

METHOD AND SYSTEM FOR OPERATING AUTOMATIC GUIDED VEHICLE

BACKGROUND OF THE INVENTION

5 The present invention relates to an automatic guided vehicle operating method and an automatic guided vehicle operating system that allow a plurality of automatic guided vehicles to travel along a path.

10 In the following description, the automatic guided vehicle will be hereinafter referred to merely as AGV. The AGV operating system disclosed by Japanese Patent Application Publication No. 2004-252631 includes a plurality of stations where loading and unloading AGVs are performed, a plurality of unit traveling zones arranged between the stations and forming a traveling path along which the AGVs travel, and an AGV control unit for controlling the operation of
15 the AGVs. In the traveling path having point of merging and/or point of intersection, the AGVs need to be controlled carefully so as to prevent collision of the AGVs. In order to avoid such collision, AGV may be required to wait for another AGV to pass by depending on the situation. In the above-described publication, however, no consideration is given to such requirement.

20 The loading system disclosed by Japanese Patent Application Publication No. 2007-320364 includes a plurality of AGVs that are allowed to travel along a path and a gantry crane (loading unit) that performs loading and unloading of cargos between the AGVs and a containership. Due to the
25 operating time varying depending, e.g., on the loading locations (or loading and unloading locations) of containers in the containership, a situation may occur that the loading unit cannot start the loading operation at the scheduled loading start time.

30 The present invention is directed to an AGV operating method and an AGV operating system according to which waiting of an AGV at point of merging and/or point of intersection of the traveling path is forestalled.

SUMMARY OF THE INVENTION

In accordance with an aspect of the present invention, the automatic
5 guided vehicle (AGV) operating method includes the following steps of allowing a
plurality of AGVs to travel along a path and dividing the path into a plurality of
sections. The sections have a starting section from which each of the AGVs
starts to travel and a destination section at which the AGV arrives. The method
further includes steps of setting scheduled time of arrival at which the AGV is to
10 arrive at the destination section and setting scheduled times of passage at which
the AGV is to pass through the respective sections in the path from the starting
section to the destination section, on the basis of the scheduled time of arrival.
The setting of the scheduled times of passage is made in order that is reverse to
order in which the AGV passes through the respective sections. The method
15 further includes a step of controlling the traveling of the AGV in accordance with
the scheduled times of passage for the respective sections.

In accordance with another aspect of the present invention, the
automatic guided vehicle (AGV) operating system comprises a plurality of AGVs,
20 a path and a controller. The AGVs are allowed to travel along the path. The
path is divided into a plurality of sections. The sections have a starting section
from which each of the AGVs starts to travel and a destination section at which
the AGV arrives. The controller controls the traveling of the AGVs. The
controller includes a first time setting device, a second time setting device, a
25 data-storage device and an AGV traveling control device. The first time setting
device sets scheduled time of arrival at which the AGV is to arrive at the
destination section. The second time setting device sets scheduled times of
passage at which the AGV is to pass through the respective sections in the path
from the starting section to the destination section, on the basis of the scheduled
30 time of arrival. The setting of the scheduled times of passage is made in order
that is reverse to order in which the AGV passes through the respective sections.
The data-storage device stores data on the scheduled times of passage for the

respective sections. The AGV traveling control device controls the traveling of the AGV in accordance with the scheduled times of passage for the respective sections.

5 Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

15 Fig. 1 is a schematic view showing a loading system including an AGV operating system according to an embodiment of the present invention;

Fig. 2 is a fragmentary view showing a path along which a plurality of AGVs in the loading system of Fig. 1 travels;

20 Fig. 3 is a configuration block diagram showing the loading system and including a functional block of a controller of Fig. 1;

25 Fig. 4 is a fragmentary view showing the traveling path of Fig. 2, wherein the traveling path is divided into a plurality of sections;

Fig. 5 is a flow chart showing steps of procedure performed by an AGV control device of the controller of Fig. 3;

30 Fig. 6 is a flow chart showing steps of procedure performed by a loading schedule setting device of the controller of Fig. 3;

Fig. 7 is a schematic view showing the loading operation performed by a gantry crane of Fig. 1;

Fig. 8 is a time table showing an example of loading schedule; and

Fig. 9 is a flow chart showing steps of procedure performed by a loading schedule correction device of the controller of Fig. 3.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The following will describe the embodiment of the AGV operating system according to the present invention with reference to the accompanying drawings.

Referring to Fig. 1, the loading system designated generally by numeral 1 is usable, for example, to load a containership 2 with containers 3 in a port terminal. The containers 3 serve as the goods of the present invention.

The loading system 1 includes a plurality of AGVs 4 (only one AGV being shown in the drawing) that convey the containers 3, a gantry crane (GC) 5 that loads the containership 2 with the containers 3 on the AGVs 4, and a controller 6 that controls the operation of the whole loading system 1 including the operation of the AGVs 4.

The AGV operating system will now be described. Referring to Fig. 2 showing a loop traveling path 7 along which the AGVs 4 are allowed to travel in a single direction, the path 7 includes merging points 7A and branching points 7B. Each AGV 4 is operable to convey the container 3 from a container storage area 8 to the gantry crane 5. Each AGV 4 has a traction motor that spins the vehicle wheels, a steering motor that steers the wheels, a control unit that controls the operation of the traction motor and the steering motor, and a radio communication device that communicates with the controller 6 (each component

not being shown).

The gantry crane 5 serves as a loading unit that loads and unloads each container 3 through manual operation by gantry crane operator. The gantry crane 5 has a pair of vertical legs 5A that is self propelled, and a horizontal boom 5B connected to the upper ends of the paired legs 5A for movement therewith. One end of the boom 5B extends above the containership 2 and the other end extends above the path 7. In addition, the gantry crane 5 has a crane unit 5C mounted to the boom 5B via a wire rope 5D. The crane unit 5C is adapted to lift the container 3 and movable in the extending direction of the boom 5B. The gantry crane 5 has an encoder (not shown) for detecting the current position of the gantry crane 5.

Referring to Fig. 3 showing in block diagram the loading system 1 and including a functional block of the controller 6, a radio unit 9 is connected to the controller 6 and communicates with the AGVs 4.

The controller 6 has a data-storage device 10, a loading schedule database (DB) 11, an AGV control device 12, a loading schedule setting device 13 and a loading schedule correction device 14.

The path 7 is divided into a plurality of sections and the data on such sections are set and stored in the data-storage device 10. The time at which the AGV 4 passes through each section (or the times at which the AGV 4 enters into and exits from each section) can be set and recorded in the section.

Fig. 4 shows as an example a plurality of sections B formed by dividing the path 7 in the region A of Fig. 2. The sections B may have the same size, or may have different sizes. The merging point 7A or the branching point 7B of the path 7 is included in a single section B.

Data on the loading schedule is registered in the loading schedule

database 11. This data includes the storage locations of the containers 3 in the container storage area 8, the loading locations of the containers 3 in a container loading warehouse 2A of the containership 2, the gross weight of the container 3, the target operating time taken for the gantry crane 5 to perform the loading operation, and the scheduled loading start time at which the gantry crane 5 is to start to perform the loading operation. The loading locations of the containers 3 serve as the loading and unloading locations of the present invention.

The AGV control device 12 receives the data registered in the data-storage device 10 and the data on the loading schedule registered in the loading schedule database 11. The AGV control device 12 performs a predetermined processing and then sends a control signal to each AGV 4 via the radio unit 9 for allowing the AGV 4 to travel.

The loading schedule setting device 13 sets the aforementioned target operating time and the scheduled loading start time as the loading schedule.

The loading schedule correction device 14 receives data on actual loading time taken for the gantry crane 5 to perform the loading operation and, if necessary, changes the scheduled loading start time on the basis of the actual loading time, thereby correcting the loading schedule.

Referring to Fig. 5 showing the steps of procedure performed by the AGV control device 12 in flow chart, the AGV control device 12 calculates scheduled time of arrival, or the time at which the container 3 conveyed by an AGV 4 is to arrive in front of the gantry crane 5, on the basis of the data on the loading schedule registered in the loading schedule database 11, at the step S51. Specifically, the AGV control device 12 sets the time that is, for example, thirty seconds before the scheduled loading start time as the scheduled time of arrival of the container 3.

Then, the AGV control device 12 selects one AGV 4 for conveying the

container 3 to be conveyed for loading, at the step S52. In this case, the selected AGV 4 that is then located at a position closest to the storage location of the container 3 is selected.

5 At the step S53, on the basis of the performance data (such as acceleration or maximum speed) of the selected AGV 4, the AGV control device 12 calculates the time taken for the AGV 4 to pass through the respective sections B (refer to Fig. 4) from the current position (or starting section) of the AGV 4 to the destination (or destination section) in front of the gantry crane 5.

10 The acceleration and the maximum speed of the AGV 4 vary depending on the gross weight of the container 3. At a section in front of any storage location of the container 3 in the container storage area 8, it takes some time to transfer the container 3 from the container storage area 8 to the AGV 4. The times taken for the AGV 4 to pass through the sections are calculated in view of such additional
15 time.

 In the data B on the sections shown in Fig. 4, the AGV control device 12 calculates the times taken for the AGV 4 to pass through the respective sections B (B_1 to B_8) in the path 7 from the section B_1 (or starting section) in front of the
20 current position of the AGV 4 to the section B_8 (or destination section) in front of the gantry crane 5.

 At the step S54, the AGV control device 12 sets the time of passage (or the time of entry) of the AGV 4 for the destination section on the basis of the
25 scheduled time of arrival of the container 3 which was calculated at the step S51 and also the time taken for the AGV 4 to pass through each section B which was calculated at the step S53.

 At the step S55, the AGV control device 12 sets the time of passage (or
30 the time of entry and the time of exit) for the section that is one section before the destination section.

At the step S56, the AGV control device 12 determines whether or not there is any overlap between the time of passage of the AGV 4 and the times of passage of any other AGVs 4 which have been already set for the above section. If YES at the step S56, the AGV control device 12 delays at the step S57 the
5 scheduled time of arrival of the container 3 conveyed by the AGV 4 whose time of passage was set this time and the procedure is returned to the step S54. Then the AGV control device 12 repeats the steps S54 and S55.

If NO at the step S56, the AGV control device 12 determines at the step
10 S58 whether or not setting of the time of passage (or the time of exit) of the AGV 4 at the starting section is completed. If NO at the step S58, the procedure is returned to the step S55 and the AGV control device 12 repeats the steps S55 and S56.

If YES at the step S58, the AGV control device 12 calculates at the step
15 S59 the start time of the traveling of the AGV 4 (or traveling start time) from the time of exit and sends the data on the traveling start time to the above AGV 4 via the radio unit 9.

By taking such steps of procedure, the times of passage at which the
20 AGV 4 passes through the respective sections in the path 7 from the starting section B_1 to the destination section B_8 are set one after another in the order (as indicated by thick arrow in Fig. 4) that is reverse to the order in which the AGV 4 passes through the respective sections.

25 In the data on the sections B shown in Fig. 4, the times at which the AGV 4 passes through the respective sections B_8 to B_1 are set one after another in this order and the traveling start time is sent to the AGV 4, accordingly. At the traveling start time, the AGV 4 starts traveling from the starting section toward
30 the destination section in accordance with the set times of passage at the respective sections B_1 to B_8 .

In the above-described embodiment, the steps S51 and S57 of the AGV control device 12 cooperate to form a first time setting device that sets the scheduled time of arrival of the AGV 4 at the destination section that is located in front of the gantry crane 5. The steps S52 to S55 and S58 of the AGV control device 12 cooperate to form a second time setting device that sets the times of passage at which the AGV 4 passes through the respective sections in the path 7 from the starting section to the destination section, on the basis of the scheduled time of arrival. The setting of the times of passage is made in the order that is reverse to the order in which the AGV 4 passes through the respective sections. The step S59 of the AGV control device 12 and the radio unit 7 cooperate to form an AGV traveling control device that controls the traveling of the AGV 4 in accordance with the times of passage set by the second time setting device.

The step S56 of the AGV control device 12 forms a detecting device that determines whether or not there is any overlap between the time of passage of the AGV 4 and the times of passage of any other AGVs 4 which have been already set for any section. If the AGV control device 12 detects any overlap, the AGV control device 12 delays the scheduled time of arrival of the container 3 and resets the time of passage of the AGV 4 for each section.

Since the AGV 4 traveling along the path 7 from its starting section toward the destination section in front of the gantry crane 5 need not wait for any other AGV 4 to pass through the merging point 7A, traffic jam of the AGVs 4 is forestalled. Thus, the mean traveling speed of the AGVs 4 is prevented from decreasing and the transport capacity of the containers 3 is prevented from decreasing, accordingly. In addition, since the order in which the containers 3 arrive at the gantry crane 5 need not be changed, the loading operation is performed in the sequence of order according to the original loading schedule.

Referring to Fig. 6 showing in flow chart the steps of procedure performed by the loading schedule setting device 13, the loading schedule

setting device 13 sets, at the step S61, the target loading time taken for the gantry crane 5 to perform each loading operation from the data on the loading location of the containers 3 in the container loading warehouse 2A of the containership 2 which were registered in the loading schedule database 11. If the containers 3 have different loading locations as shown in Fig. 7, the moving distance of the crane unit 5C of the gantry crane 5 varies depending on the loading locations in the containership 2 as indicated by two arrows with different lengths and the loading time taken for the gantry crane 5 to perform the loading operation varies, accordingly.

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As shown in Figs. 7 and 8, the loading time is the sum of the time taken for the container 3 to be transferred from the AGV 4 to the gantry crane 5, and the operating time that is performed by the gantry crane 5. The transfer time is the time from the moment when the gantry crane 5 starts to lower the crane unit 5C from the initial position until the moment when the transferring of the container 3 from the AGV 4 to the crane member 5C is completed.

The operating time of the gantry crane 5 is the time taken for the gantry crane 5 to perform any operation other than the operation involving the AGV 4. Basically, the operating time of the gantry crane 5 is the time from the moment when the gantry crane 5 starts to move the crane unit 5C for transferring the container 3 on the crane unit 5C to the loading location in the container loading warehouse 2A of the containership 2 until the moment when the crane unit 5C returns to its initial position. If the hatch cover of the containership 2 needs to be removed, the operating time of the gantry crane 5 includes the time taken to remove and return the hatch cover.

The container loading warehouse 2A of the containership 2 may be divided into different areas such as a lower right area, a lower left area, a lower middle area, an upper right area, an upper left area, an upper middle area. Assuming that the wharf is on the left side of the containership 2 as viewed in Fig. 7, the container 3 to be transferred to the lower right area of the container

loading warehouse 2A requires a longer moving distance of the crane unit 5C than the container 3 to be transferred to the upper left area of the container loading warehouse 2A, and the operating time of the gantry crane 5 is longer in the former case.

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The target loading time may be changed depending on the kinds of the containership 2. The target loading time may also be changed on the skill of operator who manipulates the gantry crane 5 and/or on the environmental condition, such as wind and rain, under which the gantry crane 5 is operated.

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At the step S62, the loading schedule setting device 13 calculates the aforementioned scheduled loading start time of the gantry crane 5 for each loading operation on the basis of the target loading time set at the step S61. That is, the loading schedule setting device 13 calculates the scheduled time (scheduled transfer start time) at which the transferring of the container 3 from the AGV 4 to the gantry crane 5 is to be started.

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When the loading operation B is to be performed subsequent to the loading operation A, as exemplified in Fig. 8, the loading schedule setting device 13 sets the scheduled transfer start time of the loading operation B by adding seventy seconds, i.e. the target loading time of the loading operation A, to the scheduled transfer start time of the loading operation A.

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At the step S63, the loading schedule setting device 13 registers the target loading time set at the step S61 and the scheduled transfer start time calculated at the step S62 as the original loading schedule to the loading schedule database 11.

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Referring to Fig. 9 showing in flow chart the steps of procedure performed by the loading schedule correction device 14, at the step S71, the loading schedule correction device 14 determines whether or not the loading operation has been performed by the gantry crane 5. If YES at the step S71,

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the loading schedule correction device 14 acquires the actual loading time taken to perform the loading operation, at the step S72. Whether or not a loading operation has been performed is detectable, for example, from an output from a load-presence sensor mounted to the AGV 4. The actual loading time may be
5 calculated from the period of time during which the gantry crane 5 is operated and also the period of time during which the control lever is operated.

At the step S73, the loading schedule correction device 14 recalculates the scheduled transfer start time for the subsequent loading operation for
10 transferring from the AGV 4 to the gantry crane 5 in accordance with the difference between the target operating time set by the loading schedule setting device 13 (refer to the step S61 of Fig. 6) and the actual operating time. In the loading schedule as exemplified in Fig. 8, when the actual loading time of the loading operation A was fifteen seconds behind the target loading time, the
15 loading schedule correction device 14 sets the scheduled transfer start time for the loading operation B with a delay of fifteen seconds.

At the step S74, the loading schedule correction device 14 registers the changed scheduled transfer start time as the updated loading schedule in the
20 loading schedule database 11.

In the above-described embodiment, the loading schedule database 11 and the step S61 of the loading schedule setting device 13 cooperate to form a third time setting device that sets the target loading time taken for the gantry
25 crane 5 to perform the loading operation on the basis of the loading location in the container loading warehouse 2A. The step S62 of the loading schedule setting device 13 forms a fourth time setting device that sets the scheduled loading start time at which the gantry crane 5 is start to perform the loading and unloading operation, on the basis of the target loading time. The steps S71 and
30 S72 of the loading schedule correction device 14 cooperate to form an actual operating time acquisition device that acquires the actual loading time taken for the gantry crane 5 to perform the loading and unloading operation. The step

S73 of the loading schedule correction device 14 forms a fifth time setting device that resets the scheduled loading start time at which the gantry crane 5 is to start to perform the subsequent loading and unloading operation in accordance with difference between the target loading time and the actual loading time.

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The gantry crane 5 which is manually operated by operator may cause the following trouble. That is, the time of operation of the gantry crane 5 is varied widely depending on the loading location of the container 3 in the container loading warehouse 2A of the containership 2, as shown in Figs. 7 and 8, and also on the skill of operator, environmental condition such as wind and rain, and the type of containership 2. Therefore, the loading operation may not be started at the scheduled loading start time set as the original loading schedule.

15 In the present embodiment, however, the loading schedule correction device 14 acquires the actual loading time taken for the gantry crane 5 to perform loading and unloading operation and changes the scheduled loading start time for the subsequent loading operation in accordance with the difference between the preset target loading time and the acquired actual loading time. Therefore, the loading operation may be started at the scheduled loading start time irrespective of the loading location of the container 3 and/or the skill of the operator, so that accurate loading schedule is obtainable.

The present invention is not limited to the above-described embodiment. In the above-described embodiment, if the AGV control device 12 detects any overlap between the time of passage of the AGV 4 and the times of passage of any other AGVs 4 which have been already set for any section, the AGV control device 12 delays the scheduled time of arrival of the container 3 conveyed by the AGV 4 whose time of passage was set this time. However, if the AGV control device 12 detects such overlap, the AGV control device 12 may accelerate the scheduled time of arrival of any AGV 4.

The loading schedule may be reexamined every predetermined period of time (such as everyday or every week) on the basis of the difference between the target loading time and the actual loading time for each loading operation. Specifically, the loading schedule setting device 13 resets the target loading time
5 for each loading operation, recalculates the scheduled start time of transferring the container 3 from the AGV 4 to the gantry crane 5, and registers the reset target loading time and the recalculated scheduled transfer start time as updated loading schedule in the loading schedule database 11. In this case, the accuracy of the loading schedule is further improved.

10 Although in the above-described embodiment the AGV control device 12, the loading schedule setting device 13 and the loading schedule correction device 14 are provided in a single controller 6, these devices may be provided in separate controllers.

15 In the above-described embodiment, no specific consideration is made of loading the container 3 onto a manned trailer. However, when the gantry crane 5 receives a container 3 from an AGV 4 to load it onto a manned trailer after loading another container 3 onto the containership 2, the time taken for the
20 gantry crane 5 to receive and load the container 3 is added to the aforementioned operating time of the gantry crane 5.

25 Though the present embodiment has been described in the case of the loading system 1 that is operable to convey the container 3 stored in the container storage area 8 and to load it onto the containership 2, the present invention is applicable to a loading system that is operable to unload the container 3 from the containership 2 and to convey it to the container storage area 8.

30 The present invention is also applicable to a loading system that loads and unloads goods other than container.

What is claimed is:

1. An automatic guided vehicle (AGV) operating method, comprising the steps of:

- 5 allowing a plurality of AGVs to travel along a path;
 dividing the path into a plurality of sections, the sections having a starting section from which each of the AGVs starts to travel and a destination section at which the AGV arrives;
 setting scheduled time of arrival at which the AGV is to arrive at the
10 destination section;
 setting scheduled times of passage at which the AGV is to pass through the respective sections in the path from the starting section to the destination section, on the basis of the scheduled time of arrival, wherein the setting of the scheduled times of passage is made in order that is reverse to order in which the
15 AGV passes through the respective sections; and
 controlling the traveling of the AGV in accordance with the scheduled times of passage for the respective sections.

2. An automatic guided vehicle (AGV) operating system, comprising:

- 20 a plurality of AGVs;
 a path along which the AGVs are allowed to travel, the path being divided into a plurality of sections, the sections having a starting section from which each of the AGVs starts to travel and a destination section at which the AGV arrives;
25 a controller for controlling the traveling of the AGVs; comprising:
 a first time setting device for setting scheduled time of arrival at which the AGV is to arrive at the destination section;
 a second time setting device for setting scheduled times of
30 passage at which the AGV is to pass through the respective sections in the path from the starting section to the destination section, on the basis of the scheduled time of arrival, wherein the setting of the scheduled times of passage is made in order that is reverse to order in which the

AGV passes through the respective sections;

a data-storage device for storing data on the scheduled times of passage for the respective sections; and

an AGV traveling control device for controlling the traveling of the AGV in accordance with the scheduled times of passage for the respective sections.

3. The AGV operating system according to claim 2, wherein the controller comprises a detecting device for determining whether or not there is any overlap between the scheduled times of passage of the AGVs for any section, wherein if the detecting device determines the overlap, the first setting device resets scheduled time of arrival at which any of the AGVs is to arrive at the destination section.

4. The AGV operating system according to claim 2, further comprising:
a goods loading warehouse for storing goods; and
a loading unit for loading and unloading the goods between the goods loading warehouse and the AGVs, wherein the controller further comprises:

a third time setting device for setting target loading time taken for the loading unit to load and unload the goods, on the basis of a loading and unloading location of the goods loading warehouse;

a fourth time setting device for setting scheduled loading start time at which the loading unit is to start to load and unload the goods, on the basis of the target loading time;

an actual operating time acquisition device for acquiring actual operating time taken for the loading unit to load and unload the goods; and

a fifth time setting device for resetting scheduled operating start time at which the loading unit is to start to perform subsequent loading and unloading of the goods in accordance with difference between the target operating time and the actual operating time.

5. The AGV operating system according to claim 4, wherein the third time setting device resets the target operating time on the basis of at least one of skill of operator which manipulates the loading unit and environmental condition under which the loading unit is operated.