

Specification

Title of the Invention

CONTROL APPARATUS AND METHOD OF CONVEYANCE SYSTEM

Field of the Invention

[0001]

The present invention relates to a control apparatus and a control method for conveyance systems.

Background of the Invention

[0002]

In recent years, automatic systematisation in logistics has been steadily progressing, and technologies related to automating warehouse management and handling of conveyance items such as checked luggage and parcels at airports have been developed. The technologies related to automated systems in logistics include, for example, US Patent No. 10,322,883 B2 Publication. In this US patent, a technique is suggested to select either the shortest length route or the shortest time route for a conveying route in a belt.

Related Art Documents

[0003]

Patent Literature No 1: US Patent No. 10,322,883 B2

[0004]

Nevertheless, it is still not easy to automatically choose a preferable conveyance route in automatic conveyance systems.

For example, in a Baggage Handling System (BHS) operated in an airport, checked luggage is finally loaded to a destination airplane via multiple

routes.

Whilst automation is progressing in such Baggage Handling Systems with the diversification of services at airports, the control of routing of checked baggage in baggage handling systems has become more complex.

Moreover, there has been an increasing demand in recent years to improve the processing speed and accuracy of baggage handling systems.

[0005]

An object of the present invention is provide a control apparatus and a control method of a conveyance system to improve operational efficiency of conveyance systems.

Summary of the Invention

[0006]

A control apparatus of a conveyance system having a plurality of lanes, through which a conveyance element travels, the control apparatus comprises:

- a candidate finder for setting a plurality of prospective routes each including a plurality of segments of the lanes through which the conveyance element may travel to a destination;

- a cost estimator for calculating a possible cost of each lane segment of the prospective routes;

- a route decider for setting a conclusive route, which has a combination of the lane segments, by designating one of the prospective routes based on the possible cost calculated by the cost estimator; and

- a conveyor controller for controlling the conveyor system to dispatch the conveyance element to the destination along the lanes corresponding to the conclusive route set by the route decider, wherein

- the cost estimator includes,

- a static-cost calculator for calculating a static cost which is an effort value related to a static-required time if the conveyance element travels

to the destination through the respective lane segments,

a status-cost calculator for calculating a status cost which is an effort value related to lane status of the respective lane segments,

a dynamic-cost calculator for calculating a dynamic cost which is an effort value in accordance with a dynamic factor, and

a total-cost estimator for setting the possible cost by totalising the static cost, the status cost and the dynamic cost calculated by the static-cost calculator, the status-cost calculator and the dynamic-cost calculator, respectively.

[0007]

The prospective routes include,

a basic route having a basic combination of the lane segments through which the conveyance element may travel to the destination, and

a plurality of alternative routes, which are defined in a route list, each having an alternative combination of the lane segments, which is different to the basic combination, through which the conveyance element may travel to the destination.

The cost estimator calculates the possible cost of the lane segments of each of the basic and alternative routes.

The route decider sets the conclusive route by designating one of the basic route and the alternative routes based on the possible cost calculated by the cost estimator.

[0008]

The route decider sets the conclusive route by designating one of the prospective routes which has the lowest possible cost.

[0009]

A gridlock preventer restricts additional entry of the conveyance element into a congestion area, which is an area defined in the conveyance system, if

an existing number of the conveyance element in the congestion area has reached a congestion capacity of the congestion area.

[0010]

A divergent-blockage preventer prevents a divergent-point blockage at a divergent point from which the plurality of lanes are branched.

The divergent-blockage preventer controls the conveyor system, irrespective of the conclusive route set by the route decider, to divert the conveyance element to an available lane of the branch lanes, if the divergent-blockage preventer predicts that the conveyance element stops at the divergent point for entering into a blocked lane of the branch lanes.

[0011]

The conveyor system is a tray-conveyor system including a tray-conveyor network in which a tray travels for carrying a transport object on the tray.

[0012]

The static-cost calculator calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments.

[0013]

The dynamic factor is based on element status of the conveyance element.

The element status is related to at least one of:

tray state of the tray;

tray type of the tray;

transport-object state of the transport object put on the tray; and

transport-object type of the transport object put on the tray.

[0014]

An empty-tray managing module manages each empty tray in the tray-conveyor network.

[0015]

The empty-tray control module includes an empty-tray dispatcher.

The empty-tray dispatcher carries out an empty-tray-allocation control for dispatching each of the empty trays to either a tray-demand area or a tray-supply area.

[0016]

The empty-tray dispatcher carries out the empty-tray-allocation control for the tray-demand area in accordance with an empty-tray priority calculated based on at least one of:

- a receivable capacity related to a number of available slots in which the empty trays can be accommodated in the tray-demand area;

- a waiting number of the transport objects lining up for being placed onto the respective empty trays in the tray-demand area;

- an in-stock number of the empty trays lining up for receiving the transport objects in the tray-demand area; and

- an under-way number of the empty trays travelling towards the tray-demand area.

[0017]

A loading controller controls both a loading unit and a buffer lane.

The tray-conveyor system further includes,

- the loading unit for respectively placing each of the plurality of transport objects onto each of the plurality of empty trays, and

- the buffer lane for keeping the empty trays on standby for receiving the transport objects fed from the loading unit.

The loading controller controls the loading unit and the buffer lane by carrying out an empty-tray-synchronising control so as to synchronise each empty tray at a loading point, which is adjacent to the loading unit in the buffer lane, with each of the transport objects fed from the loading unit.

[0018]

A tray releaser prevents a buffer-lane blockage at a buffer-lane inlet from which the plurality of lanes including the buffer lane are branched.

If the tray releaser predicts that another empty tray, which is approaching to the buffer lane, stops at the buffering-lane inlet to enter the buffer lane, then the tray releaser forcibly releases at least one of the empty trays kept in the buffer lane towards a downstream and permits the approaching empty tray entering into the buffer lane.

[0019]

A history recorder records a tray history of each of the trays.

A due-tray dispatcher dispatches a due tray to a maintenance lane in which maintenance work is performed on the due tray.

The due tray is an empty tray of which the tray history satisfies a maintenance condition.

[0020]

The conveyor system is a belt conveyor system including a belt-conveyor network having a plurality of belt-conveyor lanes by which a transport object is carried.

[0021]

The static-cost calculator calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments of the belt-conveyor network.

[0022]

The dynamic factor is based on element status of the conveyance element.

The element status is related to at least one of:

transport-object state of the transport object; and

transport-object type of the transport object put on the tray.

[0023]

The dynamic factor is based on time status.

The time status is related to at least one of:

- time ranges of a day;
- days of a week; and
- type of a touristic season.

[0024]

The conveyance system is installed in a transport facility.

The dynamic factor is based on transport status.

The transport status is related to at least one of:

- a departure time of public transport; and
- a number of operations of the public transport in a time window.

[0025]

A element-history analyser analyses an element history of the conveyance element; and

An analysis concierge explains a result of the element-history analysis carried out by the element-history analyser to a questioner.

[0026]

A control method of a conveyance system having a plurality of lanes, through which a conveyance element travels, the control method comprises steps of:

- setting a plurality of prospective routes each including a plurality of segments of the lanes through which the conveyance element may travel to a destination;

- calculating a possible cost of each lane segment of the prospective routes;

- setting a conclusive route, which has a combination of the lane segments, by designating one of the prospective routes based on the possible cost calculated by the cost estimator; and

- controlling the conveyor system to dispatch the conveyance element to the destination along the lanes corresponding to the conclusive route set by

the route decider, wherein

the possible-cost-calculating step includes steps of,

calculating a static cost which is an effort value related to a static-required time if the conveyance element travels to the destination through the respective lane segments,

calculating a status cost which is an effort value related to lane status of the respective lane segments,

calculating a dynamic cost which is an effort value in accordance with a dynamic factor, and

setting the possible cost by totalising the static cost, the status cost and the dynamic cost calculated by the static-cost-calculating step, the status-cost calculating step and the dynamic-cost calculating step, respectively.

[0027]

The prospective routes includes,

a basic route having a basic combination of the lane segments through which the conveyance element may travel to the destination, and

a plurality of alternative routes, which are defined in a route list, each having an alternative combination of the lane segments, which is different to the basic combination, through which the conveyance element may travel to the destination.

The step possible-cost calculating step calculates the possible cost of the lane segments of each of the basic and alternative routes.

The conclusive-route setting step sets the conclusive route by designating one of the basic route and the alternative routes based on the possible cost calculated by the possible-cost calculating step.

[0028]

The conclusive-route setting step sets the conclusive route by designating one of the prospective routes which has the lowest possible cost.

[0029]

A gridlock preventing step restricts additional entry of the conveyance element into a congestion area, which is an area defined in the conveyance system, if an existing number of the conveyance element in the congestion area has reached a congestion capacity of the congestion area.

[0030]

A divergent-blockage preventing step prevents a divergent blockage at a divergent point from which the plurality of lanes are branched.

The divergent-blockage preventing step controls the conveyor system, irrespective of the conclusive route set by the route decider, to divert the conveyance element to an available lane of the branch lanes, if the conveyance element is predicted to stop at the divergent point for entering into a blocked lane of the branch lanes.

[0031]

The conveyor system is a tray-conveyor system including a tray-conveyor network in which a tray travels for carrying a transport object on the tray.

[0032]

The static-cost calculating step calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments.

[0033]

The dynamic factor is based on element status of the conveyance element.

The element status is related to at least one of:

tray state of the tray;

tray type of the tray;

transport-object status of the transport object put on the tray; and

transport-object type of the transport object put on the tray.

[0034]

An empty-tray managing step manages each empty tray in the tray-conveyor network.

[0035]

The empty-tray managing step includes a step of carrying out an empty-tray-allocation control that dispatches each of the empty trays to either a tray-demand area or a tray-supply area.

[0036]

The empty-tray dispatching step carries out the empty-tray-allocation control for the tray-demand area in accordance with an empty-tray priority calculated based on at least one of:

- a receivable capacity related to a number of available slots in which the empty trays can be accommodated in the tray-demand area;

- a waiting number of the transport objects lining up for being placed onto the respective empty trays in the tray-demand area;

- an in-stock number of the empty trays lining up for receiving the transport objects in the tray-demand area; and

- an under-way number of the empty trays travelling towards the tray-demand area.

[0037]

A load controlling step controls both a loading unit and a buffer lane.

The tray-conveyor system further includes,

- the loading unit for respectively placing each of the plurality of transport objects onto each of the plurality of empty trays, and

- the buffer lane for keeping the empty trays on standby for receiving the transport objects fed from the loading unit.

The load controlling step controls the loading unit and the buffer lane by carrying out an empty-tray synchronising control so as to synchronise each empty tray at a loading point, which is adjacent to the loading unit in the buffer lane, with each of the transport objects fed from the loading unit.

[0038]

A buffer-lane blockage preventing step prevents a buffer-lane blockage at a buffer-lane inlet from which the plurality of lanes including the buffer lane are branched by such a manner that if another empty tray, which is approaching to the buffer lane, is predicted to stop at the buffering-lane inlet to enter the buffer lane, then forcibly releasing at least one of the empty trays kept in the buffer lane towards a downstream and permits the approaching empty tray entering into the buffer lane.

[0039]

A tray-history recording step records a tray history of each of the trays.

A due-tray dispatching step dispatches a due tray to a maintenance lane in which maintenance work is performed on the due tray.

The due tray is an empty tray of which the tray history satisfies a maintenance-required condition.

[0040]

The conveyor system is a belt conveyor system including a belt-conveyor network having a plurality of belt-conveyor lanes by which a transport object is carried.

[0041]

The static-cost calculating step calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments of the belt-conveyor network.

[0042]

The dynamic factor is based on element status of the conveyance element.

The element status is related to at least one of:

transport-object state of the transport object; and

transport-object type of the transport object put on the tray.

[0043]

The dynamic factor is based on time status.

The time status is related to at least one of:

time ranges of a day;
days of a week; and
type of a touristic season.

[0044]

The conveyance system is installed in a transport facility.

The dynamic factor is based on transport status.

The transport status is related to at least one of:

a departure time of public transport; and
a number of operations of the public transport in a time window.

[0045]

An element-history analysing step analyses an element-history of the conveyance element.

An analysis explaining step explains a result of the analysis carried out by the element-history analysis step to a questioner.

Brief Description of the Drawings

[0046]

FIG 1 is a schematic block diagram showing a conveyance-system control apparatus according to an embodiment of the present invention.

FIG 2 is a schematic view showing a part of a baggage tray system which is managed by the conveyance-system control apparatus.

[0047]

FIG 3 is a schematic diagram of a tray-conveyor network of the baggage tray system which is managed by the conveyance-system control apparatus.

[0048]

FIG 4 is an enlarged schematic diagram showing a part of the tray-conveyor network shown in FIG 3.

[0049]

FIG 5(A) is a schematic diagram showing the results of a route search based only on a static cost in the tray-conveyor network shown in FIG 4.

FIG 5(B) is a schematic diagram showing the results of a route search based on the static cost and a status cost in the tray-conveyor network shown in FIG 5(A).

FIG 5(C) is a schematic diagram showing lane segments of the tray-conveyor network shown in FIG 5(B) to which a dynamic cost is applied.

[0050]

FIG 6(A) is a schematic diagram showing a conclusive route set for a standard tray in a loaded state in the tray-conveyor network shown in FIG 5(C).

FIG 6(B) is a schematic diagram showing the conclusive route set for a long tray in a loaded state in an empty state in the tray-conveyor network shown in FIG 5(C).

[0051]

FIG 7 is an enlarged schematic diagram showing a part of the tray-conveyor network shown in FIG 3.

[0052]

FIG 8(A) is a schematic diagram showing a case where two trays exist in a congestion area in the tray-conveyor network shown in FIG 7.

FIG 8(B) is a schematic diagram showing a case where three trays exist in the congestion area in the tray-conveyor network shown in FIG 7.

[0053]

FIG 9(A) is a schematic diagram showing a case where four trays exist in the congestion area in the tray-conveyor network shown in FIG 7.

FIG 9(B) is a schematic diagram showing a case where entry of a new tray into the congestion area is temporarily prohibited in the tray-conveyor network shown in FIG 7.

[0054]

FIG 10(A) is a schematic diagram showing a case where entry of the new tray into the congestion area is permitted in the tray-conveyor network shown in FIG 7.

FIG 10(B) is a schematic diagram showing a case where the new tray has entered the congestion area in the tray-conveyor network shown in FIG 7.
[0055]

FIG 11(A) is an enlarged schematic diagram showing a part of the tray-conveyor network shown in FIG 3.

FIG 11(B) is a schematic diagram showing a case where branch point blockage occurs in the tray transport network shown in FIG 11(A).
[0056]

FIG 12(A) is a schematic diagram showing a case where a tray is detoured to an available lane in the tray-conveyor network shown in FIG 11(A).

FIG 12(B) is a schematic diagram showing a case where a subsequent tray was not hindered from travelling in the tray-conveyor network shown in FIG 12(A).
[0057]

FIG 13 is an enlarged schematic diagram showing a part of the tray-conveyor network shown in FIG 3.
[0058]

FIG 14 is a schematic diagram showing a case where a buffer-lane blockage occurs in tray-conveyor network shown in FIG 13.
[0059]

FIG 15 is a schematic diagram showing a case where a waiting tray is forcibly released in the tray transport network shown in FIG 14.
[0060]

FIG 16 is a schematic diagram showing a case where a new tray has entered a buffer lane in the tray-conveyor network shown in FIG 15.
[0061]

FIG 17 is a main flow chart schematically showing operation of the conveyance-system control apparatus and the conveyance-system control method according to the embodiment of the present invention.

[0062]

FIG 18 is a sub-flowchart, relating to empty-tray management, schematically showing operation of the conveyance-system control apparatus and the conveyance according to the embodiment of the present invention.

[0063]

FIG 19 is a sub-flowchart, relating to override control, schematically showing operation of the conveyance-system control apparatus and the conveyance according to the embodiment of the present invention.

Description of the Preferred Embodiments

[0064]

An embodiment of the present invention will now be described with reference to FIGs 1 to 19.

[0065]

As shown in FIG 1, the conveyance-system control apparatus in this embodiment is configured as a flow-control server 1 of a baggage tray system (BTS) 2 installed at an airport.

[0066]

This baggage tray system 2 is mainly composed of a BTS controller 3 and a BTS network (tray-conveyor network) 4.

The BTS controller 3 is a control device including a plurality of Programmable Logic Controller (PLC) units.

The BTS controller 3 is connected to electric devices of the BTS network 4 so that these electric devices can be individually or integrally controlled.

Furthermore, the BTS controller 3 is also connected to the flow-control server 1 so as to be able to communicate with each other. Hence, the flow-

control server 1 can always monitor the operational status of the BTS network 4 and control the BTS network 4 via the BTS controller 3.

[0067]

As shown in FIG 2, the baggage tray system 2, unlike a general belt conveyor system, conveys transport objects (e.g., soft bags (not shown), suitcases 6002-6004, parcels (not shown), etc.). Each of transport objects is individually mounted on the trays 6005-6007 travelling in a lane 6001 and transported.

Each of the trays 6005-6007 is driven by an electric motor (not shown) provided in the lane 6001 so that each of the trays 6005-6007 can individually travel within the BTS network 4.

Tray types include standard size and long size. A tray of a standard size is called a standard tray, and a tray of a long size is called a long tray.

In the baggage tray system 2 of this embodiment, standard trays are used in principle, but long trays can also be used depending on the situation.

[0068]

Each tray is assigned an individual identification ID (tray ID).

An RFID tag (not shown) is attached to each tray. Also, each lane of the BTS network 4 is provided with a plurality of RFID sensors (not shown).

Furthermore, the BTS network 4 is provided with a plurality of photoelectric sensors (not shown).

The flow-control server 1, based on the detection results of various sensors including these RFID sensors and photoelectric sensors, constantly monitors a tray state including, but not limited to, position, travel speed, loaded/empty with regard to each tray in the BTS network 4.

In this embodiment, a tray loaded with a transport object is called a 'loaded tray', and a tray loaded with nothing is called an 'empty tray'.

In this embodiment, the name 'conveying element(s)' may be used as a generic name for the transport object(s) the tray(s).

[0069]

As shown in FIG 3, the BTS network 4 has multiple lanes.

Each lane is assigned an individual identification number. However, in this embodiment, in order to make the description clearer, only the lanes shown below are labelled.

A-lane group 24: lanes 101-110

B-lane group 25: lanes 201-206

C-lane group 26: lanes 301-303

D-lane group 27: lanes 401-404

[0070]

As shown in FIG 1, the flow-control server 1 is equipped with application software as follows.

[0071]

Conveyor controller 5

Status monitor 6

Loaded-tray dispatcher 7

Candidate finder 8

Cost estimator 9

Route decider 14

Gridlock preventer 15

Divergent-blockage preventer 16

Empty-tray dispatcher 17

Loading controller 18

Tray releaser 19

History recorder 20

Due-tray dispatcher 21

Element-history analyser 22

Analysis concierge 23

[0072]

The flow control server 1 includes hardware devices (not shown) such as a central processing unit (CPU), a storage device, a communication device, and a power supply device.

The conveyor controller 5 is a program module that controls the baggage tray system 2 via the BTS controller 3 so as to dispatch the trays to the destination along the lanes corresponding to the conclusive route set by the route decider 14.

The control executed by the conveyor controller 5 is called 'conveyor control'.

The conveyor controller 5 may, exceptionally, dispatch the trays according to another route that takes precedence over the conclusive route as described further below.

The destination of each tray is set by the loaded-tray dispatcher 7 or the empty-tray dispatcher 17. These features are also described further below.

[0073]

The status monitor 6 is a program module that monitors the operational status of the baggage tray system 2 via the BTS controller 3.

In other words, the status monitor 6 obtains various kinds of information in the baggage tray system 2 such as the status of each lane (lane status), the position of each tray (tray position), the actual travelling speed of each tray (tray speed), the loaded/empty state of each tray, and the type of each tray (standard/long).

[0074]

The loaded-tray dispatcher 7 is a program module for setting the destination of each loaded tray in the BTS network 4.

For example, if a passenger's suitcase is loaded on a tray, in order to be able to deliver the suitcase to a destination in the BTS network 4 corresponding with the aircraft this passenger is to board, the loaded-tray dispatcher 7 sets a lane segment, which corresponds to the place of delivery to this airplane, as

the destination of this loaded tray.

[0075]

The candidate finder 8 is a program module for searching and setting a plurality of prospective routes each of which includes a plurality of segments of the lanes through which a tray will travel to reach its destination.

The control executed by the candidate finder 8 is called 'prospective-route setting control'.

The prospective route includes a basic route and multiple alternative routes. In other words, the candidate finder 8 can calculate a possible cost for each of the lane segments of the basic route and the alternative route.

The basic route is a route composed of a basic combination of the lane segments along which the tray will travel to its destination.

Each alternative route, which is defined in a route list, is a route configured in accordance with an alternative combination of the lane segments through which the tray will travel to the destination.

Each alternate combination of each alternate route is different from the base combination.

[0076]

The cost estimator 9 is a program module that calculates the prospective cost of each lane segment included in each prospective route.

More specifically, the cost estimator 9 calculates the prospective cost for each lane segment included in the basic combination.

The cost estimator 9 also calculates the prospective cost for each lane segment included in each alternative combination.

That is, the cost estimator 9 individually calculates the prospective cost for each lane segment included in the basic route and each alternative route.

The cost estimator 9 has submodules such as a static-cost calculator 10, a status-cost calculator 11, a dynamic-cost calculator 12, and a total-cost calculator 13.

[0077]

The static-cost calculator 10 is a program module that calculates a static cost, which is an effort value related to the time (static-required time) required for a tray to travel to its destination through the corresponding lane segments. .

The status-cost calculator 11 is a program module that calculates a status cost, which is an effort value related to the lane status of the corresponding lane segment.

The dynamic-cost calculator 12 is a program module that calculates a dynamic cost, which is an effort value related to dynamic factors.

The static-cost calculator 10, the status-cost calculator 11, and the dynamic-cost calculator 12 will be described in more detail later.

[0078]

The total-cost calculator 13 is a program module that sums the static-, status- and dynamic-costs calculated by the static-cost calculator 10, the static-cost calculator 11 and the dynamic-cost calculator 12 respectively to set the possible cost for each lane segment.

The route decider 14 is a program module that designates one of the prospective routes based on the possible cost calculated by the cost estimator 9 and sets the conclusive route consisting of a combination of lane segments.

The control executed by the route decider 14 is called 'route-decision control'.

In this embodiment, the route decider 14 sets the conclusive route by designating one of the plurality of prospective routes with the lowest possible cost.

[0079]

The static-cost calculator 10 is a program module that calculates the static cost of each lane segment based on the length of each lane segment and the forwarding speed of each lane segment.

The static-cost calculator 10 will be described by taking ten lanes 101-

110 forming the A-lane group 24 shown in FIG 4 as an example.

In this example, a tray is going from the lane 101 to the lane 105.

[0080]

Hence, in this example, the candidate finder 8 sets all prospective routes that the tray will take from starting from the lane 101 to arriving at the lane 105.

Thus, in this example, the candidate finder 8 sets up five predicted routes as shown in the list below.

[0081]

First prospective route:

Lane 101 → Lane 106 → Lane 107 → Lane 108 → Lane 105

Second prospective route:

Lane 101 → Lane 106 → Lane 109 → Lane 103 → Lane 110 → Lane 108
→ Lane 105

Third prospective route:

Lane 101 → Lane 106 → Lane 109 → Lane 103 → Lane 104 → Lane 105

Fourth prospective route:

Lane 101 → Lane 102 → Lane 103 → Lane 110 → Lane 108 → Lane 105

Fifth prospective route:

Lane 101 → Lane 102 → Lane 103 → Lane 104 → Lane 105

[0082]

The static-cost calculator 10, based on the length (lane-segment length) of each lane segment corresponding to each prospective route set by the candidate finder 8 and the forwarding speed of each lane, calculates the time (static-required time) required for the tray to complete travelling through each prospective route.

At this time, the static-cost calculator 10 sets an effort value corresponding to the static-required time as the static cost of each prospective route.

The control executed by the static-cost calculator 10 is called 'static-cost calculation control'.

Also, the candidate finder 8 recognises the one with the lowest static cost among the prospective routes as the basic route.

In addition, the candidate finder 8 recognises each prospective route, other than the basic route, as the alternative route.

In this example, among the prospective routes, the one with the lowest static cost is the route indicated by the bold arrow in FIG 5A, that is, the fifth prospective route.

[0083]

However, in reality, the status of each lane (lane status) is always changing. For example, assume that a failure occurs in the lane 104, as indicated by a cross mark 'X' in FIG 5B.

In this case, the status-cost calculator 11 sets an effort value, according to the degree of failure status (e.g., jam, emergency stop, offline, etc.) of the lane 104, as the status cost of the lane segment related to this lane 104.

The control executed by the status-cost calculator 11 is called 'status-cost calculation control'.

In this example, among the prospective routes, the one with the smallest sum of the static cost and the status cost is the route indicated by the bold arrow in FIG 5B, that is, the fourth predicted route.

[0084]

The lane status is not the only situation that can fluctuate.

The dynamic-cost calculator 12 in this embodiment considers 'element status' as a dynamic factor with respect to the baggage tray system 2.

The control executed by the dynamic-cost calculator 12 is called 'dynamic-cost calculation control'.

[0085]

The element status includes tray status and tray type.

The tray status is a factor indicating the current status of each tray. In the present embodiment, a factor relating to the loaded/empty state of each tray (i.e. whether the tray is loaded or empty) correspond to the tray state.

The tray type is a factor that indicates the type of each tray. In this embodiment, the factor of class of each tray (i.e. standard tray or long tray) corresponds to the tray type.

[0086]

Here, as shown in FIG 5(C), it is assumed that only empty trays can pass through the lane 103, and only standard trays can pass through the lane 107.

In this case, if the tray is a loaded tray, the dynamic-cost calculator 12 sets the dynamic cost of the lane 103 as the maximum value of the calculation range.

On the other hand, if the tray is empty, the dynamic-cost calculator 12 sets the dynamic cost of the lane 103 to the minimum value of the computational range, that is, zero.

Also, when the tray is a long tray, the dynamic-cost calculator 12 sets the dynamic cost of lane 107 as the maximum value of the calculation range.

On the other hand, if the tray is a standard tray, the dynamic-cost calculator 12 sets the dynamic cost of the lane 107 to the minimum value of the computational range (i.e. zero).

[0087]

Accordingly, in this example, if the tray is a standard tray in the loaded state, the one with the smallest sum of the static cost, the status cost, and the dynamic cost among the prospective routes is the one indicated by the thick arrow shown in FIG 6(A), that is, the first prospect route.

Also, in this example, if the tray is an empty long tray, the one with the smallest sum of the static cost, the status cost, and the dynamic cost among the prospective routes is the one indicated by the thick arrow shown in FIG

6(B), that is, the fourth prospect route.

Note that, in the case shown in FIG 5(C), loaded long trays cannot reach the lane 105 from the lane 101.

Accordingly, in this case, when a tray to be controlled is a loaded long tray, the dynamic cost calculator 12 sets the dynamic cost of the lane 101 as the maximum value of the computational range. As a result, it is possible to prevent the loaded long tray from going to the A-lane group 24.

[0088]

The gridlock preventer 15 of the flow-control server 1 is a program module that executes gridlock-prevention control to restrict further entry of new trays into a congestion area when the existing number of trays in the congestion area reaches the congestion capacity of the congestion area.

The gridlock-prevention control will be described by taking six lanes 201-206 forming the B-lane group 25 as shown in FIG 7 as an example.

Note that the lanes 201-203 form a circular-lane segment 6008 in this B-lane group 25.

Also note that in this embodiment, this circular-lane segment 6008 is set as the congestion area.

Also, in this embodiment, the number of congestion capacity is set to 'four'.

That is, if there are four or more trays in the circular-lane segment 6008, the gridlock preventer 15 determines that the congestion capacity has been reached.

[0089]

For example, as shown in FIG 8(A), there are two trays present in the circular-lane segment 6008 (i.e. tray 2001 and tray 2002).

In this case, the existing number of trays has not reached the congestion capacity, so the gridlock preventer 15 does not carry out the gridlock-prevention control.

As a result, as shown in FIG 8(B), a new tray 2003 can enter the lane 201 from the lane 206.

Also, in the situation shown in FIG 8(B), there are three trays present in the circular-lane segment 6008 (i.e. tray 2001, tray 2002 and tray 2003).

Even in this case, the existing number of trays has not reached the congestion capacity, so the gridlock preventer 15 does not execute the gridlock-prevention control.

[0090]

Accordingly, as shown in FIG 9(A), a new tray 2004 can enter the lane 202 from the lane 204.

In the situation shown in FIG 9(A), there are four trays present in the circular-lane segment 6008 (i.e. tray 2001, tray 2002, tray 2003 and tray 2004).

At this time, the gridlock preventer 15 determines that the existing number of trays in the circular-lane segment 6008 has reached the congestion capacity, and executes the gridlock-prevention control.

Then, as shown in FIG 9(B), while the gridlock-prevention control is being executed, the gridlock preventer 15 does not allow a new tray 2005 traveling from the lane 206 toward the circular-lane segment 6008 to enter the lane 201.

[0091]

Then, as shown in FIG 10(A), consider the case where the tray 2001 exits the lane 202 and enters the lane 205.

At this time, there are three trays in the circular-lane segment 6008 (that is, tray 2002, tray 2003 and tray 2004).

That is, since the existing number of trays has fallen below the congestion capacity, the gridlock preventer 15 stops executing the gridlock-prevention control.

As a result, the tray 2005 waiting in the lane 206 can enter the lane 201

as shown in FIG 10(B).

[0092]

The divergent-blockage preventer 16 of the flow-control server 1 is a program module that prevents a divergent-point blockage at a divergent point where a plurality of lanes branch.

Note that the control executed by the divergent-blockage preventer 16 is called 'divergent-blockage-prevention control'.

Also, each lane extended from the divergent point is called a branch lane.

Here, the divergent-blockage preventer 16 will be described with reference to FIGs 11(A) and (B) and FIGs 12(A) and (B), taking three lanes 301-306 forming the C-lane group 26 as an example.

As shown in FIGs 11(A) and (B), the lanes 302 and 303 branch from the divergent point 28.

In other words, in this example, each of the lanes 302 and the lane 303 is the branch lane.

Also, in the example shown in FIG 11(B), a tray 3004 that blocks the divergent point 28 is the divergent-point blockage.

[0093]

Further, in this example, as shown in FIG 11(A), the lane 302 is congested and no new tray can enter (i.e. in a blockage state). The lane 302 in the blockage state is called a blocked lane.

Also, in this example, the lane 303 is not congested, and therefore a new tray can be entered without any problem (that is, in an available state).

The lane 303 in the available state is called an available lane.

In this example, it is assumed that the tray 3004 must enter the blocked lane 302 when complying with the original route (conclusive route) of the tray 3004.

[0094]

In this example, the divergent-blockage preventer 16 predicts a

situation where the tray 3004, which is about to enter the blocked lane 302, stops at the divergent point 28 (see FIG 11(B)).

At this time, as shown in FIG 12(A), the divergent-blockage preventer 16 sets a route (detour route) for detouring the tray 3004 to the available lane 303 instead of the lane 302 which is the original route.

In other words, when the divergent-blockage preventer 16 predicts the situation shown in FIG 11(B), then the divergent-blockage preventer 16 locally sets the detour route which has a higher priority than the conclusive route set by the route decider 14.

[0095]

The empty-tray dispatcher 17 is a program module that manages each empty tray within the BTS network 4.

That is, the empty-tray dispatcher 17 sets the destination of each empty tray in the BTS network 4 and dispatches the empty trays to respective destinations.

In addition, the empty-tray dispatcher 17 executes 'empty-tray-allocation control'.

The empty-tray-allocation control is control for setting, as the destination of empty trays, either a tray-demand area or a tray-supply area.

The tray-demand area is an area within the BTS network 4 where the empty trays to be loaded. In this embodiment, a buffer lane 402 and an in-line buffer (not shown) correspond to the tray-demand area.

The tray supply area is an area within the BTS network 4 where the empty trays are stored. In this embodiment, a tray stacker (not shown), a storage line (not shown), and an in-line buffer (not shown) correspond to the tray supply area.

[0096]

Further, the empty-tray dispatcher 17 executes the empty-tray-allocation control according to an empty-tray priority.

The empty-tray priority is calculated based on at least one of the following four factors.

- Receivable capacity of empty trays
- Waiting number of transport objects
- In-stock number of empty trays
- Under-way number of empty trays

[0097]

Among these factors, the receivable capacity is a capacity related to the number of slots that can accommodate empty trays (available-slot number) in the tray-demand area.

The waiting number is the number of transport objects waiting in line to be loaded on a corresponding empty tray in the tray-demand area.

[0098]

The in-stock number is the number of empty trays lined up for receiving transport objects to be conveyed in the tray-demand area.

The under-way number is the number of empty trays that are traveling toward the tray-demand area.

[0099]

As shown in FIG 13, the baggage tray system 2 in this embodiment has a top-loader (loading unit) 601 and a buffer lane 402.

Top-loader 601 is a belt conveyor. In an example shown in FIG 13, this top-loader 601 loads a plurality of suitcases 5001-5005 to the corresponding empty trays 4001-4005, respectively.

The buffer lane 402 is a lane that holds a plurality of empty trays 4001-4006 for receiving a plurality of suitcases 5001-5005 (transport objects) supplied from the top loader 601.

[0100]

The loading controller 18 of the flow-control server 1 is a program module that controls both the top-loader 601 and buffer lane 402.

The loading controller 18 executes 'empty-tray-synchronising control'.

This empty-tray-synchronising control will be described with reference to FIG 13.

The empty-tray-synchronising control is a control that controls both the buffer lane 402 and the top-loader 601 so that the empty trays 4001-4006 and the suitcases 5001-5005 supplied from the top loader 601 are synchronized at a loading point 29.

The loading point 29 is a space which is provided on the buffer lane 402 and is directly below an end of the top loader 601.

[0101]

The tray releaser 19 of the flow-control server 1 is a program module that executes 'tray-release control'.

Focusing on the four lanes 401-404 forming the D-lane group 27, the 'tray-release control' will be described using an examples shown in FIGs 14-16.

In this D-lane group 27, the lane 402 is provided downstream of the lane 401, and the lane 403 is provided downstream of the lane 402.

The lane 402 is the buffer lane for storing up to six empty trays.

Further, the lane 402 and the lane 404 are branched from the entrance (buffer-lane inlet 30) of the buffer lane 402.

[0102]

The tray-release control prevents the occurrence of a blockage (buffer-lane blockage) which would obstruct entry into the buffer lane 402 at the buffer-lane inlet 30.

Note that an empty tray 4017' indicated by the dotted line in FIG 14 is the buffer-lane blockage in this example.

In other words, in this tray-release control, when the tray releaser 19 predicts that the empty tray 4017 approaching (see an arrow A4017 in FIG 14) the buffer lane 402 will stop at the buffer-lane inlet to enter the buffer lane

402, as shown in FIG 15, the tray releaser 19 forcibly releases at least one of the empty trays 4011-4016 held in the buffer lane 402 toward the downstream lane 403.

In the example shown in FIG 15, only the tray 4011 was waiting at the loading point 29 is released.

[0103]

As a result, as shown in FIG 16, each of the trays 4012-4016 remaining in the buffer lane 402 is then sequentially moved downstream.

Accordingly, an empty slot for accommodating one empty tray is secured in the buffer lane 402, and the tray releaser 19 allows the approaching empty tray 4017 to enter the buffer lane 402.

In addition, since the tray release unit 19 executed the tray-release control, as shown in FIG 16, the subsequent tray 4018, which was originally instructed to enter the lane 404, passes through the buffer-lane inlet without any problem, and proceeds to the lane 404 as planned.

[0104]

The history recorder 20 of the flow-control server 1 is a program module that records a tray history of each of the trays used in the BTS network 4.

The tray history includes information about each tray, such as travel distance, maintenance history, and loading history.

In this embodiment, each tray is determined that its maintenance-required condition is satisfied and undergoes a maintenance check whenever its travel distance reaches a predetermined distance threshold (e.g., 5000 km) or the cumulative number of times the tray has loaded transport objects (i.e., loading number) reaches a predetermined loading-number threshold (e.g., 500 times).

This maintenance check is carried out in a maintenance lane (not shown) provided in the BTS network 4.

[0105]

The due-tray dispatcher 21 of the flow-control server 1 is a program module that dispatches due trays to the maintenance lane.

The due tray is an empty tray whose tray history satisfies the distance threshold.

In other words, the due-tray dispatcher 21 always monitors the tray history of each tray. Further, when the due-tray dispatcher 21 finds that the travel distance of a tray has reached the distance threshold since its previous maintenance check, and the tray is empty, then the due-tray dispatcher 21 recognises this tray as a due tray.

[0106]

At this time, the due-tray dispatcher 21 executes 'maintenance control' for setting the destination of the tray recognized as a due tray to the maintenance lane.

In principle, the destination set by the due-tray dispatcher 21 (i.e. the maintenance lane) has higher priority than those of the general destination set by the empty-tray dispatcher 17 (i.e. the tray-demand area or the tray-supply area).

That is, when an empty tray is a due tray, the empty-tray-allocation control of the empty-tray dispatcher 17 is not executed, but instead the maintenance control of the due-tray dispatcher 21 is executed.

[0107]

The element-history analyser 22 of the flow-control server 1 is a program module that analyses an element history of each transport element (that is, each transport object and each tray).

The analysis concierge 23 (i.e., explaining module) of the flow-control server 1 is a program module that explains the result of the analysis by the element-history analyser 22 to a questioner (e.g., external systems, operators, etc.).

In this embodiment, the element-history analyser 22 and the analysis

concierge 23 are implemented in the flow-control server 1 as artificial intelligence (AI) modules.

[0108]

With the above-mentioned arrangement, the conveyance-system control apparatus according to the embodiment of the present invention operates as follows and provides the following advantages.

[0109]

The flow-control server 1 operates according to a main flowchart shown in FIG 17.

First, when a transport object is loaded on a tray (Yes in step S1), the loaded-tray dispatcher 7 of the flow-control server 1 sets the destination of the loaded tray according to the loaded transport object (step S2).

On the other hand, if no transport object is loaded on this tray (No in step S1), a subroutine program relating to empty-tray management control is executed (step S3), and the destination of this empty tray is set. This empty-tray management control will be described later with reference to FIG 18.

[0110]

Then, in step S4, the candidate finder 8 of the flow-control server 1 executes the prospective-route setting control.

Thereby, a plurality of prospective routes through which this tray can reach its destination are set.

[0111]

Then, in step S5, the static-cost calculator 10 executes the static-cost calculation control for each lane segment of each prospective route set in step S4.

In the example described above with reference to FIG 5(A), the prospective route with the smallest total static cost is indicated by the thick arrow in FIG 5(A).

[0112]

In step S6, the status-cost calculator 11 executes the status-cost calculation control for each lane segment of each prospective route.

That is, the status-cost calculator 11 sets the effort value according to the degree of the lane failure status (e.g., jam, emergency stop, offline, etc.) as the status cost of each lane segment included in each prospective lane.

Also, at this time, the total-cost calculator 13 sums the static cost obtained by the static-cost calculation control and the status cost obtained by the status-cost calculation control.

In the example described above with reference to FIG 5(B), the prospective route with the smallest total value of the static cost and the status cost is indicated by the thick arrow in FIG 5(B).

[0113]

Thereafter, in step S7, the dynamic-cost calculator 12 executes the dynamic-cost calculation control for each lane segment of each prospective route.

That is, the dynamic-cost calculator 12 sets the dynamic cost of each lane segment according to the loaded/empty state of the tray and the class of the tray.

At this time, the total-cost calculator 13 sums the static cost obtained by the static-cost calculation control, the status cost obtained by the static-cost calculation control, and the dynamic cost obtained by the dynamic-cost calculation control.

In the example using FIGs 6(A) and (B), the prospective route with the smallest sum of the static cost, the status cost and the dynamic cost is indicated by the thick arrows in each of FIGs 6(A) and (B).

[0114]

In step S8, the route decider 14 executes the route-decision control.

That is, the route decider 14 designates one of the prospective routes reflecting the static cost, the status cost and the dynamic cost, and sets the

designated route as the conclusive route.

Accordingly, as described above, in the A-lane group 24, if the tray departing from the lane 101 and arriving at the lane 105 is a standard tray with the loaded state, the route indicated by the thick arrows in FIG 6(A), that is, the first predicted route is set as the conclusive route.

On the other hand, if this tray is an empty long tray, the route indicated by the thick arrows in FIG 6(B), that is, the fourth predicted route is set as the conclusive route.

[0115]

After that, if there is no need to execute any other control with priority (i.e., No in step S9), the conveyor controller 5 executes the conveyor control in step S11.

That is, the conveyor controller 5 controls the baggage tray system 2 via the BTS controller 3 so as to dispatch the tray to the destination along the lanes corresponding to the conclusive route set in step S8.

When the tray is already loaded, the destination (lane-segment destination) of this loaded tray has been set in step S2.

On the other hand, if the tray is empty, the destination (lane-segment destination) of this empty tray has been set in step S14 or step S16 shown in FIG 18.

[0116]

If it is necessary to execute another control with priority (i.e., Yes in step S9), a subroutine program relating to override control is executed (step S10).

Note that this override control will be described later with reference to FIG 19.

[0117]

The empty-tray management control is executed according to the flowchart shown in FIG 18.

First, in step S13, the due-tray dispatcher 21 determines whether or not

a tray is a due tray.

That is, the due-tray dispatcher 21 determines whether or not the tray is empty, and either the travel distance of the tray has reached the distance threshold or the cumulative loading number of transport objects reaches a predetermined loading-number threshold.

[0118]

If the determination result in step S13 is affirmative (i.e., Yes in step 013), the due-tray dispatcher 21 executes the maintenance control in step S14.

That is, in step S14, the due-tray dispatcher 21 sets the destination of this tray recognised as a due tray to the maintenance lane.

[0119]

On the other hand, if the determination result in step S13 is negative (i.e., No in step 013), the empty-tray dispatcher 17 executes the empty-tray-allocation control in steps S15 and S16.

That is, in step S15, the empty-tray dispatcher 17 calculates the empty-tray priority based on at least one of the four factors: (a) the receivable capacity of empty trays, (b) the waiting number of transport objects, (c) the in-stock number of empty trays, and (d) the under-way number of empty trays.

[0120]

Thereafter, in step S16, the empty-tray dispatcher 17 sets either the tray-demand area or the tray-supply area as the destination of the empty tray based on the empty-tray priority calculated in step S15.

[0121]

The override control is executed according to the flowchart shown in FIG 19.

First, in step S17, the divergent-blockage preventer 16 determines whether a divergent-point blockage (see the tray 3004 in FIG 11B) occurs.

Here, when the divergent-blockage preventer 16 predicts that a divergent-point blockage will occur (i.e., Yes in step S17), then in step S18,

the divergent-blockage preventer 16 judges whether or not there is an available lane at this divergent point.

Then, when the divergent-blockage preventer 16 determines that there is an available lane (i.e., Yes in step S18), the divergent-blockage preventer 16 sets the detour route for detouring the tray to the available lane instead of an original lane that was part of the original route (step S19).

[0122]

On the other hand, in step S17, when the divergent-blockage preventer 16 predicts that the divergent-point blockage due to this tray will not occur (i.e., No in step S17) and this tray is headed to a congestion area (step S20 Yes), then the gridlock preventer 15 executes the gridlock-prevention control (steps S21 and S22).

In this embodiment, as described with reference to FIG 7, the congestion capacity of the circular-lane segment 6008 (i.e., congestion area) is set as four.

Accordingly, in this embodiment, in step S21, the gridlock preventer 15 determines whether four or more trays are present in the congestion area.

When the gridlock preventer 15 determines that four or more trays exist in the congestion area (i.e., Yes in step S21), the gridlock preventer 15 prevents this tray from entering the congestion area (step S22).

[0123]

On the other hand, if this tray is not directed to the congestion area (i.e., No in step S20) but is directed to the buffer lane (i.e., Yes in step S23), the tray releaser 19 executes the tray-release control depending on the situation (steps S24 and S25).

That is, as indicated by the dotted line in FIG 14, the empty tray 4017', in step S24, the tray releaser 19 predicts whether or not a buffer-lane blockage will occur.

Here, when the tray releaser 19 predicts that a buffer-lane blockage will

occur (Yes in step S24), the tray releaser 19 forcibly forces at least one of the empty trays 4011-4016 held in the buffer lane 402 (only the tray 4011 is waiting at the loading point in the example shown in FIG 15) toward the downstream lane 403 (step S25).

[0124]

The present invention is not limited to the above-described embodiment. It is envisaged that the present invention can be modified and implemented in various manners.

[0125]

For example, in the above-described embodiment, the conveyance system is the baggage tray system, but it is not limited to this configuration.

The control apparatus and control method according to the present invention can also be applied to various types of tray-conveyor systems that are not specialised for baggage transportation.

The transport objects to be conveyed is not limited to being placed on the trays. In other words, it is possible to apply the control apparatus and control method according to the present invention to many types of conveyor systems individually conveying carriers which are forwarding-cases (e.g., trays, pallets, tubs, foldable containers, non-foldable containers, and so on) in/on which transport objects are put.

In addition, except for the features only related to the forwarding-containers such as trays, it is possible to apply the control apparatus and control method according to the present invention to a number of belt conveyor systems.

Also, the control apparatus and control method according to the present invention can be applied to belt conveyor systems in which the forwarding-cases containing transport objects are forwarded by its belt conveyors.

[0126]

Although two types of trays (standard tray and long tray) have been

described in the above-described embodiment, the present invention is not limited to this arrangement.

For example, two or more types of the trays may be used. Alternatively, one type of the trays may also be used.

[0127]

In the above-described embodiment, the flow-control server 1 constantly monitors the tray state based on the detection results obtained from the RFID sensors and photoelectric sensors provided in the BTS network 4. However, the present invention is not limited to this arrangement.

For example, the conveying elements (i.e., the transport objects and/or trays) may be captured by optical cameras. Then, the state of the conveying elements may be always monitored by analysing the captured image.

[0128]

In the above-described embodiment, the case where the circular-lane segment 6008 of the B-lane group 25 is set as the congestion area has been described as an example, but the present invention is not limited to this configuration.

An area where congestion should be avoided may be defined as the congestion area.

[0129]

In the above embodiment, the case where the dynamic-cost calculator 12 considers the element status as the dynamic factor has been described, but the present invention is not limited to this configuration.

For example, the dynamic cost calculator may consider not only the element status, but also the time status and/or the transport status as dynamic factors.

[0130]

In the above-described embodiment, the element status includes the tray state and the tray type, but it is not limited to this configuration.

For example, the element status may further include the transport-object state and the transport-object type.

The 'transport-object state' is a factor indicating the current state of a transport object.

For example, factors such as "completion/non-completion of an explosive-check for a transport object" and/or "whether operator assistance is required for a transport object" correspond to the transport-object state.

The transport-object type is a factor that indicates the current status of a transport object. For example, factors such as the size (i.e., height, depth, and width) and class (e.g., soft bag, suitcase, parcel, and etc.) of a transport object correspond to the transported object type.

[0131]

The tray state is not limited to the case described in the above embodiment.

For example, for a tray, factors such as 'loaded with a load error', 'empty but allocated', and 'discharged to be confirmed' may be set as those corresponding to the tray state.

[0132]

In the above-described embodiment, the case where the distance threshold is set at 5000 km has been described, but the present invention is not limited to this arrangement.

Further, in the above-described embodiment, the case where the loading-number threshold is set at 500 times has been described, but the present invention is not limited to this arrangement.

The distance and loading-number thresholds can be set depending on various factors such as configurations of baggage tray systems and the durability of trays.

[0133]

In the above-described embodiment, the dynamic factor is based on the

element status, but it is not limited to this arrangement.

For example, the dynamic factor may be set to be based on 'time status'.

Further, the time status may relate to at least one of 'time ranges of a day', 'days of a week' and 'type of a touristic season'.

According to this arrangement, for example, the dynamic-cost calculator can calculate different dynamic costs depending on when a condition "Friday, 6:00 pm to 7:00 pm, Christmas period (holiday season)" is met, and when another condition "Monday, 8:00 am to 9:00 am, general period (non-holiday season)" is met.

[0134]

In the above-described embodiment, the case where the baggage tray system 2 is installed at the airport has been described as an example, but the present invention is not limited to this configuration.

In other words, the control apparatus and control method according to the present invention can be applied to conveyance systems in any kind of facilities (e.g., factories, warehouses, postal freight facilities, courier freight facilities, train stations, ports, and etc.).

[0135]

That is, the conveyance system may be installed in transport facilities such as airports, railway stations, bus terminals, and ship ports.

In this configuration, the dynamic factor may be set to be based on 'transport status'.

The transport status may relate to at least one of "a departure time of public transport" (e.g., an airplane's departure time)" and "the number of operations of the public transport in a time window" (e.g., the number of flights in a particular time range).

[0136]

For example, assume that the departure time of an airplane on which a passenger's suitcase is to be loaded is 9:30 am.

In this example, the dynamic-cost calculator calculates different dynamic costs depending on the check-in time of the suitcase such as 7:00 am or 9:00 am.

[0137]

As another example, assume that "there are 12 flights departing from an airport during the time range of 2:00 to 3:00 pm" and "there are 36 flights departing from the airport during the time period of 5:00 pm to 6:00 pm".

In this example, the dynamic-cost calculator can individually calculate the dynamic cost for the time range of 2:00 to 3:00 pm and the dynamic cost for the time range of 5:00 to 6:00 pm.

[0138]

In the above embodiment, the candidate finder 8 sets multiple prospective routes according to the destination of the tray, and the static-cost calculator 10 calculates the static cost for each of these prospective routes. However, the present invention is not limited to this configuration.

For example, the candidate finder may search and register all possible prospective routes from one lane segment to another in advance.

In addition, the static-cost calculator may calculate and register the static costs of all prospective routes in advance.

Also, each of the pre-searched prospective routes and the corresponding static cost may be associated and registered as an XML format file in advance.

[0139]

As described in detail above, according to the conveyance-system control apparatus and conveyance-system control method of the present invention, the operating efficiency of the conveyance system can be further improved.

[0140]

In addition, simple processing based on the possible cost allows faster setting of the conclusive route.

[0141]

Further, by setting the conclusive route with the lowest possible cost, conveyance using a route with high efficiency can be realised in practice.

[0142]

Still further, in a conveyance system, it is possible to set the dense area as an area in which preventing congestion is highly required.

Also, by preventing congestion in this congestion area, it is possible to improve the operating efficiency of a conveyance system as a whole.

[0143]

In addition, by preventing the divergent-point blockage, it is possible to improve the operating efficiency of a conveyance system as a whole.

[0144]

Also, even when a baggage tray system is employed as the conveyance system, the operational efficiency of the baggage tray system can be further improved.

[0145]

Further, the static cost can be obtained by a simple arithmetic operation based on the length of each lane segment and the forwarding speed of each lane segment in the baggage tray system.

[0146]

The dynamic cost may be associated with at least one of the tray state, the tray type, the transport-object state, and the transport-object type.

As a result, it is possible to efficiently operate the baggage tray system while reflecting the conditions of the trays and transport objects in real time.

[0147]

In addition to managing each loaded tray, each empty tray may be managed individually.

This arrangement makes it possible to realise control specific to empty trays.

[0148]

In addition, it is possible to realise detailed control according to the purpose of 'use' or 'store' of empty trays.

[0149]

Also, by taking into account the empty-tray priority, it is possible to achieve more efficient allocation of the empty trays.

[0150]

In addition, by cooperatively controlling the loading unit and the buffer lane, the transport objects can be efficiently and accurately loaded onto each tray.

[0151]

In addition, by timely executing the tray-release control, it is possible to improve the operational efficiency of the conveyance system as a whole.

[0152]

Further, by automatically dispatching the due trays to the maintenance lane, it is possible to efficiently avoid troubles in advance caused by failures of the trays.

[0153]

Moreover, even when a belt conveyor system is adopted as the conveyance system, the operational efficiency of the belt conveyor system can be further improved.

[0154]

Also, the static cost can be obtained by simple arithmetic processing based on the length of each lane segment and the forwarding speed of each lane segment in the belt conveyor network.

[0155]

Further, the dynamic cost may be associated with at least one of the transport-object state and the transport-object type.

According to this arrangement, the belt conveyor network can be

operated efficiently with reflecting the status of the transport objects in real time.

[0156]

In addition, dynamic costs may also reflect time status such as time of day, day of week, and type of tourist season.

[0157]

Also, the dynamic cost may reflect factors specific to transport systems such as airplanes and buses.

According to this arrangement, it is possible to realise detailed operation of the conveyance system according to the type of means of transportation.

[0158]

The history regarding the operation of the conveyance system may be analysed, and the analysis result can be output as necessary.

As a result, it is possible to increase satisfaction of users of the conveyance system.

This arrangement also allows future improvements in the operation of the conveyance system.

[0159]

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" are used in an inclusive sense, i.e., to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

[0160]

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that the prior art forms part of the common general knowledge.

[0161]

Reference Signs List

- 1 flow-control server (conveyance-system control apparatus/ control apparatus)
- 2 baggage tray system (tray-conveyor system/ baggage handling system/ conveyance system)
- 3 BTS controller
- 4 BTS network (tray-conveyor network)
- 5 conveyor controller
- 6 status monitor
- 7 loaded-tray dispatcher
- 8 candidate finder
- 9 cost estimator
- 10 static-cost calculator
- 11 status-cost calculator
- 12 dynamic-cost calculator
- 13 total-cost calculator
- 14 route decider
- 15 gridlock preventer
- 16 divergent-blockage preventer
- 17 empty-tray dispatcher
- 18 loading controller
- 20 history recorder
- 21 due-tray dispatcher
- 22 element-history analyser
- 23 analysis concierge
- 24 A-lane group
- 25 B-lane group
- 26 C-lane group

- 27 D-lane group
- 28 divergent point
- 29 loading point
- 6008 circular-lane segment (congestion area)

Claims

1. A control apparatus of a conveyance system having a plurality of lanes, through which a conveyance element travels, the control apparatus comprising:

a candidate finder for setting a plurality of prospective routes each including a plurality of segments of the lanes through which the conveyance element may travel to a destination;

a cost estimator for calculating a possible cost of each lane segment of the prospective routes;

a route decider for setting a conclusive route, which has a combination of the lane segments, by designating one of the prospective routes based on the possible cost calculated by the cost estimator; and

a conveyor controller for controlling the conveyor system to dispatch the conveyance element to the destination along the lanes corresponding to the conclusive route set by the route decider, wherein

the cost estimator includes,

a static-cost calculator for calculating a static cost which is an effort value related to a static-required time if the conveyance element travels to the destination through the respective lane segments,

a status-cost calculator for calculating a status cost which is an effort value related to lane status of the respective lane segments,

a dynamic-cost calculator for calculating a dynamic cost which is an effort value in accordance with a dynamic factor, and

a total-cost estimator for setting the possible cost by totalising the static cost, the status cost and the dynamic cost calculated by the static-cost calculator, the status-cost calculator and the dynamic-cost calculator, respectively.

2. The control apparatus according to 1, wherein

the prospective routes include,

a basic route having a basic combination of the lane segments through which the conveyance element may travel to the destination, and

a plurality of alternative routes, which are defined in a route list, each having an alternative combination of the lane segments, which is different to the basic combination, through which the conveyance element may travel to the destination,

the cost estimator calculates the possible cost of the lane segments of each of the basic and alternative routes, and

the route decider sets the conclusive route by designating one of the basic route and the alternative routes based on the possible cost calculated by the cost estimator.

3. The control apparatus according to claim 1 or 2, wherein

the route decider sets the conclusive route by designating one of the prospective routes which has the lowest possible cost.

4. The control apparatus according to any one of claims 1 to 3, further comprising:

a gridlock preventer for restricting additional entry of the conveyance element into a congestion area, which is an area defined in the conveyance system, if an existing number of the conveyance element in the congestion area has reached a congestion capacity of the congestion area.

5. The control apparatus according to any one of claims 1 to 4, further comprising:

a divergent-blockage preventer for preventing a divergent-point blockage at a divergent point from which the plurality of lanes are branched,

the divergent-blockage preventer controls the conveyor system, irrespective of the conclusive route set by the route decider, to divert the

conveyance element to an available lane of the branch lanes, if the divergent-blockage preventer predicts that the conveyance element stops at the divergent point for entering into a blocked lane of the branch lanes.

6. The control apparatus according to any one of claims 1 to 5, wherein the conveyor system is a tray-conveyor system including a tray-conveyor network in which a tray travels for carrying a transport object on the tray.

7. The control apparatus according to claim 6, wherein the static-cost calculator calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments.

8. The control apparatus according to claim 7, wherein the dynamic factor is based on element status of the conveyance element,

the element status is related to at least one of:

- tray state of the tray;
- tray type of the tray;
- transport-object state of the transport object put on the tray; and
- transport-object type of the transport object put on the tray.

9. The control apparatus according to any one of claims 6 to 8, further comprising:

an empty-tray managing module for managing each empty tray in the tray-conveyor network.

10. The control apparatus according to claim 9, wherein the empty-tray control module includes an empty-tray dispatcher,

the empty-tray dispatcher carries out an empty-tray-allocation control for dispatching each of the empty trays to either a tray-demand area or a tray-supply area.

11. The control apparatus according to claim 10, wherein

the empty-tray dispatcher carries out the empty-tray-allocation control for the tray-demand area in accordance with an empty-tray priority calculated based on at least one of:

a receivable capacity related to a number of available slots in which the empty trays can be accommodated in the tray-demand area;

a waiting number of the transport objects lining up for being placed onto the respective empty trays in the tray-demand area;

an in-stock number of the empty trays lining up for receiving the transport objects in the tray-demand area; and

an under-way number of the empty trays travelling towards the tray-demand area.

12. The control apparatus according to any one of claims 6 to 11, further comprising:

a loading controller for controlling both a loading unit and a buffer lane, wherein

the tray-conveyor system further includes,

the loading unit for respectively placing each of the plurality of transport objects onto each of the plurality of empty trays, and

the buffer lane for keeping the empty trays on standby for receiving the transport objects fed from the loading unit, and

the loading controller controls the loading unit and the buffer lane by carrying out an empty-tray-synchronising control so as to synchronise each empty tray at a loading point, which is adjacent to the loading unit in the buffer lane, with each of the transport objects fed from the loading unit.

13. The control apparatus according to claim 12, further comprising:

a tray releaser for preventing a buffer-lane blockage at a buffer-lane inlet from which the plurality of lanes including the buffer lane are branched, wherein

if the tray releaser predicts that another empty tray, which is approaching to the buffer lane, stops at the buffering-lane inlet to enter the buffer lane, then the tray releaser forcibly releases at least one of the empty trays kept in the buffer lane towards a downstream and permits the approaching empty tray entering into the buffer lane.

14. The control apparatus according to any one of claims 1 to 13, further comprising:

a history recorder for recording a tray history of each of the trays; and

a due-tray dispatcher for dispatching a due tray to a maintenance lane in which maintenance work is performed on the due tray, wherein

the due tray is an empty tray of which the tray history satisfies a maintenance-required condition.

15. The control apparatus according to any one of claims 1 to 5, wherein

the conveyor system is a belt conveyor system including a belt-conveyor network having a plurality of belt-conveyor lanes by which a transport object is carried.

16. The control apparatus according to claim 15, wherein

the static-cost calculator calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments of the belt-conveyor network.

17. The control apparatus according to claim 16, wherein

the dynamic factor is based on element status of the conveyance element,

the element status is related to at least one of:

transport-object state of the transport object; and

transport-object type of the transport object put on the tray.

18. The control apparatus according to any one of claims 1 to 17, wherein

the dynamic factor is based on time status,

the time status is related to at least one of:

time ranges of a day;

days of a week; and

type of a touristic season.

19. The control apparatus according to any one of claims 1 to 18, wherein

the conveyance system is installed in a transport facility,

the dynamic factor is based on transport status,

the transport status is related to at least one of:

a departure time of public transport; and

a number of operations of the public transport in a time window.

20. The control apparatus according to any one of claims 1 to 19, further comprising:

a element-history analyser for analysing an element history of the conveyance element; and

an analysis concierge for explaining a result of the element-history analysis carried out by the element-history analyser to a questioner.

21. A control method of a conveyance system having a plurality of lanes,

through which a conveyance element travels, the control method comprising steps of:

- setting a plurality of prospective routes each including a plurality of segments of the lanes through which the conveyance element may travel to a destination;

- calculating a possible cost of each lane segment of the prospective routes;

- setting a conclusive route, which has a combination of the lane segments, by designating one of the prospective routes based on the possible cost calculated by the cost estimator; and

- controlling the conveyor system to dispatch the conveyance element to the destination along the lanes corresponding to the conclusive route set by the route decider, wherein

- the possible-cost-calculating step includes steps of,

- calculating a static cost which is an effort value related to a static-required time if the conveyance element travels to the destination through the respective lane segments,

- calculating a status cost which is an effort value related to lane status of the respective lane segments,

- calculating a dynamic cost which is an effort value in accordance with a dynamic factor, and

- setting the possible cost by totalising the static cost, the status cost and the dynamic cost calculated by the static-cost-calculating step, the status-cost calculating step and the dynamic-cost calculating step, respectively.

22. The control method according to 21, wherein

- the prospective routes include,

- a basic route having a basic combination of the lane segments through which the conveyance element may travel to the destination, and

- a plurality of alternative routes, which are defined in a route list,

each having an alternative combination of the lane segments, which is different to the basic combination, through which the conveyance element may travel to the destination,

the step possible-cost calculating step calculates the possible cost of the lane segments of each of the basic and alternative routes, and

the conclusive-route setting step sets the conclusive route by designating one of the basic route and the alternative routes based on the possible cost calculated by the possible-cost calculating step.

23. The control method according to claim 21 or 22, wherein

the conclusive-route setting step sets the conclusive route by designating one of the prospective routes which has the lowest possible cost.

24. The control method according to any one of claims 21 to 23, further comprising a step of:

restricting additional entry of the conveyance element into a congestion area, which is an area defined in the conveyance system, if an existing number of the conveyance element in the congestion area has reached a congestion capacity of the congestion area.

25. The control method according to any one of claims 21 to 24, further comprising a step of:

preventing a divergent blockage at a divergent point from which the plurality of lanes are branched,

the divergent-blockage preventing step controls the conveyor system, irrespective of the conclusive route set by the route decider, to divert the conveyance element to an available lane of the branch lanes, if the conveyance element is predicted to stop at the divergent point for entering into a blocked lane of the branch lanes.

26. The control method according to any one of claims 21 to 25, wherein the conveyor system is a tray-conveyor system including a tray-conveyor network in which a tray travels for carrying a transport object on the tray.

27. The control method according to claim 26, wherein the static-cost calculating step calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments.

28. The control method according to claim 27, wherein the dynamic factor is based on element status of the conveyance element,

the element status is related to at least one of:

tray state of the tray;

tray type of the tray;

transport-object status of the transport object put on the tray;

and

transport-object type of the transport object put on the tray.

29. The control method according to any one of claims 26 to 28, further comprising a step of:

managing each empty tray in the tray-conveyor network.

30. The control method according to claim 29, wherein

the empty-tray managing step includes a step of

carrying out an empty-tray-allocation control that dispatches each of the empty trays to either a tray-demand area or a tray-supply area.

31. The control method according to claim 30, wherein

the empty-tray dispatching step carries out the empty-tray-allocation control for the tray-demand area in accordance with an empty-tray priority calculated based on at least one of:

- a receivable capacity related to a number of available slots in which the empty trays can be accommodated in the tray-demand area;

- a waiting number of the transport objects lining up for being placed onto the respective empty trays in the tray-demand area;

- an in-stock number of the empty trays lining up for receiving the transport objects in the tray-demand area; and

- an under-way number of the empty trays travelling towards the tray-demand area.

32. The control method according to any one of claims 26 to 31, further comprising a step of:

- load controlling both a loading unit and a buffer lane, wherein

- the tray-conveyor system further includes,

- the loading unit for respectively placing each of the plurality of transport objects onto each of the plurality of empty trays, and

- the buffer lane for keeping the empty trays on standby for receiving the transport objects fed from the loading unit, and

- the load controlling step controls the loading unit and the buffer lane by carrying out an empty-tray synchronising control so as to synchronise each empty tray at a loading point, which is adjacent to the loading unit in the buffer lane, with each of the transport objects fed from the loading unit.

33. The control method according to claim 32, further comprising a step of:

- preventing a buffer-lane blockage at a buffer-lane inlet from which the plurality of lanes including the buffer lane are branched by such a manner that

- if another empty tray, which is approaching to the buffer lane, is

predicted to stop at the buffering-lane inlet to enter the buffer lane, then forcibly releasing at least one of the empty trays kept in the buffer lane towards a downstream and permits the approaching empty tray entering into the buffer lane.

34. The control method according to any one of claims 21 to 33, further comprising steps of:

recording a tray history of each of the trays; and

dispatching a due tray to a maintenance lane in which maintenance work is performed on the due tray, wherein

the due tray is an empty tray of which the tray history satisfies a maintenance-required condition.

35. The control method according to any one of claims 21 to 25, wherein

the conveyor system is a belt conveyor system including a belt-conveyor network having a plurality of belt-conveyor lanes by which a transport object is carried.

36. The control method according to claim 35, wherein

the static-cost calculating step calculates the static cost based on a length of the respective lane segments and a forwarding speed of the respective lane segments of the belt-conveyor network.

37. The control method according to claim 36, wherein

the dynamic factor is based on element status of the conveyance element,

the element status is related to at least one of:

transport-object state of the transport object; and

transport-object type of the transport object put on the tray.

38. The control method according to any one of claims 30 to 37, wherein the dynamic factor is based on time status, the time status is related to at least one of:

- time ranges of a day;
- days of a week; and
- type of a touristic season.

39. The control method according to any one of claims 21 to 38, wherein the conveyance system is installed in a transport facility, the dynamic factor is based on transport status, the transport status is related to at least one of:

- a departure time of public transport; and
- a number of operations of the public transport in a time window.

40. The control method according to any one of claims 21 to 39, further comprising steps of:

- analysing an element-history of the conveyance element; and
- explaining a result of the analysis carried out by the element-history analysis step to a questioner.