

AUTOMATIC CRANE OPERATION SYSTEM

BACKGROUND

[0001] Field

The following description relates to an automatic crane operation system.

[0002] Description of Related Art

Japanese Laid-Open Patent Publication No. H10-258989 discloses an automatic operation device for a crane. The automatic operation device performs automatic operation of a tower crane that includes a mast fixed to a base structure, a turning body mounted on the mast in a manner allowing for turning left and right, a jib arranged on the turning body in a manner allowing for raising and lowering, and a hook block suspended from a distal end of the jib. During automatic operation of the tower crane, an operator in an operator cabin located on the turning body inputs a start point and an end point of movement of a suspended load (hook block) to an operation schedule input device. When there is an obstacle, the operator also inputs the location of the obstacle. The start point, end point, and location of the obstacle input by the operator are sent to an automatic operation control device from the operation schedule input device. The automatic operation control device calculates a movement path of the suspended load from the start point to the end point based on the start point, end point, and location of the obstacle, and then moves the actual suspended load.

[0003] At a construction site, there may be multiple pickup locations, at which a suspended load starts to move, and multiple drop-off locations, at which the suspended load stops moving. Also, there may be various types of subjects (suspended loads) of a lifting operation. Thus, when performing a new lifting operation, the operator in the operator cabin (hereinafter, simply referred to as “the operator”) may need to specify and input such

information to the crane automatic operation device. However, it may be difficult for the operator to visually recognize information (e.g., type, size, or weight) related to the subject of the next lifting operation or the start position and the end position of the subject from the operator cabin, since the operator cabin of the tower crane is located at a relatively high position and there is often a building under construction below the operator cabin.

Accordingly, a worker, such as a slinger, at the new start position or the new end position may convey the information related to the subject of the next lifting operation as well as the start position and end position of the subject to the operator using a transceiver or the like.

Then, the operator inputs the information to an automatic crane operation system.

[0004] Nonetheless, when a worker, such as a slinger, conveys information related to a subject of a lifting operation and a start position and an end position of the subject to the operator, work efficiency may be reduced. Also, the burden on the operator may be increased by human errors, such as miscommunication.

[0005] An objective of the present invention is to provide an automatic crane operation system that improves work efficiency and avoids occurrence of human errors.

SUMMARY

[0006] In one general aspect, an automatic crane operation system for moving a suspended load support of a crane from a start position to an end position is provided. The suspended load support is configured to support a suspended load. The system includes a control device configured to control a drive device of the crane, and a terminal communicatively connected to the control device. The terminal includes a suspended load position setting means that sets suspended load position information, and a suspended load information setting means that sets suspended load information related to the suspended load. The suspended load position

information includes position information related to at least one of the start position and the end position. The terminal is configured to send the set suspended load position information and the set suspended load information to the control device. The control device includes a route generating means that generates a route from the start position to the end position based on the suspended load position information and the suspended load information received from the terminal, and a crane controlling means that executes automatic control of the drive device so that the suspended load support of the crane is moved in accordance with the generated route.

[0007] In an embodiment, the terminal may further include a display unit, a three-dimensional information obtaining means that obtains three-dimensional information indicating a state of a construction site, and a display processing means that reproduces the construction site in a virtual space based on the three-dimensional information and three-dimensionally displays the reproduced construction site on the display unit. The suspended load position setting means of the terminal may be configured to use a position specified on the construction site in the virtual space shown on the display unit as the suspended load position information.

[0008] In an embodiment, the terminal may further include a terminal position obtaining means that obtains terminal position information. The terminal position information indicates a present position of the terminal. The terminal may be configured to send the terminal position information to the control device. The control device may further include a terminal position determining means that determines, based on the terminal position information and the suspended load position information received from the terminal, whether the present position of the terminal is separated from a position indicated by the suspended load position information by a predetermined distance or greater. The crane

controlling means may be configured to not execute automatic control of the drive device when the terminal position determining means determines that the present position of the terminal is separated from the position indicated by the suspended load position information by the predetermined distance or greater.

[0009] In an embodiment, the terminal may further include a terminal position obtaining means that obtains terminal position information. The terminal position information indicates a present position of the terminal. The suspended load position information setting means of the terminal may be configured to use the terminal position information as the suspended load position information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1 is a schematic diagram showing the overall configuration of an automatic crane operation system in accordance with an embodiment.

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

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

Fig. 4 is a diagram illustrating an example of a display unit of a terminal.

Fig. 5 is a flowchart of a process executed by the automatic crane operation system.

DETAILED DESCRIPTION

[0011] An embodiment of the present invention will now be described with reference to the drawings.

[0012] An automatic crane operation system 100 in accordance with an embodiment of the present invention is a system for moving a suspended load support 2 of a crane 1 from a start position to an end position. The suspended load support 2 is configured to support a

suspended load O.

[0013] As shown in Fig. 1, the crane 1 of the present embodiment is a tower crane of a fixed type. 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.

[0014] 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.

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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 the various state quantities of the crane 1 may be acquired by a different method. For example, the 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.

[0020] As shown in Figs. 1 and 2, the automatic crane operation system 100 includes a control device 20 and a terminal 30. The control device 20 is configured to control the crane 1. The terminal 30 is communicatively connected to the control device 20. The control device 20 controls the drive device, such as the turning device 7, the luffing winch 8, the hoisting winch 9, or the like, of the crane 1 based on the various state quantities (turning angle of the turning body 5, luffing angle of the jib 6, and hoisting position of the suspended load support 2) of the crane 1.

[0021] As shown in Fig. 3, both the control device 20 and the terminal 30 are devices configured to perform computations, such as computers. The control device 20 and the terminal 30 each include a central processing unit (CPU) 41, random-access memory (RAM) 42, read-only memory (ROM) 43, a display unit 44, and a communication unit 45 that are connected via a bus 46 in a manner accessible to one another.

[0022] The CPU 41 is a central processing unit that deploys programs stored in the ROM 43 to the RAM 42, and governs various types of control and computation processing according to the programs.

[0023] The RAM 42 is a volatile memory that temporarily stores various types of data, calculation results obtained by the CPU 41, or the like.

[0024] The ROM 43 is a non-volatile memory that stores programs or the like (e.g., application for the automatic crane operation system 100 of the present embodiment).

[0025] The display unit 44 is a touch panel type display device capable of responding to

various setting inputs. In addition to the display function, the display unit 44 also has a functionality of an input unit that receives various types of inputs. The control device 20 and the terminal 30 may each include an input unit separate from the display unit 44.

[0026] The communication unit 45 is a communication interface for controlling communication with an external device. For example, the communication unit 45 is a network interface, a wireless interface, or the like. In the present embodiment, the communication unit 45 of the control device 20 and the communication unit 45 of the terminal 30 are communicatively connected to each other via a network N. The network N may be a closed network or an open network.

[0027] In the description hereafter, “the CPU of the control device 20” will refer to the hardware configuration of the CPU 41 arranged on the control device 20, and “the CPU of the terminal 30” refers to the hardware configuration of the CPU 41 arranged on the terminal 30.

[0028] As shown in Figs. 1 and 2, the terminal 30 is a portable terminal, such as a tablet, that can be carried by a worker P. The terminal 30 includes a terminal position obtainer (terminal position obtaining means) 31, a suspended load position setter (suspended load position setting means) 32, a suspended load information setter (suspended load information setting means) 33, a three-dimensional information obtainer (three-dimensional information obtaining means) 34, and a display processor (display processing means) 35. The CPU of the terminal 30 functions as the terminal position obtaining means, the suspended load position setting means, the suspended load information setting means, the three-dimensional information obtaining means, and the display processing means by performing information processing in cooperation with software, such as the programs stored in the ROM of the terminal 30. In the present embodiment, the terminal 30 includes the terminal position

obtainer 31, the three-dimensional information obtainer 34, and the display processor 35.

However, these components may be omitted.

[0029] The terminal position obtainer 31 obtains terminal position information indicating the present position of the terminal 30. The terminal position information includes three-dimensional coordinate information (X coordinate, Y coordinate, and Z coordinate). For example, the terminal position obtainer 31 may obtain information (latitude, longitude, and altitude) of a GPS receiver arranged on the terminal 30 as the terminal position information of the terminal 30. Alternatively, the terminal position obtainer 31 may receive information (latitude, longitude, and altitude) of a GNSS receiver carried by the worker P, and obtain the information as the terminal position information of the terminal 30.

[0030] The suspended load position setter 32 sets suspended load position information for the control device 20. The suspended load position information includes position information of at least one (in the present embodiment, both) of a start position and an end position of movement of the suspended load O. The suspended load position setter 32 accepts an input or obtainment of the suspended load position information, and sends the input or obtained suspended load position information to the control device 20. For example, in the present embodiment, the suspended load position setter 32 uses position information of a position specified (input) on a three-dimensional model of a construction site in a virtual space VS, which will be described later, shown on the display unit of the terminal 30, and sets such position information as the suspended load position information for the control device 20. In another embodiment, the suspended load position setter 32 may use the terminal position information obtained by the terminal position obtainer 31 under the assumption that the worker P who performs a slinging operation or the like at the start position or the end position operates the terminal 30, and set the terminal position information as the suspended

load position information for the control device 20.

[0031] The suspended load position information may include any information that allows the control device 20 to identify 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 the control device 20 in advance in association with three-dimensional coordinate information of the positions or the areas, the control device 20 may use one of the area IDs 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.

[0032] In the present embodiment, the suspended load position setter 32 sets the suspended load position information related to both a start position and an end position for the control device 20. However, there is no limitation to such a configuration. For example, when one of a start position and an end position is a specific position that does not change, and the specific position is set in the control device 20 in advance, the suspended load position setter 32 does not have to set the suspended load position information related to the one of the start position and the end position for the control device 20 and may set only the suspended load position information related to the other one of the start position and the end

position for the control device 20.

[0033] The suspended load information setter 33 sets suspended load information related to the suspended load O for the control device 20. The suspended load information includes various types of information related to the suspended load O. Preferably, the suspended load information allows the control device 20 to identify the size and weight of the suspended load O. The suspended load information setter 33 accepts an input of the suspended load information, and sends the input suspended load information to the control device 20. For example, when ID numbers are associated with suspended loads O in advance such that information (size, weight, and the like) of a suspended load O may be obtained from its ID number, the suspended load information setter 33 may use the ID number as the suspended load information.

[0034] The three-dimensional information obtainer 34 obtains, from a predetermined storing means, three-dimensional information for reproducing a construction site in the virtual space VS and three-dimensionally showing the reproduced construction site on the display unit of the terminal 30. The predetermined storing means storing such three-dimensional information may include a predetermined storage unit (storage) of the terminal 30. 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.

[0035] The three-dimensional information for reproducing a construction site in the virtual space VS and three-dimensionally showing the reproduced construction site on the display unit of the terminal 30 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. For example, point cloud data refers to data indicating a set of points associated with three-dimensional coordinates. For example, a digital twin refers to 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.

[0036] In the present embodiment, the three-dimensional information obtainer 34 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 34 via the network N. 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 N.

[0037] 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 structure is formed in accordance with the construction progress, and recognizes the state (three-dimensional information) of the construction site 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 34 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.

[0038] As shown in Fig. 4, the display processor 35 reproduces a construction site in the virtual space VS based on three-dimensional information obtained by the three-dimensional information obtainer 34, and displays the reproduced construction site on the display unit of the terminal 30. Hereinafter, a model produced in the virtual space VS based on three-dimensional information will be referred to as “three-dimensional model”.

[0039] As shown in Figs. 1 and 2, the control device 20 controls the drive device of the crane 1 based on various state quantities (turning angle of the turning body 5, luffing angle of the jib 6, and the hoisting position of the suspended load support 2) of the crane 1. The control device 20 includes a route generator (route generating means) 21, a crane controller (crane controlling means) 22, and a terminal position determiner (terminal position determining means) 23. The route generator 21 generates a route from a start position to an end position. The crane controller 22 executes automatic control of the drive device of the crane 1 to move the suspended load support 2. The terminal position determiner 23

determines whether the terminal 30 is located at a proper position. The CPU of the control device 20 functions as the route generating means, the crane controlling means, and the terminal position determining means by performing information processing in cooperation with software, such as the programs stored in the ROM of the control device 20. Also, in the same manner as the three-dimensional information obtainer 34 of the terminal 30, the control device 20 of the present embodiment includes a three-dimensional information obtainer 24. In the present embodiment, the control device 20 includes the terminal position determiner 23. However, the terminal position determiner 23 may be omitted. Some of the functionality of the CPU of the control device 20 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.

[0040] The three-dimensional information obtainer 24 is substantially the same as the three-dimensional information obtainer 34 of the terminal 30 and thus will not be described.

[0041] The route generator 21 generates a route (transport path) of the suspended load O based on the suspended load position information of a start position and an end position set by the terminal 30, and the suspended load information set by the terminal 30. The route generator 21 generates the route of the suspended load O using a three-dimensional model of a construction site that is reproduced based on three-dimensional information obtained by the three-dimensional information obtainer 24. The route of the suspended load O includes a path of the suspended load support 2 from the start position to the end position. The control device 20 generates a safe transfer path from the start position to the end position on the three-dimensional model of the construction site in accordance with the size of the suspended load O, so that the suspended load O does not come into contact with ambient obstacles (e.g., constructed building or the like).

[0042] The crane controller 22 executes automatic control of the drive device of the crane 1 based on the route generated by the route generator 21 and the suspended load information set by the terminal 30 to move the suspended load support 2. The crane controller 22 determines control parameters (acceleration and deceleration) that minimize load swing (swing of suspended load) from the route generated by the route generator 21 and the suspended load information. For example, the crane controller 22 determines a transfer speed in accordance with the size and weight of the suspended load O using a speed determination table stored in the control device 20 in advance. The crane controller 22 executes 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, so that the suspended load support 2 is moved from the start position to the end position along the route generated by the route generator 21 at a determined speed. The crane controller 22 may execute automatic control of the drive device of the crane 1 while correcting the control parameters based on external factors (information from a wind speed sensor mounted on the crane 1, load swing, or the like).

[0043] The terminal position determiner 23 determines, based on the terminal position information and the suspended load position information received from the terminal 30, whether the present position of the terminal 30 is separated from a position indicated by the suspended load position information by a predetermined distance (for example, 10 m) or greater. For example, when the suspended load position information indicates a pinpoint position, the terminal position determiner 23 determines whether the terminal 30 is located in a spherical determination area having a radius of the predetermined distance from a center

corresponding to the suspended load position information. When the suspended load position information indicates a predetermined range (area), the terminal position determiner 23 may determine whether the terminal 30 is located in the above-mentioned predetermined area (determination area). Alternatively, the terminal position determiner 23 may determine whether the terminal 30 is located in a determination area that is expanded from the above-mentioned predetermined area by the predetermined distance in all directions (X-coordinate direction, Y-coordinate direction, and Z-coordinate direction). When the terminal 30 is not located in the determination area, the terminal position determiner 23 determines that the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater.

[0044] When the terminal position determiner 23 determines that the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater, the crane controller 22 does not execute automatic control of the drive device of the crane 1. When the terminal position determiner 23 determines that the distance between the present position of the terminal 30 and the position indicated by the suspended load position information is less than the predetermined distance, the crane controller 22 executes automatic control of the drive device of the crane 1.

[0045] Switching of Input Modes

The route generator 21 may be configured to generate a route of the suspended load O based on suspended load position information and suspended load information directly input to the control device 20, in addition to generating a route of the suspended load O based on the suspended load position information and the suspended load information set by the terminal 30. For example, the control device 20 of the present embodiment includes a

three-dimensional information obtainer and a display processor that are the same as those of the terminal 30. Therefore, the control device 20 is capable of generating a route of the suspended load O based on suspended load position information specified (input) on a three-dimensional model of a construction site in the virtual space VS shown on the display unit of the control device 20, and the suspended load information input to the display unit of the control device 20. The present embodiment assumes that a crane operator inputs suspended load position information and suspended load information on the three-dimensional model shown on the display unit of the control device 20. Accordingly, the control device 20 is arranged inside an operator cabin located on the turning body 5 of the crane 1. The position of the control device 20 is not limited to inside of the operator cabin located on the turning body 5 of crane 1.

[0046] The control device 20 of the present embodiment is capable of switching between a remote input mode in which the suspended load position information and the suspended load information are input from the terminal 30, and a direct input mode in which the suspended load position information and the suspended load information are directly input to the control device 20. When generating a route of the suspended load O based on the suspended load position information and the suspended load information set by the terminal 30, the remote input mode is switched ON (direct input mode is switched OFF). When generating a route of the suspended load O based on the suspended load position information and the suspended load information directly input to the control device 20, the direct input mode is switched ON (remote input mode is switched OFF).

[0047] The drive device of the crane 1 of the present embodiment may be manually controlled by the crane operator or the like using an operation lever or the like that is arranged inside the operator cabin located on the turning body 5 of the crane 1. Accordingly,

the control device 20 includes an automatic operation switch for switching between manual control and automatic control of the crane 1.

[0048] Setting of Suspended Load Position Information and Suspended Load Information

An example in which the terminal 30 sets the suspended load position information and the suspended load information will now be described. In this example, as shown in Fig. 4, material C is lifted from area A on the ground to area B on a building under construction. In this case, a worker who operates the terminal 30 corresponds to a worker P who performs a slinging operation in area A on the ground or in area B on the building (hereafter, may be referred to as “the operator P”).

[0049] As shown in Fig. 4, the display unit of the terminal 30 of the present embodiment shows a three-dimensional model of the construction site in the virtual space VS (hereafter, simply referred to as “the three-dimensional model of the construction site”). On the three-dimensional model of the construction site shown on the display unit of the terminal 30, the operator P of the terminal 30 taps (selects) a three-dimensional model of material C out of materials C and D in area A. In this manner, the suspended load position setter 32 of the terminal 30 sends position information of area A to the control device 20 as the suspended load position information of the start position. Further, the suspended load information setter 33 of the terminal 30 sends the ID number of material C to the control device 20 as the suspended load information. Then, the operator P of the terminal 30 taps (selects) area B on the three-dimensional model of the construction site shown on the display unit of the terminal 30. In this manner, the suspended load position setter 32 of the terminal 30 sends position information of area B to the control device 20 as the suspended load position information of the end position. That is, the suspended load position setter 32 of the terminal 30 uses the position specified on the three-dimensional model of the construction site in the

virtual space VS shown on the display unit as the suspended load position information.

[0050] In the present embodiment, the terminal 30 includes the three-dimensional information obtainer 34 and the display processor 35. Further, the suspended load position information and the suspended load information 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 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 name or an area ID may be input or selected from a list or the like on the display unit of the terminal 30 so as to set the suspended load position information for the control device 20. Further, suspended load information may be set in the same manner. ID numbers set for various materials may be stored in advance in association with the suspended load information related to the various materials. Then, an ID number of a material may be input or selected from a list or the like on the display unit of the terminal 30 so as to set the suspended load information for the control device 20.

[0051] In another example in which the terminal 30 sets the suspended load position information, the operator P of the terminal 30 may send the terminal position information obtained by the terminal position obtainer 31 (information obtained by GPS receiver or GNSS receiver) to the control device 20 as the suspended load position information of one of the start position and the end position. In this case, the suspended load position information of the other one of the start position and the end position and the suspended load information may be set for the control device 20 by specifying the above-described area ID or ID number of the material.

[0052] Automatic Operation Process

An automatic operation process executed by the automatic crane operation system

100 will now be described with reference to Fig. 5. The automatic operation process is repeated from when the automatic crane operation system 100 is activated to when the automatic crane operation system 100 is deactivated.

[0053] As shown in Fig. 5, in the automatic operation process, first, the control device 20 determines whether the automatic operation switch is ON (step S1). When the automatic operation switch is not ON (OFF, step S1: NO), the crane 1 is manually controllable. Thus, automatic control of the crane 1 is not executed, and step S1 is repeated.

[0054] When the automatic operation switch is ON, the control device 20 determines whether the remote input mode is ON (step S2). When the remote input mode is ON (step S2: YES), the control device 20 determines whether the suspended load position information and the suspended load information are obtained from the terminal 30 (step S3). A case in which the remote input mode is not ON (OFF, step S2: NO) will be described later.

[0055] When the control device 20 obtains the suspended load position information and the suspended load information from the terminal 30 (step S3: YES), the control device 20 proceeds to a determination performed by the terminal position determiner 23 (step S4).

When the control device 20 does not obtain the suspended load position information and the suspended load information from the terminal 30 (step S3: NO), the control device 20 returns to step S1. In other words, the control device 20 continuously determines whether the automatic operation switch is ON (step S1) and whether the remote input mode is ON (step S2) while waiting for inputs of suspended load position information and suspended load information from the terminal 30.

[0056] In step S4, the terminal position determiner 23 determines whether the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater based on the terminal position

information and the suspended load position information received from the terminal 30.

When the terminal position determiner 23 determines that the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater (step S4: NO), it can be determined that the operator P operating the terminal 30 is far away from the start position or the end position. In this case (step S4: NO), the operator P of the terminal 30 may not be able to monitor the tasks performed at the start position or the end position. Accordingly, in order to ensure safety, the control device 20 returns to step S1 without executing automatic control of the drive device of the crane 1 by the crane controller 22. In the present embodiment, when the terminal position determiner 23 determines that the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater (step S4: NO), the route generator 21 does not generate the route of the suspended load O. Alternatively, the route of the route generator 21 may generate the route for the suspended load O.

[0057] When the terminal position determiner 23 determines that the distance between the present position of the terminal 30 and the position indicated by the suspended load position information is less than the predetermined distance (step S4: YES), it can be determined that the user P operating the terminal 30 is near the start position or the end position. In this case (step S4: YES), it may be presumed that the operator P of the terminal 30 is able to monitor the tasks performed at the start position or the end position, thereby ensuring safety.

Accordingly, the route generator 21 generates the route of the suspended load O (step S5), and then the crane controller 22 initiates automatic control of the crane 1 (step S6).

[0058] When the crane controller 22 initiates automatic control of the drive device of the crane 1, the control device 20 determines whether the suspended load support 2 of the crane

1 reaches the end position (step S7). The control device 20 continues the automatic control of the crane 1 by the crane controller 22 until the suspended load support 2 of the crane 1 reaches the end position (step S7: NO). When the suspended load support 2 of crane 1 reaches the end position (step S7: YES), the control device 20 ends the process.

[0059] When the remote input mode is not ON (step S2: NO) in step S2, the control device 20 permits acceptance of inputs of the suspended load position information and the suspended load information from the display unit of the control device 20 (step S8). For example, when the remote input mode is ON, acceptance of inputs of the suspended load position information and the suspended load information from the display unit of the control device 20 (direct input) may be disabled. When the remote input mode is OFF, acceptance of inputs of the suspended load position information and the suspended load information from the display unit of the control device 20 (direct input) may be enabled.

[0060] When acceptance of inputs of the suspended load position information and the suspended load information from the display unit of the control device 20 is permitted (step S8), the control device 20 determines whether the suspended load position information and the suspended load information are input to the display unit of the control device 20 (step S9). When the suspended load position information and the suspended load information are not input to the display unit of the control device 20 (step S9: NO), the control device 20 returns to step S1. In other words, the control device 20 continuously determines whether the automatic operation switch is ON (step S1) and whether the remote input mode is ON (step S2) while waiting for inputs of suspended load position information and suspended load information to the display unit of the control device 20. When the suspended load position information and the suspended load information are input to the display unit of the control device 20 (step S9: YES), the route generator 21 of the control device 20 generates the route

of the suspended load O (step S5), and the crane controller 22 initiates automatic control of the drive device of the crane 1 (step S6).

[0061] The automatic crane operation system 100 configured as described above includes the control device 20 configured to control the drive device of the crane 1, and the terminal 30 communicatively connected to the control device 20. The route generator 21 of the control device 20 generates a route from a start position to an end position based on the suspended load position information and the suspended load information received from the terminal 30. The crane controller 22 executes automatic control of the drive device of the crane 1 in accordance with the route generated by the route generator 21 to move the suspended load support 2 of the crane 1. As described above, in the automatic crane operation system 100, the suspended load position information and the suspended load information may be set by the terminal 30 for the control device 20. Therefore, even when it is difficult for the crane operator in the operator cabin located on the turning body 5 of the crane 1 to visually recognize the information (type, size, weight, or the like) of the suspended load O and the start position and the end position, relatively accurate suspended load position information and suspended load information may be set for the control device 20.

[0062] In addition, since the suspended load position information and the suspended load information may be set by the terminal 30 for the control device 20, compared to a case in which a worker, such as a slinger, at the start position or the end position conveys the suspended load position information and the suspended load information to the operator using a transceiver or the like, work efficiency may be improved and human errors may be avoided. This also reduces the load on the crane operator.

[0063] In this manner, the present embodiment provides the automatic crane operation

system 100 that improves work efficiency and avoids occurrence of human errors.

[0064] The terminal 30 includes the display unit, the three-dimensional information obtainer 34, and the display processor 35. Further, the suspended load position setter 32 of the terminal 30 uses a position specified on a construction site in the virtual space VS shown on the display unit as the suspended load position information. Thus, the start position and the end position may be specified after viewing the three-dimensional model of the construction site. This minimizes mistakes that could occur when specifying these positions.

[0065] When the terminal position determiner 23 determines that the present position of the terminal 30 is separated from the position indicated by the suspended load position information by the predetermined distance or greater, the crane controller 22 of the control device 20 does not execute automatic control of the drive device of the crane 1. That is, automatic control of the drive device of the crane 1 is not executed when it can be determined that the operator P operating the terminal 30 is far away from the start position or the end position. This ensure safety.

[0066] The terminal position information obtained by the terminal position obtainer 31 of the terminal 30 may be used as the suspended load position information of one of the start position and the end position. This may ensure accuracy of the suspended load position information of the start position or the end position, and facilitates input of the suspended load position information. Also, the terminal 30 and the operator P are always present at the set start position or end position, thereby ensuring safety at the set position.

[0067] 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 system for moving a suspended load support of a crane from a start position to an end position, the suspended load support being configured to support a suspended load, the system comprising:

a control device configured to control a drive device of the crane; and
a terminal communicatively connected to the control device, wherein:

the terminal includes a suspended load position setting means that sets suspended load position information, the suspended load position information including position information related to at least one of the start position and the end position, and a suspended load information setting means that sets suspended load information related to the suspended load, the terminal being configured to send the set suspended load position information and the set suspended load information to the control device; and

the control device includes a route generating means that generates a route from the start position to the end position based on the suspended load position information and the suspended load information received from the terminal, and a crane controlling means that executes automatic control of the drive device so that the suspended load support of the crane is moved in accordance with the generated route.

2. The automatic crane operation system according to claim 1, wherein:
the terminal further includes a display unit, a three-dimensional information obtaining means that obtains three-dimensional information indicating a state of a construction site, and a display processing means that reproduces the construction site in a virtual space based on the three-dimensional information and three-dimensionally displays

the reproduced construction site on the display unit; and

the suspended load position setting means of the terminal is configured to use a position specified on the construction site in the virtual space shown on the display unit as the suspended load position information.

3. The automatic crane operation system according to claim 1 or 2, wherein:

the terminal further includes a terminal position obtaining means that obtains terminal position information, the terminal position information indicating a present position of the terminal, the terminal being configured to send the terminal position information to the control device;

the control device further includes a terminal position determining means that determines, based on the terminal position information and the suspended load position information received from the terminal, whether the present position of the terminal is separated from a position indicated by the suspended load position information by a predetermined distance or greater; and

the crane controlling means is configured to not execute automatic control of the drive device when the terminal position determining means determines that the present position of the terminal is separated from the position indicated by the suspended load position information by the predetermined distance or greater.

4. The automatic crane operation system according to claim 1, wherein:

the terminal further includes a terminal position obtaining means that obtains terminal position information, the terminal position information indicating a present position of the terminal; and

the suspended load position information setting means of the terminal is configured to use the terminal position information as the suspended load position information.