

DESCRIPTION

FLOOR SURFACE HEIGHT MEASUREMENT ROBOT SYSTEM AND FLOOR SURFACE HEIGHT MEASUREMENT METHOD

5

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a floor surface height measurement robot system and a floor surface height measurement method.

10 Description of the Related Art

[0002]

A worker measures the height of a floor surface at a predetermined interval to determine unevenness on a concrete surface of each floor of a building.

15 A construction is formed by placing a concrete surface and installing a floor surface above the concrete surface with a gap interposed therebetween. Deformation occurs to the concrete surface due to building conditions, change of water in concrete, loading and conveyance of a heavy weight object, and the like and causes unevenness on the order of several millimeters, and accordingly, an uneven part is generated. The uneven part would cause a problem in construction of the floor surface, and thus any uneven part on the concrete
20 surface needs to be investigated.

[0003]

In a large number of methods employed to investigate an uneven part of a concrete surface, the uneven part of the concrete surface is measured by a device configured to measure levelness, and a floor surface is repaired by placing concrete again. The following patent
25 document 1 discloses an invention that the irregularity level of a floor surface is measured based on the position of a measurement target measured by a three-dimensional measuring unit and a printing unit prints, on the floor surface, unevenness level information indicating the unevenness level.

[0004]

30 Patent Document 1: Japanese Patent No. 7149903

SUMMARY OF THE INVENTION

[0005]

The invention disclosed in Patent document 1 has a problem that a long measurement time is needed because a sensor configured to sense a floor surface moves in the up-down direction. Another problem is that the height of a concrete surface is unknown because
5 height as a reference (reference height: height higher than a floor level by a predetermined value) is not measured.

Thus, the present invention is intended to measure the height of a floor surface in a short time.

[0006]

10 To solve the above-described problems, a floor surface height measurement robot system of the present invention includes: a traveling unit configured to travel on a floor surface; a robot controlling unit configured to control a robot to travel to a predetermined position on the floor surface by using the traveling unit; a three-dimensional measuring unit configured to measure position and height of a measurement target of the robot; a robot
15 operating unit configured to instruct the robot controlling unit to move the robot to coordinates of the measurement point information by using the traveling unit based on measurement point information in coordinates of a floor surface drawing; and a height calculating unit configured to calculate a height of the floor surface at a position of the measurement point information based on a height of the measurement target, which is measured by the three-dimensional
20 measuring unit.

[0007]

A floor surface height measurement method of the present invention includes: controlling a robot to travel to a measurement point on a floor surface; measuring a height of a measurement target of the robot by a three-dimensional measuring unit while the robot is
25 positioned at the measurement point, and calculating a height of the floor surface at the measurement point based on the height of the measurement target.

Any other means will be described in embodiments.

[0008]

According to the present invention, it is possible to measure the height of a floor
30 surface in a short time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a diagram showing a functional configuration of a floor surface height measurement robot system;

FIG. 2 is a perspective view schematically showing a marking robot;

5 FIG. 3 is a block diagram of a controller;

FIG. 4A is a flowchart showing operation of the controller;

FIG. 4B is a flowchart showing operation of the controller;

FIG. 5 is a diagram showing unevenness of a concrete surface;

FIG. 6 is a diagram showing operation of calculating the height of $FL\pm 0$;

10 FIG. 7 is a flowchart of processing of calculating the height of $FL\pm 0$;

FIG. 8 is a diagram showing operation of calculating the height of the concrete surface at a reference point;

FIG. 9 is a flowchart of processing of calculating the height of the concrete surface the reference point;

15 FIG. 10 is a diagram showing operation of calculating the height from the concrete surface to a prism of a measurement target of the layout robot;

FIG. 11 is a flowchart of processing of calculating relative heights of the reference point and the marking robot;

FIG. 12 is a map showing the relation between the robot and each measurement point;

20 FIG. 13 is a diagram for description of a method of calculating an actual value;

FIG. 14 is a flowchart of floor surface height measurement and printing processing;

FIG. 15 is a flowchart of the floor surface height measurement and printing processing;

25 FIG. 16 is a flowchart of floor surface height measurement and slant calculation processing;

FIG. 17 is a flowchart of two-dimensional code generation processing of measurement data;

FIG. 18 is a diagram showing measurement data in a CSV format;

FIG. 19 is a diagram showing a two-dimensional code display screen;

30 FIG. 20 is a diagram showing a floor surface height menu selection screen;

FIG. 21 is a diagram showing a reference height measurement screen;

FIG. 22 is a diagram showing a prism height measurement screen;

FIG. 23 is a diagram showing a robot height measurement check screen;
FIG. 24 is a diagram showing a robot height in-measurement screen;
FIG. 25 is a diagram showing a reference measurement result screen;
FIG. 26 is a diagram showing a measurement point selection screen;
5 FIG. 27 is a diagram showing a measurement point check screen;
FIG. 28 is a diagram showing a floor surface height in-measurement screen;
FIG. 29 is a diagram showing a floor surface height measurement result screen; and
FIG. 30 is a mode transition diagram of floor surface height measurement.

10 DESCRIPTION OF THE EMBODIMENTS

[0010]

Embodiments of the present invention will be hereinafter described in detail with reference to the accompanying drawings.

A seemingly flat floor surface at a construction site has unevenness in units of several
15 mm in some cases. In current site operations, an on-site worker measures floor surface unevenness (height) by using a surveying instrument, and workforce and labor of on-site work can be reduced by performing the measurement with a robot.

[0011]

In order to measure the floor surface height with a robot and determine existence of
20 unevenness, work needs to be performed through operations below.

[0012]

(1) Office work

Drawing preparation and production are performed. Specifically, diagram data with written floor surface height measurement points is prepared and converted by using drawing
25 conversion software.

[0013]

(2) On-site work

(2-1) Preparation

A floor surface height measurement robot system measures a reference height and
30 measures the height of a robot. The height of the robot is the height from a floor surface on which the robot is installed to a measurement target installed on the robot.

Like a reference core or a known point, a reference height that is height as a reference

at a site is set for the site. The floor surface height measurement robot system measures the reference height by using a measurement target the position of which is optically measured by a tracking three-dimensional meter. Accordingly, the floor surface height measurement robot system can determine the reference height in a surveying instrument coordinate system.

5 The height of the robot has device variation due to device variation of the robot such as tire abrasion. Thus, the floor surface height measurement robot system measures/calculates the height of a measurement target of the device (height of the robot) relative to the floor surface. In a case where deviation of the height of the robot due to device variation can be ignored, the height of the robot may be fixed to calculate the height of
10 the floor surface.

[0014]

(2-2) Floor surface height measurement

The floor surface height measurement robot system controls the robot to travel on the floor surface, measures the height of the measurement target installed on the robot at the
15 position of a work site corresponding to a measurement point on a drawing, and calculates the height of the floor surface relative to the floor level. A result of the calculation is displayed as a two-dimensional code (for example, QR code (registered trademark)) on a display unit so that data can be extracted without passing through a medium such as a Universal Serial Bus (USB) memory.

20 [0015]

(3) Office work

In order to check the measurement result, the data read from the two-dimensional code is transmitted to a personal computer by means of e-mail or the like and edited with a spreadsheet software, for example.

25 The following describes a floor surface height measurement robot system 1 for achieving these kinds of work.

[0016]

FIG. 1 is a diagram showing a functional configuration of the floor surface height measurement robot system 1. FIG. 2 is a perspective view schematically showing a marking
30 robot 2.

The floor surface height measurement robot system 1 disclosed in the present embodiment includes the marking robot 2 configured to travel at a work site based on position

information measured by a tracking three-dimensional meter 4, and a controller 3 operated by an operator of the marking robot 2. The marking robot 2 is also a robot that measures the height of the floor surface.

[0017]

5 As shown in FIG. 2, the marking robot 2 includes a frame 20, a printer 22, a printer mover 212, a marking robot controller 210, a travel driver 211, and wheels 21F and 21R. The travel driver 211 drives the wheels 21F to move the frame 20. Accordingly, the frame 20, the travel driver 211, and the wheels 21F and 21R function as a traveling unit configured to travel on the floor surface.

10 [0018]

The printer mover 212 enables the printer 22 and a measurement target 23 to move in the forward, backward, right, left, up, and down directions relative to the frame 20. Accordingly, the printer mover 212 is a movement unit that movably supports the printer 22 and the measurement target 23.

15 The printer 22 includes a print head and performs marking printing on the floor surface. Accordingly, the printer 22 functions as a printing unit for printing on the floor surface. The marking robot controller 210 controls the printer 22 to print, on the floor surface, height information related to unevenness of the floor surface and information of that the height of the floor surface is out of a predetermined range. The marking robot controller
20 210 may print no information of the height of the floor surface if the height of the floor surface is within a predetermined range.

The marking robot controller 210 also controls the printer 22, the printer mover 212, and the travel driver 211.

[0019]

25 The position of the measurement target 23 is optically measured by the tracking three-dimensional meter 4, and the measurement target 23 is constituted as, for example, a prism. The measurement target 23 is installed vertically above the printer 22. Thus, the position of the measurement target 23 indicates printing position of the printer 22.

[0020]

30 Description continues with reference to FIG. 1. The tracking three-dimensional meter 4 is, for example, an automatic tracking three-dimensional measuring unit or surveying instrument, measures the position and height of a reference core or/and a known point at a

work site and the position and height of the marking robot 2 at the work site, and notifies the marking robot controller 210 of results of the position and height measurement. The tracking three-dimensional meter 4 is a three-dimensional measuring unit configured to measure the position and height of the measurement target in the surveying instrument coordinate system.

5 [0021]

The controller 3 communicates with the marking robot controller 210 of the marking robot 2 and instructs the marking robot controller 210 to perform floor surface height measurement processing.

10 The marking robot controller 210 transmits and receives information to and from the tracking three-dimensional meter 4 and the controller 3 by using a communicator 24. The marking robot controller 210 stores measurement point information of the height of the floor surface in a non-shown storage. The marking robot controller 210 controls the marking robot 2 to travel on the floor surface and move to the position of each measurement point and controls the tracking three-dimensional meter 4 to measure the position and height of the
15 measurement target 23 installed on the marking robot 2 at the position of the measurement point on the floor surface. A height calculator 214 calculates the height of the floor surface with respect to the floor level (FL±0) at the measurement point based on the height of the measurement target 23 of the marking robot 2, which is measured by the tracking three-dimensional meter 4 when the marking robot 2 is positioned at the measurement point.

20 A height determiner 215 determines whether the height of the floor surface, which is calculated by the height calculator 214 is qualified. The marking robot controller 210 prints, on the floor surface, the height information of the floor surface with respect to the floor level (FL±0).

[0022]

25 When having acquired measurement point information produced by a measurement point information producer 52 from a site management server 53, the controller 3 displays an edit screen for a worker to edit editable information. The controller 3 generates customized measurement point information based on a result of an operation on the edit screen and transmits the measurement point information to the marking robot controller 210.

30 [0023]

With the floor surface height measurement robot system 1 according to the present disclosure, the marking robot 2 measures height information related to unevenness of the floor

surface and prints the height information on the floor surface, and unevenness measurement of the floor surface can be automated.

[0024]

Controller 3

5 The controller 3 will be described below. The controller 3 is constituted as, for example, a tablet-type personal computer, a laptop-type personal computer, a desktop-type personal computer, a cellular phone (including a smartphone), a portable information terminal, a watch-type wearable terminal, or a glass-type wearable terminal.

[0025]

10 The controller 3 performs bidirectional communication with the marking robot 2 and also performs bidirectional communication with the tracking three-dimensional meter 4. The controller 3 acquires measurement point information from the measurement point information producer 52 and transmits customized measurement point information of the acquired measurement point information to the marking robot 2. The measurement point information
15 producer 52 produces marking information based on three-dimensional CAD data acquired from a CAD data storage 51 storing three-dimensional CAD data. The layout robot 2 moves to a measurement point based on the customized measurement point information and prints, on the floor surface, height information related to unevenness of the floor surface, which is measured by the tracking three-dimensional meter 4.

20 [0026]

 The controller 3 includes, for example, a processor 31, a RAM 32, a large-capacity storage 33, a touch panel display 34, and a communicator 35, and these circuits are connected to each other through a bus to mutually perform communication therebetween.

 The processor 31 as an arithmetic device is not limited to a central processing unit
25 (CPU) but may be, for example, a digital signal processor (DSP), a field programmable gate array (FPGA), or an application specific integrated circuit (ASIC). The controller 3 may include a plurality of arithmetic devices.

[0027]

 The RAM 32 stores computer programs and data that are read and written by the
30 processor 31. The RAM 32 is constituted as, for example, a dynamic ram (DRAM) or a static ram (SRAM).

 The large-capacity storage 33 is constituted as a relatively large-capacity storage

device and is, for example, a flash memory, a hard disk, a magnetic tape, an optical disk, or a magneto optical disc.

[0028]

5 The touch panel display 34 has a configuration in which a transparent touch panel is stacked on a display. The touch panel display 34 displays various kinds of information and receives information of an operation by the worker.

[0029]

10 The communicator 35 is a device configured to perform communication among the marking robot 2, the tracking three-dimensional meter 4, the measurement point information producer 52, and the site management server 53 by using, for example, a wireless local area network (LAN). Information transmission is not limited to wireless but may use infrared or sound wave. Any or both of wireless communication and wired communication may be used.

[0030]

15 Marking robot 2

The marking robot 2 will be described below. The marking robot 2 is a robot that is deployed at a work site, moves to a predetermined marking position, and automatically performs marking printing. The work site is, for example, a construction site of a building or the like, or a civil engineering site of a road or the like.

20 [0031]

The marking robot 2 autonomously travels in accordance with an operation command input to the controller 3 by the worker by using position information measured by the tracking three-dimensional meter 4. The position information of the marking robot 2, which is measured by the tracking three-dimensional meter 4 is transmitted to the marking robot 2. 25 When having moved to a scheduled measurement point, the marking robot 2 measures the height of the measurement target 23 installed on the marking robot 2 by the tracking three-dimensional meter 4, calculates height information related to unevenness of the floor surface at the measurement point, and prints the height information related to unevenness of the floor surface on the floor surface by the printer 22.

30 [0032]

The marking robot 2 includes the frame 20, the wheels 21F and 21R, the printer 22, the measurement target 23, the communicator 24, and operation buttons 25. The marking

robot 2 further includes a front side sensor 26, bumper sensors 27F and 27R, a lower side sensor 28, the marking robot controller 210, the travel driver 211, the printer mover 212, a measurement target driver 213, and a battery (not shown).

[0033]

5 The marking robot controller 210 is a device storing position information of measurement points and collectively controlling the marking robot 2. The marking robot controller 210 includes the height calculator 214 and the height determiner 215.

 The printer 22 is a device configured to print on the floor surface under control of the marking robot controller 210. The travel driver 211 is a device configured to travel and
10 move the marking robot 2. The printer mover 212 is a device configured to two-dimensionally or three-dimensionally move the printer 22 installed on the frame 20.

[0034]

 When used, the measurement target 23 may be removed from the marking robot 2 instead of being installed on the marking robot 2. To measure the reference height in
15 advance, the worker may remove the measurement target 23 from the marking robot 2, place the measurement target 23 at desired position and height, and measure the desired position and height where the measurement target 23 is placed by the tracking three-dimensional meter 4. In a case where a wall, a floor, or the like is measured, as well, the measurement target 23 is removed from the marking robot 2 and used. After the measurement of a wall, a floor, or the
20 like, the measurement target 23 is installed on the marking robot 2 again.

[0035]

 The marking robot controller 210 may be an information instrument having functions of a normal calculator. Specifically, the marking robot controller 210 includes a storage and an arithmetic processing unit (both not shown). The arithmetic processing unit is connected
25 to the controller 3 to perform communication therebetween through the communicator 24.

[0036]

 The storage stores a control program that performs entire control of the marking robot 2, measurement point information, and information necessary for operation. In accordance with the control program, the arithmetic processing unit moves the marking robot 2 to the
30 position of a measurement point to align the positions of the printer 22 and the measurement target 23 with the position of the measurement point, measures the height of the measurement target 23 installed on the marking robot 2, and calculates the height of the floor surface at the

measurement point. The arithmetic processing unit further controls the printer 22 to print, on the floor surface, the height information related to unevenness of the floor surface.

[0037]

The entire printer 22 moves in the forward, backward, right, and left directions on a flat surface of (floor surface) of the work site by the printer mover 212. In other words, the printer 22 and the printer mover 212 operate like an XY plotter as a whole. Instead of the printer 22 and the printer mover 212 of such an XY plotter type, a triaxial arm robot may be mounted on the travel driver 211 and the print head may be attached to an arm distal end of the triaxial arm robot.

[0038]

The frame 20 is provided with the wheels 21F and 21R below. The marking robot 2 moves as the travel driver 211 drives the wheels 21F and 21R. The travel driver 211 may be a front-wheel drive type or a rear-wheel drive type that drives any one of the front and rear wheels 21F and 21R or may be a four-wheel drive type that drives all wheels 21F and 21R. The travel driver 211 may drive a crawler in place of the wheels 21F and 21R.

[0039]

The operation buttons 25 are provided at the frame 20 and manually operated by the worker as necessary. The operation buttons 25 are, for example, a power source switch and a stop switch (both not shown).

[0040]

The marking robot 2 includes the front side sensor 26, the bumper sensors 27F and 27R, and the lower side sensor 28 for ensuring safety at the work site. The front side sensor 26 is constituted as, for example, light detection and ranging (LiDAR) and senses any object in the traveling direction of the marking robot 2. The bumper sensors 27F and 27R are provided at bumpers 201 provided at front and rear parts of the frame 20 and sense contact of the bumpers 201 with an object. FIG. 2 only shows the bumper 201 on the front side. The lower side sensor 28 senses, for example, unevenness and openings of the floor surface of the work site. The marking robot 2 may include a sensor other than the shown sensors, for example, a three-dimensional camera, an ultrasonic wave sensor, or a radiation thermometer.

[0041]

As described above, the printer mover 212 is disposed on the frame 20 and attached to the printer 22 below. The printer mover 212 moves and positions the printer 22 and the

measurement target 23 to the position of a measurement point under positioning control by the marking robot controller 210. The printer mover 212 in the present embodiment can move the printer 22 in two-dimensional directions (planar directions) of X and Y directions and also in a Z direction (vertical direction). Such mobility is for positioning the printer 22 and the measurement target 23 to a measurement point. Moreover, the measurement target driver 213 constantly holds the position of the measurement target 23 at a predetermined height relative to the floor surface.

[0042]

The marking robot controller 210 moves and positions the marking robot 2 to each measurement point based on information of the measurement point and the position information of the marking robot 2, which is measured by the tracking three-dimensional meter 4. After the marking robot 2 reaches the position of each measurement point, the marking robot controller 210 highly accurately positions the printer 22 to the measurement point by the printer mover 212. Then, the height of the measurement target 23 installed on the marking robot 2 is measured by the tracking three-dimensional meter 4, and the height of the floor surface relative to the floor level is calculated by the height calculator 214. Thereafter, the printer 22 prints, on the floor surface, the height information related to unevenness of the floor surface. The height calculator 214 functions as a height calculating unit configured to calculate the height of the floor surface.

[0043]

The above-described tracking three-dimensional meter 4 tracks the measurement target 23 installed on the marking robot 2 with a laser beam. The tracking three-dimensional meter 4 measures the position and height of the measurement target 23 installed on the marking robot 2, in other words, the position and height of the marking robot 2 in a three-dimensional space by using reflected light from the prism of the measurement target 23.

[0044]

The tracking three-dimensional meter 4 accurately measures the position and height of the marking robot 2 by measuring the position and height of the measurement target 23 installed on the marking robot 2. The tracking three-dimensional meter 4 is not limited to a device using a laser beam but may be any device capable of measuring the position of the marking robot 2. The position of the marking robot 2, which is measured by the tracking three-dimensional meter 4 is transmitted to the marking robot controller 210 to be used for

movement control (positioning) of the marking robot 2 to a measurement point. The position of the marking robot 2 is also transmitted to the controller 3 as necessary based on command information from the controller 3.

[0045]

5 As described above, the controller 3 is a computer terminal configured to control operation of the marking robot 2 and the tracking three-dimensional meter 4 by transmitting and receiving information to and from the marking robot 2 and the tracking three-dimensional meter 4. The controller 3 in the present example has a function to edit (customize) information of a measurement point through an operation by the worker on the controller 3
10 side based on information of the measurement point, which is received from the marking robot controller 210. Thus, the controller 3 can share information of a measurement point with the marking robot controller 210 by transmitting and receiving information to and from the marking robot controller 210. The controller 3 has a function to acquire information of a measurement point and "editable information" for customization and display an edit screen to
15 be operated by the worker, and an operation function for selection operations by the worker on the edit screen.

[0046]

Configuration of robot control device

The configuration of the controller 3 according to the present embodiment will be
20 described below with reference to FIG. 3. FIG. 3 is a block diagram of the controller 3.

[0047]

As shown in FIG. 3, the controller 3 includes the processor 31 configured to control operation, the large-capacity storage 33 configured to store various computer programs and data, the communicator 35 configured to perform communication with an external device, and
25 the touch panel display 34 configured to function as an input unit and a display unit.

The processor 31 embodies an operation receiver 31a, a reader 31b, an installation point setter 31c, a measurement point setter 31d, a surveying instrument operator 31e, a robot operator 31f, a traveling range setter 31g, a route setter 31h, a communication controller 31i, and a screen controller 31j.

30 [0048]

The operation receiver 31a receives an operation by the operator.

The reader 31b reads measurement point data 332 from an external device. In the

present embodiment, the reader 31b reads the information of a measurement point from the measurement point information producer 52.

5 The installation point setter 31c performs processing of aligning the coordinate position of a designed installation point and the coordinate position of an actual installation point at the work site.
[0049]

10 The measurement point setter 31d sets the marking robot 2 to execute height measurement related to unevenness of the floor surface at an optional measurement point. Information of the measurement point may be determined in advance or designated through a user operation.

The surveying instrument operator 31e operates the tracking three-dimensional meter 4 that is a surveying instrument.

15 The robot operator 31f is a robot operating unit configured to operate the marking robot 2. The robot operator 31f is an operating unit configured to instruct the marking robot 2 to move to the coordinate of measurement point information in the coordinates of a CAD drawing (floor surface drawing) by using the travel driver 211 based on the measurement point information. The measurement point information may be predetermined or designated through a user operation and is not limited in particular.
[0050]

20 The traveling range setter 31g sets a traveling range of the marking robot 2.

The route setter 31h sets, by Dijkstra's algorithm or the like, a travel route of the marking robot 2 to a measurement point where measurement is set.

The communication controller 31i controls operation of the communicator 35.
[0051]

25 The screen controller 31j produces a display screen and displays the display screen on the touch panel display 34.
[0052]

30 The central processing unit (CPU) included in the processor 31 implements these units by executing a robot control program 331 stored in the large-capacity storage 33 in advance.

The robot control program 331 is stored in the large-capacity storage 33 in advance. In addition, for example, the measurement point data 332 and travel path data 333 that

designates a travel path of the marking robot 2 are stored in the large-capacity storage 33.

[0053]

Operation of controller 3

Operation of the controller 3 will be described below with reference to FIG. 4. FIG. 4 is a flowchart showing operation of the controller 3. FIG. 4 shows operation of producing the measurement point data 332 from CAD drawing data including a work site drawing.

[0054]

When having acquired CAD drawing data including a work site drawing from, for example, a construction owner of the work site, a producer of the measurement point data 332 inputs the CAD drawing data to the measurement point information producer 52 to produce the measurement point data 332 based on the CAD drawing data. An operator of the controller 3 inputs the measurement point data 332 to the controller 3, produces the travel path data 333 by using the measurement point data 332, and executes work of height measurement related to unevenness of the floor surface relative to the floor level. FIG. 4A shows processing of producing the measurement point data 332 in this case. FIG. 4B shows an example of measurement work by the marking robot 2.

[0055]

As shown in FIG. 4A, the producer of the measurement point data 332 starts production of the measurement point data 332 by operating the measurement point information producer 52.

In this case, the measurement point information producer 52 first reads CAD drawing data based on an operation by an operator (step S405).

[0056]

Subsequently, the measurement point information producer 52 performs designation and automatic acquisition of a reference core and a measurement point based on an operation by the operator (step S410). The reference core is a reference line in construction of a building. The measurement point is a point where the height of the floor surface is measured. The operator designates the reference core and the measurement point in a CAD drawing (floor surface drawing) displayed on the controller 3.

[0057]

Subsequently, the measurement point information producer 52 receives processing of checking and editing component names and coordinate values in the CAD drawing (floor

surface drawing) based on an operation by the operator (step S415). The component names in the CAD drawing are the names of the reference core, the measurement point, and the like. The operator checks and edits the names of the reference core and the measurement point in the CAD drawing displayed on the controller 3 and checks and edits the coordinate values of the reference core and the measurement point.

[0058]

Subsequently, based on an operation by the operator, the measurement point information producer 52 outputs the measurement point data 332 in a predetermined data format to the site management server 53 to store the measurement point data 332 in the site management server 53 (step S420), and ends the processing in FIG. 4A.

[0059]

FIG. 4B is a flowchart showing operation of the controller 3.

After the measurement point data 332 is stored in the site management server 53, the operator of the controller 3 starts measurement work with the marking robot 2 by operating the controller 3 at an optional timing.

[0060]

In this case, the processor 31 of the controller 3 first reads the measurement point data 332 from the site management server 53 based on an operation by the operator (step S505). The measurement point data 332 is stored in the large-capacity storage 33.

Subsequently, the processor 31 performs measurement and coordinate conversion processing of the known point and the reference core based on an operation by the operator (step S510). The processor 31 converts the coordinates of the known point or/and the reference core in the CAD drawing coordinate system into those in the coordinate system of the surveying instrument.

[0061]

Subsequently, the processor 31 designates the traveling range of the marking robot 2 based on an operation by the operator (step S515).

Subsequently, the processor 31 automatically produces data indicating a travel path and a route of the marking robot 2 based on an operation by the operator (step S520).

[0062]

Subsequently, once the measurement processing by the marking robot 2 is completed, the processor 31 performs processing of registering measured data (step S525), and ends the

processing in FIG. 4B.

Since the controller 3 can automatically produce data indicating a travel path and a route of the marking robot 2, a load on the operator can be reduced.

[0063]

5 FIG. 5 is a diagram showing unevenness of a concrete surface 70.

First in measurement of the height of the concrete surface 70, consider a designed height that is the height of a floor when a building is completed. This setting floor height is the floor level and expressed as $FL\pm 0$. In FIG. 5, $FL\pm 0$ is marked on a pillar 71.

[0064]

10 However, the position of $FL\pm 0$ often cannot be determined once the building is completed, and thus $FL+1000$ with 1000 mm added to the floor height (the floor level) when the building is completed is typically used as the reference height. Alternatively, $FL+900$ with 900 mm added is used as the reference height in some cases. The floor surface height measurement robot system 1 measures the reference height in the surveying instrument
15 coordinate system, and then measures and records the height of each measurement point on the floor surface with the floor level ($FL\pm 0$) as a reference. Measurement points in FIG. 5 correspond to the heights of -99 mm, -104 mm, -98 mm, and -101 mm from the left.

[0065]

Measurement of reference height ($FL+1000$)

20 Like the reference core and the known point, the reference height (height of a predetermined value relative to the floor level: $FL+1000$) is set for the work site. The height of $FL\pm 0$ is calculated by subtracting the predetermined value (1000 mm) from the reference height.

[0066]

25 FIG. 6 is a diagram showing operation of calculating the height of $FL\pm 0$.

The tracking three-dimensional meter 4 is installed at a predetermined position on the concrete surface 70. A measurement target 23a is installed at the reference height of $FL+1000$ on the pillar 71. The controller 3 instructs the tracking three-dimensional meter 4 to measure a relative height H_K between the tracking three-dimensional meter 4 and the
30 measurement target 23a. In this case, XYZ coordinates in the surveying instrument coordinate system of the measurement target 23a are transmitted from the tracking three-dimensional meter 4 to the controller 3. The surveying instrument coordinate system is

a three-dimensional coordinate system with an origin at the position of the tracking three-dimensional meter 4 and with a Z axis set to be upward in the vertical direction. An X axis is set to be on the near side of the sheet of the drawing. A Y axis is set to be on the right side of the sheet. “Height” described below is a value on the Z axis of the surveying instrument coordinate system unless any other reference is clearly stated.

The processor 31 of the controller 3 calculates the height of the floor level ($FL\pm 0$) in the surveying instrument coordinate system by subtracting a predetermined value $H_0 = 1000$ mm from the measured height H_K . The height of the floor level in the surveying instrument coordinate system is expressed by $(H_K - H_0)$. The floor level is -50 mm in a case where the height H_K is 950 mm.

[0067]

FIG. 7 is a flowchart of processing of calculating the height of $FL\pm 0$.

First, the worker installs the measurement target 23a at the height of $FL+1000$ on the pillar 71 (step S40). The height of $FL+1000$ is height as a reference at the work site and thus also called reference height.

The processor 31 of the controller 3 measures the measurement target 23a installed at the reference height of $FL+1000$ by the tracking three-dimensional meter 4 (step S41).

Then, the processor 31 calculates the height of $FL\pm 0$ by subtracting the predetermined value $H_C = 1000$ mm from the measured height H_K of the measurement target 23a (step S42), and ends the processing in FIG. 6.

In a case where a plurality of values of the height of $FL+1000$ are measured, the processor 31 calculates the average value thereof. Instead of the average value, the processor 31 may calculate the median or the mode of the values. In a case where the position of the tracking three-dimensional meter 4 is changed, it is needed to measure again the height of the measurement target 23a installed at $FL+1000$ and then calculate the height of $FL\pm 0$ again.

[0068]

Height measurement of marking robot 2

The height of the marking robot 2 potentially changes due to device variation of the marking robot 2 such as assembly accuracy or aging. The height of the marking robot 2 is a width from the floor surface on which the marking robot 2 is installed to the center of the prism of the measurement target 23 installed on the marking robot 2.

A height H_R from the concrete surface 70 to the prism of the measurement target 23

installed on the marking robot 2 is calculated at a reference point 72 to accurately calculate the height of the marking robot 2.

The coordinate of the center of the prism of the measurement target 23a in the surveying instrument coordinate system can be measured by the tracking three-dimensional meter 4. A base height H_P at which the prism of the measurement target 23a is placed needs to be subtracted from the center coordinates H_{P2} of the prism of the measurement target 23a to calculate a height H_F of the concrete surface at the reference point 72 based on the coordinate H_{P2} of the center of the prism of the measurement target 23a installed on the floor surface. The base height H_P is a width from the floor surface on which the measurement target 23a is installed to the center of the prism of the measurement target 23a. Thus, the height H_R from the concrete surface 70 to the prism of the measurement target 23 installed on the marking robot 2 is calculated after the height H_{P2} of the center of the prism of the measurement target 23a placed at the reference point 72 on the concrete surface 70 is measured/calculated.

[0069]

FIG. 8 is a diagram showing operation of calculating the height H_F of the concrete surface 70 at the reference point 72.

In this case, the measurement target 23a is placed at the reference point 72 on the concrete surface 70. The measurement target 23a has a configuration in which the prism is placed on a base. The base height H_P is a height from the concrete surface 70 to the center of the prism of the measurement target 23a and is a fixed value. The height H_{P2} is the height of the center of the prism of the measurement target 23a in the surveying instrument coordinate system of the tracking three-dimensional meter 4 and is a measured value of the tracking three-dimensional meter 4. The height H_F of the concrete surface at the reference point 72 is height in the surveying instrument coordinate system and calculated by subtracting the fixed base height H_P from the measured value height H_{P2} .

In a case where the base height H_P is 20 mm and the height H_{P2} is -79 mm, the height H_F of the concrete surface at the reference point 72 is calculated to be -99 mm.

[0070]

FIG. 9 is a flowchart of processing of calculating the height H_F of the concrete surface at the reference point 72.

First, the worker installs the measurement target 23a at the reference point 72 on the concrete surface 70 (step S60). The reference point 72 is a point at a predetermined position

as a reference for height measurement of the concrete surface 70.

[0071]

Subsequently, the processor 31 measures the height H_{P2} of the measurement target 23a installed at the reference point 72 by using the tracking three-dimensional meter 4 (step S61). The height H_{P2} of the measurement target 23a is height in the surveying instrument coordinate system.

[0072]

Then, the processor 31 calculates the concrete surface height H_F at reference point by subtracting the base height H_P from the measured height H_{P2} at center position of prism of measurement target 23a (step S62), and ends the processing in FIG. 9. The base height H_P is a predetermined value in product specifications or the like. In this case where a plurality of values of the height H_{P2} of the measurement target 23a installed at the reference point 72 are measured with consideration on swing of a building at the site or the like, the processor 31 calculates the average value thereof. Instead of the average value, the processor 31 may measure a plurality of values of the height H_{P2} of the measurement target 23a and may calculate the median or the mode thereof.

[0073]

FIG. 10 is a diagram showing operation of calculating the height H_R from the concrete surface 70 to the prism of the measurement target 23 of the marking robot 2.

When the marking robot 2 is moved to the reference point 72, a height H_{R2} of the prism of the measurement target 23 of the marking robot 2 can be measured by the tracking three-dimensional meter 4. The height H_F of the concrete surface at the reference point 72 is calculated in accordance with the flowchart in FIG. 9. Then, the height H_R from the concrete surface 70 to the prism of the measurement target 23 of the marking robot 2 can be calculated by subtracting the height H_F from the height H_{R2} .

In a case where the height H_{R2} of the prism of the measurement target 23 of the marking robot 2 in the surveying instrument coordinate system is -29 mm and the height H_F of the concrete surface at the reference point 72 in the surveying instrument coordinate system is -149 mm, the height H_R of the prism of the measurement target 23 of the marking robot 2 is calculated to be +120 mm. When the work site is in an environment that is not suitable for measurement with powder dust, stones, puddles, and the like, a theoretical design value of the height of the marking robot 2 or the previous measured value may be used.

[0074]

FIG. 11 is a flowchart of processing of calculating relative heights of the reference point 72 and the marking robot 2.

First, the processor 31 moves the marking robot 2 to the reference point 72 (step S70).

5 Then, the processor 31 measures the height H_{R2} of the prism of the measurement target 23 of the marking robot 2 (step S71). The height H_{R2} is the height of the marking robot 2.

The processor 31 calculates the height H_R from the concrete surface 70 to the prism of the measurement target 23 of the marking robot 2 based on the difference between the height H_F of the floor surface (concrete surface) at the reference point 72 and the height H_{R2} of the prism of the measurement target 23 of the marking robot 2 (step S72), and then ends the processing in FIG. 11. An accurate height can be acquired by measuring the height of the marking robot 2 each time.

[0075]

The processor 31 records measurement data of the reference height and measurement data of the robot height in drawing data. Update timing and target data of the drawing data will be described below.

[0076]

(1) Reference height measurement

Once the reference height is successfully measured, the floor surface height measurement robot system 1 updates a reference height designated value, a reference height measured value, and a reference height corrected value. The reference height designated value is a reference height with respect to the floor level and is, for example, 1000 mm. The reference height measured value is a measured value of the reference height in the surveying instrument coordinate system. The floor surface height measurement robot system 1 further updates the actual value of the floor surface height in a case where the reference height measured value, a base measured value, and a robot measured value are already measured. Even with the same drawing data, the position of the tracking three-dimensional meter 4 is moved due to an obstacle such as a pillar in some cases. In such a case, the height of the surveying instrument coordinate system is likely to be changed, and the updated actual value of the floor surface height may be held instead of being updated.

[0077]

(2) Floor surface height measurement

The floor surface height measurement robot system 1 updates the floor surface height in the drawing data after the height of a prism installed on the floor at the reference point 72 is successfully measured. The floor surface height may be held inside a computer program after the measurement is successful, and the drawing data may be updated after the robot height is successfully measured.

[0078]

(3) Robot height measurement

After the robot height relative to the floor surface is successfully measured, the floor surface height measurement robot system 1 updates the measured value of the robot height by using the measured value of the base height, which is held inside the drawing data or the computer program.

[0079]

FIG. 12 is a map showing the relation between the marking robot 2 and each measurement point.

FIG. 12 shows a two-dimensional map when the concrete surface 70 is viewed from top. The measurement points 73 are disposed on the concrete surface 70, and the marking robot 2 is positioned nearby. The marking robot 2 measures the height of the concrete surface 70 relative to the floor level (FL±0) at each measurement point 73 while traveling through the measurement points 73. These measurement points are produced on CAD drawing data and converted from the CAD drawing coordinate system into the surveying instrument coordinate system.

[0080]

FIG. 13 is a diagram for description of an actual value calculation method.

A height H_A is the height of the floor level (FL±0) in the surveying instrument coordinate system. The height H_{R2} is the height of the measurement target 23 of the marking robot 2 in the surveying instrument coordinate system. The robot height H_R is the height of the measurement target 23 of the marking robot 2 relative to the concrete surface 70, which is measured/calculated at the reference point 72. A height H_M is the height of the concrete surface 70 relative to the floor level (FL±0) and is the actual value of the height of the concrete surface 70. The height H_M as an actual value can be calculated by Expression (1) below.

$$H_M = (H_{R2} - H_R) - H_A \dots (1)$$

[0081]

The height H_M as an actual value is -99 mm in a case where the height H_A is -50 mm, the height H_{R2} is -29 mm, and the height H_R is +120 mm. At a construction site, the position of the tracking three-dimensional meter 4 in measurement is changed in some cases to avoid an obstacle such as a pillar. In such a case where the position of the tracking three-dimensional meter 4 is changed, the height of the origin of the surveying instrument coordinate system is changed. Thus, correct measurement results are not obtained when height values before the position of the tracking three-dimensional meter 4 is changed and height values after the change are calculated in mixture. The values before the position of the tracking three-dimensional meter 4 is changed should not be updated with the values after the position of the tracking three-dimensional meter 4 is changed. However, the height H_R is the height of the measurement target 23 of the marking robot 2, and its value is unlikely to largely change in a short time. Thus, influence on measurement results is small even when the same value is used for the height H_R of the measurement target 23 of the marking robot 2 before and after the position of the tracking three-dimensional meter 4 is changed.

[0082]

Robot operation

Error occurs to a measurement result when a stone or the like exists near a measurement point. Thus, for each measurement point of the floor surface height, the height of the floor surface is measured at a plurality of measurement points in a pattern as described below, and the middle value, average value, or minimum value a plurality of measured values is determined as the height of the floor surface at the measurement point. Thus, measurement error can be reduced.

[0083]

(1) Height is measured at two points of a target coordinate and a closer coordinate. The distance between measurement points is, for example, a quarter of the circumference of a wheel of the marking robot 2 and is long enough to overcome small stones. The distance between measurement points may be determined based on the radius of a wheel of the marking robot 2 and the size of an obstacle (such as a stone) assumed at a site.

[0084]

(2) The marking robot 2 moves by, for example, a quarter of the circumference of a wheel of the marking robot 2 from an optional current position in a drawing to the vicinity of

each measurement point 73. The position of the marking robot 2 after the movement is set as a first measurement point at the measurement start position, the middle between the first measurement point and the target coordinate is set as a second measurement point, and the target coordinate is set as a third measurement point.

5 [0085]

(3) In a case where the distance from the current position of the marking robot 2 to the target coordinate is shorter than a lowest travel distance setting, the height is measured for only one point at the current position.

[0086]

10 (4) In a case where the distance from the current position of the marking robot 2 to the target coordinate is equal to or longer than the lowest travel distance setting but a lowest travel distance would not be satisfied if a relay point is provided, the current position of the marking robot 2 is set as the first measurement point, the target coordinate is set as the second measurement point, and the height is measured for two points.

15 In a case where the height is measured for three points, the height measured value may be the average value or median of all measured values. In a case where the height is measured for two points, the height measured value may be the average value of all measured values or may be the first or second height measured value.

[0087]

20 FIG. 14 is a flowchart of floor surface height measurement and printing processing.

It is assumed that measurement of the reference height (FL+1000) is completed before the floor surface height measurement and printing processing is started.

At step S10, the robot operator 31f repeats processing up to S15 for each measurement point as a movement target.

25 [0088]

The robot operator 31f instructs the marking robot controller 210 to move the marking robot 2 to a measurement point (step S11). The marking robot controller 210 measures the height of the measurement target 23 of the marking robot 2 by using the tracking three-dimensional meter 4 (step S12). Then, the height calculator 214 calculates the height relative to the floor level (FL±0) at the measurement point on the concrete surface 70 (step S13).

[0089]

The height determiner 215 determines whether the measured height at the measurement point on the concrete surface 70 is qualified (step S14). The qualified height means that the height is within a predetermined range. In a case where the measured height at the measurement point on the concrete surface 70 is qualified, the height determiner 215 proceeds to step S16, or in a case where the measured height is disqualified, the height determiner 215 controls the marking robot 2 to print information of the disqualification at step S15 and then proceeds to step S16.

[0090]

At step S16, the robot operator 31f determines whether the processing is repeated for all measurement points as movement targets. In a case where there is a measurement point yet to be subjected to the processing, the robot operator 31f sets the measurement point as the next target and returns to step S10. In a case where the processing is performed for all measurement points, the robot operator 31f ends the processing in FIG. 14.

Each processing executed by the robot in FIG. 14 may be executed by the processor 31 and the present invention is not limited to a particular configuration. The loop processing executed through measurement points by the robot operator 31f may be autonomously executed by the marking robot controller 210 and the present invention is not limited to a particular configuration.

[0091]

FIG. 15 is a flowchart of the floor surface height measurement and printing processing.

In the processing, based on data of marking points in place of measurement points, the floor surface height measurement robot system 1 prints marking information at each marking point by the marking robot 2 and measures the floor surface height.

At step S20, the robot operator 31f repeats processing up to S28 for each marking point as a movement target.

[0092]

The robot operator 31f instructs the marking robot controller 210 to move the marking robot 2 to a marking point (step S21). The marking robot controller 210 prints marking information on the floor surface by using the tracking three-dimensional meter 4 (step S22) and measures the height of the measurement target 23 of the marking robot 2 (step S23). Then, the height calculator 214 calculates the height relative to the floor level (FL±0) at the

measurement point on the concrete surface 70 (step S24).

[0093]

The height determiner 215 determines whether the measured height at the measurement point on the concrete surface 70 is qualified (step S25). The qualified height means that the height is within a predetermined range (for example, the range of -98 mm to -102 mm). In a case where the measured height at the measurement point on the concrete surface 70 is qualified (Yes), the height determiner 215 prints information of the qualification on the floor surface (step S26) and proceeds to step S28. In a case where the measured height at the measurement point on the concrete surface 70 is disqualified (No), the height determiner 215 prints information of the disqualification on the floor surface at step S26 and then proceeds to step S28. Characters would overlap if information of the qualification or information of the disqualification is printed over the printed marking information, and thus the height determiner 215 does not necessarily need to perform printing at steps S26 and S27.

[0094]

At step S28, the robot operator 31f determines whether the processing is repeated for all marking points as movement targets. In a case where there is a marking point yet to be subjected to the processing, the robot operator 31f sets the marking point as the next target and returns to step S20. In a case where the processing is performed for all marking points, the robot operator 31f ends the processing in FIG. 15.

[0095]

At the position of each measurement point information, the tracking three-dimensional meter 4 measures the measurement target 23 of the marking robot 2, and in a case where the height of the floor surface, which is calculated by the height calculator 214 is out of a predetermined range, the marking robot controller 210 prints information of the out-of-range. Moreover, at the position of each measurement point information, the tracking three-dimensional meter 4 measures the measurement target 23 of the marking robot 2, and in a case where the height of the floor surface, which is calculated by the height calculator 214 is within the predetermined range, the marking robot controller 210 does not print information of the within-range.

[0096]

Each processing executed by the marking robot controller 210 in FIG. 15 may be executed by the processor 31, and the present invention is not limited to a particular

configuration. The loop processing executed through measurement points by the robot operator 31f may be autonomously executed by the marking robot controller 210 and the present invention is not limited to a particular configuration.

[0097]

5 Slant measurement at measurement point

Slant at a measurement point can be calculated through measurement at four points around the measurement point, and a slant direction (for example, the upper-right point is lower by several millimeters) can be printed. The present invention is not limited to four points around a measurement point but slant at the measurement point may be calculated
10 through measurement at a plurality of points more than two points.

Although slant of the entire floor can be measured by measuring the height at all measurement points in a lattice shape, slant at an optional point can be measured through measurement at four points before measurement at all points. Moreover, in a case where slant is determined by height measurement at four points, the average value, median, or mode
15 across the four points may be selected.

[0098]

FIG. 16 is a flowchart of floor surface height measurement and slant calculation processing.

At step S30, the robot operator 31f repeats processing up to S36 for each
20 measurement point as a movement target.

[0099]

The robot operator 31f instructs the marking robot controller 210 to move the marking robot 2 to a measurement point (step S31). The marking robot controller 210 measures the height of the prism of the measurement target 23 of the marking robot 2 at four
25 points around the measurement point by using the tracking three-dimensional meter 4 (step S32). Subsequently, the height calculator 214 calculates the height of the floor surface at the four points around the measurement point (step S33).

[0100]

The height calculator 214 calculates slant information based on the values of the floor
30 surface height at the four points on the concrete surface 70, which are calculated at step S33 (step S34). The marking robot controller 210 prints the average value of the floor surface height and slant (step S35) and then proceeds to step S36.

[0101]

At step S36, the robot operator 31f determines whether the processing is repeated for all measurement points as movement targets. In a case where there is a measurement point yet to be subjected to the processing, the robot operator 31f sets the measurement point as the next target and returns to step S30. In a case where the processing is performed for all measurement points, the robot operator 31f ends the processing in FIG. 16.

Each processing executed by the robot in FIG. 16 may be executed by the processor 31 and the present invention is not limited to a particular configuration. The loop processing executed through measurement points by the robot operator 31f may be autonomously executed by the marking robot controller 210 and the present invention is not limited to a particular configuration.

[0102]

Data of actual values measured by the marking robot controller 210 is transmitted to the controller 3. Then, the controller 3 displays the data on the touch panel display 34 as a two-dimensional code such as a QR code (registered trademark) so that the data can be read by a user computer system not through a medium such as a Universal Serial Bus (USB) memory and edited. Such a two-dimensional code is generated and displayed to achieve an assumed operation described below.

[0103]

FIG. 17 is a flowchart of two-dimensional code generation processing of measurement data.

The processor 31 starts the following processing when QR code display is instructed. The processor 31 acquires measurement data from drawing data (step S70). Then, the processor 31 generates data in a comma separated values (CSV) format from the measurement data (step S71). The processor 31 encodes a two-dimensional code from the data in the CSV format (step S72), stores the two-dimensional code (step S73), and then ends the processing in FIG. 17. The storage and display of a two-dimensional code are performed a plurality of times, depending on the number of measurement points.

[0104]

FIG. 18 is a diagram showing measurement data in the CSV format.

Measurement data in the CSV format has a configuration in which "No", "X coordinate", "Y coordinate", and "actual value" (floor surface height) are partitioned from each

other by a comma and written on each row. The measurement data is displayed on the touch panel display 34 by the screen controller 31j.

[0105]

FIG. 19 is a diagram showing a measurement data screen 81. The measurement data screen 81 is displayed on the touch panel display 34 of the controller 3.

A two-dimensional code 811 and an end button 812 are displayed on the measurement data screen 81. The measurement data screen 81 is displayed on the touch panel display 34 by the screen controller 31j. The height of the floor surface information at each measurement point is encoded in the two-dimensional code 811. The measurement data can be read by a worker terminal or the like by capturing and decoding an image of the two-dimensional code 811 with the worker terminal.

[0106]

FIG. 20 is a diagram showing a floor surface height menu selection screen 61. The floor surface height menu selection screen 61 is displayed on the touch panel display 34 of the controller 3.

The floor surface height menu selection screen 61 displays a map 619 and guidance of "Perform floor surface height measurement after reference height measurement and prism height measurement.". The map 619 displays measurement points and the like.

[0107]

The floor surface height menu selection screen 61 displays a reference height measurement button 611, a prism height measurement button 612, a "floor surface height measurement (all-point measurement)" button 613, a "floor surface height measurement (designated point measurement)" button 614, a measurement result check button 615, and a "return to menu" button 616.

[0108]

When the reference height measurement button 611 is tapped, the touch panel display 34 of the controller 3 switches to a reference height measurement screen 62 in FIG. 21.

When the prism height measurement button 612 is tapped, the touch panel display 34 of the controller 3 switches to a prism height measurement screen 63 in FIG. 22.

When the "floor surface height measurement (all-point measurement)" button 613 is tapped, the touch panel display 34 of the controller 3 switches to a floor-surface-height-in-measurement-screen 69 in FIG. 28.

When the "floor surface height measurement (designated point measurement)" button 614 is tapped, the touch panel display 34 of the controller 3 switches to a measurement point selection screen 67 in FIG. 26.

When the measurement result check button 615 is tapped, the touch panel display 34 of the controller 3 switches to a non-shown measurement check screen.
[0109]

When the "return to menu" button 616 is tapped, the touch panel display 34 of the controller 3 switches to a non-shown menu screen before the floor surface height menu selection screen 61 is called.
[0110]

FIG. 21 is a diagram showing the reference height measurement screen 62. The reference height measurement screen 62 is displayed on the touch panel display 34 of the controller 3.

The reference height measurement screen 62 displays measurement guidance 629 and guidance of "Place the prism at the reference height (FL+1000) of the pillar, point the surveying instrument toward the prism, and then presses "measure". Press "proceed to measurement check" after the measurement."

The reference height measurement screen 62 displays a +100 button 621, a -100 button 622, and a measurement result table 623. The reference height measurement screen 62 further displays a leftward rotation button 6241, a rightward rotation button 6242, a search button 6243, a measure button 6244, a selected row delete button 6245, an all-delete button 6246, a return button 625, and a measurement check button 626.
[0111]

The +100 button 621 and the -100 button 622 are buttons for adjusting the height (FL) value. When the +100 button 621 is tapped, the height is increased by 100. When the -100 button 622 is tapped, the height is decreased by 100.

When the leftward rotation button 6241 is tapped, the tracking three-dimensional meter 4 rotates leftward.

When the rightward rotation button 6242 is tapped, the tracking three-dimensional meter 4 rotates rightward.

When the search button 6243 is tapped, the prism position of the measurement target 23a is searched by the tracking three-dimensional meter 4. When the measure button 6244 is

tapped, the prism position of the measurement target 23a installed at the reference height (FL+1000) is measured by the tracking three-dimensional meter 4. The prism position of the measurement target 23a, which is measured by the tracking three-dimensional meter 4 is displayed in the measurement result table 623.

5 [0112]

The measurement result table 623 displays measurement results of the reference height. When any row of the measurement result table 623 is tapped, a measurement result on the row is selected. When the selected row delete button 6245 is tapped in this state, the selected measurement result is deleted.

10 When the all-delete button 6246 is tapped, all measurement results of the reference height are deleted.

[0113]

When the return button 625 is tapped, the touch panel display 34 of the controller 3 switches to a screen before the reference height measurement screen 62 is called. When the measurement check button 626 is tapped, the touch panel display 34 of the controller 3 switches to a reference measurement result screen 66 in FIG. 25.

[0114]

FIG. 22 is a diagram showing the prism height measurement screen 63. The prism height measurement screen 63 is displayed on the touch panel display 34 of the controller 3.

20 The prism height measurement screen 63 displays measurement guidance 639 and guidance of "Install the prism at the reference point, point the surveying instrument toward the prism, and then press "measure". Install the prism on the robot and press the "proceed to robot height measurement" button after the measurement."

The prism height measurement screen 63 displays a measurement result table 631, a leftward rotation button 6341, a rightward rotation button 6342, a search button 6343, a measure button 6344, a selected row delete button 6345, an all-delete button 6346, a return button 635, and a robot height measurement button 636.

[0115]

When the leftward rotation button 6341 is tapped, the tracking three-dimensional meter 4 rotates leftward.

When the rightward rotation button 6342 is tapped, the tracking three-dimensional meter 4 rotates rightward.

When the search button 6343 is tapped, the prism position of the measurement target 23a is searched by the tracking three-dimensional meter 4. When the measure button 6344 is tapped, the prism position of the measurement target 23a is measured by the tracking three-dimensional meter 4. The prism position of the measurement target 23a, which is measured by the tracking three-dimensional meter 4 is displayed in a measurement result table 633.

[0116]

The measurement result table 633 displays measurement results of the prism height. When any row of the measurement result table 633 is tapped, a measurement result on the row is selected. When the selected row delete button 6345 is tapped in this state, the selected measurement result is deleted.

When the all-delete button 6346 is tapped, all measurement results of the reference height are deleted.

[0117]

When the return button 635 is tapped, the touch panel display 34 of the controller 3 switches to a screen before the prism height measurement screen 63 is called. When the robot height measurement button 636 is tapped, the touch panel display 34 of the controller 3 switches to a robot height measurement check screen 64 in FIG. 23.

[0118]

FIG. 23 is a diagram showing the robot height measurement check screen 64. The robot height measurement check screen 64 is displayed on the touch panel display 34 of the controller 3.

The robot height measurement check screen 64 displays a map 649 and guidance of "Return the prism onto the robot and press the "robot travel" button.".

The robot height measurement check screen 64 displays a prism position table 642 of the reference point measured through the prism height measurement screen 63, a leftward rotation button 6411, a rightward rotation button 6412, a search button 6413, a return button 643, and a robot travel button 644.

[0119]

When the leftward rotation button 6411 is tapped, the tracking three-dimensional meter 4 rotates leftward.

When the rightward rotation button 6412 is tapped, the tracking three-dimensional

meter 4 rotates rightward.

When the search button 6413 is tapped, the prism position of the measurement target 23 is searched by the tracking three-dimensional meter 4.

[0120]

5 The prism position table 642 of the reference point displays the coordinates of the reference point measured by the prism height measurement screen 63.

[0121]

When the return button 643 is tapped, the touch panel display 34 of the controller 3 switches to a screen before the robot height measurement check screen 64 is called. When
10 the robot travel button 644 is tapped, the robot starts traveling and the touch panel display 34 of the controller 3 switches to a robot height in-measurement screen 65 in FIG. 24.

[0122]

FIG. 24 is a diagram showing the robot height in-measurement screen 65. The robot height in-measurement screen 65 is displayed on the touch panel display 34 of the controller 3.

15 The robot height in-measurement screen 65 displays a map 659 and guidance of "In robot height measurement. Wait for a moment." Together with an approximate remaining time.

The robot height in-measurement screen 65 displays a robot state label 651, a path table 652 listing the coordinates of the reference point and the coordinates of any relay point to
20 be relayed, and an abort button 653.

The robot state label 651 displays an operation state of the robot, such as robot traveling or measurement. The path table 652 displays any waypoint position up to the reference point. When the abort button 653 is tapped, the marking robot 2 aborts traveling or measurement. When measurement of the reference point ends, the touch panel display 34 of
25 the controller 3 switching to the reference measurement result screen 66 in FIG. 25.

[0123]

FIG. 25 is a diagram showing the reference measurement result screen 66. The reference measurement result screen 66 is displayed on the touch panel display 34 of the controller 3.

30 The reference measurement result screen 66 displays a map 669 and guidance of "Compare a measured value with its reference value and press "Confirm" in a case where the measured value is not to be changed. Perform reference height measurement and prism

height measurement again in a case where the measured value is to be changed."

[0124]

The reference measurement result screen 66 displays a measurement result table 661, a reference height measurement button 663, a prism height measurement button 664, a confirm
5 button 665, and a return button 662.

[0125]

The measurement result table 661 displays a set value of the reference height and measurement results of the prism height.

When the reference height measurement button 663 is tapped, transition is made to
10 the reference height measurement screen 62 in FIG. 21 and the reference height is measured again. When the prism height measurement button 664 is tapped, switch is made to the prism height measurement screen 63 in FIG. 22 and the prism height is measured again.

[0126]

When the confirm button 665 is tapped, the measurement results are confirmed and
15 then the touch panel display 34 of the controller 3 switches to the floor surface height menu selection screen 61 in FIG. 20. When the return button 662 is tapped, the touch panel display 34 of the controller 3 switches to a screen before switching to the reference measurement result screen 66.

[0127]

20 FIG. 26 is a diagram showing the measurement point selection screen 67. The measurement point selection screen 67 is displayed on the touch panel display 34 of the controller 3.

The measurement point selection screen 67 displays a map 679 and guidance of "Select any floor surface height measurement point from the list and press "end selection"."

25 [0128]

The measurement point selection screen 67 displays a clear button 671, a filter condition setting button 672, a measurement point table 673, an all-selection cancel button 674, a return button 676, and a selection end button 675.

[0129]

30 When the clear button 671 is tapped, a selected filter condition is cleared. When the filter condition setting button 672 is tapped, a filter condition setting dialog is called. Accordingly, a filter condition on measurement points displayed in the measurement point

table 673 can be set as appropriate.

[0130]

The measurement point table 673 displays measurement points.

When the all-selection cancel button 674 is tapped, any selected measurement point is
5 canceled. When the return button 676 is tapped, the touch panel display 34 of the controller
3 switches to a screen before switching to the measurement point selection screen 67. When
the selection end button 675 is tapped, the touch panel display 34 of the controller 3 ends
measurement point selection and switches to a measurement point check screen 68 in FIG. 27.

[0131]

10 FIG. 27 is a diagram showing the measurement point check screen 68. The
measurement point check screen 68 is displayed on the touch panel display 34 of the controller
3.

The measurement point check screen 68 displays a map 689 and guidance of "Check
points to be measured and press "measure" if there is no problem."

15 [0132]

The measurement point check screen 68 displays a leftward rotation button 6811, a
rightward rotation button 6812, a search button 6813, a measurement point table 682, a work
time prediction button 683, a path prioritization radio button 684, a designated order
prioritization radio button 685, a return button 686, and a measure button 687.

20 [0133]

When the leftward rotation button 6811 is tapped, the tracking three-dimensional
meter 4 rotates leftward.

When the rightward rotation button 6812 is tapped, the tracking three-dimensional
meter 4 rotates rightward.

25 When the search button 6813 is tapped, the prism position of the measurement target
23 is searched by the tracking three-dimensional meter 4.

[0134]

The measurement point table 682 displays measurement points.

When the work time prediction button 683 is tapped, a predicted value of a work time
30 taken for measurement of the floor surface height is calculated. The path prioritization radio
button 684 and the designated order prioritization radio button 685 are used to instruct a path
of the marking robot 2. In a case where the path prioritization radio button 684 is selected,

an optimum path is calculated irrespective of a designated order. In a case where the designated order prioritization radio button 685 is selected, a path is calculated in accordance with the designated order.

[0135]

5 When the return button 686 is tapped, the touch panel display 34 of the controller 3 switches to a screen before switching to the measurement point check screen 68. When the measure button 687 is tapped, the touch panel display 34 of the controller 3 switches to the floor surface height in-measurement screen 69 and the floor surface height measurement robot system 1 starts measuring the height of the floor surface.

10 [0136]

FIG. 28 is a diagram showing the floor surface height in-measurement screen 69. The floor surface height in-measurement screen 69 is displayed on the touch panel display 34 of the controller 3.

15 The floor surface height in-measurement screen 69 displays a map 699 and guidance of "In floor surface height measurement. Wait for a moment." Together with an approximate remaining time.

[0137]

 The floor surface height in-measurement screen 69 displays a robot state label 691, a measurement point table 692, and an abort button 693.

20 The robot state label 691 displays an operation state of the marking robot 2, such as robot traveling or measurement.

[0138]

 The measurement point table 692 displays measurement results.

25 When the abort button 693 is tapped, measurement is aborted and the touch panel display 34 of the controller 3 switches to a floor surface height measurement result screen 60 in FIG. 29. When measurement at designated measurement points is completed, the touch panel display 34 of the controller 3 switches to the floor surface height measurement result screen 60 in FIG. 29.

[0139]

30 FIG. 29 is a diagram showing the floor surface height measurement result screen 60. The floor surface height measurement result screen 60 is displayed on the touch panel display 34 of the controller 3.

The floor surface height measurement result screen 60 displays a map 609 and guidance of "Floor surface height measurement is completed. Check results in the list. To extract measurement data, press "display two-dimensional code" and read a two-dimensional code."

5 [0140]

The floor surface height measurement result screen 60 displays a measurement result table 601, a two-dimensional code display button 602, and a check button 603.

The measurement result table 601 displays measurement results. Any measurement point where the height is out of a predetermined range may be highlighted by changing the background and/or text color of the table.

When the two-dimensional code display button 602 is tapped, the touch panel display 34 of the controller 3 switches to a screen that displays a two-dimensional code in which measurement results are encoded. When the check button 603 is tapped, the touch panel display 34 of the controller 3 switches to the floor surface height menu selection screen 61 in FIG. 20.

15 [0141]

FIG. 30 is a mode transition diagram of floor surface height measurement.

First, the floor surface height measurement robot system 1 transitions to a floor surface height menu selection mode M10. In this case, the controller 3 displays the floor surface height menu selection screen 61 in FIG. 20.

When the reference height measurement button 611 in FIG. 20 is tapped in the floor surface height menu selection mode M1, the floor surface height measurement robot system 1 transitions to a reference height measurement mode M11.

When the prism height measurement button 612 in FIG. 20 is tapped in the floor surface height menu selection mode M1, the floor surface height measurement robot system 1 transitions to a prism height measurement mode M12.

25 [0142]

When the "floor surface height measurement (all-point measurement)" button 613 in FIG. 20 is tapped in the floor surface height menu selection mode M1, the floor surface height measurement robot system 1 transitions to an all-measurement point measurement mode M16 and then transitions to a measurement point check mode M17.

When the "floor surface height measurement (designated point measurement)" button

614 in FIG. 20 is tapped in the floor surface height menu selection mode M1, the floor surface height measurement robot system 1 transitions to a designated measurement point measurement mode M18 and then transitions to a measurement point selection mode M19.

When the measurement result check button 615 in FIG. 20 is tapped in the floor surface height menu selection mode M1, the floor surface height measurement robot system 1 transitions to a floor surface height measurement result mode M21.

[0143]

The floor surface height measurement robot system 1 displays the reference height measurement screen 62 in FIG. 21 on the controller 3 in the reference height measurement mode M11. When the measurement check button 626 in FIG. 21 is tapped, the floor surface height measurement robot system 1 transitions to a reference measurement result mode M15.

[0144]

The floor surface height measurement robot system 1 displays the prism height measurement screen 63 in FIG. 22 on the controller 3 in the prism height measurement mode M12. When the robot height measurement button 636 in FIG. 22 is tapped, the floor surface height measurement robot system 1 transitions to a robot height measurement check mode M13.

[0145]

The floor surface height measurement robot system 1 displays the robot height measurement check screen 64 in FIG. 23 on the controller 3 in the robot height measurement check mode M13. When the robot travel button 644 in FIG. 23 is tapped, the floor surface height measurement robot system 1 transitions to a robot height in-measurement mode M14.

[0146]

The floor surface height measurement robot system 1 displays the robot height in-measurement screen 65 in FIG. 24 on the controller 3 in the robot height in-measurement mode M14. The floor surface height measurement robot system 1 transitions to the reference measurement result mode M15 when measurement of the robot height ends.

[0147]

The floor surface height measurement robot system 1 displays the reference measurement result screen 66 in FIG. 25 on the controller 3 in the reference measurement result mode M15. When the confirm button 665 in FIG. 25 is tapped, the floor surface height measurement robot system 1 transitions to the floor surface height menu selection mode M10.

[0148]

The floor surface height measurement robot system 1 displays the measurement point selection screen 67 in FIG. 26 on the controller 3 in the measurement point selection mode M19. When the selection end button 675 in FIG. 26 is tapped, the floor surface height measurement robot system 1 transitions to the measurement point check mode M17.

[0149]

The floor surface height measurement robot system 1 displays the measurement point check screen 68 in FIG. 27 on the controller 3 in the measurement point check mode M17. When the measure button 687 in FIG. 27 is tapped, the floor surface height measurement robot system 1 transitions to a floor surface height in-measurement mode M20.

[0150]

The floor surface height measurement robot system 1 displays the floor surface height in-measurement screen 69 in FIG. 28 on the controller 3 in the floor surface height in-measurement mode M20. The floor surface height measurement robot system 1 transitions to the floor surface height measurement result mode M21 when measurement ends.

[0151]

The floor surface height measurement robot system 1 displays the floor surface height measurement result screen 60 in FIG. 29 on the controller 3 in the floor surface height measurement result mode M21. When the check button 603 in FIG. 29 is tapped, the floor surface height measurement robot system 1 transitions to the floor surface height menu selection mode M10.

[0152]

Modifications

The present invention is not limited to the above-described embodiment but includes various modifications. For example, the above-described embodiment is described in detail for clear understanding of the present invention and is not necessarily limited to a configuration including all described components. Any component according to an embodiment may be replaced with a component according to another embodiment, and a component according to an embodiment may be added to a component according to another embodiment. Moreover, any component according to each embodiment may be subjected to addition, deletion, and replacement with another component.

[0153]

Some or all of the above-described configurations, functions, processing units, processing means, and the like may be implemented as hardware such as integrated circuits. The above-described configurations, functions, and the like may be implemented as software by a processor interpreting and executing a computer program that implements each function.

- 5 Information of a computer program, a table, a file, or the like with which each function is implemented may be stored in a recording device such as a memory, a hard disk, or a solid state drive (SSD), or in a recording medium such as a flash memory card or a digital versatile disk (DVD).

[0154]

- 10 In each embodiment, only control lines and information lines that are thought to be necessary for sake of description are presented, and not all control lines nor information lines of a product are necessarily presented. It may be assumed that substantially all components are mutually connected in reality.

15 Explanation of Reference Characters

[0155]

1 floor surface height measurement robot system

2 marking robot (robot)

20 frame

- 20 201 bumper

210 marking robot controller (robot controller)

211 travel driver

212 printer mover

213 measurement target driver

- 25 214 height calculator (height calculating unit)

215 height determiner (height determining unit)

21F wheel

21R wheel

22 printer

- 30 23 measurement target

24 communicator

25 operation button

	26 front side sensor
	27F bumper sensor
	27R bumper sensor
	28 lower side sensor
5	3 controller
	31 processor
	32 RAM
	33 large-capacity storage
	34 touch panel display
10	35 communicator
	31a operation receiver
	31b reader
	31c installation point setter
	31d measurement point setter
15	31e surveying instrument operator
	31f robot operator (robot operating unit)
	31g traveling range setter
	31h route setter
	31i communication controller
20	31j screen controller
	331 robot control program
	332 measurement point data
	333 travel path data
	4 tracking three-dimensional meter (three-dimensional measuring unit: surveying instrument)
25	51 CAD data storage
	52 measurement point information producer
	53 site management server
	70 concrete surface
	71 pillar
30	72 reference point

CLAIMS

What is claimed is:

1. A floor surface height measurement robot system comprising:
5 a traveling unit configured to travel on a floor surface;
a robot controlling unit configured to control a robot to travel to a predetermined position on the floor surface by using the traveling unit;
a three-dimensional measuring unit configured to measure position and height of a measurement target of the robot;
10 a robot operating unit configured to instruct the robot controlling unit to move the robot to coordinates of the measurement point information by using the traveling unit based on measurement point information in coordinates of a floor surface drawing; and
a height calculating unit configured to calculate a height of the floor surface at a position of the measurement point information based on a height of the measurement target,
15 which is measured by the three-dimensional measuring unit.
2. The floor surface height measurement robot system according to claim 1, wherein the height calculating unit calculates the height of the floor surface at the position of the measurement point information based on reference height information on measurement of a
20 reference height and the height of the measurement target.
3. The floor surface height measurement robot system according to claim 1, wherein the robot further includes a printing unit configured to perform printing on the floor surface, and
25 the robot controlling unit controls the printing unit to print height information of the floor surface on the floor surface once, for each position of the measurement point information, the three-dimensional measuring unit measures the measurement target and the height calculating unit calculates the height of the floor surface.
- 30 4. The floor surface height measurement robot system according to claim 3, further comprising a height determining unit configured to determine whether the height of the floor surface, which is calculated by the height calculating unit is within a predetermined range,

wherein in response to the height determining unit determining that the height of the floor surface is out of the predetermined range, the robot controlling unit prints information of out-of-range.

5 5. The floor surface height measurement robot system according to claim 4, wherein in response to the height determining unit determining that the height of the floor surface is within the predetermined range, the robot controlling unit does not print information of the height of the floor surface on the floor surface.

10 6. The floor surface height measurement robot system according to claim 3, wherein the robot controlling unit additionally prints, on the floor surface, marking information in accordance with each position of the measurement point information.

15 7. The floor surface height measurement robot system according to claim 3, wherein the robot controlling unit prints information of the height of the floor surface on the floor surface.

20 8. The floor surface height measurement robot system according to claim 1, wherein the height calculating unit calculates slant information of the floor surface at the position of the measurement point information based on the height of the floor surface at a plurality of points around the position of the measurement point information.

25 9. The floor surface height measurement robot system according to claim 1, further comprising a screen controller configured to display a calculation result of the height of the floor surface on a screen.

10. The floor surface height measurement robot system according to claim 1, wherein the measurement point information in the coordinates of the floor surface drawing is determined in advance.

30 11. The floor surface height measurement robot system according to claim 1, wherein the measurement point information in the coordinates of the floor surface drawing is designated by a user operation.

12. A floor surface height measurement method comprising:
- controlling a robot to travel to a measurement point on a floor surface;
 - measuring a height of a measurement target of the robot by a three-dimensional
- 5 measuring unit while the robot is positioned at the measurement point; and
- calculating a height of the floor surface at the measurement point based on the height of the measurement target.