

MARKING ROBOT SYSTEM AND CONTROL METHOD OF MARKING ROBOT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a marking robot system and a control method of a marking robot.

2. Description of Related Art

In recent years, at a construction site, there has been an increasing trend toward automating operations such as marking, which could only be performed by skilled operators, by using a robot. A marking robot system automatically performing such marking is disclosed in, for example, Patent Literature 1.

Although it is not a technique related to marking, Patent Literature 2 is known as a technique for correcting map data. Patent Literature 2 discloses a technique of "detecting a difference or an error between a map and a real space and correcting the map so as to reflect situation of structures by using a detection result".

Examples of related art include JP2021-043114A (Patent Literature 1) and JP2021-196489A (Patent Literature 2).

In the related art, in a marking work performed by skilled operators, the marking work of the entire

construction work site is performed manually. The marking robot described in Patent Literature 1 can automatically perform the marking work under predetermined conditions. However, in the vicinity of structures such as walls or openings, physical interference between the marking robot and the structure is likely to occur. Therefore, there is room for improvement in the range in which the marking work is automatically performed.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a marking robot system and a control method of a marking robot that can be implemented so as to improve efficiency of a marking work of the marking robot.

In order to solve the above-described problems, a marking robot system includes: a marking robot provided with a sensor detecting an obstacle, traveling in a work site based on position information measured by a position measurement device and printing at a marking position; and an operation device setting a position of a structure at the work site and instructing the marking robot to perform a marking process, in which the marking robot: sets a predetermined range of the structure set by the operation

device as a caution area; and sets a relay point to be passed through when moving to a predetermined marking position in the caution area, in which, when moving from the relay point to the predetermined marking position, detection sensitivity of the sensor is reduced below a normal value used in a normal area outside the caution area.

According to the present invention, when the marking robot is moved to a predetermined marking position in a caution area, detection sensitivity of a sensor is reduced below a normal value, so that a marking robot reaching a structure can perform printing at a predetermined marking position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an explanatory diagram illustrating an overall overview of a marking robot system;

FIG. 2 is a diagram illustrating a functional configuration of the marking robot system;

FIG. 3 is a perspective view illustrating an overview of a marking robot;

FIG. 4 is a flowchart illustrating overall processes of a marking work;

FIG. 5 is a flowchart illustrating a method of setting

a wall area;

FIG. 6 is an example of a screen used when setting the wall area by actual measurement;

FIG. 7 is a flowchart illustrating a process for generating a travel path for the marking robot;

FIG. 8 is a flowchart of a process for setting a caution area outside the wall area;

FIG. 9 is an explanatory diagram illustrating one example of setting a travel path;

FIG. 10 is an explanatory diagram illustrating another example of setting the travel path;

FIG. 11 is an explanatory diagram illustrating a setting example of the caution area;

FIG. 12 is a flowchart illustrating a process in which the marking robot moves and marks a work site;

FIG. 13 is a flowchart illustrating a marking process by a marking robot according to a second embodiment;

FIG. 14 is a flowchart illustrating a process of providing a result of a marking work to an operator according to a third embodiment; and

FIG. 15 is a flowchart illustrating a marking process by a marking robot according to a fourth embodiment.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the present invention will be described by using the drawings. The present invention is not to be construed as being limited to contents of the embodiments described below. Those skilled in the art will easily understand that the configuration can be changed without departing from the technical idea or spirit of the present invention. In addition, in the configurations of the embodiments described below, the same devices and portions having similar operations and functions are denoted by the same reference numerals, and redundant description may be omitted. In addition, the position, size, shape, range, or the like of each component illustrated in the drawings is intended to facilitate understanding of the present invention, and does not represent the actual position, size, shape, range, or the like of each component. For example, the configurations of the marking robots described in the embodiments are examples, and are not limited to the configurations described in the embodiments.

A marking robot system 1 disclosed in the present embodiment includes a marking robot 2 that travels on a work site FL based on position information measured by a position measurement device 4 and an operation device 3 to be operated

by an operator (operator of the marking robot 2) (refer to FIG. 1).

As illustrated in FIG. 2, the marking robot 2 includes, for example, a printer 22 performing marking printing, a printer drive unit 212 allowing the printer 22 to be movable, a mobile body 20 provided with the printer 22 and the printer drive unit 212 moving, and a marking robot control unit 210 controlling the printer 22, the printer drive unit 212, and the mobile body 20.

The position measurement device 4 is configured, for example, as an automatic tracking three-dimensional surveying device, and thus, measures the position of the marking robot 2 at the work site FL and notifies the marking robot control unit 210 of a position measurement result (position information).

The operation device 3 communicates with the marking robot control unit 210 and instructs the marking robot control unit 210 to perform a marking process.

The marking robot control unit 210 transmits and receives information between the position measurement device 4 and the operation device 3 by using a communication unit 24. The marking robot control unit 210 stores marking information configured with basic marking information and

editable information corresponding to the basic marking information.

The operation device 3 takes in the marking information, displays an editing screen for the operator to edit the editable information, generates the customized marking information based on an operation result on the editing screen, and transmits the marking information to the marking robot control unit 210. The marking robot control unit 210 performs the marking printing according to the customized marking information.

According to the marking robot system according to the present disclosure, there is an increased possibility that the marking robot 2 can perform marking even in an area close to a structure where it is difficult for the marking robot 2 to travel, so that the efficiency of the marking work by the marking robot 2 is improved.

The present disclosure includes a system or method including the following configurations.

(Expression 1) A marking robot system includes: a marking robot 2 provided with a sensor 26 detecting an obstacle 5, traveling in a work site FL based on position information measured by a position measurement device 4, and printing at a marking position MP; and an operation device 3

setting a position of a structure 5 at the work site FL and instructing the marking robot 2 to perform a marking process, in which the marking robot 2: sets a predetermined range of the structure 5 set by the operation device 3 as a caution area 6, and sets a relay point RP to be passed through when moving to a predetermined marking position MP2 in the caution area 6, and in which, when moving from the relay point RP to the predetermined marking position MP2, detection sensitivity of the sensor 26 is reduced below a normal value used in a normal area 9 outside the caution area 6.

(Expression 2) The marking robot system according to Expression 1, in which the marking robot sets the relay point so that printing can be performed in a posture when the marking robot starts traveling from the relay point to the predetermined marking position.

(Expression 3) The marking robot system according to any one of expressions 1 and 2, in which when the marking robot moves from the relay point to the predetermined marking position, the detection sensitivity of the sensor is reduced below the normal value, and a movement speed is also reduced below a normal speed in the normal area.

(Expression 4) The marking robot system according to

any one of expressions 1 to 3, in which the marking robot reduces at least one of the detection sensitivity of the sensor and the movement speed in the caution area in a plurality of stages from the normal value or the normal speed.

(Expression 5) The marking robot system according to any one of expressions 1 to 4, in which, when printing at the predetermined marking position, the marking robot returns from the predetermined marking position to the relay point in the posture at the time of printing.

(Expression 6) The marking robot system according to any one of expressions 1 to 5, in which, when the sensor detects an obstacle while moving from the relay point to the predetermined marking position, the marking robot stops on a spot and returns to the relay point while maintaining the posture.

(Expression 7) The marking robot system according to any one of expressions 1 to 6, in which, when the marking robot cannot print at the predetermined marking position, the marking robot notifies the operation device of that information.

(Expression 8) The marking robot system according to any one of expressions 1 to 7, in which the marking robot selects, as the relay point, coordinate points with the

shortest distance to the predetermined marking position among the coordinate points of the normal area.

(Expression 9) The marking robot system according to any one of expressions 1 to 8, in which the marking robot selects, as the relay point, the coordinate points with the shortest distance to the predetermined marking position among the coordinate points of the normal area where a path from the relay point to the predetermined marking position is parallel or perpendicular to a core of the work site.

(Expression 10) The marking robot system according to any one of expressions 1 to 9, in which the marking robot sets the caution area by enlarging an outer edge of the structure.

(Expression 11) The marking robot system according to any one of expressions 1 to 10, in which, when an area obtained by enlarging the outer edge of the structure is larger than a predetermined value or more, the marking robot sets the caution area by deleting a predetermined amount of areas of vertexes of the area.

(Expression 12) The marking robot system according to any one of expressions 1 to 11, in which the operation device sets the position of the structure by using one or more of actual measurement of the work site, manual setting, three-

dimensional design data, and an analysis of images obtained by imaging the work site.

(Expression 13) A control method of a marking robot, in which a marking robot is provided with a sensor detecting obstacles, in which the marking robot: travels in a work site based on position information measured by a position measurement device, and prints at a marking position, sets a predetermined range of a structure set by an operation device as a caution area, and sets a relay point to be passed through when moving to a predetermined marking position in the caution area, and in which, when moving from the relay point to the predetermined marking position, detection sensitivity of the sensor is reduced below a normal value used in a normal area outside the caution area.

[First Embodiment]

A first embodiment will be described with reference to FIGS. 1 to 12. A configuration of a marking robot system 1 will be described with reference to FIGS. 1 to 3. FIG. 1 is an explanatory diagram illustrating an overall overview of the marking robot system 1. FIG. 2 is a diagram illustrating a functional configuration of the marking robot system 1. FIG. 3 is a perspective view illustrating an overview of a marking robot 2.

As illustrated in FIG. 1, the marking robot system 1 includes, for example, a marking robot 2, a tracking three-dimensional measurement device 4 as an example of a "position measurement device" measuring a position of the marking robot 2, and an operation device 3 operated by an operator.

A work site FL such as a building site or a construction site may have, for example, a structure 5 such as a wall or a pillar. In addition to permanent objects such as walls and columns, the structures 5 may also be temporary structures that exist for a relatively long period of time. The structure 5 is also called a wall area 5.

Also in the vicinity of the structure 5, for example, ink dots (also called marking points or marking positions) indicating the positions of electrical outlets, through-holes for piping, and the like may be printed. When printing ink dots in the vicinity of the structure (wall area) 5, the marking robot 2 needs to reach the structure 5. However, the marking robot 2 is provided with a front sensor 26 as an example of a safe traveling sensor for realizing safe traveling as described later. For this reason, the front sensor 26 may detect the existence of the structure 5, and may be likely not to be able to reach the ink dot (predetermined marking position MP2 in FIG. 1) in the

vicinity of the structure 5.

Therefore, in this embodiment, a caution area 6 is set outside the structure 5, and the marking robot 2 reduces detection sensitivity of the front sensor 26 in the caution area 6 to be less than the detection sensitivity (normal value) in a normal area 9. Furthermore, the marking robot 2 reduces a movement speed in the caution area 6 to be lower than a normal speed in the normal area 9. Accordingly, the marking robot 2 can reach a predetermined ink dot MP2 in the caution area 6 at a low speed.

Furthermore, in this embodiment, a relay point RP is set at the boundary between the normal area 9 and the caution area 6 so that the marking robot 2 can safely reach the predetermined ink dot MP2 in the caution area 6. The marking robot 2 moves from an ink dot MP1, which is the previous work position, to the relay point RP.

When the marking robot 2 reaches the relay point RP, the marking robot 2 aligns a posture toward the predetermined ink dot MP2 and reduces the movement speed and the sensor detection sensitivity. Then, the marking robot 2 travels at a low speed from the relay point RP to the predetermined ink dot MP2 and prints with the predetermined ink dot MP2. When the printing is completed, the marking robot 2 moves backward

to the relay point RP while maintaining the posture.

That is, the relay point RP is set so that printing can be performed with the predetermined ink dot MP2 in the posture when the marking robot 2 starts from the relay point RP. A printer 22 is provided closer to the front side than the center of a frame 200 and is located in the vicinity of a front bumper 201. Therefore, the position of the printer 22 can reach the structure 5 by directing the marking robot 2 in the direction of the predetermined ink dot MP2.

In addition, when the marking robot 2 changes the posture by circulation or the like in the caution area 6, the marking robot 2 is likely to be in contact with the structure 5. In order to prevent contact by turning or the like, the width of the caution area 6 is necessarily lengthened so that the marking robot 2 can rotate in the caution area 6, and the area to move at a low speed increases, so that the time required for the marking work becomes longer.

The marking robot 2 can move parallel or perpendicular to a reference core BL toward the predetermined ink dot MP2. When there are a plurality of candidates for the relay point RP, the relay point RP with the shortest movement distance from the relay point RP to the predetermined ink dot MP2 is selected.

When the printing with the predetermined ink dot MP2 is completed, the marking robot 2 moves backward to the relay point RP in the posture at the time of completing the printing. That is, the marking robot 2 moves backward as it is without rotating 180 degrees or the like. When the marking robot 2 returns to the relay point RP, the detection sensitivity of the front sensor 26 returns to the normal value, and the movement speed also returns to the normal speed. Then, the marking robot 2 moves toward an ink dot MP3, which is the next work position.

A method of setting the caution area 6 will be described later. A distance d_L between the caution area 6 and the structure 5 (wall area 5 described later) may be a constant value over the entire circumference of the structure 5 or may be changed.

In order to reduce the detection sensitivity of the front sensor 26 in the caution area 6, the marking robot 2 can move to the predetermined ink dot MP2 in the vicinity of the structure 5. Since the detection sensitivity of the front sensor 26 is returned to the normal value in the normal area 9, obstacles existing in the traveling direction of the marking robot 2 can be detected early.

Since the movement speed of the marking robot 2 is

reduced in the caution area 6, the marking robot 2 can safely move to the predetermined ink dot MP2. Since the marking robot 2 travels at a normal speed in the normal area 9, the marking robot 2 can quickly reach the ink dot MP3 in the normal area 9 and perform printing.

The operation device 3 will be explained. The operation device 3 communicates bidirectionally with the marking robot 2 and also bidirectionally communicates with the tracking three-dimensional measurement device 4. The operation device 3 acquires marking information from a marking information generation unit 7 and transmits the marking information customized from the acquired marking information to the marking robot 2. The marking information generation unit 7 generates the marking information based on three-dimensional CAD data acquired from a storage unit 8 storing the three-dimensional CAD data. The marking robot 2 performs the marking printing according to the customized marking information.

The functional configuration of the marking robot system 1 will be described with reference to FIG. 2.

First, the operation device 3 will be described. The operation device 3 is, for example, a tablet personal computer, a laptop personal computer, a desktop personal

computer, a mobile phone (including a smart phone), a portable information terminal, a watch-type wearable terminal, and a glasses-type wearable terminal.

The operation device 3 includes, for example, a processor (CPU in the drawing) 31, a main storage device 32, an auxiliary storage device 33, a user interface unit (UI unit in the drawing) 34, and a communication unit 35, and these circuit units are communicatively connected to a bus 36.

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

The main storage device 32 is a device storing computer programs and data that are read and written by the processor 31. For example, a dynamic RAM (DRAM), a static RAM (SRAM), or the like is used for the main storage device 32.

The auxiliary storage device 33 is a relatively large-capacity storage device, and a flash memory, a hard disk, a magnetic tape, an optical disk, an optical-magneto disk, or the like is used.

The communication unit 35 is a device communicating with the marking robot 2, the tracking three-dimensional measurement device 4, and the marking information generation unit 7 by using, for example, a wireless local area network (LAN). Information may be transmitted not only by wireless but also by using infrared rays or sound waves. Either or both of wireless communication and wired communication may be used.

The marking robot 2 will be described. The marking robot 2 is a robot deployed at the work site FL, moves to a predetermined marking position, and automatically performs the marking printing. The work sites FL include, for example, construction of buildings and the like, civil engineering of roads and the like.

The marking robot 2 travels autonomously by using position information measured by the tracking three-dimensional measurement device 4 according to an operation command input to the operation device 3 by the operator. The position information of the marking robot 2 measured by the tracking three-dimensional measurement device 4 is transmitted to the marking robot 2. When the marking robot 2 moves to a scheduled marking point (marking printing position), the printer 22 executes the marking printing

according to the marking information.

As described later, the marking robot 2 includes a traveling unit 20, wheels 21F and 21R, the printer 22, a measurement target 23, a communication unit 24, an operation button 25, the front sensor 26, bumper sensors 27F and 27R, a lower sensor 28, a marking robot control unit 210, a traveling drive unit 211, a printer moving unit 212, a measurement target drive unit 213, and a battery (not illustrated).

The marking robot control unit 210 is a device storing the "marking information", which is information for marking printing and controls the entire marking robot 2. The marking robot control unit 210 will be further described later.

The printer 22 is a device that performs the marking printing under the control of the marking robot control unit 210. The traveling unit 20 is a device that moves the entire marking robot 2. The printer moving unit 212 is a device that moves the printer 22 installed on the traveling unit 20 in a two-dimensional direction or a three-dimensional direction. The measurement target 23 is configured as, for example, a prism. The measurement target 23 is installed on the printer moving unit 212 and moves together with the

printer 22 on an XY plane (refer to FIG. 3). Therefore, the position of the measurement target 23 indicates the printing position of the printer 22. The position of the measurement target 23 is changed by the measurement target drive unit 213. A change in the position of the measurement target 23 is detected by the tracking three-dimensional measurement device 4, and accordingly, the current position of the marking robot 2 is calculated.

The measurement target 23 can be removed from the marking robot 2 to be used. When the marking robot 2 cannot print ink dots, the operator can remove the measurement target 23 from the marking robot 2, can dispose the measurement target 23 at a desired position, and can measure the position with the tracking three-dimensional measurement device 4. It is noted that, even when actually measuring the structure (wall area) 5, the measurement target 23 is used with the measurement target 23 removed from the marking robot 2. After the wall area 5 has been actually measured, the measurement target 23 is attached to the marking robot 2.

For the marking robot control unit 210, an information device having a function of a normal computer can be used. That is, the marking robot control unit 210 includes a storage unit and an arithmetic processing unit (both not illustrated).

The communication processing function of the arithmetic processing unit is connected to the operation device 3 via the communication unit 24.

The storage unit stores a control program controlling the entire marking robot 2, marking information, and information necessary for the operation. The arithmetic processing unit moves the marking robot 2 to the marking position according to the control program, aligns the position of the printer 22 with the marking position, and drives the printer 22 to perform marking printing according to the marking information. The entire printer 22 is moved back and forth and left and right on a plane (on a floor surface) of the work site FL by the printer moving unit 212. That is, the printer 22 and the printer moving unit 212 as a whole operate like an XY plotter. Instead of the XY plotter type printer 22 and printer drive unit 212, a three-axis arm robot may be mounted on the traveling unit 20, and a print head may be attached to the tip of the arm of the three-axis arm robot.

The traveling unit 20 includes, for example, the frame 200, the wheels 21F and 21R provided below the frame 200, and the traveling drive unit 211 driving the wheels 21F and 21R. The traveling drive unit 211 may drive either one of the

front and rear wheels 21F and 21R (front wheel drive or rear wheel drive) or may drive all wheels 21F and 21R (four wheel drive). Instead of the wheels 21F and 21R, a crawler may be used.

The operation button 25 is provided to the frame 200 and manually operated by the operator as needed. The operation button 25 is, for example, a power switch and a stop switch (both not illustrated).

The marking robot 2 is provided with various sensors 26, 27F, 27R, and 28 for ensuring safety in order to travel safely on the work site FL. The front sensor 26 is configured with, for example, a light detection and ranging (LiDAR) and detects the object in the traveling direction of the marking robot 2. The bumper sensors 27F and 27R are provided to the bumpers 201 provided to the front and rear of frame 200 and detect that the bumpers 201 come into contact with the object (only the front bumper is illustrated in FIG. 3). The lower sensor 28 detects unevenness, openings, and the like of the floor surface of the work site FL. Sensors other than the illustrated sensors, for example, a three-dimensional camera, an ultrasonic sensor, a radiation thermometer, and the like may be mounted on the marking robot 2.

As described above, the printer moving unit 212 is

arranged on the traveling unit 20 and is attached with the printer 22 at a lower portion. The printer moving unit 212 moves and position-aligns the printer 22 to the marking printing position under the positioning control by the marking robot control unit 210. The printer moving unit 212 in this embodiment can move the printer 22 in the two-dimensional directions of XY and can also move the printer 22 in the Z direction. This is for positioning the print head of the printer 22 at a position suitable for printing on the marking surface (floor surface, wall, and ceiling).

The marking robot control unit 210 moves the marking robot 2 based on the marking position (target printing position) included in the marking information and the position information of the marking robot 2 measured by the tracking three-dimensional measurement device 4 to the marking position (marking point) and position-aligns the marking robot 2. When the marking robot 2 reaches the marking position, the marking robot control unit 210 causes the printer moving unit 212 to position-align the printer 22 to the marking point (marking printing position) with high accuracy. Then, the printer 22 prints predetermined contents at the marking points.

The tracking three-dimensional measurement device 4

described above tracks the measurement target 23 attached to the marking robot 2 with a laser beam. The tracking three-dimensional measurement device 4 measures the position of the measurement target 23 in a three-dimensional space, that is, the position of the marking robot 2 by using reflected light from the measurement target 23.

The tracking three-dimensional measurement device 4 measures the position of the marking robot 2 with high accuracy by measuring the position of the measurement target 23 attached to the marking robot 2. The tracking three-dimensional measurement device 4 is not limited to those using the laser beam, and any device that can measure the position of the marking robot 2 can be used. The position of the marking robot 2 measured by the tracking three-dimensional measurement device 4 is transmitted to the marking robot control unit 210 for use in movement control (position-aligning) of the marking robot 2 to the marking position. The position of the marking robot 2 is also transmitted to the operation device 3 as necessary based on command information from the operation device 3.

As described above, the operation device 3 is a computer terminal that transmits and receives information between the marking robot 2 and the tracking three-dimensional

measurement device 4 and controls the operations of the marking robot 2 and the tracking three-dimensional measurement device 4. The operation device 3 in this embodiment has a function of editing (customizing) the marking information by the operation of operator on the operation device 3 side based on the marking information received from the marking robot control unit 210. Therefore, the operation device 3 can transmit and receive information to and from the marking robot control unit 210 and share the marking information with the marking robot control unit 210. The operation device 3 has a function of taking in the "marking basic information", which is the basic marking information in the "marking information", and "editable information" for customization and displaying an editing screen for operation by the operator and has an operation function for the operator selecting and operating by using the editing screen.

Overall processes of the marking work will be described by using the flowchart of FIG. 4. On-site work is roughly divided into marking preliminary preparation procedures and marking work.

In step S11, the operator measures the two or more reference cores BL (refer to FIG. 1) in order to specify an

installation position of the tracking three-dimensional measurement device 4 and performs instrument point setting.

In step S12, structures such as pillars and walls on site are registered as the wall area 5 (refer to FIG. 1). The wall area can also be called, for example, a structure area or an avoidance area. In this embodiment, it is called a wall area. By setting the wall area and further reducing the safety margin of the caution area 6 (refer to FIG. 1) provided outside the wall area, the marking robot 2 can reach the ink dots in the vicinity of the wall area 5 and perform printing. The work up to this point is a preliminary preparation before executing the marking.

Steps S13 to S15 are operations for performing marking on site. When the operator selects one or more ink dots to be marked out by using the operation device 3, the marking robot control unit 210 generates a movement path to the selected ink dots (also called marking points or marking positions).

In steps S14 and S15, the marking robot 2 performs the movement and the marking printing according to the path generated in step S13.

The marking robot 2 determines in step S15 whether the marking printing of all designated ink dots has been

completed, and when the marking printing is not completed, steps S13 and S14 are repeated again. The marking robot 2 stops when the marking printing of all designated ink dots is completed.

The method of setting the wall area 5 (S12) will be described by using the flowchart of FIG. 5. In this embodiment, the wall area 5 can be set by using the operation device 3 in several methods. That is, in this embodiment, the position of the wall area 5 can be set by using any one or more of a plurality of methods such as by actually measuring at the work site FL, by manually setting, by using three-dimensional design data, and by analyzing an image obtained by imaging the work site FL.

The operator selects the wall area setting method from a menu displayed on the operation device 3 (S121). The method of setting the wall area 5 by the actual measurement (S1221) is a method of accurately setting the wall area 5, and is also called accurate area setting. In the accurate area setting, a measurement target such as a prism is installed at each vertex of the wall area 5 (S1222), and the position of the measurement target is measured by the tracking three-dimensional measurement device 4. The position information measured by the tracking three-

dimensional measurement device 4 is transmitted to and stored in the operation device 3 (S1223).

FIG. 6 is an example of an actual measurement setting screen G1 for setting the wall area by actually measuring the wall area accurately. The actual measurement setting screen G1 includes, for example, a guidance display unit G11, a map display unit G12, a measurement data operation unit G13, a measurement data display unit G131, a survey instrument operation unit G14, a button G15 to return to a previous screen, and a button G16 for determining setting of the wall area.

A message for prompting the operator to operate is displayed in the guidance display area G11. The message is, for example, "Please place the prism on the vertex of the area and press "measurement". When the measurement cannot be performed due to obstacles, long-press the position that is desired to be set on the map. After measuring at least three points, please press "determination"" and the like.

The map information of the work site FL is displayed in the map display unit G12. The map information may be generated from three-dimensional CAD data. The measurement data operation unit G13 is an operation unit for the operator to select or delete the measured data. The buttons of "up

one", "down one", "delete selected row", or the like are arranged in the measurement data operation unit G13.

The measurement data display unit G131 displays the actually measured vertex coordinates of the wall area or the vertex coordinates of the wall area designated on the map.

The buttons for operating the tracking three-dimensional measurement device 4, for example, "turn left", "turn right", "measure", and the like are arranged in the survey instrument operation unit G14.

It is desirable to set the position of the wall area 5 accurately. That is, the screen G1 is an example of a screen for measuring a wall edge by using the tracking three-dimensional measurement device 4 and the measurement target 23.

When there is an obstacle such as a wall or a pillar between the position to be measured by using the measurement target 23 and the tracking three-dimensional measurement device 4, the tracking three-dimensional measurement device 4 cannot measure the position of the measurement target 23. In this case, the operator can designate coordinates by long-pressing a predetermined position on the map displayed in the map display unit G12.

The process returns to FIG. 5. When the mode for

manually setting the wall area 5 is selected (S1231), the operator can input the position (coordinates of the apex) of the wall area 5 (S1232) by selecting a position on the map displayed in the map display unit G12.

When the mode for processing drawing data and setting the wall area 5 is selected (S1241), the operation device 3 acquires the three-dimensional CAD data (S1242) and extracts the wall area 5 from the acquired three-dimensional CAD data and performs setting (S1243). The three-dimensional CAD data also includes, for example, building information modeling (BIM) data. The wall area 5 may be set from wall information (wall) included in the drawing data such as the BIM.

When the mode of processing sensor data to set the wall area is selected (S1251), the operation device 3 acquires data from a predetermined sensor for recognizing the three-dimensional space (S1252) and extracts the wall area 5 from the sensor data (S1253).

For example, a measurement range sensor or an image sensor (a camera capable of measuring the distance) can be used as a predetermined sensor.

The process (step S13 in FIG. 4) for the marking robot 2 generating the traveling path will be described in detail by using the flowchart in FIG. 7.

The marking robot 2 moves the measurement target 23, and the tracking three-dimensional measurement device 4 measures the positions of the measurement target 23 at two points. Accordingly, the orientation and position of the marking robot 2 are calculated (S131).

The marking robot 2 generates the caution area 6 from the shape of the wall area 5 for the ink dots in the vicinity of the wall area 5 (S132). A method of setting the caution area 6 will be described later, but as illustrated in FIG. 9, when described in brief, the caution area 6 can be calculated, for example, as an enlarged area of the outer edge of the wall area 5. As illustrated in FIG. 10, when the wall area 5 is triangular, the caution area 6 may become unnecessarily large. Therefore, when the caution area obtained by enlarging the outer edge of the wall area 5 is larger than a predetermined value or more, the marking robot 2 deletes a predetermined amount of the area of the apex of the caution area 6.

The marking robot 2 calculates the candidates for the relay point RP (S133). The marking robot 2 calculates a perpendicular line 101 from the ink dot MP to each side (outer edge of the caution area 6) of the caution area 6 (S133). Among the perpendicular lines, the perpendicular lines

crossing the wall area 5 are excluded. This is because the marking robot 2 cannot move across the wall area 5. Among the perpendicular lines, the perpendicular lines that do not cross the wall area 5 are selected. The points RPC where the selected perpendicular line 101 and each side of the caution area 6 intersect are points (coordinates) that are the candidates for the relay point RP.

Among calculated relay point candidates RPC, the relay point candidates RPC in the area where the marking robot 2 cannot travel are excluded (S134).

The marking robot 2 calculates the distance between the ink dot in the caution area 6 and each relay point candidate RPC and selects the shortest relay point candidate RPC as the relay point RP (S135).

The marking robot 2 generates a travel path connecting the selected relay point RP and other ink dots in the normal area 9 (S136). The marking robot 2 transmits the generated path to the operation device 3 in response to the request from the operation device 3 (S137). The operator can also correct the path generated by the marking robot 2 on the operation device 3.

The process of setting the caution area 6 (step S132 in FIG. 7) will be described by using the flowchart in FIG. 8.

The marking robot 2 enlarges the outer edge of the wall area 5 (S1321) and determines whether there is a portion where the enlarged area is larger than a predetermined value or more (S1322).

When there is a position where the area is larger than the predetermined value or more (YES in S1322), the marking robot 2 deletes that position (S1323). Then, the marking robot 2 stores the generated caution area 6 (S1324). When there is no position where the enlarged area is larger than the predetermined value or more (NO in S1322), step S1323 is skipped, and the process proceeds to step S1324.

The explanatory diagram of FIG. 9 illustrates an overview of setting the caution area 6 and the relay point RP with respect to the rectangular wall area 5. The caution area 6 can be set by enlarging the outer edge of the rectangular wall area 5 without changing the shape. Therefore, the caution area 6 and the wall area 5 are similar.

A perpendicular line is drawn from a predetermined ink dot MP in the caution area 6 to each side of the caution area 6. Among those perpendicular lines, the perpendicular lines crossing the wall area 5 and going upwards are excluded. Therefore, the perpendicular lines are not illustrated. The points where the other three perpendicular lines 101(1) to

101(3) and the caution area 6 intersect become relay point candidates RPC1 to RPC3.

The marking robot 2 calculates the distance from the predetermined ink dot MP to each of the relay point candidates RPC1 to RPC3. The shortest distance is a distance between the predetermined ink dot MP and the first relay point candidate RPC1, and since the first relay point candidate RPC1 is located in an opening 51, the marking robot 2 cannot move to the first relay point candidate RPC1. Therefore, the first relay point candidate RPC1 is not selected as the relay point and is excluded. The opening 51 may be a hole or a depression in the floor or the like.

The next shortest distance is a distance from the predetermined ink dot MP to the second relay point candidate RPC2. The second relay point candidate RPC2 does not have other obstacles around in the normal area 9. Therefore, as illustrated in the lower portion of FIG. 9, the second relay point candidate RPC2 is selected as the relay point RP.

It is noted that the relay point RP need not be exactly aligned with the intersection of the perpendicular line 101 and the caution area 6. The relay point RP may be set in the vicinity of the normal area 9 from the intersection of the perpendicular line 101 and the caution area 6. Accordingly,

the marking robot 2 can be allowed to travel more safely. In contrast, the relay point RP can also be set near the wall area 5 from the intersection between the perpendicular line 101 and the caution area 6 to such an extent that the marking robot 2 and the wall area 5 do not come into contact with each other. Accordingly, the path along which the marking robot 2 travels at a normal speed can be lengthened, and the time of the marking work at the entire work site FL can be shortened.

FIG. 10 illustrates an overview of setting the caution area 6 and the relay point RP for the triangular wall area 5. When the wall area 5 is enlarged, as it is, without changing the shape thereof, an area 61 in the upper right of FIG. 10 becomes uselessly large. Therefore, as illustrated in the lower portion of FIG. 10, the marking robot 2 sets the caution area 6 by deleting the useless area 61.

Then, the marking robot 2 calculates the distances from the predetermined ink dot MP in the caution area 6 to the relay point candidates RPC1 and RPC2 and selects the relay point candidate RPC1, which has the shortest distance, as the relay point RP.

As in the modified example illustrated in FIG. 11, the areas 61(1) to 61(3) in the vicinity of each vertex of caution

area 6 expanded without changing the shape of the wall area 5 may be deleted by a predetermined amount. In this manner, the caution area 6 can be set with a minimum necessary area. As a result, the range in which the marking robot 2 can travel at a normal speed can be expanded, and thus, the time required for the marking work can be shortened.

A process (step S14 in FIG. 4) in which the marking robot 2 moves and marks the work site FL will be described by using the flowchart of FIG. 12.

The marking robot 2 determines whether the point to move next is an ink dot (S1401). When the next dot is an ink dot (YES in S1401), the marking robot 2 moves to the ink dot at a normal speed (S1402).

When the marking robot 2 detects an object during the movement (YES in S1403), the marking robot 2 stops on the spot (S1404) and ends this process. The detection sensitivity of the front sensor 26 is a normal value. In step S1403, when any one of the sensors 26, 27F, 27R, and 28 detects an obstacle, the marking robot 2 stops (S1404).

When the marking robot 2 reaches the ink dot of the destination and determines that printing is possible (YES in S1405), predetermined contents are printed on the ink dot by using the printer 22 and the printer moving unit 212 (S1406).

The marking robot 2 returns to step S1402 until the marking robot 2 reaches the ink dot and can perform printing.

In contrast, when the point to be moved next is not an ink dot, that is, when the point to be moved next is a relay point (NO in S1401), the marking robot 2 moves to the relay point at a normal speed (S1401). When the marking robot 2 reaches the relay point, the marking robot 2 controls the posture thereof so that the marking robot 2 faces the direction of the ink dot in the caution area 6 (S1412). This is because the marking robot 2 moves to the ink dot while maintaining the posture and prints with the ink dot without rotating.

The marking robot 2 reduces the detection sensitivity of the front sensor 26 from the normal value in the normal area 9 (S1413). The marking robot 2 sets the detection sensitivity (detection range) of the front sensor 26 to be less than the detection sensitivity (normal value) in the normal area 9. For example, the detection sensitivity in the caution area 6 may be set to half or less of the normal value. The detection sensitivity in the caution area 6 may be set to one-third or less or one-fourth or less of the normal value.

The detection sensitivity is a distance of the detection

range of the front sensor 26. For example, when the detection sensitivity is N meters, the front sensor 26 will detect the object in a range of N meters ahead. Therefore, the front sensor 26 can reach the wall area 5 by reducing the detection sensitivity of the front sensor 26.

However, when the detection sensitivity of the front sensor 26 is reduced too much, the bumper 201 or the like protruding further forward than the front sensor 26 may be likely to be in contact with the wall area 5. Therefore, the lower limit of the detection sensitivity of the front sensor 26 in the caution area 6 can be set to the length of the portion (such as the bumper 201) that protrudes forward from the front sensor 26. However, the bumper 201 is provided with the bumper sensor 27F, and when it is detected that the bumper sensor 27F comes into contact with the object, the marking robot 2 immediately stops. Therefore, the detection sensitivity of the front sensor may be set equal to or less than the length of the forward projecting object such as the bumper 201.

The marking robot 2 reduces the movement speed when traveling in the caution area 6 (referred to as a second movement speed) to, for example, a value less than the normal speed (S1414). The second movement speed can also be reduced

to about half the normal speed. The second movement speed can also be reduced to about one third of the normal speed. The second movement speed may be a fixed value or may be a value set according to the situation of the work site FL. The situation of the work site FL includes, for example, a state of the floor surface (whether uneven or slippery, or the like), the number of wall area 5, the size of a gap dL between the caution area 6 and the wall area 5, and the like. The second movement speed may be set in consideration of factors other than these situations.

It is noted that the order of steps S1413 and S1414 may be changed, or these steps may be executed simultaneously.

The marking robot 2 moves toward the ink dot in the caution area 6 at the movement speed lower than the normal speed while the detection sensitivity of the front sensor 26 is reduced (S1415). When the object is detected while moving in the caution area 6 (YES in S1416), the marking robot 2 stops at the spot (S1417). The marking robot 2 may wait for the arrival of the operator or may move backward to the relay point.

When the marking robot 2 reaches the ink dot in the caution area 6 and determines that printing is possible (YES in S1418), the marking robot 2 prints predetermined contents

on the ink dot (S1419).

After the printing with the ink dots is completed, the marking robot 2 moves backward to the relay point, which is the starting point, while maintaining the posture (S1420). This is because, when a posture change such as rotation occurs in the caution area 6, there is a concern of contact with the wall area 5 or other obstacles. However, even when the marking robot 2 comes into contact with an obstacle at a speed lower than the normal speed, the marking robot 2 stops immediately, so that there is no problem and safety is maintained.

When the marking robot 2 detects the object while moving backward to the relay point (YES in S1421), the marking robot 2 stops on the spot (S1422). When the marking robot 2 returns to the relay point (YES in S1423), the detection sensitivity of the front sensor 26 is returned to the normal value (S1424), and the movement speed is returned to the normal speed (S1425). The order of steps S1424 and S1425 may be changed, or may be executed simultaneously.

According to this embodiment configured as described above, since the caution area 6 is set outside the wall area 5 and the movement speed and the detection sensitivity of the sensor in the caution area 6 are reduced to be lower than the

set values in the normal area 9, the marking robot 2 can move to the ink dot in the vicinity of the wall area 5 and can perform printing. Therefore, the marking robot system 1 of the present embodiment can safely and automatically travel the work site FL and can enlarge the range in which ink dots can be printed safely. When the caution area 6 is set and the detection sensitivity of the sensor is not reduced and the movement speed of the marking robot 2 is not reduced, since the safety is reduced, the range in which the marking work can be automatically performed becomes narrow.

When both the detection sensitivity of the sensor and the movement speed are reduced, the safety is heightened in maximum, but only the detection sensitivity of the sensor may be reduced to move to the ink dot in the vicinity of the wall area 5 at a normal speed. It is noted that, when starting to travel in the caution area 6, the marking robot 2 may issue a voice message or flash a light to alert surrounding people.

[Second Embodiment]

A second embodiment will be described with reference to FIG. 13. In each of the following embodiments including the present embodiment, differences from the first embodiment will be mainly described. FIG. 13 is a flowchart

illustrating a marking process S14A by the marking robot 2. In this embodiment, while the marking robot 2 moves forward to the ink dot in the caution area 6, the process when the sensors 26, 27F, and 28 for detecting safety ahead detect the object is changed from the first embodiment (YES in S1416).

When the sensors 26, 27F, and 28 detecting safety ahead detect the object, the marking robot 2 immediately stops at the spot (S1417) and, after that, moves backward to the relay point without changing the posture (S1430).

This embodiment, which is configured in this manner, also has the same functions and effects as those of the first embodiment.

[Third Embodiment]

A third embodiment will be described with reference to FIG. 14. In this embodiment, a work result is reported from the marking robot 2 to the operation device 3.

When the marking work based on the marking information is completed (when it is determined as YES in step S15 in FIG. 4), the marking robot 2 generates a work report and transmits the work report to the operation device 3 (S161 to S163). For example, the marking robot 2 acquires information on the ink spots that could be printed and information on the ink spots that could not be printed (S161 and S162), generates

a daily work report, and transmits the daily work report to the operation device 3 (S163). The operator can check the status of an unmanned work by viewing the daily work report.

This embodiment, which is configured in this manner, also has the same functions and effects as those of the first embodiment. This embodiment can be combined with the second embodiment.

[Fourth Embodiment]

A fourth embodiment will be described with reference to FIG. 15. FIG. 15 is a flowchart illustrating a marking process S14B by the marking robot 2. In this embodiment, the marking robot 2 gradually reduces the movement speed as the marking robot 2 reaches the ink dot of the caution area 6 (S1440). For example, the marking robot 2 sets the movement speed to 70% of the normal speed when starting from the relay point, and sets the movement speed to 50% of the normal speed when passing the half of the path length from the relay point to the ink dot, and thus, the movement speed can be reduced as the ink dot is reached.

This embodiment, which is configured in this manner, also has the same functions and effects as those of the first embodiment. Furthermore, in the present embodiment, since the movement speed of the marking robot 2 is reduced as the

ink dot is reached, the marking robot 2 travels in the caution area 6 at the fastest speed possible which is less than the normal speed, and since the movement speed is reduced in the vicinity of the ink dot, the safety can be improved while suppressing reduction in the efficiency of the marking work. This embodiment can also be combined with the second and third embodiments.

It is noted that, the present invention is not limited to the above-described embodiments, and includes various modifications. For example, the above-described embodiments have been described in detail for explaining the present invention in an easy-to-understand manner, and are not necessarily limited to those having all the described configurations. In addition, a portion of the configuration of one embodiment can be replaced with the configuration of another embodiment, and the configuration of another embodiment can also be added to the configuration of one embodiment. Moreover, it is possible to add, delete, or replace a portion of the configuration of each embodiment with another configuration.

In addition, each of the above-described configurations may be implemented partially or totally by hardware, or may be implemented by a processor executing a program. In

addition, the control lines and the information lines indicate those considered necessary for explanation, and not all control lines and information lines are necessarily indicated on the product. Actually, it may be considered that almost all configurations are interconnected.

What is claimed is:

1. A marking robot system, comprising:

a marking robot provided with a sensor detecting an obstacle, traveling in a work site based on position information measured by a position measurement device, and printing at a marking position; and

an operation device setting a position of a structure at the work site and instructing the marking robot to perform a marking process,

wherein the marking robot:

sets a predetermined range of the structure set by the operation device as a caution area, and

sets a relay point to be passed through when moving to a predetermined marking position in the caution area, and

wherein, when moving from the relay point to the predetermined marking position, detection sensitivity of the sensor is reduced below a normal value used in a normal area outside the caution area.

2. The marking robot system according to claim 1, wherein the marking robot sets the relay point so that printing can be performed in a posture when the marking robot starts traveling from the relay point to the predetermined

marking position.

3. The marking robot system according to claim 2, wherein, when the marking robot moves from the relay point to the predetermined marking position, the detection sensitivity of the sensor is reduced below the normal value, and a movement speed is also reduced below a normal speed in the normal area.

4. The marking robot system according to claim 3, wherein the marking robot reduces at least one of the detection sensitivity of the sensor and the movement speed in the caution area in a plurality of stages from the normal value or the normal speed.

5. The marking robot system according to claim 4, wherein, when printing at the predetermined marking position, the marking robot returns from the predetermined marking position to the relay point in the posture at the time of printing.

6. The marking robot system according to claim 5, wherein, when the sensor detects an obstacle while moving

from the relay point to the predetermined marking position, the marking robot stops on a spot and returns to the relay point while maintaining the posture.

7. The marking robot system according to claim 6, wherein, when the marking robot cannot print at the predetermined marking position, the marking robot notifies the operation device of that information.

8. The marking robot system according to claim 1, wherein the marking robot selects, as the relay point, coordinate points with the shortest distance to the predetermined marking position among the coordinate points of the normal area.

9. The marking robot system according to claim 8, wherein the marking robot selects, as the relay point, the coordinate points with the shortest distance to the predetermined marking position among the coordinate points of the normal area where a path from the relay point to the predetermined marking position is parallel or perpendicular to a core of the work site.

10. The marking robot system according to claim 1, wherein the marking robot sets the caution area by enlarging an outer edge of the structure.

11. The marking robot system according to claim 10, wherein, when an area obtained by enlarging the outer edge of the structure is larger than a predetermined value or more, the marking robot sets the caution area by deleting a predetermined amount of areas of vertexes of the area.

12. The marking robot system according to claim 1, wherein the operation device sets the position of the structure by using one or more of actual measurement of the work site, manual setting, three-dimensional design data, and an analysis of images obtained by imaging the work site.

13. A control method of a marking robot,
wherein a marking robot is provided with a sensor detecting obstacles,

wherein the marking robot:

travels in a work site based on position information measured by a position measurement device, and prints at a marking position,

sets a predetermined range of a structure set by an operation device as a caution area, and

sets a relay point to be passed through when moving to a predetermined marking position in the caution area, and

wherein, when moving from the relay point to the predetermined marking position, detection sensitivity of the sensor is reduced below a normal value used in a normal area outside the caution area.