

DESCRIPTION

CEILING BOARD INSTALLATION ROBOT

TECHNICAL FIELD

5 [0001] The present invention relates to a ceiling board installation robot.

BACKGROUND ART

[0002] JP2018-123645A discloses a ceiling board installation robot for
10 attaching ceiling boards to ceiling joists provided on a ceiling part.

SUMMARY OF INVENTION

[0003] The ceiling board installation robot described in JP2018-123645A attaches the ceiling boards to the ceiling joists by
15 using screws. Therefore, in a method of installing the ceiling board by placing the ceiling board on a frame body supported by a ceiling slab, it has not been possible to employ the ceiling board installation robot described in JP2018-123645A.

[0004] An object of the present invention is to provide a ceiling board
20 installation robot capable of placing a ceiling board on a frame body supported by a ceiling slab.

[0005] According to one aspect of the present invention, a ceiling board installation robot for placing a ceiling board onto a frame body supported by a ceiling slab, the ceiling board installation robot includes:

a base carriage unit configured to be movable on a floor surface; a lifting and lowering part mounted on the base carriage unit; an arm part configured to extend from the lifting and lowering part towards the frame body; a holding part provided on a tip end side of the arm part, the holding part being configured to hold the ceiling board; a state detector configured to detect a frame body state related to a shape of the frame body; and a controller configured to control an operation of the arm part. The controller controls the operation of the arm part based on the frame body state detected by the state detector such that the ceiling board held by the holding part is placed onto the frame body by being lowered down from above the frame body.

BRIEF DESCRIPTION OF DRAWINGS

[0006]

FIG. 1 is a conceptual diagram showing a conceptual image of a ceiling board installation operation performed by a ceiling board installation robot according to an embodiment of the present invention.

FIG. 2 is a conceptual diagram showing a conceptual image of a space state detection operation performed by the ceiling board installation robot according to the embodiment of the present invention.

FIG. 3 is a conceptual diagram showing a conceptual image of a ceiling board receiving operation performed by the ceiling board installation robot according to the embodiment of the present invention.

FIG. 4A is an enlarged view showing a portion indicated by an arrow A shown in FIG. 3 in enlargement and is a diagram showing a state before the ceiling board installation robot holds a ceiling board.

FIG. 4B is an enlarged view showing the portion indicated by the arrow A shown in FIG. 3 in enlargement and is a diagram showing a state after the ceiling board installation robot has held the ceiling board.

FIG. 5 is a block diagram showing a configuration of an entire control system including the ceiling board installation robot and a carrier robot.

FIG. 6 is a diagram showing a part of the carrier robot viewed from the direction indicated by an arrow B shown in FIG. 3.

FIG. 7 is a flow chart showing a procedure of an operation performed by the ceiling board installation robot.

FIG. 8A is a schematic view for explaining the ceiling board installation operation performed by the ceiling board installation robot.

FIG. 8B is a schematic view for explaining the ceiling board installation operation performed by the ceiling board installation robot and is a diagram showing a state that follows the state shown in FIG. 8A.

FIG. 8C is a schematic view for explaining the ceiling board installation operation performed by the ceiling board installation robot and is a diagram showing a state that follows the state shown in FIG. 8B.

FIG. 8D is a schematic view for explaining the ceiling board installation operation performed by the ceiling board installation robot and is a diagram showing a state that follows the state shown in FIG. 8C.

FIG. 9 is a diagram showing a modification of the ceiling board installation robot according to the embodiment of the present invention.

FIG. 10 is an enlarged sectional view showing a cross-section, in enlargement, taken along line C-C in FIG. 9.

5 FIG. 11 is a diagram for explaining operation of the ceiling board installation robot shown in FIG. 9.

FIG. 12 is an enlarged sectional view showing a cross-section, in enlargement, taken along line D-D in FIG. 9.

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DESCRIPTION OF EMBODIMENTS

[0007] In the following, the ceiling board installation robot according to the embodiment of the present invention will be described with reference to the drawings.

[0008] A ceiling board installation robot 100 according to an
15 embodiment of the present invention (hereinafter referred to as "installation robot") is an autonomous robot that does not require any operation from the outside, and as shown in FIG. 1, the ceiling board installation robot 100 performs an operation of placing ceiling boards 8 on a frame body 6 that is supported by a ceiling slab 1.

20 [0009] The ceiling slab 1 shown in FIG. 1 is a deck plate to which concrete has been poured, and a plurality of inserts 3 are attached to the deck plate in advance, before concrete is poured, at a predetermined positions. The inserts 3 are members that are provided for attaching hanger bolts 4 for hanging and supporting the frame body 6, on which

the ceiling boards 8 are placed, via hangers 5. The ceiling slab 1 may also be a concrete slab that is formed by pouring concrete on plywood forms.

[0010] The ceiling board 8 is a rock wool acoustic board having a flat plate shape with a predetermined thickness, and the frame body 6, on
5 which the ceiling board 8 is placed, is formed by connecting bar members (T bars) having substantially T-shaped cross section in a grid shape.

[0011] The frame body 6 and the ceiling boards 8 configure a so called
10 grid-type integrated ceiling, and each of the ceiling boards 8 is supported by the frame body 6 from below in the vertical direction as the ceiling board 8 is lowered down from the above onto the opening portion of the frame body 6 sectioned by the bar members.

[0012] As shown in FIG. 1, in addition to the operation of placing the
15 ceiling board 8 to the frame body 6, the installation robot 100 can also perform an operation of detecting a space state in a space between the ceiling slab 1 and the frame body 6 as shown in FIG. 2 and an operation of receiving the ceiling board 8 carried by a carrier robot 110 from the carrier robot 110 as shown in FIG. 3. FIGs. 1 to 3 are exaggerated
20 conceptual diagrams showing the operation performed by the installation robot 100 for the clarity, and some parts may differ from the actual size and proportions.

[0013] Similarly to the installation robot 100, the carrier robot 110 is also an autonomous robot that does not require any operation from the

outside. A single carrier robot 110 may be provided for every installation robot 100, or the single carrier robot 110 may be provided for a plurality of installation robots 100.

[0014] The installation robot 100 and the carrier robot 110 each has a
5 base carriage unit 10 having the same configuration, and the installation robot 100 is configured by assembling an installation unit 20 to the base carriage unit 10, and the carrier robot 110 is configured by assembling a carrier unit 60 to the base carriage unit 10.

[0015] The configuration of the installation robot 100 will be described
10 first with reference to FIGs. 1 to 5. FIGs. 4A and 4B are enlarged views showing a portion indicated by an arrow A shown in FIG. 3 in enlargement, and FIG. 5 is a block diagram showing a configuration of an entire control system including the installation robot 100 and the carrier robot 110.

15 [0016] As shown in FIGs. 1 to 3, the installation robot 100 is provided with: the base carriage unit 10 that can move on a floor surface 2; a lifting and lowering part 21 that is mounted on the base carriage unit 10; an arm part 30 that extends from the lifting and lowering part 21 towards the frame body 6; a holding part 40 that is provided on the tip
20 end side of the arm part 30 and that can hold the ceiling board 8; and a controller 50 that controls operations of the base carriage unit 10, the lifting and lowering part 21, and the arm part 30. In the above, the installation unit 20 is configured of other mechanisms than the base carriage unit 10.

[0017] The base carriage unit 10 is a traveling device that is movable in all directions on the floor surface 2, and the base carriage unit 10 is provided with a main body portion 11, a pair of wheels 14 that are attached to the main body portion 11, a pair of motors (not shown) that
5 are provided so as to be able to drive the pair of wheels 14 separately, and a battery (not shown) that supplies electric power to the pair of motors. As described above, by driving the pair of wheels 14 in a separate manner, the base carriage unit 10 can turn on the spot. The battery provided in the base carriage unit 10 is also used as an electric
10 power source for supplying electric power to the installation unit 20.

[0018] As the configuration for turning the base carriage unit 10 on the spot, instead of employing the pair of wheels 14, for example, a configuration in which three omni-directional wheels or four mecanum wheels are provided may be employed, or alternatively, a configuration
15 in which a plurality of spherical bodies capable of rotating in the all directions that function as driving wheels in contact with the floor surface 2 may also be employed. Although it is preferable that the base carriage unit 10 can rotate on the spot from the view point of improving an operation efficiency, the base carriage unit 10 may also be a generally
20 used traveling device that is movable on the floor surface 2 back and forth and left and right so as to be able to move to a predetermined location.

[0019] In addition, the base carriage unit 10 is provided with an information acquisition device 15 that is capable of acquiring

surrounding information around the base carriage unit 10. The information acquisition device 15 is a 360-degree or 180-degree camera capable of acquiring an image of the surrounding of the base carriage unit 10 or an image above the base carriage unit 10. The image
5 acquired by the information acquisition device 15 is transmitted to the controller 50 and is used for specifying the self-location of the base carriage unit 10 or for detecting any obstacle. As the information acquisition device 15, instead of employing the camera, or in addition to the camera, a three-dimensional range sensor such as a laser scanner,
10 etc. capable of detecting distances in all directions, the so-called 3D-LiDAR (Light Detection and Ranging) sensor, may also be used.

[0020] The lifting and lowering part 21 of the installation unit 20 attached on the base carriage unit 10 is a multi-stage type electric jack and has a configuration that allows extension and contraction along the
15 up and down direction. A flange portion 24 for mounting the arm part 30 is provided on an upper end of the lifting and lowering part 21. By providing the lifting and lowering part 21 for moving the arm part 30 in the up and down direction as described above, the movable range of the arm part 30 is extended, and so, it is possible to employ the arm part 30
20 of a relatively small size.

[0021] It is also possible to extend the movable range of the arm part 30 by increasing the size of the arm part 30 without providing the lifting and lowering part 21. However, if the movable range is extended by increasing the size of the arm part 30, a safety area required to be

ensured is also increased, and a site worker is not allowed to perform operations around the installation robot 100. As a result, there is a risk in that an operation efficiency is deteriorated. In addition, if the size of the arm part 30 is increased, the arm part 30 becomes less maneuverable around the frame body 6 and more likely to interfere with the frame body 6, and thus, there is a risk in that the operation of placing the ceiling board 8 becomes difficult. Also from such a reason, it is preferable to provide the lifting and lowering part 21 and to employ the arm part 30 of a relatively small size.

10 [0022] The arm part 30 is a so-called perpendicular articulated robot arm capable of controlling a posture of the holding part 40, which is attached to the tip end of the arm part 30 as an end effector, to an arbitrary posture in three dimensions.

[0023] Specifically, the arm part 30 has: a base portion 32a that is fixed to a mount plate 26; a first linked portion 32b that is linked to the base portion 32a via a first rotating portion 31a so as to be rotatable about the linkage direction axis; a second linked portion 32c that is linked to the first linked portion 32b via a second rotating portion 31b so as to be rotatable about the horizontal direction axis; a third linked portion 32d that is linked to the second linked portion 32c via a third rotating portion 31c so as to be rotatable about the horizontal direction axis; a fourth linked portion 32e that is linked to the third linked portion 32d via a fourth rotating portion 31d so as to be rotatable about the linkage direction axis; a fifth linked portion 32f that is linked to the fourth linked

portion 32e via a fifth rotating portion 31e so as to be rotatable about the axis orthogonal to the rotation axis of the fourth rotating portion 31d; and a sixth linked portion 32g that is linked to the fifth linked portion 32f via a sixth rotating portion 31f so as to be rotatable about the linkage direction axis.

[0024] The rotating portions 31a to 31f are each provided with a servomotor and a speed-reduction gear (not shown) for rotating each of the rotating portions 31a to 31f.

[0025] The arm part 30 is not limited to that with six axes as described above, and the arm part 30 may be that with seven or more axes.

[0026] The arm part 30 having the above-described configuration is attached to the flange portion 24 of the lifting and lowering part 21 via the mount plate 26.

[0027] Next, a configuration of the holding part 40 that is attached to the sixth linked portion 32g, which is a tip end portion of the arm part 30, will be described with reference to FIGs. 4A and 4B. FIG. 4A shows a state before the ceiling board 8 is held by the holding part 40, and FIG. 4B shows a state after the ceiling board 8 is held by the holding part 40.

[0028] As shown in FIG. 4A, the holding part 40 has: a main body portion 41 having a disc shape that is attached to the sixth linked portion 32g; a plurality of needles 42 (protrusions) that protrude from the main body portion 41 towards the opposite direction from the sixth linked portion 32g; a protection ring 43 having a ring shape that is arranged so as to surround the plurality of needles 42; a plurality of rod

members 44 whose first ends are connected to the protection ring 43 and whose second ends are supported by the main body portion 41; and spring members 45 that bias the protection ring 43 in the direction in which the protection ring 43 is moved away from the main body portion
5 41.

[0029] The main body portion 41 is provided with a ring-shaped accommodating groove 41a that accommodates the spring members 45 and that can accommodate the protection ring 43 and through holes 41b that are formed in a bottom surface of the accommodating groove 41a so
10 as to penetrate therethrough and through which the rod members 44 are respectively inserted.

[0030] With the holding part 40 having the above-described configuration, in a state before the ceiling board 8 is held by the holding part 40, as shown in FIG. 4A, tip ends of the needles 42 are covered by
15 the protection ring 43 when viewed from the radially outside. Therefore, it is possible to prevent a damage of the ceiling board 8 caused when the needles 42 carelessly come into contact with the ceiling board 8 and to prevent the site worker from coming into contact with the needles 42.

20 [0031] On the other hand, when the holding part 40 is pushed against a front surface 8a of the ceiling board 8, as shown in FIG. 4B, the spring members 45 are compressed and the protection ring 43 is accommodated in the accommodating groove 41a of the main body portion 41, and thereby, the needles 42 are exposed. As the plurality of

needles 42 exposed as described above are stuck into the front surface 8a of the ceiling board 8, the ceiling board 8 is held by the holding part 40.

[0032] The configuration of the holding part 40 is not limited to the configuration described above, and the holding part 40 may be configured simply of the main body portion 41 that is attached to the sixth linked portion 32g and the plurality of needles 42 that protrude from the main body portion 41, without providing a member such as the protection ring 43 for covering the needles 42, or alternatively, the holding part 40 may be configured such that the plurality of needles 42 protrude out towards the ceiling board 8 when it is detected that the holding part 40 approaches the ceiling board 8.

[0033] In addition, the holding part 40 is not limited to that holds the ceiling board 8 by sticking the needles 42 into the ceiling board 8, and that holds the front surface 8a of the ceiling board 8 by suction by a negative pressure may also be employed. In general, because a plurality of air holes are formed in the rock wool acoustic board (the ceiling board 8), if the ceiling board 8 is to be held by the suction, a relatively large suction force is required. Therefore, in order to hold the ceiling board 8 reliably, it is preferred to use the holding part 40 having the needles 42.

[0034] In addition to the respective mechanisms, the installation robot 100 is further provided with, in order to detect the frame body state related to the shape of the frame body 6 and the space state in the space

between the ceiling slab 1 and the frame body 6, a first distance sensor 51 (state detector) and a second distance sensor 52 (state detector) that can detect these states.

[0035] The first distance sensor 51 is a single point laser distance
5 sensor having a relatively high measurement accuracy and is fixed to the fifth linked portion 32f of the arm part 30. Specifically, as shown in FIG. 4A, the first distance sensor 51 is fixed to a trunnion part of the fifth linked portion 32f such that a detection face 51a faces in the linkage axis direction for the fifth linked portion 32f and the sixth linked portion 32g,
10 in other words, such that the direction for detecting the distance is always directed to the holding part 40 side. The first distance sensor 51 may also be fixed to the sixth linked portion 32g.

[0036] When the measurement is to be performed by the first distance sensor 51, by performing a scanning measurement by rotating the fifth
15 rotating portion 31e and the fourth rotating portion 31d in a predetermined range, it is possible to accurately obtain the distances from the mounted position of the first distance sensor 51 to the measurement targets over a relatively wide range. As the first distance sensor 51, a ToF (Time of Flight) three-dimensional distance sensor or a
20 two-dimensional range sensor that can perform scanning measurement of distance to the measurement target on a plane including the linkage axis between the fifth linked portion 32f and the sixth linked portion 32g, a so called 2D-LiDAR (Light Detection and Ranging) sensor, may also be used. However, from the view point of ensuring the

measurement accuracy, it is preferable to use the single point laser distance sensor.

[0037] In addition, because the first distance sensor 51 is provided in a vicinity of the tip end of the arm part 30, for example, as shown in FIG.

5 2, it is possible to accurately detect the frame body state related to the shape of the frame body 6 and the space state in the space between the ceiling slab 1 and the frame body 6, and as shown in FIG. 3, it is possible to accurately detect a ceiling board state related to the shape of the ceiling board 8 carried by the carrier robot 110.

10 [0038] The distance detected by the first distance sensor 51 is sent to the controller 50 and is used to mainly control the operation of the arm part 30 as described below.

[0039] The second distance sensor 52 is the ToF (Time of Flight) three-dimensional distance sensor that is mounted so as to be directed
15 towards the ceiling slab 1 side and is a sensor that can acquire depth data indicating the distance from the mounted position of the second distance sensor 52 to the measurement target. The second distance sensor 52 is fixed to the mount plate 26 together with the arm part 30. In order to cause the second distance sensor 52 to approach the frame
20 body 6, for example, the second distance sensor 52 may be fixed to the mount plate 26 via a column that is freely extendable/contractable in the up and down direction.

[0040] As described above, by providing the second distance sensor 52 so as to be directed vertically upward, for example, as shown in FIG. 1, it

is possible to monitor the operation of placing the ceiling board 8, and as shown in FIG. 2, it is possible to detect the frame body state related to the shape of the frame body 6 and the space state in the space between the ceiling slab 1 and the frame body 6.

5 [0041] The distance detected by the second distance sensor 52 is sent to the controller 50 and is mainly used, as described below, when the installation robot 100 is to be accurately moved to a position below the frame body 6, for the monitoring of the placement operation, for determination of suitability of the placement operation, and so forth.

10 When it is possible to sufficiently ascertain the position of the frame body 6 and a situation of the placement of the ceiling board 8 by the above-described information acquisition device 15 provided on the base carriage unit 10, the second distance sensor 52 may not be provided.

[0042] As shown in FIG. 5, the controller 50 controls the operations of
15 the base carriage unit 10, the lifting and lowering part 21, and the arm part 30 on the basis of the data acquired by the first distance sensor 51, the second distance sensor 52, and the information acquisition device 15, and on the basis of pre-imported data related to operation area such as a BIM (Building Information Modeling), etc. The specific control
20 performed by the controller 50 will be described below in detail in a following description of a method of placing the ceiling board 8 onto the frame body 6.

[0043] Specifically, the controller 50 is configured of a microcomputer provided with a CPU (a central processing unit), a ROM (a read-only

memory), a RAM (random-access memory), and an I/O interface (an input-output interface). The RAM stores data processed by the CPU, the ROM stores a control program, etc. of the CPU in advance, and the I/O interface is used for input/output of information with devices and
5 detectors connected to the controller 50. The controller 50 may be configured of a plurality of microcomputers, and for example, the controller 50 may be provided on each of the installation unit 20 and the base carriage unit 10.

[0044] In addition, as shown in FIG. 5, the controller 50 is provided
10 with a communication unit 50a that performs transmission and reception of data with an external server 120 that instructs the installation robot 100 and the carrier robot 110 to perform the operation and that monitors the operation state. The communication unit 50a may be a general wireless communication device capable of transmitting
15 data through an Internet connection or may be a near-field wireless communication device such as BLE (Bluetooth® Low Energy) or Wi-Fi®. The communication unit 50a is also used to perform communication with a controller 90 of the carrier robot 110.

[0045] Next, the carrier robot 110 that carries the ceiling boards 8 will
20 be described with reference to FIGs. 3, 5, and 6. FIG. 6 is a diagram partially showing an upper surface of the carrier robot 110 viewed from the direction indicated by an arrow B shown in FIG. 3, and the base carriage unit 10, etc. is omitted in FIG. 6.

[0046] As shown in FIGs. 3, 5, and 6, the carrier robot 110 is provided with: the base carriage unit 10 that can move on the floor surface 2; a roller conveyor 64 on which the plurality of ceiling boards 8 are loaded in a state in which they are layered in the horizontal direction; a sending
5 out mechanism 65 that sends out the plurality of ceiling boards 8 along the roller conveyor 64; a first tip-over prevention mechanism 66 and a second tip-over prevention mechanism 67 that prevent tipping over of the ceiling board 8 layered in the horizontal direction; a turning mechanism 68 that turns the ceiling board 8 such that the front surface
10 8a of the ceiling board 8 faces the installation robot 100 side; a column 62 that is vertically provided on the base carriage unit 10 to support these respective mechanisms; and the controller 90 that controls the operations of the base carriage unit 10, the sending out mechanism 65, the first tip-over prevention mechanism 66, the second tip-over
15 prevention mechanism 67, and the turning mechanism 68. The carrier unit 60 is configured of the mechanism other than the base carriage unit 10.

[0047] Because the configuration of the base carriage unit 10 is the same as that of the base carriage unit 10 of the installation robot 100,
20 the description thereof will be omitted.

[0048] The roller conveyor 64 has a plurality of rotary rollers 64a and an endless belt 64b that is provided so as to surround the plurality of rotary rollers 64a, and the roller conveyor 64 is fixed to the column 62

via a bracket (not shown) such that the ceiling boards 8 are loaded on a flat upper surface thereof.

[0049] The sending out mechanism 65 has a rail member 65a that extend along the rotating direction of the roller conveyor 64 and that is
5 fixed to the column 62, a pushing part 65b that can be moved along the rail member 65a, an electric slide (not shown) that moves the pushing part 65b, and a moved-amount sensor 65c that can measure a moved amount of the pushing part 65b.

[0050] When it is determined that the ceiling board 8 is received by the
10 installation robot 100, the sending out mechanism 65 moves all of the plurality of ceiling boards 8 along the roller conveyor 64 by driving the electric slide to press the pushing part 65b against the ceiling boards 8. By doing so, the succeeding ceiling board 8 to be passed over to the installation robot 100 is sent out to a predetermined position. Whether
15 or not the ceiling board 8 is received by the installation robot 100 and whether or not the ceiling board 8 is sent out to the predetermined position are detected by a proximity sensor, etc. (not shown).

[0051] In addition, by successively measuring the moved distance of the pushing part 65b by using the moved-amount sensor 65c when the
20 ceiling boards 8 are sent out, it is possible to ascertain how many ceiling boards 8 have been supplied to the installation robot 100, in other words, how many ceiling boards 8 remain on the carrier robot 110.

[0052] The rail member 65a of the sending out mechanism 65 may be a pair of rail members that are arranged so as to sandwich the roller

conveyor 64, and in such a case, the pushing part 65b is supported from below by the pair of rail members.

[0053] The first tip-over prevention mechanism 66 prevents the ceiling board 8 to be passed over to the installation robot 100 from being tipped over before being held by the installation robot 100, and the second tip-over prevention mechanism 67 prevents, when the ceiling board 8 is received by the installation robot 100, the second ceiling board 8 that is layered with the ceiling board 8 to be received by the installation robot 100 from being tipped over.

[0054] The first tip-over prevention mechanism 66 has a main body portion 66a that extends along the rotating direction of the roller conveyor 64 and that is fixed to the column 62 via a bracket 66c and a pressing part 66b that extends downwards from the main body portion 66a and that is pressed against the ceiling board 8. The pressing part 66b has a built-in electric cylinder that can extend and contract in the up and down direction, and as the pressing part 66b is extended, a state in which the ceiling board 8 is clamped between the pressing part 66b and the roller conveyor 64 is achieved.

[0055] The second tip-over prevention mechanism 67 has a cylinder portion 67a that extends along the rotating direction of the roller conveyor 64 and that is fixed to the column 62 via a bracket 67d, a rod portion 67b that projects out from the cylinder portion 67a, and a pressing part 67c that extends downwards from a tip end of the rod portion 67b and that is pressed against the ceiling board 8.

[0056] The pressing part 67c has an built-in electric cylinder that can extend and contract in the up and down direction, and as the pressing part 67c is extended, a state in which the ceiling board 8 is clamped between the pressing part 67c and the roller conveyor 64 is achieved.

5 [0057] In addition, the cylinder portion 67a and the rod portion 67b form an electric cylinder that can extend and contract along the rail member 65a of the sending out mechanism 65 and are controlled so as to be extended in accordance with a sending speed of the sending out mechanism 65. Therefore, it is possible to prevent the ceiling board 8
10 from tipping over when the plurality of ceiling boards 8 are sent out by the sending out mechanism 65.

[0058] The turning mechanism 68 has a holding part 68a that can hold the ceiling board 8 and an arm part 68b that is provided with the holding part 68a on a first end thereof and that is attached to the column 62 via
15 a bracket 68c on a second end thereof. The arm part 68b is supported by the bracket 68c so as to be rotatable about a rotation shaft 68d, and the position of the arm part 68b is switched by a servomotor (not shown) between two positions shown in in FIG. 6, the position indicated by a solid line and the position indicated by a broken line.

20 [0059] The holding part 68a has the same configuration as that of the holding part 40 of the installation robot 100 and has an electric actuator (not shown) that is operated so as to push the protection ring 43 accommodated in the accommodating groove 41a of the main body portion 41 out from the inside of the accommodating groove 41a. The

electric actuator is operated when it is detected that the ceiling board 8 is held by the holding part 40 of the installation robot 100, and thereby, the held state of the ceiling board 8 by the holding part 68a of the turning mechanism 68 is released.

5 [0060] In general, when the ceiling boards 8 are distributed in the market, in order to protect the front surface 8a, two ceiling boards 8 are stacked in a state in which the front surfaces 8a thereof face with each other, and a multiple sets of the ceiling boards 8 are stacked together. In other words, in a case in which the plurality of ceiling boards 8
10 brought into a construction site are supplied to the installation robot 100 without taking any countermeasures, the front surface 8a and a back surface 8b are exposed alternately as a consequence.

[0061] However, as described above, the holding part 40 of the installation robot 100 is configured to hold the front surface 8a of the
15 ceiling board 8.

[0062] Therefore, in the carrier robot 110, by using the turning mechanism 68 having the above-described configuration, when the back surface 8b of the ceiling board 8 is facing the installation robot 100 side, the ceiling board 8 is turned such that the front surface 8a of the ceiling
20 board 8 faces the installation robot 100 side.

[0063] As described above, the carrier robot 110 ascertains how many ceiling boards 8 are loaded on the roller conveyor 64 on the basis of detected value by the moved-amount sensor 65c that measures the moved amount of the pushing part 65b. When the number of the

ceiling boards 8 remaining on the roller conveyor 64 is an odd number, the front surface 8a of the ceiling board 8 faces the installation robot 100 side, and when the number of the ceiling boards 8 is an even number, the back surface 8b of the ceiling board 8 faces the installation robot 100 side. Therefore, by operating the turning mechanism 68 only when it is determined that the number of the ceiling boards 8 is even number, it is possible to set the ceiling board 8 such that the front surface 8a of the ceiling board 8 faces the installation robot 100 side all the time.

[0064] In a case in which the plurality of ceiling boards 8 are stacked such that the front surface 8a and the back surface 8b face each other in advance, in other words, in a case in which the plurality of ceiling boards 8 can be loaded on the roller conveyor 64 such that the front surface 8a of the ceiling board 8 faces the installation robot 100 side all the time, the turning mechanism 68 may not be provided.

[0065] The controller 90 of the carrier robot 110 controls the operations of the base carriage unit 10, the sending out mechanism 65, the first tip-over prevention mechanism 66, the second tip-over prevention mechanism 67, and the turning mechanism 68 on the basis of the data acquired by the information acquisition device 15 and the moved-amount sensor 65c and on the basis of the pre-imported data related to the operation area including such as the BIM, etc. In addition, similarly to the controller 50 of the installation robot 100, the controller 90 is provided with a communication unit 90a. Because the specific configuration of the controller 90 is the same as that of the

controller 50 of the installation robot 100, the description thereof will be omitted.

[0066] Next, a method of placing the ceiling board 8 onto the frame body 6 by using the installation robot 100 having the above-described configuration will be described with main reference to FIGs. 1 to 3, 7, and 8. FIG. 7 is a flow chart showing a procedure of the operation performed by the installation robot 100, FIGs. 8A to 8D are schematic views for explaining an installation operation of the ceiling board 8 performed by the installation robot 100 and respectively show states for placing the ceiling board 8 onto the frame body 6 in order along a time series.

[0067] In Step S11, the data related to the operation area is first imported and stored in the controller 50 of the installation robot 100. Specifically, the plot data such as the BIM, etc. is acquired from the server 120 via the communication unit 50a of the controller 50, and it is stored in a storage unit. The data imported in this step includes, in addition to the plot data such as the BIM, etc., the position of the frame body 6, an order of attaching the ceiling board 8, and so forth.

[0068] Next, in Step S12, by using the information acquisition device 15 of the base carriage unit 10, the controller 50 acquires the surrounding information around the installation robot 100, for example, distances to posts and placement of the posts, and identifies the self-location of the installation robot 100, in other words, the coordinate of the installation robot 100 on the plot by collating the stored plot data

such as the BIM, etc. with the acquired information. In order to specify the self-location, the controller 50 may have a function of a SLAM (Simultaneous Localization and Mapping).

[0069] In following Step S13, the controller 50 extracts the coordinate of the frame body 6 to which the ceiling board 8 is to be attached for first time from the data imported in Step S11 and controls the base carriage unit 10 to move the installation robot 100 towards the thus-extracted coordinate of the frame body 6. The frame body 6 to which the ceiling board 8 is to be attached for first time may be the frame body 6 that is located at the closest distance from the location of the installation robot 100.

[0070] Once the movement of the installation robot 100 is completed, the controller 50 performs recognition of the frame body 6 targeted for the operation by the second distance sensor 52 (Step S14). Specifically, the distance to the frame body 6 targeted for the operation is measured by the second distance sensor 52, and a shape of the four sides forming the opening portion of the frame body 6 is detected.

[0071] In the above, when any one of the four sides forming the opening portion of the frame body 6 cannot be detected, there is a possibility that some sort of obstacle is present between the frame body 6 and the installation robot 100 and the opening portion of the frame body 6 is covered by the obstacle. Thus, in a case in which the frame body 6 cannot be recognized normally, it is determined that the operation cannot be performed, and the process proceeds to Step S22. In a case

in which the frame body 6 is recognized normally, in order to acquire further detailed information, the process proceeds to Step S15.

[0072] In Step S15, the controller 50 controls the base carriage unit 10 to move the installation robot 100 to the position directly below the frame body 6 that has been subjected to the recognition in Step S14. Specifically, the controller 50 calculates the center coordinate of the frame body 6 on the basis of the positions of the four sides of the frame body 6 recognized in Step S14 and moves the installation robot 100 such that the base portion 32a of the arm part 30 is located directly below the thus-calculated center coordinate.

[0073] Once the movement of the installation robot 100 is completed, in following Step S16, the frame body state related to the shape of the frame body 6 is acquired.

[0074] Specifically, a relative positional relationship between the four sides forming the opening portion of the frame body 6 and the arm part 30 is measured by the first distance sensor 51, which is attached to the fifth linked portion 32f that is the linked portion of the arm part 30 on the tip end side. By doing so, the controller 50 can three-dimensionally ascertain the positional relationship between the arm part 30 and the frame body 6.

[0075] The measurement by the first distance sensor 51 is performed in a state in which the arm part 30 is extended upwards and the detection face 51a of the first distance sensor 51 is directed vertically upward. When the frame body 6 is positioned at a relatively high position, in

order to bring the first distance sensor 51 closer to the frame body 6, the lifting and lowering part 21 may be extended to a length that is set in advance.

[0076] The acquisition of the state of the frame body 6 performed in
5 Step S16 may also be achieved by measurement by the second distance
sensor 52 instead of or in addition to the measurement by the first
distance sensor 51. By performing the measurement by two distance
sensors 51 and 52, it is possible to more accurately ascertain the
positional relationship between the arm part 30 and the frame body 6.
10 Especially, because the first distance sensor 51 and the second distance
sensor 52 are directly attached to the installation robot 100, even if the
frame body 6 and/or the floor surface 2 is inclined with respect to the
horizontal plane, it is possible to accurately detect the relative positional
relationship of the frame body 6 with respect to the installation robot
15 100.

[0077] In following Step S17, the space state in the space between the
ceiling slab 1 and the frame body 6 is acquired.

[0078] Specifically, as shown in FIG. 2, in a state in which the lifting
and lowering part 21 is extended to the length set in advance, the
20 distance from the frame body 6 to the ceiling slab 1 is measured and
distances to pipes, wires, braces, and the hanger bolt 4 arranged
between the frame body 6 and the ceiling slab 1 are measured by the
second distance sensor 52 that is attached to the mount plate 26.

[0079] In addition, for a blind spot of the second distance sensor 52, as shown in FIG. 2, the measurement is performed by the first distance sensor 51, for example, in a state in which the detection face 51a of the first distance sensor 51 is directed obliquely upward. The measurement by the first distance sensor 51 is performed, for example, over about 360 degrees by rotating the first rotating portion 31a of the arm part 30. In order to perform the detection of the state of the space between the frame body 6 and the ceiling slab 1 with a higher reliability, it is preferable to perform the measurement in a state in which the detection face 51a of the first distance sensor 51 is directed in the substantially horizontal direction after the first distance sensor 51 is moved to the position beyond the frame body 6 in the direction towards the ceiling slab 1.

[0080] By doing so, the controller 50 can three-dimensionally ascertain the relative positional relationship between a path through which the ceiling board 8 and the arm part 30 are moved when the ceiling board 8 is to be placed onto the frame body 6 and the pipes, etc. that are arranged between the frame body 6 and the ceiling slab 1. Especially, because the first distance sensor 51 and the second distance sensor 52 are directly attached to the installation robot 100, even if the floor surface 2 is inclined with respect to the horizontal plane, it is possible to accurately detect the relative positional relationship of the pipes, etc. with respect to the installation robot 100. The acquisition of the state

of the frame body 6 performed in Step S16 and the acquisition of the space state performed in Step S17 may be performed at the same time.

[0081] Once the state of the frame body 6 and the space state are acquired as described above, the process proceeds to Step S18, and the
5 controller 50 determines whether or not the operation of placing the ceiling board 8 onto the frame body 6 can be performed.

[0082] In order to place the ceiling board 8 onto the frame body 6, it is required to move the ceiling board 8 through the opening portion of the frame body 6 to the position above the frame body 6 temporarily. In a
10 case in which the pipe, etc. is on the path through which the ceiling board 8 and the arm part 30 are moved while the ceiling board 8 is being positioned above the frame body 6 as described above, it is not possible to place the ceiling board 8 onto the frame body 6 through the opening portion of the frame body 6.

15 [0083] When the ceiling board 8 is to be positioned above the frame body 6, the ceiling board 8 is inserted obliquely upward through the diagonal line of the opening portion of the frame body 6. However, for example, in a case in which the pipe or the brace is present in all of four corners when viewed through the opening portion of the frame body 6,
20 even if the insertion direction of the ceiling board 8 is changed in any way, the ceiling board 8 comes into contact with these objects, and therefore, it is not possible to place the ceiling board 8 onto the frame body 6.

[0084] In addition, in order to position the ceiling board 8 above the frame body 6, the ceiling board 8 may be oriented in the vertical direction, and the ceiling board 8 may then be inserted directly upward through the diagonal line of the opening portion of the frame body 6.

5 However, if the distance from the frame body 6 to the lower surface of the ceiling slab 1 is shorter than the length of the ceiling board 8, the ceiling board 8 comes into contact with the ceiling slab 1, and therefore, it is not possible to place the ceiling board 8 onto the frame body 6 by inserting the ceiling board 8 in the straight direction.

10 [0085] Thus, in Step S18, on the basis of the space state acquired, the controller 50 determines whether or not it is possible to place the ceiling board 8 onto the frame body 6, in other words, whether or not there is a path that enables the placement of the ceiling board 8 onto the frame body 6 by avoiding the pipe, etc.

15 [0086] Specifically, for example, in a case in which the pipe or the brace is present in three corners when viewed through the opening portion of the frame body 6, the controller 50 determines that it is possible to place the ceiling board 8 by using the path extending through the last one corner, and for example, in a case in which the pipe, etc. is arranged
20 directly above the opening portion of the frame body 6 and the ceiling board 8 cannot be inserted in the straight direction, the controller 50 determines that it is possible to place the ceiling board 8 by using the path in which the ceiling board 8 is inserted by being inclined by at least a predetermined angle with respect to the vertical plane.

[0087] When it is determined that, with consideration of the movable range of the arm part 30, there is the path that enables the placement of the ceiling board 8 onto the frame body 6 by avoiding the pipe, etc., the process proceeds to Step S19 in order to hold the ceiling board 8 by the
5 holding part 40. On the other hand, when it is determined that there is no path that enables the placement of the ceiling board 8 onto the frame body 6, it is determined that the operation of placing the ceiling board 8 cannot be performed, and the process proceeds to Step S22.

[0088] In Step S19, the controller 50 causes the holding part 40 to hold
10 the ceiling board 8 loaded on the carrier robot 110 by controlling the operation of the arm part 30.

[0089] Prior to the above process, the controller 50 sends, to the carrier robot 110 via the communication unit 50a, a request signal that requests delivery of the ceiling board 8.

15 [0090] When the carrier robot 110 receives the request signal by the communication unit 90a of the controller 90, the carrier robot 110 moves to the vicinity of the installation robot 100 in order to deliver the ceiling board 8. In the above, in a case in which single carrier robot 110 is not provided for every installation robot 100, and two to three carrier
20 robots 110 are shared between the plurality of installation robots 100 for example, the carrier robot 110 located in the shortest distance is moved to the vicinity of the installation robot 100 in response to the request signal.

[0091] When approach of the carrier robot 110 is detected, as shown in FIG. 3, the controller 50 first causes the first distance sensor 51 attached to the fifth linked portion 32f of the arm part 30 to recognize a state of the ceiling board 8 loaded on the carrier robot 110. By the time
5 the process has proceeded to Step S19, the lifting and lowering part 21 is contracted in advance in accordance with the height of the ceiling board 8 loaded on the carrier robot 110.

[0092] When the state of the ceiling board 8, in other words, the positions of the four sides of the ceiling board 8 are recognized, a center
10 C1 of the ceiling board 8 is recognized on the basis of the positions of the four sides. Then, the controller 50 controls an amount of rotation of each of the rotating portions 31a to 31f of the arm part 30 such that a center C2 of the holding part 40 is positioned on the extension of the center C1 of the ceiling board 8 that has been recognized (see FIG. 4A).

15 [0093] By further moving the holding part 40 towards the ceiling board 8 from the state shown in FIG. 4A, the needles 42 of the holding part 40 are stuck into the front surface 8a of the ceiling board 8 (see FIG. 4B). By doing so, a state in which the ceiling board 8 is held by the holding part 40 is achieved.

20 [0094] The first distance sensor 51 detects that the state in which the ceiling board 8 is held by the holding part 40 is achieved as described above. A detection result from the first distance sensor 51 is sent from the controller 50 of the installation robot 100 to the controller 90 of the carrier robot 110 as a hold completion signal.

[0095] By the controller 90 of the carrier robot 110 that has received the hold completion signal, the pressing part 66b of the first tip-over prevention mechanism 66 is contracted, the clamped state of the ceiling board 8 by the pressing part 66b and the roller conveyor 64 is released,
5 and a clamp released signal is sent to the controller 50 of the installation robot 100.

[0096] The controller 50 of the installation robot 100 that has received the clamp released signal controls the amount of rotation of each of the rotating portions 31a to 31f of the arm part 30 and moves the ceiling
10 board 8 held by the holding part 40 towards the frame body 6.

[0097] As shown in FIG. 6, when two of the ceiling boards 8 loaded on the carrier robot 110 are held side by side so as to face the installation robot 100 side, the ceiling board 8 on the right side when viewed from the installation robot 100, in other words, the ceiling board 8 held by the
15 turning mechanism 68 of the carrier robot 110 is selected as the ceiling board 8 to be held by the holding part 40.

[0098] When the delivery of the ceiling board 8 from the carrier robot 110 to the installation robot 100 is completed as described above, the process proceeds to Step S20, and the placement operation of the ceiling
20 board 8 onto the frame body 6 is executed.

[0099] Specifically, as shown in FIGs. 8A to 8D, the controller 50 appropriately controls the amount of rotation of each of the rotating portions 31a to 31f of the arm part 30 to three-dimensionally change the position of the holding part 40 such that the ceiling board 8 does not

come into contact with the frame body 6 or the pipe, and thereby, the ceiling board 8 is ultimately placed onto the frame body 6.

[0100] FIG. 8A shows a state in which the ceiling board 8 is inserted obliquely upward into an opening portion 6c of the frame body 6, which is surrounded by bar members 6a and 6b that are connected to form the grid shape, so as to be moved through the diagonal line of the opening portion 6c. Specifically, the ceiling board 8 is inserted into the opening portion 6c obliquely upward so as to be moved through the diagonal line of the opening portion 6c in a state in which the ceiling board 8 is inclined by about 45 degrees with respect to the vertical plane. In the above, the inclined angle of the ceiling board 8 is set appropriately in accordance with the distance to the obstacle directly above the opening portion 6c and/or the distance from the frame body 6 to the lower surface of the ceiling slab 1.

[0101] After the state shown in FIG. 8A is established, when a state in which an entirety of the ceiling board 8 is positioned above the frame body 6 is achieved, as shown in FIG. 8B, the amount of rotation of each of the rotating portions 31a to 31f is controlled such that the center of the ceiling board 8 is substantially aligned with the center of the opening portion 6c of the frame body 6.

[0102] By rotating the first rotating portion 31a, the fourth rotating portion 31d, or the sixth rotating portion 31f from the state shown in FIG. 8B, as shown in FIG. 8C, the directions of the four sides of the

ceiling board 8 are substantially aligned with the directions of the four sides of the opening portion 6c .

[0103] By gradually rotating the second rotating portion 31b, the third rotating portion 31c, and the fifth rotating portion 31e from the state shown in FIG. 8C, the ceiling board 8 and the holding part 40 are moved vertically downward (see FIG. 1).

[0104] By moving the ceiling board 8 vertically downward as described above, the ceiling board 8 is lowered down from the above onto the opening portion 6c of the frame body 6, and thereby, as shown in FIG. 8D, a state in which the four sides are respectively supported by the bar members 6a and 6b from vertically below is achieved.

[0105] By further moving the holding part 40 vertically downward from this state, the needles 42 stuck into the front surface 8a of the ceiling board 8 are gradually pulled out from the ceiling board 8. When the needles 42 are completely pulled out from the ceiling board 8, the placement of the ceiling board 8 onto the frame body 6 is completed.

[0106] In the above, a series of movements of the arm part 30 shown in FIGs. 8A to 8D is only an example, and the present invention is not limited thereto. For example, from the state shown in FIG. 8C, instead of moving the entirety of the ceiling board 8 vertically downward, a state in which only one side of the four sides of the ceiling board 8 is first brought into contact with the bar member 6a or 6b in parallel is achieved, in other words, a state in which the ceiling board 8 is slightly inclined with respect to the horizontal plane is achieved, and

subsequently, the ceiling board 8 may be lowered down to the frame body 6 such that remaining three sides of the ceiling board 8 approach the bar members 6a and 6b about the side in contact with the bar member 6a or 6b serving as the fulcrum.

5 [0107] In addition, the step of moving the ceiling board 8 vertically downward from the state shown in FIG. 8C is monitored by the second distance sensor 52, and if the directions of the four sides of the ceiling board 8 are misaligned with the directions of the four sides of the opening portion 6c, the first rotating portion 31a, the fourth rotating portion 31d,
10 or the sixth rotating portion 31f is appropriately rotated such that the misalignment is resolved.

[0108] Once the placement of the ceiling board 8 is completed, in following Step S21, it is determined whether or not the placement operation of the ceiling board 8 has been suitably performed, in other
15 words, it is confirmed whether or not the placement operation of the ceiling board 8 has been completed normally.

[0109] In a case in which the ceiling board 8 is normally placed onto the frame body 6, in other words, in a case in which the four sides of the ceiling board 8 are respectively in substantial contact with the bar
20 members 6a and 6b, when viewed from the installation robot 100 side, the difference between the distance to the lower surface of the frame body 6 and the distance to the front surface 8a of the ceiling board 8 is substantially the same as the thickness of a flange portion of the frame body 6 that supports the ceiling board 8 from below, and the equal

values are obtained in the vicinities of the four sides of the ceiling board 8.

[0110] Therefore, in Step S21, the distance to the lower surface of the frame body 6 and the distance to the front surface 8a of the ceiling board 8 are measured in the vicinities of the four sides of the ceiling board 8 by either one or both of the first distance sensor 51 and the second distance sensor 52, and then, it is determined whether or not the difference between thus-measured distances is smaller than the threshold value set in advance in the vicinities of any of the sides, and thereby, it is determined whether or not the placement operation of the ceiling board 8 has been completed normally. In the above, the threshold value is set on the basis of the thickness of the flange portion of the frame body 6 that supports the ceiling board 8 from below.

[0111] When the difference between the distances is smaller than the threshold value in the vicinities of all of the four sides of the ceiling board 8, it is estimated that a state in which the four sides of the ceiling board 8 are in substantial contact with the frame body 6 is achieved, and therefore, the controller 50 determines that the placement operation of the ceiling board 8 onto the frame body 6 at a predetermined location is completed normally and stores the completion of the operation, and the process proceeds to Step S23.

[0112] On the other hand, when the difference between the distances in the vicinities of any of the sides is equal to or greater than the threshold value, it is estimated that a state in which a gap that is larger than

expected is formed between the ceiling board 8 and the frame body 6 is caused, and therefore, it is determined that the operation is not completed normally, and the process proceeds to Step S22. In the above, before the process proceeds to Step S22, it may be possible to add
5 a step of improving a placement state of the ceiling board 8 by slightly moving the ceiling board 8 up and down by pressing the arm part 30 against the position at which the difference between the distances is equal to or greater than the threshold value.

[0113] In Step S22, the controller 50 determines that the placement of
10 the ceiling board 8 onto the frame body 6 at a predetermined location is not completed, and the controller 50 stores that the placement operation cannot be performed or the placement operation is in-completed, together with the cause therefor. In the above, the information related to the operation state stored in the controller 50 in Steps S21 and S22 is
15 sent to the server 120 via the communication unit 50a of the controller 50 successively.

[0114] Therefore, an operator or the site worker who monitors the operation state of the installation robot 100 via the server 120 can easily confirm that, at which location, the placement operation of the ceiling
20 board 8 onto the frame body 6 is completed normally. At the same time, they can easily ascertain which of the ceiling boards 8 needs to be subjected to the placement operation again, or they can easily ascertain the cause of the failure to perform the placement operation of the ceiling board 8.

[0115] As described above, once the storage of the operation state is completed in Steps S21 and 22, the process proceeds to Step S23, and the controller 50 confirms whether or not all of the planned placement operations have been completed.

5 [0116] When all of the planned placement operations have been completed, the process is terminated, and the installation robot 100 is shifted to a standby state until an instruction for a next operation is received from the server 120.

[0117] On the other hand, when the planned placement operations
10 have not been completed yet, the process returns to Step S13, and the installation robot 100 is moved to the location of the frame body 6 onto which subsequent ceiling board 8 is to be placed. Subsequently, the placement operation of the ceiling board 8 is executed by following the above-described steps.

15 [0118] According to the embodiment mentioned above, the advantages described below are afforded.

[0119] With the controller 50 of the installation robot 100 having the above-described configuration, the frame body state related to the shape of the frame body 6 is detected by at least one of the first distance sensor
20 51 and the second distance sensor 52, and the arm part 30 is operated on the basis of the thus-detected frame body state, and thereby, the ceiling board 8 held by the holding part 40 is placed onto the frame body 6 by lowering the ceiling board 8 down from the above frame body 6.

- [0120] As described above, the ceiling board 8 is placed onto the frame body 6 after the shape of the frame body 6 is checked, and thereby, regardless of the directions of the four sides of the frame body 6 with respect to the installation robot 100, it is possible to place the ceiling board 8 onto the frame body 6 smoothly and automatically. In addition, by using the installation robot 100 to perform the placement operation of the ceiling board 8, which is the operation at a high place, it is possible to reduce a burden placed on the site worker for the operation and to ensure the safety.
- 10 [0121] In addition, the controller 50 of the installation robot 100 having the above-described configuration determines whether or not the placement of the ceiling board 8 onto the frame body 6 can be performed on the basis of the space state in the space between the ceiling slab 1 and the frame body 6 that has been detected in advance.
- 15 [0122] As described above, in a case in which there are obstacles such as the pipe, etc. in the space between the ceiling slab 1 and the frame body 6, thoughtless execution of the operation of placing the ceiling board 8 onto the frame body 6 is avoided, and it is possible to ensure the safety for the operations performed by the installation robot 100. In addition, even in a case in which there are obstacles such as the pipe, etc. in the space between the ceiling slab 1 and the frame body 6, the path that can avoid these obstacles is computed and the ceiling board 8 is moved so as to follow the thus-computed path, and so, it is possible to
- 20

place the ceiling board 8 onto the frame body 6 smoothly and automatically.

[0123] In addition, the controller 50 of the installation robot 100 having the above-described configuration sets, when the ceiling board 8 is to be
5 held by the holding part 40, the position for holding the ceiling board 8 by the holding part 40 on the basis of the ceiling board state related to the shape of the ceiling board 8 that is detected by the first distance sensor 51.

[0124] The path that is followed by the ceiling board 8 is set to have a
10 certain clearance by considering dimensional errors of the ceiling board 8 and/or errors in the holding position of the ceiling board 8 such that the ceiling board 8 does not come into contact with the frame body 6. However, because it is now become possible to hold the ceiling board 8 by the holding part 40 at the same holding position every time, it is
15 possible to employ a path with less clearance as the path that is followed by the ceiling board 8. Because a range of the path that enables the placement of the ceiling board 8 is increased thereby, it is possible to improve an efficiency of the placement operation of the ceiling board 8. In addition, because the ceiling board 8 is held by the holding part 40 at
20 the center C1, a maneuverability of the ceiling board 8 is stabilized, and as a result, it is possible to stably perform the operation of placing the ceiling board 8 onto the frame body 6.

[0125] Following modifications are also within the scope of the present invention, and it is also possible to combine the configurations shown in

the modifications with the configurations described in the above-described embodiment and to combine the configurations described in the following different modifications.

[0126] In the above-mentioned embodiment, the space state in the space between the ceiling slab 1 and the frame body 6 is detected by the first distance sensor 51 and the second distance sensor 52 that are provided on the installation robot 100. Instead of this configuration, the space state may be detected in advance by the two-dimensional range sensor that can perform scanning measurement of distances in the horizontal plane, the so called 2D-LiDAR (Light Detection and Ranging) sensor, provided on a robot independent from the installation robot 100 or the installation robot 100. Specifically, by moving the two-dimensional range sensor through the opening portion of the frame body 6 from below the frame body 6 to above the frame body 6 towards the ceiling slab 1, the space state in the space between the ceiling slab 1 and the frame body 6 may be acquired for every frame body 6 in advance.

[0127] As described above, if the space state is detected in advance for each frame body 6, it becomes possible to determine, in advance, whether or not the placement operation can be performed. Therefore, by excluding the frame body 6 to which the placement operation cannot be performed from the operation targets in advance, it is possible to effectively perform the placement operation of the ceiling board 8 by the installation robot 100. In the above, whether or not the placement

operation can be performed may be determined by the robot independent from the installation robot 100. In addition, in addition to the space state, the state of the frame body 6 may also be acquired in advance for every frame body 6.

5 [0128] In addition, in the above-mentioned embodiment, the installation robot 100 is provided with the base carriage unit 10 and the lifting and lowering part 21 having the characteristic configurations. Instead of this configuration, a generally used aerial work platform may be used as the part formed of the base carriage unit 10 and the lifting
10 and lowering part 21, and in such a case, the arm part 30 is provided on an operation stage of the aerial work platform.

[0129] In addition, in the above-mentioned embodiment, the base portion 32a of the arm part 30 is fixed to the mount plate 26 such that the linkage direction axis with the first linked portion 32b extends along
15 the vertical direction. Instead of this configuration, the base portion 32a may be fixed to the mount plate 26 in a state in which the linkage direction axis with the first linked portion 32b is inclined with respect to the vertical direction. By providing the base portion 32a so as to be inclined as described above, the ceiling board 8 can be received from the
20 carrier robot 110 with ease.

[0130] In addition, in the above-mentioned embodiment, the installation robot 100 receives the ceiling board 8 from the carrier robot 110. Instead of this configuration, the installation robot 100 may be provided with a storage part that can temporarily store the plurality of

ceiling boards 8. In such a case, the storage part is provided on the base carriage unit 10, for example, and the ceiling boards 8 are stored in the storage part such that the ceiling boards 8 can be held by the holding part 40 attached to the arm part 30. Specifically, as in a modification shown in FIGs. 9 to 12, the installation robot 100 may be provided with a storage part 130 in which the plurality of ceiling boards 8 can be stored. FIG. 9 is a side view of the installation robot 100 provided with the storage part 130, FIG. 10 is an enlarged sectional view showing a cross-section, in enlargement, taken along the line C-C in FIG. 9, FIG. 11 is a diagram for explaining the operation of the installation robot 100 provided with the storage part 130, and FIG. 12 is an enlarged sectional view showing a cross-section, in enlargement, taken along the line D-D in FIG. 9.

[0131] The storage part 130 has a loading mechanism 70 in which the plurality of ceiling boards 8 are loaded by being stacked in the vertical direction and a temporal placement part 74 on which the ceiling board 8 is temporarily placed before being placed onto the frame body 6. On the temporal placement part 74, a single ceiling board 8, which has been transferred from the loading mechanism 70 by the above-described installation unit 20, is temporarily placed.

[0132] The loading mechanism 70 has a loading part 71 on which the ceiling boards 8 are loaded, a plurality of pillars 72 that are vertically provided on an upper surface of the base carriage unit 10 and support the loading part 71 such that the loading part 71 is movable in the

vertical direction, and an electric actuator (not shown) that moves the loading part 71 in the vertical direction along the pillars 72.

[0133] The height of the loading part 71 is adjusted by the electric actuator such that the height of the top ceiling board 8 among the loaded ceiling boards 8 stays the same constantly. In other words, as the number of the loaded ceiling boards 8 is reduced, the loading part 71 is gradually moved upwards. When the ceiling boards 8 are supplied to the loading part 71 by the site worker, the loading part 71 is lowered to the lowest position, and once the supply is completed, the loading part 71 is then lifted upwards until the height of the top ceiling board 8 among the loaded ceiling boards 8 reaches a predetermined height. It is detected whether or not the height of the top ceiling board 8 among the loaded ceiling boards 8 has reached a predetermined height by using a proximity sensor, etc. that is attached to any of the pillars 72, for example.

[0134] As shown in FIGs. 9 and 10, the temporal placement part 74 is a mount base that is provided for temporarily holding the succeeding ceiling board 8, which will be placed onto the frame body 6 next, in a state in which the front surface 8a is substantially parallel with the vertical plane and in which one of corner portions is directed vertically downward, and the temporal placement part 74 has first support members 76 that respectively support side surfaces 8c of the ceiling board 8; second support members 77 that support the back surface 8b of the ceiling board 8; and supporting columns 79 that are vertically

provided on the upper surface of the base carriage unit 10 and that are respectively attached to the first support members 76 and the second support members 77 directly or indirectly.

[0135] As shown in FIG. 10, each of the first support members 76 is a member with a substantially L-shaped cross section having: a mount portion 76a that has a mount surface 76b on which the side surface 8c of the ceiling board 8 is to be mounted; and an opposing portion 76c that opposes to the front surface 8a of the ceiling board 8, and a pair of the first support members 76 are arranged symmetrically about the center portion of the ceiling board 8 so as to respectively support two side surfaces 8c of a single ceiling board 8. Specifically, as shown in FIG. 9, the pair of first support members 76 are arranged such that the mount surfaces 76b of the mount portions 76a, onto which the side surfaces 8c of the ceiling board 8 are respectively mounted, are perpendicular to each other.

[0136] The opposing portion 76c is formed to have a tapered shape such that the distance from the front surface 8a of the ceiling board 8 is gradually increased towards the upper side, and as described later, the opposing portion 76c functions as a guiding portion that guides the side surface 8c of the ceiling board 8 when the ceiling board 8 is to be temporarily placed on the temporal placement part 74.

[0137] Each of the second support members 77 is a flat member having a mount surface 77a on which the back surface 8b of the ceiling board 8 is mounted, and similarly to the first support members 76, a

pair of the second support members 77 are arranged symmetrically about the center of the ceiling board 8. Specifically, as shown in FIG. 10, the second support members 77 are arranged such that the mount surfaces 77a are perpendicular to the mount surfaces 76b of the mount portions 76a of the first support members 76.

[0138] In addition, as shown in FIG. 10, the mount surfaces 77a of the second support members 77 are inclined by a predetermined first angle θ (for example, 5° to 10° , preferably about 6°) with respect to the vertical plane VP. Therefore, when the ceiling board 8 is temporarily placed on the temporal placement part 74, the two side surfaces 8c are respectively brought into contact with the mount surfaces 76b of the mount portions 76a of the pair of first support members 76, and at the same time, the back surface 8b is brought into contact with the mount surfaces 77a of the pair of second support members 77. The first angle θ is not limited to the above-described range, and the first angle θ may be any angle as long as the ceiling board 8 comes into contact with each of the mount surfaces 76b and the mount surfaces 77a by its weight because of the inclination of the mount surfaces 77a with respect to the vertical plane VP. For example, the first angle θ may be larger than 10° .

[0139] As described above, in general, when the ceiling boards 8 are distributed in the market, in order to protect the front surfaces 8a, two ceiling boards 8 are stacked to form a pair in a state in which the front surfaces 8a thereof face with each other, and a multiple pairs of ceiling boards 8 are stacked together.

[0140] In other words, if the ceiling boards 8, which have been stacked on the loading part 71 of the loading mechanism 70 in the vertical direction, are placed onto the frame body 6 by holding them by the holding part 40 of the installation unit 20 without taking any countermeasures, the back surface 8b sides are placed onto the frame body 6 at every other ceiling board 8.

[0141] Thus, in this modification, the ceiling boards 8 loaded on the loading mechanism 70 are each temporarily placed on the temporal placement part 74 once by the installation unit 20, and the front surface 8a of the ceiling board 8, which has been temporarily placed, is held by the holding part 40 of the installation unit 20.

[0142] Next, steps of temporarily placing the ceiling boards 8, which have been loaded on the loading part 71 of the loading mechanism 70, to the temporal placement part 74 will be described.

[0143] The operation of the arm part 30 is controlled by the controller 50, and thereby, the upper surface of the top ceiling board 8 among the ceiling boards 8 loaded on the loading part 71 is held by the holding part 40. In the above, because the ceiling board 8 is later placed on the temporal placement part 74 temporarily, there is no need to align the center C2 of the holding part 40 with the center C1 of the ceiling board 8 at this time. Therefore, for example, because there is no need to recognize the position of the center C1 of the ceiling board 8, it is possible to reduce the time required for holding the ceiling board 8 loaded on the loading part 71 by the holding part 40.

[0144] When it is confirmed that the ceiling board 8 is held by the holding part 40, the controller 50 controls the arm part 30 such that one of the corner portions of the ceiling board 8 is directed vertically downward, and thereafter, the controller 50 controls the arm part 30 such that the ceiling board 8 is inserted between the opposing portions 76c and the second support members 77 of the temporal placement part 74. During the ceiling board 8 is being inserted between the opposing portions 76c and the second support members 77, the ceiling board 8 is guided by the portions having the tapered shape of the opposing portions 76c and the portions having the tapered shape of the second support members 77.

[0145] When the face of the ceiling board 8 held by the holding part 40 is the front surface 8a, as shown in FIG. 9, the temporal placement of the ceiling board 8 to the temporal placement part 74 is performed in a state in which the holding part 40 is positioned on the opposite side of the second support members 77 with the ceiling board 8 being positioned therebetween. On the other hand, when the face of the ceiling board 8 held by the holding part 40 is the back surface 8b, as shown in FIG. 11, the temporal placement is performed in a state in which the holding part 40 is positioned on the side of the second support members 77. As described above, because the pair of the ceiling boards 8 is formed by stacking two ceiling boards 8 such that the front surfaces 8a thereof face with each other, the ceiling boards 8 are held by the

holding part 40 on the front surface 8a side and the back surface 8b side, alternately.

[0146] As described above, when the ceiling board 8 is temporarily placed to the temporal placement part 74, the back surface 8b side of the ceiling board 8 is always positioned on the side of the second support members 77, and the back surface 8b comes to contact with the inclined mount surfaces 77a.

[0147] At the temporal placement part 74, the held state of the ceiling board 8 by the holding part 40 is released by moving the holding part 40 in the direction in which the needles 42 are pulled out from the ceiling board 8, for example. However, at this time, the ceiling board 8 is pressed by the first support members 76 or the second support members 77. Therefore, there is a risk in that a mark may be formed on the ceiling board 8 by being pressed against the first support members 76 or the second support members 77.

[0148] In order to avoid such an event and to smoothly release the held state of the ceiling board 8 by the holding part 40, it is preferred to provide a hold release mechanism 46 on the holding part 40 as shown in FIG. 12.

[0149] As shown in FIG. 12, the hold release mechanism 46 has an electric actuator 48 that is provided at the center portion of the main body portion 41 of the holding part 40 and a pressing part 47 that is moved back and forth by the electric actuator 48 along the center C2 of the holding part 40.

[0150] As shown in FIG. 12(a), while the pressing part 47 is received within the main body portion 41 when the ceiling board 8 is to be held by the holding part 40, when the held state of the ceiling board 8 by the holding part 40 is to be released, as shown in FIG. 12(b), the pressing
5 part 47 is projected out from the main body portion 41, thereby pushing the ceiling board 8 such that the ceiling board 8 is moved away from the holding part 40. Although a state in which the front surface 8a side of the ceiling board 8 is held by the holding part 40 is shown in FIG. 12, the same applies to the case in which the back surface 8b side of the ceiling
10 board 8 is held by the holding part 40.

[0151] The ceiling board 8 is not pushed by the pressing part 47 instantaneously, but is pushed gradually over about several seconds, for example. Therefore, as the electric actuator 48, it is preferred to use, for example, an actuator that is capable of finely adjusting an amount of
15 expansion and contraction, such as an electric cylinder, in which a ball screw and a rotary motor is combined, rather than an electromagnetic solenoid which is of ON/OFF type. In addition, a driving system of the actuator is not limited to the electric driving system, and a pneumatic driving system or a hydraulic driving system may be also employed.

20 [0152] In addition, in order to improve a holding capacity of the holding part 40 holding the ceiling board 8, as shown in FIG. 12, the plurality of needles 42 may be arranged not only in the circumferential direction, but also in the radial direction. As described above, by arranging the plurality of needles 42 in the circumferential direction and

the radial direction, it is possible to lift up the ceiling board 8 loaded on the loading part 71 by the holding part 40 with ease. The needles 42 may be arranged in anyway on the holding part 40, and for example, the needles 42 may be arranged in a ring shape, an oval shape, or a rectangular shape.

[0153] After the held state of the ceiling board 8 by the holding part 40 is released and the ceiling board 8 is temporarily placed on the temporal placement part 74, due to the weight of the ceiling board 8, the back surface 8b comes into contact with the mount surfaces 77a of the second support members 77 and the two side surfaces 8c respectively come into contact with the mount surfaces 76b of the mount portions 76a, and thereby, the ceiling board 8 is stabilized at this state. In other words, when the ceiling board 8 is temporarily placed on the temporal placement part 74, the front surface 8a side is always directed to the same direction, and the center C1 is always positioned at the same position.

[0154] As described above, similarly to the installation unit 20 including the arm part 30, the temporal placement part 74, on which the ceiling board 8 is temporarily placed, is provided on the base carriage unit 10, and therefore, the coordinate system of the arm part 30 and the coordinate system of the temporal placement part 74 belong to the same coordinate system. In other words, in the coordinate system of the arm part 30, the position coordinate of the center C1 of the front surface 8a of the ceiling board 8 is always set at the same position coordinate.

[0155] Therefore, when the ceiling board 8, which has been temporarily placed on the temporal placement part 74, is to be held by the holding part 40 for placing the ceiling board 8 onto the frame body 6, it is possible to align the center C2 of the holding part 40 with the center
5 C1 of the ceiling board 8 only by moving the holding part 40 to a predetermined position coordinate.

[0156] As described above, when the ceiling board 8, which has been temporarily placed the temporal placement part 74, is to be held by the holding part 40, a step of detecting the center C1 of the ceiling board 8,
10 for example, such as a step of recognizing positions of four sides of the ceiling board 8, is no longer required, and thus, it is possible to reduce the operation time required for the operation of placing the ceiling board 8 onto the frame body 6.

[0157] In addition, because the ceiling board 8, which has been
15 temporarily placed on the temporal placement part 74, is in a state in which the ceiling board 8 is supported by the support members 77 from the back surface 8b side, by causing the holding part 40 to approach at the front surface 8a side of the ceiling board 8, the needles 42 of the holding part 40 are stuck into the front surface 8a of the ceiling board 8
20 with ease. Therefore, it is possible to hold the ceiling board 8 by the holding part 40 with ease.

[0158] As shown in FIG. 9, when it is confirmed that the front surface 8a side of the ceiling board 8 is held by the holding part 40, the controller 50 appropriately controls the amount of rotation of the

respective rotating portions 31a to 31f of the arm part 30 in a similar manner as in the above-mentioned embodiment, thereby placing the ceiling board 8 onto the frame body 6.

[0159] As described above, in this modification, because the storage
5 of the ceiling board 8 and the placement of the ceiling board 8 onto the frame body 6 are performed by a single installation robot 100, it is possible to more efficiently perform the placement operation of the ceiling board 8.

[0160] In addition, as in the above-described carrier robot 110, in a
10 case in which the plurality of ceiling boards 8 are loaded on the roller conveyor 64 in a state in which they are layered in the horizontal direction, there is a risk in that the side surface 8c of the ceiling board 8 that is in contact with the roller conveyor 64 is damaged. In contrast, in this modification, because the plurality of ceiling boards 8 are loaded
15 on the loading mechanism 70 in a state in which they are stacked in the vertical direction, it is possible to avoid the cause of such a damage. In addition, in this modification, the supply of the ceiling boards 8 to the installation robot 100 is completed by loading the plurality of ceiling boards 8, which have been delivered, on the loading mechanism 70
20 while still being packed and by unpacking the ceiling boards 8, and therefore, it is possible to reduce the site worker's workload in the supply operation.

[0161] In addition, in the above-mentioned embodiment or in the above-described modification, although the description has been given

for the case in which the actuator, such as the cylinder and the motor, mounted on the installation robot 100 and the carrier robot 110 is of the electrically driven type, the driving system of the actuator is not limited to the electric driving system, and the pneumatic driving system or the
5 hydraulic driving system may also be employed.

[0162] In addition, in the above-mentioned embodiment, the installation robot 100 recognizes the self-location on the basis of the surrounding information around the installation robot 100 acquired by the information acquisition device 15 of the base carriage unit 10. The
10 installation robot 100 may also be provided with a gyroscope sensor, a geomagnetic sensor, and an acceleration sensor in addition to the information acquisition device 15 in order to improve recognition accuracy of the self-location.

[0163] Although the embodiments of the present invention have been
15 described in the above, the above-mentioned embodiments merely illustrate a part of application examples of the present invention, and the technical scope of the present invention is not intended to be limited to the specific configurations of the above-described embodiments.

CLAIMS

1. A ceiling board installation robot for placing a ceiling board onto a frame body supported by a ceiling slab, the ceiling board installation
5 robot comprising:

a base carriage unit configured to be movable on a floor surface;

a lifting and lowering part mounted on the base carriage unit;

an arm part configured to extend from the lifting and lowering part
towards the frame body;

10 a holding part provided on a tip end side of the arm part, the
holding part being configured to hold the ceiling board;

a state detector configured to detect a frame body state related to a
shape of the frame body; and

a controller configured to control an operation of the arm part,
15 wherein

the controller controls the operation of the arm part based on the
frame body state detected by the state detector such that the ceiling
board held by the holding part is placed onto the frame body by being
lowered down from above the frame body.

20

2. The ceiling board installation robot according to claim 1,
wherein

the controller determines whether or not the ceiling board can be placed
onto the frame body based on a space state of a space between the

ceiling slab and the frame body, the space state being detected in advance.

3. The ceiling board installation robot according to claim 1 or 2,
5 wherein the controller is configured to detect a ceiling board state related to a shape of the ceiling board by the state detector, and set a position of holding the ceiling board by the holding part based on the ceiling board state when the ceiling board is to be held by the holding part.

10

4. The ceiling board installation robot according to claim 1 or 2, wherein the holding part has a protrusion configured to be stuck into the ceiling board.