AUTOMATED VEHICLE FOR USE IN INVENTORY MANAGEMENT SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to automated vehicles configured to perform inventory management tasks in a warehouse, storage and/or distribution environment.

Description of the Related Art

[0002] 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.

[0003] 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~~

[0003a] In an aspect, the present disclosure refers to a vehicle configured to perform inventory management tasks in an inventory management handling system having a plurality of destination areas and a guide system, the vehicle comprising: a platform dimensioned and arranged to receive an item to be at least one of transferred to or received from one of the destination areas; a plurality of motors; a first drive system having a first plurality of drive elements configured to engage the guide system, by operation of a first subset of the plurality of

motors, to move the vehicle along a vertical path segment extending between a support surface underlying the vehicle and one of the destination areas; a second drive system having a first plurality of drive elements configured, by operation of a second subset of the plurality of motors, to engage the underlying support surface and drive movement of the vehicle in a non-vertical direction; a transfer mechanism configured to at least one of transfer an item from the platform to one of the plurality of destination areas or retrieve an item from one of the plurality of destination areas; and a clutch mechanism configured to engage and disengage the transfer mechanism from the second subset of motors, whereby the second drive system drives movement of the vehicle independently of the transfer mechanism.

[0003b] In another aspect, the present disclosure refers to a vehicle operable in an inventory management system having a plurality of destination areas and a guide system, the vehicle comprising: a first motorized drive system configured to engage the guide system to guide movement of the vehicle along a vertical path segment; a second motorized drive system dimensioned and arranged to maneuver the vehicle upon a surface while the first drive system is out of engagement with the guide system; a clutch mechanism operative to engage and to disengage transmission of power from to the transfer mechanism, whereby each of the first drive system and second drive system is operable independently of the transfer mechanism; and a transfer mechanism operative to transfer an item between the vehicle and one of the plurality of destination areas; wherein the first motorized drive system includes first and second pairs of motor driven rotary elements, the rotary elements of each pair being configured to interact with the guide system to control the position of the vehicle along the guide system.

[0003c] In another aspect, the present disclosure refers to a vehicle operable in an inventory management system, the vehicle comprising: a first motor and a second motor; a first pair of omnidirectional rollers and a second pair of omnidirectional rollers, wherein a first omnidirectional roller of each pair is dimensioned and arranged to rotate about a first axis of rotation and wherein a second omnidirectional roller of each pair is driven by the first motor or the second motor for rotation about a second axis of rotation; a fifth roller driven by the first motor or the second motor; and an actuator having an actuation surface configured to move from a first position to a second position to selectively urge the fifth roller in a direction toward an underlying support surface; wherein a surface of each of the first and second pairs of omnidirectional rollers, and a surface of the fifth roller are dimensioned and arranged to contact the underlying support surface while the actuator is maintained in the first position, and wherein movement of the actuator into the second position causes a transfer of load from one or more of the omnidirectional rollers to the fifth roller.

[0004] In accordance with ~~embodiments~~ examples of the present disclosure, the disadvantages and problems associated with conventional warehouse automation approaches have been

substantially reduced or eliminated by one or more vehicles configurable to perform a variety of tasks relevant to an inventory management operation. In examples~~embodiments~~, each vehicle is configured and operable to perform a first set of one or more inventory management tasks according to a first mode of operation and, in order that they may perform one or more inventory management tasks according to an additional mode of operation, to interact

synergistically with any of a plurality of functional accessory modules (FAMs). Examples of tasks each vehicle is configured to perform utilizing onboard resources include operating a transfer mechanism of the vehicle to retrieve an inventory item to, and/or retrieve an inventory item from, a destination area of a vertical array of storage areas. For such tasks, each vehicle is configured to travel vertically -- along a guide system bringing the vehicle to the appropriate destination area - as well as horizontally upon, for example, a substantially planar surface which extends between an array of storage areas and a remote location such, for example, as a pick station, a packing station, or even a second vertically array of storage areas.

[0005] In examples~~embodiments~~, one or more of the functional accessory modules are dimensioned and arranged to facilitate their vertical and horizontal displacement by the vehicles. In some embodiments, discrete groups of FAMs are constructed and operative to perform respectively different sets of inventory management tasks, such that the vehicles retain their utility to an inventory management system even as the complexity of that system increases and new tasks must be accommodated. This modular approach enables the performance of different and/or additional inventory management tasks simply by substituting and/or adding new types of FAMs capable of performing those additional tasks. As such, challenges such as growing inventory differentiation (e.g., higher SKU counts), rapidly increasing order picking volumes, and greater throughput requirements can be readily and easily addressed in a scalable manner.

[0006] In an example~~embodiment~~, a vehicle configured to perform inventory management tasks comprises a vehicle configured to perform inventory management tasks in an inventory management handling system having a plurality of destination areas and a guide system, the vehicle comprising a platform dimensioned and arranged to receive an item to be at least one of transferred to or received from one of the destination areas; a plurality of motors; a first drive system having a first plurality of drive elements configured to engage the guide system, by operation of a first subset of the plurality of motors, to move the vehicle along a vertical path segment extending between a support surface underlying the vehicle and one of the destination areas; a second drive system having a first plurality of drive elements configured, by operation of a second subset of the plurality of motors, to engage the underlying support surface and drive movement of the vehicle in a non-vertical direction; a transfer mechanism configured to at least one of transfer an item from the platform to one of the plurality of destination areas or retrieve an item from one of the plurality of destination areas; and a clutch mechanism configured to engage and disengage the transfer mechanism from the second

subset of motors, whereby the second drive system drives movement of the vehicle independently of the transfer mechanism.

[0007] In some examples~~embodiments~~, the first subset of one or more motors comprises a single motor configured to rotate the first plurality of drive elements of the first drive system. In an example~~embodiment~~, the second subset of motors comprises a plurality of motors, wherein a first motor of the second subset drives rotation of a first drive element of the second drive system and a second motor of the second subset drives rotation of a second drive element of the second drive system.

[0008] In some examples~~embodiments~~, the first plurality of drive elements of the first drive system includes a plurality of gears dimensioned and arranged to interact with complementary teeth of the guide system to control the position of the vehicle along the guide system. In such an example~~embodiment~~, the first drive system may include a pair of drive axles, wherein the driven gears are fixed to the drive axles so that the gears are synchronously driven to drive the vehicle along the guide system.

[0009] In some examples~~embodiments~~, the second drive system includes a first drive element driven by a first motor of the second subset to rotate about a first axis of rotation, and a drive element driven by a second motor of the second subset to rotate about a second axis of rotation, wherein each of the first and second drive elements is dimensioned and arranged to engage a respective portion of the underlying support surface for movement of the vehicle thereupon. In one such example~~embodiment~~, the clutch mechanism comprises: a first pivotable carrier movable between a first angular orientation relative to the platform and a second angular orientation relative to the platform. wherein the first drive element is rotatably coupled to the first pivotable carrier for angular movement therewith; and a second pivotable carrier movable between the first angular orientation and the second angular orientation, wherein the second drive element is coupled to the second pivotable carrier for angular movement therewith. The first and second axes of rotation are co-axial while the first and second pivotable carriers have a common angular orientation.

[001O] Optionally, the second drive system further includes a first driven element rotatably coupled to the first pivotable carrier and a first endless loop element for transferring rotary power to the first driven element; and a second driven element rotatably coupled to the second pivotable carrier and a second endless loop element for transferring rotary power to the second driven element. Each of the first endless loop element and the second endless loop element may include a belt. In such an example~~embodiment~~, the second drive system further comprises a first pulley, the first pulley and first drive element being driven by the first motor

of the second subset, wherein the first pulley is dimensioned and arranged to engage the first endless loop element to thereby drive the first driven element; and a second pulley, the second pulley and second drive element being driven by a second motor of the second subset of motors such that the pulley is dimensioned and arranged to engage the second endless loop element to thereby drive the second driven element.

[0011] In the preceding exampleembodiment, the clutch mechanism may further include a third driven element rotatably coupled to the first driven element and coaxial therewith, the third driven element being dimensioned and arranged to drivingly engage a first portion of the transfer mechanism and thereby transfer power from the first motor of the second subset while the first pivotable carrier is in the first angular orientation, as well as a fourth driven element rotatably coupled to the second driven element and coaxial therewith, the fourth driven element being dimensioned and arranged to drivingly engage a second portion of the transfer mechanism and thereby transfer power from the second motor of the second subset while the second pivotable carrier is in the first angular orientation.

[0012] In examplesembodiments, the second drive system further includes a plurality of omnidirectional wheels dimensioned and arranged to frictionally engage respective portions of the underlying surface to thereby support the vehicle. In one such exampleembodiment, the second first drive system further includes a plurality of drive axles, wherein at least a pair of the omnidirectional wheels is driven by at least one of the second subset of motors.

[0013] In any of the preceding examplesembodiments, the vehicle may further comprise an onboard controller for directing operation of the plurality of motors, the controller including a processor and a memory containing instructions, executable by the processor, to operate the motors of the second subset to drive the first and second drive elements of the second drive system to thereby displace the vehicle along a substantially horizontal path upon the support surface. In one such exampleembodiment, the memory contains instructions executable by the processor to operate the second subset of motors to bring respective portions of the first drive system into facing alignment with corresponding portions of the guide system and/or to initiate driving engagement of respective portions of the first drive system with corresponding aligned portions of the guiding system and thereby cause elevation or descent of the vehicle relative to a datum plane.

[0014] In the preceding exampleembodiment, the clutch mechanism may be configured to enable transmission of power, from the motors of the second subset, to the transfer mechanism responsive to elevation of the vehicle to a position above the datum plane. To this end, the memory further containing instructions executable by the processor for operating a motor of

the second subset of one or motors to cause the transfer mechanism to one of transfer an item from the platform to a destination area adjacent the vehicle or to retrieve an item from the destination area to the platform. In such example~~embodiment~~, the clutch mechanism is configured to disable actuation of the transfer mechanism responsive to descent of the vehicle to a position below the datum plane.

[0015] Another example ~~embodiment~~ of a vehicle operable in an inventory management system having a plurality of destination areas and a guide system comprises: a first motorized drive system configured to engage the guide system to guide movement of the vehicle along a vertical path segment; a second motorized drive system dimensioned and arranged to maneuver the vehicle upon a surface while the first drive system is out of engagement with the guide system; a clutch mechanism operative to engage and to disengage transmission of power from to the transfer mechanism, whereby each of the first drive system and second drive system is operable independently of the transfer mechanism; and a transfer mechanism operative to transfer an item between the vehicle and one of the plurality of destination areas; wherein the first motorized drive system includes first and second pairs of motor driven rotary elements, the rotary elements of each pair being configured to interact with the guide system to control the position of the vehicle along the guide system.

[0016] In the preceding example~~embodiment~~, each rotary drive element, of the first and second pairs of rotary drive elements, may be a gear having teeth dimensioned and arranged to engage complementary teeth of the guide system as the vehicle changes elevation along the guide system. In one such example~~embodiment~~, the first drive system further includes a pair of synchronous drive axles, wherein the driven gears are fixed to the axles so that the gears are synchronously driven to drive the vehicle along the guide system. Optionally, the clutch mechanism is dimensioned and arranged to disengage the transfer mechanism as the vehicle descends to a position beyond the datum plane, thereby disabling actuation of the transfer mechanism by the controller. In such an example~~embodiment~~, the clutch mechanism may be configured to engage with the transfer mechanism as the vehicle ascends to a position above the datum plane, thereby enabling actuation of the transfer mechanism by the controller.

[0017] A vehicle operable in an inventory management system according to a further example ~~embodiment~~ comprises a first motor and a second motor, a first pair of omnidirectional rollers and a second pair of omnidirectional rollers, wherein a first omnidirectional roller of each pair is dimensioned and arranged to rotate about a first axis of rotation and wherein a second omnidirectional roller of each pair is driven by the first motor or the second motor for rotation about a second axis of rotation; a fifth roller driven by the first motor or the second motor; and

an actuator having an actuation surface configured to move from a first position to a second position to selectively urge the fifth roller in a direction toward an underlying support surface; wherein a surface of each of the first and second pairs of omnidirectional rollers, and a surface of the fifth roller are dimensioned and arranged to contact the underlying support surface while the actuator is maintained in the first position, and wherein movement of the actuator into the second position causes a transfer of load from one or more of the omnidirectional rollers to the fifth roller.

[0018] In some examples~~embodiments~~, the pair of motor driven omnidirectional rollers are driven independently of the second pair of motor driven omnidirectional rollers.

[0019] In some examples~~embodiments~~, the actuator is a first actuator, wherein the vehicle further includes a sixth roller and a second actuator movable from a third position to a fourth position, and wherein movement of the first and second actuators into the second and fourth positions, respectively, causes a transfer of load from one or more of the omnidirectional rollers to the fifth and sixth rollers.

[0020] In the preceding example~~embodiment~~, the vehicle further includes a platform and a transfer mechanism operative to at least one of transfer an item from the platform to a target surface or to retrieve an item from a target surface. Optionally, the vehicle of the preceding embodiment may further include a clutch mechanism operative to engage and disengage the transfer mechanism.

[0021] Other and further examples ~~embodiments~~ of the present invention are described below.

[0022] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. The figures are not drawn to scale and may be simplified for clarity. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] 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 drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.