aligning, the method may include the step of driving the vehicle along the horizontal path toward the first vertical track. The step of driving may include driving the vehicle so that the forward rotatable element passes through the gaps in the second vertical track. The method may also include the step of continuing to drive the vehicle along the horizontal path to position the forward rotatable element in operative engagement with the first track and the rearward rotatable element in operative engagement with the second track. The forward and rearward rotatable elements may be rotated to drive the vehicle upwardly toward a first storage location. Additionally, a first item may be transferred from the first storage location to the vehicle, the vehicle may be driven downwardly with the item and the vehicle may be driven with the first item along the horizontal path so that the rearward rotatable element passes through gaps in the first vertical track.

[0021] According to yet another exampleaspect, a method of delivery items may include a step of rotating forward and rearward rotatable elements by synchronously driving the forward and rearward rotatable elements to drive the vehicle vertically upwardly while maintaining the orientation of the vehicle relative to the horizon.

[0022] According to yet another exampleaspect, a method of delivery items may include a step of driving a vehicle out from under a track after driving the vehicle with the first item along a horizontal path.

[0023] According to another exampleaspect, a method of delivery items may include a step turning a vehicle to a path perpendicular to the horizontal path that the vehicle was travelling along. Optionally the step of turning may be performed while the vehicle is under one of the racks.

[0024] According to a further exampleaspect, a method of delivery items may include a step of driving the vehicle along the horizontal path. The step of driving may include the step of driving a plurality of horizontal drive elements about a horizontal axis that is substantially perpendicular to the horizontal path.

[0025] According to an additional exampleaspect, a method of delivery items may include the steps of providing a plurality of storage racks and a plurality of delivery vehicles. The storage racks may be spaced apart from one another forming a plurality of aisles and each storage rack may include a plurality of columns and each column may include a plurality of storage locations. Optionally, each vehicle may include a horizontal drive system operable to drive the vehicle along a horizontal surface. Each vehicle may also include a vertical drive operable to drive the vehicle vertically. Optionally, a transfer mechanism may be operable to transfer an item between the vehicle and one of the storage locations. The method may also include the step of driving a first of the vehicle under one or more of the storage racks along a path that crosses one or more aisle. The step of driving the first vehicle may include driving the first vehicle into a first of the columns in a first of the aisles. The first vehicle may be driven vertically upwardly within the first aisle until the first vehicle is adjacent a first of the storage locations. An item may be transferred from the first storage location to the first vehicle. The first vehicle may then be driven vertically downwardly within the first aisle and then driven out of the first aisle via a path that extends under at least one of the storage racks.

[0026] According to yet another exampleaspect, a method of delivery items may include a path that includes a portion passing under one of the racks and extending parallel to one of the aisles. Optionally,, a second vehicle may be driven past the first vehicle under the one rack as the first vehicle is driven along the portion of the path under the one of the racks.

[0027] According to a further exampleaspect, a method of delivery items may include a step of turning the vehicle while the vehicle is under one of the racks. The step of turning may include turning the vehicle to align the vehicle with a path perpendicular to the first aisle. Optionally, the step of turning the vehicle may include rotating the vehicle about a vertical axis passing through the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended