

AUTOMATIC CRANE OPERATION DEVICE

BACKGROUND

[0001] Field

The following description relates to an automatic crane operation device.

[0002] Description of Related Art

Japanese Laid-Open Patent Publication No. 2019-112178 discloses an automatic operation system for a tower crane. This automatic operation system reads a position of a distal end of a jib of the tower crane and a position at which a building member (suspended load) is to be installed on a coordinate system. Then, the system uses a design drawing of a building and coordinates indicating a transfer time to calculate the positional relationship (distance) between the two positions, and determines necessary motions, such as hoisting of the suspended load, luffing of the jib, and turning of a rotary body, as well as necessary motion times. In this manner, the system decides a movement speed, and outputs an automatic operation initiation signal.

[0003] In automatic operation of a tower crane such as that described in Japanese Laid-Open Patent Publication No. 2019-112178, a control parameter set for controlling an operation amount of the crane may affect safety and accuracy of the operation.

[0004] When deciding a control parameter for automatic operation of a crane, an actual crane may be operated to determine a crane operation amount in a range that minimizes load swings (swinging of suspended load) or overlaps. Then, a control parameter corresponding to that range may be used to calculate the control parameter for automatic operation.

[0005] However, multiple control parameters for various motions, such as hoisting, turning, or luffing, may need to be adjusted for each of various weight patterns of the

suspended load, thereby lowering work efficiency. Furthermore, external factors, such as wind speed at a construction site, may lower the accuracy of the control parameters. On the other hand, if a suspended load is actually lifted in a state in which the degree of load swing or overlap is unknown, the suspended load may collide with nearby objects and hinder safety assurance.

[0006] An objective of the present disclosure is to provide an automatic crane operation device that improves accuracy of a control parameter for automatic operation of a crane.

SUMMARY

[0007] In one general aspect, an automatic crane operation device is for executing automatic control of a drive device of a crane to move a suspended load support of the crane. The suspended load support being configured to support a suspended load. The device includes a position condition setting means, a suspended load condition setting means, a weather condition setting means, a crane condition setting means, a suspended load swing amount setting means, a transfer time setting means, a simulating means, and a crane controlling means. The position condition setting means sets a start position and an end position of the suspended load. The suspended load condition setting means sets a suspended load condition including a size of the suspended load and a suspended load weight. The weather condition setting means sets a weather condition including a wind direction and a wind speed. The crane condition setting means sets a crane condition including deflection information of the crane. The suspended load swing amount setting means sets a maximum permissible amount of swing of the suspended load. The transfer time setting means sets a maximum permissible amount of a transfer time of the suspended load from the start position to the end position. The simulating means performs simulation of movement of the

suspended load support of the crane based on the start position, the end position, the suspended load condition, the weather condition, the crane condition, the maximum permissible amount of swing of the suspended load, and the maximum permissible amount of the transfer time, generates a route for the suspended load support, and calculates a control parameter for executing automatic control of the drive device of the crane. The crane controlling means executes automatic control of the drive device of the crane to move the suspended load support of the crane in accordance with the route and the control parameter.

[0008] In an embodiment, the automatic crane operation device may further include a display, and a display processing means that displays a result of the simulation on the display. The simulating means may be configured to perform the simulation using a three-dimensional model. The display processing means may be configured to display the three-dimensional model and a movement path of the suspended load support on the display.

[0009] In an embodiment, the simulating means may be configured to calculate the control parameter that minimizes the transfer time.

[0010] In an embodiment, the simulating means may be configured to calculate the control parameter that minimizes a swing amount of the suspended load.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Fig. 1 is a schematic diagram showing the overall configuration of a crane automatically operated by an automatic crane operation device in accordance with an embodiment.

Fig. 2 is a block diagram of the automatic crane operation device.

Fig. 3 is a diagram illustrating an example of a hardware configuration.

Fig. 4 is a block diagram showing details of a condition setter.

Fig. 5 is a diagram illustrating an example of a screen showing a simulation result on a display.

Fig. 6 is a flowchart of a process executed by the automatic crane operation device.

DETAILED DESCRIPTION

[0012] An embodiment of the present invention will now be described with reference to the drawings.

[0013] An automatic crane operation device 100 in accordance with an embodiment of the present invention (hereinafter, simply referred to as “the automatic operation device 100”) executes automatic control of a drive device of a crane 1 and moves a suspended load support 2 of the crane 1. The suspended load support 2 is configured to support a suspended load O. In the following description, an expression “executes automatic control of the crane 1” means executing automatic control of the drive device of the crane 1 to move the suspended load support 2 of the crane 1.

[0014] As shown in Fig. 1, the crane 1 of the present embodiment is a fixed type tower crane. The crane 1 includes a mast 4, a turning body 5, a jib 6, and the suspended load support 2. The mast 4 is fixed to a foundation 3 and extends in a vertical direction. The turning body 5 is supported by an upper part of the mast 4 in a manner allowing for turning. The jib 6 is supported by the turning body 5 in a manner allowing for raising and lowering. The suspended load support 2 is suspended from a distal end of the jib 6. The mast 4 may be fixed to a building. The crane 1 is automatically controllable, which will be described later, and may also be manually operable.

[0015] The turning body 5 is supported by the upper part of the mast 4 in a manner allowing for turning, with a turning device (drive device) 7 arranged in between. The turning

body 5 is configured to be turned about an axis (turning axis) that extends in the vertical direction. The turning body 5 may be supported by the mast 4 in a manner allowing for elevating and lowering in the vertical direction.

[0016] The turning body 5 includes a luffing winch (drive device) 8, a hoisting winch (drive device) 9, and a support frame 10. The luffing winch 8 allows for raising and lowering of the jib 6. The hoisting winch 9 allows for lifting and lowering of the suspended load support 2. The support frame 10 extends upward from the turning body 5.

[0017] A luffing wire rope 11 is wound around the luffing winch 8. The luffing wire rope 11 extends from the luffing winch 8 via the support frame 10 to the jib 6, and is connected to the distal end of the jib 6. The luffing winch 8 is operated to wind or unwind the luffing wire rope 11 so that the jib 6 is raised or lowered about a basal end of the jib 6.

[0018] A hoisting wire rope 12 is wound around the hoisting winch 9. The hoisting wire rope 12 extends from the hoisting winch 9 via the support frame 10 to the distal end of the jib 6, and extends downward from the distal end of the jib 6. The hoisting wire rope 12 has a distal end connected to the suspended load support 2. The hoisting winch 9 is operated to wind or unwind the hoisting wire rope 12 so that the suspended load support 2 is lifted or lowered in the vertical direction. The suspended load support 2 is not particularly limited as long as the suspended load support 2 is configured to support the suspended load O. For example, the suspended load support 2 may be a hook block or a bucket.

[0019] As shown in Figs. 1 and 2, the crane 1 includes various types of sensors that obtain different state quantities of the crane 1. In the present embodiment, the crane 1 includes a turning angle encoder 13, a luffing angle encoder 14, and a hoisting position encoder 15. The turning angle encoder 13 obtains a turning angle of the turning body 5. The luffing angle encoder 14 obtains a luffing angle of the jib 6. The hoisting position encoder 15 obtains a

hoisting position of suspended load support 2. The turning angle encoder 13 obtains the turning angle of the turning body 5 from the number of rotations of the turning device 7. This obtains a turning angle of the jib 6. The luffing angle encoder 14 obtains the luffing angle of the jib 6 from the number of rotations of the luffing winch 8. The hoisting position encoder 15 obtains the hoisting position of the suspended load support 2 from the number of rotations of the hoisting winch 9. Since the crane 1 is a fixed type tower crane, an installation position (latitude, longitude, and altitude) of the crane 1 can be identified. Also, the height of the mast 4 and the length of the jib 6 can be identified. Thus, the actual position (latitude, longitude, and altitude) of the distal end of the jib 6 can be identified by obtaining a predetermined reference position of the crane 1 (for example, turning axis center position at the top of the mast 4) and the various state quantities of the crane 1.

[0020] In the present embodiment, the various state quantities of the crane 1 are acquired from information provided by the turning angle encoder 13, the luffing angle encoder 14, and the hoisting position encoder 15. However, there is no limitation to such a configuration, and various state quantities of the crane 1 may be acquired by various methods. For example, various state quantities of the crane 1 may be acquired using a global positioning system (GPS) receiver or a global navigation satellite system (GNSS) receiver arranged on the distal end of the jib 6 or on the suspended load support 2.

[0021] As shown in Fig. 3, the automatic operation device 100 is a device configured to perform calculations, such as a computer. The automatic operation device 100 includes a central processing unit (CPU) 31, random-access memory (RAM) 32, read-only memory (ROM) 33, a display 34, and a communicator 35 that are connected via a bus 36 in a manner accessible to one another.

[0022] The CPU 31 is a central processing unit that deploys programs stored in the ROM

33 to the RAM 32, and executes various types of control and arithmetic processing according to the programs.

[0023] The RAM 32 is volatile memory that temporarily stores various types of data, calculation results by the CPU 31, or the like.

[0024] The ROM 33 is non-volatile memory that stores programs or the like (e.g., application for the automatic operation device 100 of the present embodiment).

[0025] The display 34 is a touch panel type display device capable of responding to various setting inputs. In addition to the display function, the display 34 also has a functionality of an input unit that receives various types of inputs. The automatic operation device 100 may include an input unit separate from the display 34.

[0026] The communicator 35 is a communication interface, such as a network interface, for controlling communication with an external device. The communication interface may be for either wired communication or wireless communication.

[0027] As shown in Figs. 1 and 2, the automatic operation device 100 includes a three-dimensional information obtainer (three-dimensional information obtaining means) 21, a condition setter (condition setting means) 22, a simulator (simulating means) 23, a display processor (display processing means) 24, and a crane controller (crane controlling means) 25. The CPU 31 of the automatic operation device 100 functions as the three-dimensional information obtaining means, the condition setting means, the simulating means, the display processing means, and the crane controlling means by performing information processing in cooperation with software, such as the programs stored in the ROM 33. Some of the functionality of the CPU 31 of the automatic operation device 100 may be extracted, and a different information processor may be provided with the extracted functionality. In this case, multiple information processors may be used for the processing.

[0028] The three-dimensional information obtainer 21 obtains, from a predetermined storing means, three-dimensional information for reproducing a construction site in a virtual space VS and displaying the reproduced construction site in three dimensions on the display 34 of the automatic operation device 100. The predetermined storing means storing such three-dimensional information may include a predetermined storage unit (storage) of the automatic operation device 100. Alternatively, the predetermined storing means may be constructed in a database server. When the predetermined storing means is constructed in a database server, the database server may be arranged in a local network. Alternatively, the database server may be a cloud server that stores information via the Internet.

[0029] The three-dimensional information for reproducing a construction site in the virtual space VS and displaying the reproduced construction site in three dimensions on the display 34 of the automatic operation device 100 may include, for example, point cloud data of the construction site, a digital twin generated based on the point cloud data of the construction site, or a building information modeling (BIM) or construction information modeling (CIM) model (hereinafter, “BIM/CIM model”) in which attribute information is added to the digital twin of construction site. Point cloud data refers to, for example, data indicating a set of points associated with three-dimensional coordinates. A digital twin refers to, for example, data that produces a replica of a physical space in a digital space (virtual space) based on information acquired from the physical space. A BIM/CIM model refers to a three-dimensional model related to a building or a construction site.

[0030] In the present embodiment, the three-dimensional information obtainer 21 obtains three-dimensional information indicating the state of a construction site that corresponds to the actual construction progress from a cloud server (not shown), which is connected to the three-dimensional information obtainer 21 via a network. The three-dimensional information

stored in the cloud server may include three-dimensional information acquired from information obtained by, for example, a three-dimensional light detection and ranging (3D-LiDAR) sensor arranged at the distal end of the jib 6 of the crane 1. The 3D-LiDAR sensor obtains information of a construction site, including a construction subject near the crane 1, as three-dimensional point cloud data. The point cloud data obtained by the 3D-LiDAR sensor indicates the state of a construction site that corresponds to the actual construction progress. For example, when a frame body, such as a beam, a column, or the like, is installed in accordance with the construction progress, the newly installed frame body, such as a beam, a column, or the like, may be detected from the point cloud data. The data obtained by the 3D-LiDAR sensor is sent to the cloud server via the network.

[0031] When the 3D-LiDAR sensor is arranged at the distal end of the jib 6 of the crane 1, based on the position (latitude, longitude, and altitude) of the distal end of the jib 6 of the crane 1, three-dimensional point cloud data obtained by the 3D-LiDAR sensor that is specified by X, Y, and Z coordinates can be converted to latitudes, longitudes, and altitudes. This obtains a position (latitude, longitude, and altitude) at which a structural object is formed in accordance with the construction progress, and recognizes the state of the construction site (three-dimensional information) that corresponds to the actual construction progress. A GNSS receiver may be mounted on the crane 1 (for example, at the distal end of the jib 6) in order to obtain reference coordinates for latitudes, longitudes, and altitudes of three-dimensional point cloud data. The three-dimensional information obtainer 21 does not have to obtain three-dimensional information indicating the state of a construction site by the above-described method, and may use any other method capable of obtaining three-dimensional information indicating the state of a construction site that corresponds to the actual construction progress.

[0032] The condition setter 22 sets a condition used for simulation performed by the simulator 23, which will be described later. In a setting method performed by the condition setter 22, for example, the condition may be directly input from an input unit of the automatic operation device 100 by a crane operator or the like. Alternatively, the condition may be input from an external device through communication.

[0033] As shown in Fig. 4, the condition setter 22 includes multiple condition setters. Specifically, the condition setter 22 includes a position condition setter (position condition setting means) 221, a suspended load condition setter (suspended load condition setting means) 222, a weather condition setter (weather condition setting means) 223, a crane condition setter (crane condition setting means) 224, a suspended load swing amount setter (suspended load swing amount setting means) 225, and a transfer time setter (transfer time setting means) 226.

[0034] The position condition setter 221 sets a start position and an end position of movement of the suspended load O. The start position and the end position are set as position information (hereinafter, referred to as “suspended load position information”). For example, the position condition setter 221 uses position information of positions specified (input) on a three-dimensional model of a construction site in the virtual space VS, which will be described later, displayed on the display 34 as the suspended load position information related to the start position and the end position.

[0035] The suspended load position information may include any information that allows for identification of a position; for example, three-dimensional coordinate information (X coordinate, Y coordinate, and Z coordinate). Alternatively, when area IDs are set for positions or areas and stored in advance in association with three-dimensional coordinate information of the positions or the areas, one of the area IDs may be used as the suspended

load position information. The three-dimensional coordinate information serving as the suspended load position information may indicate a pinpoint position (X coordinate, Y coordinate, and Z coordinate) or a predetermined range (area) in two dimensions or three dimensions (X1-X2 coordinate, Y1-Y2 coordinate, and Z1-Z2 coordinate). Furthermore, the three-dimensional coordinate information may include information indicating latitude, longitude, and altitude. Alternatively, the three-dimensional coordinate information may include coordinate information (X coordinate, Y coordinate, and Z coordinate) that corresponds to a three-dimensional model of a construction site in the virtual space VS, which will be described later.

[0036] The suspended load condition setter 222 sets a suspended load condition including the size of the suspended load O and a suspended load weight (weight of the suspended load O). When setting the suspended load condition, the suspended load condition setter 222 may use a value (e.g., weight of suspended load O) input from an input unit of the automatic operation device 100 as the suspended load condition. Alternatively, for example, when ID numbers or the like are associated with suspended loads O in advance such that information (e.g., suspended load weight) of a suspended load O may be obtained from its ID number or the like, the suspended load condition setter 222 may identify a value indicating the suspended load weight or the like of the suspended load O from an ID number or the like that is input from an input unit of the automatic operation device 100, and use the identified value as the suspended load condition. In addition to the suspended load weight, the suspended load condition may include other information, such as the shape, type, or the like of suspended load O.

[0037] The weather condition setter 223 sets weather condition including a wind direction and a wind speed. The weather condition setter 223 may use the wind direction and the wind

speed input from an input unit of the automatic operation device 100 as the weather condition. Alternatively, when a wind speed sensor configured to measure the wind direction and the wind speed is arranged on the crane 1, the weather condition setter 223 may obtain the wind direction and the wind speed from the wind speed sensor in real time and use the measurements as the weather condition. In addition to the wind direction and the wind speed, the weather condition may include other information, such as temperature, presence or absence of rain, presence or absence of snow, or the like.

[0038] The crane condition setter 224 sets a crane condition including deflection information of the crane 1. When the suspended load O is suspended by the crane 1, the crane 1 may deflect due to deflection of the mast 4 or the jib 6, stretching of the luffing wire rope 11, or the like. The deflection information of the crane 1 indicates a relationship of the luffing angle, the deflection of the crane 1, and the suspended load weight. For example, the deflection information of the crane 1 indicates that when a load having a weight of 4 tons is suspended at a luffing angle of 43 degrees, the position of the distal end of the jib 6 is tilted forward (in a direction in which the jib 6 extends) by 1.5 degrees with respect to the position when the load is not suspended. In addition to the deflection information of the crane 1, the crane condition may include other information, such as the length of the mast or the jib, capacities of the crane (turning, luffing, and hoisting capacities) obtainable by lever operation (manual operation), or the like.

[0039] The suspended load swing amount setter 225 sets a maximum permissible amount of swing of the suspended load O. The suspended load O may swing due to turning or luffing of the crane 1, or external factors, such as wind. The maximum permissible amount of swing of the suspended load O includes a value indicating an extent to which swinging is permissible relative to a reference position at which the suspended load O is stationary. An

input of the maximum permissible amount of swing may be an input of a numerical value indicating a swing amount (e.g., distance from the reference position). Alternatively, an input of the maximum permissible amount of swing may be a selection of a swing amount from a drop-down list or a selection of a swing amount using a slider shown on the display 34.

[0040] The transfer time setter 226 sets a maximum permissible amount of transfer time of the suspended load O from a start position to an end position. An input of the maximum permissible amount of transfer time may be an input of a numerical value indicating time. Alternatively, an input of the maximum permissible amount of transfer time may be a selection of time from a drop-down list or a selection of time using a slider S (refer to Fig. 5) shown on the display 34.

[0041] The simulator 23 executes a program for simulating the motion of the crane 1 in accordance with various conditions set by the condition setter 22. In this manner, the simulator 23 performs simulation of movement of the suspended load support 2 of the crane 1, generates a route for the suspended load support 2, and calculates a control parameter (e.g., acceleration, deceleration, or the like) for executing automatic control of the drive device (turning device 7, luffing winch 8, and hoisting winch 9) of the crane 1. The program executed by the simulator 23 may include various types of typically used programs, such as commercially available products.

[0042] The conditions set for the simulator 23 include the start position, the end position, the suspended load condition, the weather condition, the crane condition, the maximum permissible amount of swing of the suspended load O, and the maximum permissible amount of transfer time. As described above, these conditions are set by the position condition setter 221, the suspended load condition setter 222, the weather condition setter 223, the crane condition setter 224, the suspended load swing amount setter 225, and the

transfer time setter 226.

[0043] The simulator 23 generates a route for the suspended load support 2, for example, using a three-dimensional model of a construction site. The three-dimensional model may be produced in the virtual space VS from three-dimensional information obtained by the three-dimensional information obtainer 21. The route for the suspended load support 2 includes a transfer route from the set start position to the set end position. The simulator 23 generates a safe route from the start position to the end position on a three-dimensional model of a construction site in accordance with the set size of the suspended load O, so that the suspended load O does not come into contact with nearby obstacles (e.g., constructed building or the like). Since the conditions set for the simulator 23 include the crane condition, the route generated by the simulator 23 is designed taking into consideration at least the deflection of the crane 1. Furthermore, since the conditions set for the simulator 23 include the weather condition, the route generated by the simulator 23 is designed taking into consideration at least the wind direction and the wind speed.

[0044] The simulator 23 performs simulation that moves the suspended load O, having the set suspended load weight, along the generated route weight within a range of the set maximum permissible amount of swinging and the set maximum permissible amount of transfer time, and calculates a control parameter for automatic control of the drive device of the crane 1 (hereinafter, simply referred to as “control parameter”). For example, the simulator 23 may calculate a control parameter that minimizes the transfer time within a range of the set maximum permissible amount of swing. Alternatively, the simulator 23 may calculate a control parameter that minimizes the swing amount of the suspended load O within a range of the set maximum permissible amount of the transfer time.

[0045] The simulator 23 can perform simulation even when the set weather condition

differs from the actual weather. Furthermore, the simulator 23 can perform simulation even when the set crane condition differs from the specifications of the crane 1 subject to automatic operation.

[0046] The display processor 24 executes processing that displays a result of the simulation of movement of the suspended load support 2 performed by the simulator 23 on the display 34. As shown in Fig. 5, for example, the display processor 24 reproduces a construction site in the virtual space VS based on the three-dimensional information obtained by the three-dimensional information obtainer 21, and displays the reproduced construction site on the display 34. Then, the display processor 24 displays, on the three-dimensional model, a route P1 of the suspended load support 2 (suspended load O) from the start position A to the end position B, and a movement path P2 of the suspended load O that includes swinging of the suspended load O when automatic control is executed using the decided control parameter. That is, the display processor 24 displays the three-dimensional model and the movement path P2 of the suspended load support 2 on the display 34. Further, the display processor 24 may display the transfer time when automatic control is executed using the decided control parameter. When the set value of the maximum permissible amount of swing is too small such that the transfer time cannot be included in the range of the maximum permissible amount, or when the set value of the maximum permissible amount of transfer time is too small such that the swing amount cannot be included in the range of the maximum permissible amount, the display processor 24 may display visual indication of such states (transfer time or swing amount is out of set ranges).

[0047] The crane controller 25 executes automatic control of the crane 1 in accordance with the route generated by the simulator 23 and the control parameter calculated by the simulator 23. Specifically, the crane controller 25 moves the suspended load support 2 by

executing automatic control of the turning device 7, the luffing winch 8, and the hoisting winch 9 of the crane 1 while obtaining the turning angle of the turning body 5, the luffing angle of the jib 6, and the hoisting position of suspended load support 2 from the turning angle encoder 13, the luffing angle encoder 14, and the hoisting position encoder 15. The crane controller 25 may execute automatic control of the drive device of the crane 1 while correcting the control parameter in accordance with external factors, such as information from a wind speed sensor mounted on the crane 1, load swing, or the like.

[0048] When at least one of the suspended load condition, the weather condition, and the crane condition used for the simulation performed by the simulator 23 differs from the actual suspended load O, the actual weather, or the actual specifications of the crane 1, the crane controller 25 does not have to execute automatic control of the crane 1. The actual suspended load O refers to the suspended load O serving as a subject that swings in automatic operation. The actual crane 1 refers to the crane subject to automatic operation. The actual suspended load O may be detected by, for example, a load detecting means, such as a load meter, arranged on the crane 1 to detect the weight of the suspended load O, or an image capturing means, such as a camera, arranged on the crane 1 to capture an image of the suspended load O. The actual weather may be detected by the above-mentioned wind speed sensor arranged on the crane 1, or obtained through the Internet. The actual specifications of the crane 1 may be stored in the automatic operation device 100 in advance.

[0049] Automatic Operation Process

An automatic operation process executed by the automatic operation device 100 will now be described with reference to Fig. 6. The automatic operation process is repeated from when the automatic operation device 100 is activated to when the automatic operation device 100 is deactivated.

[0050] As shown in Fig. 6, in the automatic operation process, the automatic operation device 100 first accepts all inputs of information used for simulation (step S1).

[0051] The display 34 of the automatic operation device 100 displays, for example, a three-dimensional model of a construction site in the virtual space VS (hereafter, simply referred to as “the three-dimensional model of the construction site”). A crane operator or the like (hereinafter, simply referred to as “the operator”) taps (selects) point A, serving as the start position, on the three-dimensional model of the construction site on the display 34. In this manner, the position condition setter 221 sets point A as the start position A. In the same manner as point A, the operator taps (selects) point B, serving as the end position, on the three-dimensional model of the construction site on the display 34. In this manner, the position condition setter 221 sets point B as the end position B. Further, the operator sets the suspended load condition, the weather condition, the crane condition, the maximum permissible amount of swing of the suspended load O, and the maximum permissible amount of transfer time on the display 34.

[0052] In the present embodiment, the start position and the end position are specified on the three-dimensional model of the construction site. However, there is no limitation to such a configuration. For example, area names or area IDs (hereafter, “area IDs or the like”) of a plurality of predetermined areas may be stored in advance in association with position information, such as three-dimensional coordinate information, of the areas. Then, an area ID or the like may be input or selected on the display 34 so as to set the start position or the end position.

[0053] After accepting all the information used for simulation, the simulator 23 generates a route for the suspended load support 2 (step S2). For example, when a “Start Simulation” button shown on the display 34 is tapped, the simulator 23 generates a route for the

suspended load support 2 (step S2).

[0054] The simulator 23 performs simulation that moves the suspended load O, having the set suspended load weight, along the generated route within a range of the set maximum permissible amount of swing and the set maximum permissible amount of transfer time, and calculates a control parameter (step S3). For example, the simulator 23 calculates a control parameter that minimizes the transfer time within the range of the set maximum permissible amount of swing. Alternatively, the simulator 23 calculates a control parameter that minimizes the swing amount of the suspended load O within the range of the set maximum permissible amount of transfer time.

[0055] The display processor 24 displays the simulation result of movement of the suspended load support 2 performed by the simulator 23 on the display 34 (step S4).

[0056] The crane controller 25 determines whether initiation of automatic operation is instructed (step S5). For example, the crane controller 25 determines whether a “Start Automatic Operation” button BT (refer to Fig. 5) shown on the display 34 is tapped (step S5). When initiation of automatic operation is not instructed (step S5: NO), the automatic operation device 100 returns to step S1 and accepts a condition change or the like. When initiation of automatic operation is instructed (step S5: YES), the crane controller 25 executes automatic control of the crane 1 in accordance with the route generated by the simulator 23 and the control parameter calculated by the simulator 23 (step S6). When the automatic operation of the crane 1 ends, the process also ends.

[0057] After initiation of automatic operation is instructed (step S5: YES), the crane controller 25 may determine whether at least one of the suspended load condition, the weather condition, and the crane condition used for the simulation performed by the simulator 23 differs from the actual suspended load O, the actual weather, or the actual

specifications of the crane 1, as described above. When the crane controller 25 determines that at least one of the conditions used for simulation differs from actual conditions, the crane controller 25 does not have to execute automatic control of the crane 1. In this case, the automatic operation device 100 may issue an alert (visual alert on the display 34 or audible alert) to notify the operator that the conditions used for the simulation, which calculated the route and the control parameter, may differ from actual conditions.

[0058] In the automatic operation device 100 configured as described above, the crane controller 25 executes automatic control of the crane 1 in accordance with the route generated by the simulator 23 and the control parameter calculated by the simulator 23. That is, the simulator 23 performs simulation before automatic control of the crane 1 is executed. This promptly calculates a control parameter that minimizes swinging or overlapping (load swing amount) of the suspended load O and reduces the work time (transfer time) in correspondence with various conditions (suspended load weight, transfer distance, or the like). As a result, automatic operation of the crane 1 is executed at a relatively high degree of accuracy with only minimum adjustment work, such as setting of the specifications of the crane or setting of the suspended load information.

[0059] The simulator 23 calculates the control parameter taking into consideration the deflection of the crane 1, the weather (wind speed and wind direction), the swing of the suspended load O, and the transfer time, in addition to the suspended load weight and the transfer distance (between start position and end position). This improves the accuracy of the control parameter for automatic operation of the crane 1.

[0060] Moreover, the simulation performed by the simulator 23 determines the extent of swinging of the suspended load O, in addition to the route (transfer route).

[0061] As described above, the present disclosure provides the automatic operation device

100 that improves the accuracy of the control parameter for automatic operation of the crane 1.

[0062] The display processor 24 displays, on a three-dimensional model, a movement path P2 of the suspended load O that includes swinging of the suspended load O when automatic control is executed using the decided control parameter. Therefore, the operator can visually check the simulation result on the three-dimensional model. In particular, the operator can visually check the extent of swinging of the suspended load O before a lifting operation, thereby ensuring safety.

[0063] The simulator 23 calculates a control parameter that minimizes the transfer time within the range of the maximum permissible amount of swing set by the suspended load swing amount setter 225. This allows the suspended load O to be transferred in the shortest transfer time with permissible swinging.

[0064] Further, the simulator 23 calculates a control parameter that minimizes the swing amount of the suspended load O within the range of the maximum permissible amount of transfer time set by the transfer time setter 226. This allows the suspended load O to be transferred with minimal swinging in a permissible transfer time.

[0065] In the present embodiment, the automatic operation device 100 is arranged on the turning body 5 of the crane 1 (Fig. 1). However, the position of the automatic operation device 100 is not limited. The automatic operation device 100 may be arranged at a position separated from the crane 1 (for example, on the ground).

[0066] Although the present invention has been described with reference to the above embodiment, the present invention is not limited to the details of the above embodiment and may be modified without departing from the scope of the present invention. In other words, any modified embodiments, examples, or technical applications adopted by those skilled in

the art based on the above embodiment are included in the scope of the present invention.

CLAIMS:

1. An automatic crane operation device for executing automatic control of a drive device of a crane to move a suspended load support of the crane, the suspended load support being configured to support a suspended load, the device comprising:

a position condition setting means that sets a start position and an end position of the suspended load;

a suspended load condition setting means that sets a suspended load condition including a size of the suspended load and a suspended load weight;

a weather condition setting means that sets a weather condition including a wind direction and a wind speed;

a crane condition setting means that sets a crane condition including deflection information of the crane;

a suspended load swing amount setting means that sets a maximum permissible amount of swing of the suspended load;

a transfer time setting means that sets a maximum permissible amount of a transfer time of the suspended load from the start position to the end position; and

a simulating means that performs simulation of movement of the suspended load support of the crane based on the start position, the end position, the suspended load condition, the weather condition, the crane condition, the maximum permissible amount of swing of the suspended load, and the maximum permissible amount of the transfer time, generates a route for the suspended load support, and calculates a control parameter for executing automatic control of the drive device of the crane; and

a crane controlling means that executes automatic control of the drive device of the

crane to move the suspended load support of the crane in accordance with the route and the control parameter.

2. The automatic crane operation device according to claim 1, further comprising:

a display; and

a display processing means that displays a result of the simulation on the display,

wherein

the simulating means is configured to perform the simulation using a three-dimensional model, and

the display processing means is configured to display the three-dimensional model and a movement path of the suspended load support on the display.

3. The automatic crane operation device according to claim 1 or 2, wherein the simulating means is configured to calculate the control parameter that minimizes the transfer time.

4. The automatic crane operation device according to claim 1 or 2, wherein the simulating means is configured to calculate the control parameter that minimizes a swing amount of the suspended load.