

## **DESCRIPTION**

### **Title of Invention**

ROBOT SYSTEM, DECISION SYSTEM,  
DECISION METHOD, AND PROGRAM

### **Technical Field**

[0001] The present disclosure generally relates to a robot system, a decision system, a decision method, and a program. More particularly, the present disclosure relates to a robot system, a decision system, a decision method, and a program, all of which are used to make a decision when determining a traveling route for a robot.

### **Background Art**

[0002] An autonomous mobile device (a robot) of Patent Literature 1 includes a traveling means, a plurality of obstacle detecting means, and a movement control means. The plurality of obstacle detecting means determines whether an obstacle is on the left or right side with respect to the advancing direction of the main body, thereby measuring the distance to the obstacle. The movement control means controls the traveling means based on detection outputs of the plurality of obstacle detecting means to cause the main body to move. The autonomous mobile device performs stop control when a detection distance to the obstacle detected by the obstacle detecting means is equal to or less than a maximum accessible distance.

### **Citation List**

#### **Patent Literature**

[0003] Patent Literature 1: JP 2009-169802 A

### **Summary of Invention**

[0004] An object of the present disclosure is to provide a robot system, a decision system, a decision method, and a program, all of which are able to make a decision, by simple processing, about whether circumstances do not permit a robot to pass through.

[0005] A robot system according to an aspect of the present disclosure makes a decision when determining a traveling route for a robot configured to travel autonomously in a facility. The

robot system includes the robot, a positioner, a decider, and a communications unit. The positioner generates, based on a piece of information generated by a positioning system installed in the facility, location information of one or more objects present in a predetermined area which place obstacles in the way of the robot that is moving. The decider makes a decision about whether or not the robot is able to pass through the predetermined area. The communications unit transmits, to the robot, a communication signal including a result of the decision made by the decider. The decider performs first decision processing. The first decision processing includes determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[0006] A decision system according to another aspect of the present disclosure makes a decision when determining a traveling route for a robot configured to travel autonomously in a facility. The decision system includes an acquirer, a decider, and a communications unit. The acquirer acquires location information of one or more objects present in a predetermined area which place obstacles in the way of the robot that is moving. The location information is based on a piece of information generated by a positioning system installed in the facility. The decider makes a decision about whether or not the robot is able to pass through the predetermined area. The communications unit transmits, to the robot, a communication signal including a result of the decision made by the decider. The decider performs first decision processing. The first decision processing includes determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[0007] A decision method according to still another aspect of the present disclosure is performed by a decision system to make a decision when determining a traveling route for a robot configured to travel autonomously in a facility. The decision method includes an acquiring step, a deciding step, and a communicating step. The acquiring step includes acquiring location information of one or more objects present in a predetermined area which place obstacles in the way of the robot that is moving. The location information is based on a piece of information generated by a positioning system installed in the facility. The deciding step includes making a decision about whether or not the robot is able to pass through the predetermined area. The communicating step includes transmitting, to the robot, a communication signal including a result of the decision made in the deciding step. The deciding step includes first decision processing. The first decision

processing includes determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[0008] A program according to yet another aspect of the present disclosure is designed to cause one or more processors of a computer system to perform the decision method described above.

## **Brief Description of Drawings**

[0009] [FIG. 1] FIG. 1 is a block diagram of a robot system according to an exemplary embodiment;

[FIG. 2] FIG. 2 is a flowchart showing an exemplary procedure of operation of the robot system;

[FIG. 3] FIG. 3 is a plan view illustrating an exemplary use of the robot system; and

[FIG. 4] FIG. 4 is a plan view illustrating another exemplary use of the robot system.

## **Description of Embodiments**

[0010] (Embodiment)

A robot system 1, decision system 5, decision method, and program according to an exemplary embodiment will now be described with reference to the accompanying drawings. Note that the embodiment to be described below is only an exemplary one of various embodiments of the present disclosure and should not be construed as limiting. Rather, the exemplary embodiment may be readily modified in various manners depending on a design choice or any other factor without departing from the scope of the present disclosure. The drawings to be referred to in the following description of embodiments are all schematic representations. Thus, the ratio of the dimensions (including thicknesses) of respective constituent elements illustrated on the drawings does not always reflect their actual dimensional ratio.

[0011] (Overview)

A robot 2 according to this embodiment (refer to FIG. 1) moves autonomously in a facility 6 (refer to FIGS. 3 and 4) to perform operations assigned to itself. More particularly, the robot 2 travels autonomously along a traveling route specified by the decision system 5 (refer to FIG. 1). Examples of the operations include cleaning, equipment inspection, and security guarding. Examples of the facilities 6 include a dwelling house, a shop, an office building, a factory, a warehouse, a commercial complex, a library, an art museum, a museum, an amusement facility, a theme park, a public park, an airport, a railway station, a ballpark, a hotel, and a hospital.

Alternatively, the facility 6 may also be, for example, a moving vehicle such as a ship or a railway train. Optionally, the facility 6 may also be an indoor facility or an outdoor facility, whichever is appropriate.

[0012] The number of robots 2 provided may be one or two or more, whichever is appropriate. In the following description, an exemplary embodiment will be described as being applied to one robot 2.

[0013] The robot system 1 shown in FIG. 1 makes a decision when determining a traveling route for the robot 2 that travels autonomously in the facility 6. The robot system 1 includes the robot 2, a positioner 511 (hereinafter also referred to as a “first positioner 511”), a decider 513, and a communications unit 52. The positioner 511 generates, based on a piece of information generated by a positioning system P1 installed in the facility 6 (refer to FIG. 3), location information of one or more objects (e.g., persons H1, H2 and goods G1 shown in FIG. 3) that are present in a predetermined area A1 (refer to FIG. 3) which would place obstacles in the way of the robot 2 on the move. The positioning system P1 includes, for example, a plurality of cameras 4. The decider 513 makes a decision about whether or not the robot 2 is able to pass through the predetermined area A1. The communications unit 52 transmits, to the robot 2, a communication signal including the result of the decision made by the decider 513. The decider 513 performs first decision processing. In the first decision processing, the decider 513 determines the occupancy rate of the one or more objects present in the predetermined area A1 based on the location information of the one or more objects. Then, if the occupancy rate of the one or more objects is equal to or greater than a threshold value, the decider 513 decides that the robot 2 be unable to pass through the predetermined area A1.

[0014] This embodiment allows the decider 513 to make a decision, by performing simple processing of comparing the occupancy rate with the threshold value, that circumstances would not permit the robot 2 to pass through. In particular, this embodiment allows for making a decision more quickly than in a situation where a robot 2 generates a local map of a surrounding environment around the robot 2 using the detection result obtained by, for example, a sensor, camera, and other monitor devices provided for the robot 2 to make a decision, based on the local map, that circumstances would not permit the robot 2 to pass through.

[0015] Also, a decision system 5 according to this embodiment is included in the robot system 1. The decision system 5 makes a decision when determining a traveling route for the robot 2 that travels autonomously in the facility 6. The decision system 5 includes an acquirer 514, the decider 513, and the communications unit 52. The acquirer 514 acquires location information of one or more objects present in a predetermined area A1 which would place obstacles in the way

of the robot 2 on the move. The location information is based on a piece of information generated by the positioning system P1 installed in the facility 6. The decider 513 makes a decision about whether or not the robot 2 is able to pass through the predetermined area A1. The communications unit 52 transmits, to the robot 2, a communication signal including the result of the decision made by the decider 513. The decider 513 performs the first decision processing. When performing the first decision processing, the decider 513 determines the occupancy rate of the one or more objects present in the predetermined area A1 based on the location information of the one or more objects. Then, if the occupancy rate of the one or more objects is equal to or greater than a threshold value, the decider 513 decides that the robot 2 be unable to pass through the predetermined area A1.

[0016] The functions of the decision system 5 may also be implemented as a decision method. The decision method according to this embodiment is performed by the decision system 5 to make a decision when determining a traveling route for the robot 2 that travels autonomously in the facility 6. The decision method includes an acquiring step, a deciding step, and a communicating step. The acquiring step includes acquiring location information of one or more objects present in the predetermined area A1 which would place obstacles in the way of the robot 2 on the move. The location information is based on a piece of information generated by the positioning system P1 installed in the facility 6. The deciding step includes making a decision about whether or not the robot 2 is able to pass through the predetermined area A1. The communicating step includes transmitting, to the robot 2, a communication signal including the result of the decision made in the deciding step. The deciding step includes the first decision processing. The first decision processing includes determining the occupancy rate of the one or more objects present in the predetermined area A1 based on the location information of the one or more objects to decide, if the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot 2 be unable to pass through the predetermined area A1.

[0017] The decision method may also be implemented as a program. A program according to this embodiment is designed to cause one or more processors of a computer system to perform the decision method. The program may be stored on a non-transitory storage medium which is readable for the computer system.

[0018] (Details)

(1) Robot system

The robot system 1 includes the robot 2 and the decision system 5.

[0019] (2) Robot

As shown in FIG. 1, the robot 2 includes a processing unit 21, a communications unit 22,

a storage unit 23, a detection unit 24, a beacon 25, a traveling mechanism 26, and a power supply unit 27.

[0020] The robot 2 includes a computer system including one or more processors and a memory. At least some functions of the robot 2 are performed by making the processor of the computer system execute a program stored in the memory of the computer system. The program may be stored in advance in the memory. Alternatively, the program may also be downloaded via a telecommunications line such as the Internet or distributed after having been stored in a non-transitory storage medium such as a memory card, which is readable for the computer system.

[0021] The processing unit 21 includes the one or more processors of the computer system. The processing unit 21 performs a predetermined function by executing the program. The processing unit 21 controls the communications unit 22, the storage unit 23, the detection unit 24, the beacon 25, the traveling mechanism 26, and the power supply unit 27.

[0022] The communications unit 22 includes a communication interface device. The robot 2 is ready to communicate with the decision system 5 via the communications unit 22. As used herein, the phrase “to be ready to communicate” means being able to transmit and receive signals either directly or indirectly via a network or a repeater, for example, by an appropriate wired or wireless communication method. In particular, the robot 2 according to this embodiment communicates, via wireless connection, with the decision system 5.

[0023] The storage unit 23 is a storage device implemented, for example, as a hard disk drive (HDD) or a solid state drive (SSD). The storage unit 23 stores information. For example, the storage unit 23 stores (the robot's 2) own identification information and map information (global map) of the facility 6 in which the robot 2 travels. Also, the storage unit 23 stores information about the traveling route for the robot 2 which is acquired from the decision system 5.

[0024] The detection unit 24 includes, for example, one or more sensors and at least one camera as means for detecting a surrounding environment. Each of the one or more sensors is at least one of, for example, a laser rangefinder (e.g., Lidar (Light Detection and Ranging)), an infrared sensor, or a pressure sensor. The camera is, for example, a visible light camera or an infrared camera.

[0025] The beacon 25 transmits a beacon signal. The beacon 25 transmits beacon signals at regular intervals, for example. The beacon signal includes the identification information of the robot 2 serving as a signal source of the beacon signal.

[0026] The traveling mechanism 26 includes a motor and at least one drive wheel for causing the robot 2 to travel. The motor causes the drive wheel to rotate, thereby making the robot 2 travel on the ground.

[0027] The power supply unit 27 supplies electric power required for the operation of the robot 2. The power supply unit 27 includes, for example, a battery.

[0028] The robot 2 further includes a body 20 (refer to FIG. 3). The body 20 houses or holds every constituent element of the robot 2 but the body 20 itself.

[0029] Basically, the robot 2 travels along the traveling route determined by the decision system 5. The traveling route determined by the decision system 5 is a traveling route plotted on the global map of the facility 6. The global map includes information about the locations and shapes of immobile structures. The global map includes, for example, structural information of the facility 6. The structural information of the facility 6 includes, for example, information about the location and shape of the building frame of the facility 6 (e.g., walls 61, 61, 62, and 62 shown in FIGS. 3 and 4).

[0030] Also, the processing unit 21 of the robot 2 generates a local map of the facility 6 based on the detection result obtained by the detection unit 24. The robot 2 also travels in accordance with the local map. The local map includes a piece of information about a relative location, with respect to the robot 2, of any object (such as a person or goods) present in a surrounding environment around the robot 2. Thus, by reference to the local map, the robot 2 is allowed to travel while circumventing the object present on the traveling route determined by the decision system 5.

### [0031] (3) Scanner

A plurality of scanners 3 are installed in the facility 6 (refer to FIG. 3). The plurality of scanners 3 are installed, for example, on a wall or ceiling of the facility 6. The plurality of scanners 3 are not necessarily installed in the vicinity of the predetermined area A1 but may also be installed in various places.

[0032] Each of the scanners 3 receives the beacon signal transmitted by the beacon 25 of the robot 2. Also, each of the scanners 3 measures a Received Signal Strength Indicator (RSSI) of the beacon signal thus received.

[0033] Each of the scanners 3 transmits, to the decision system 5, a signal including information about the received signal strength indicator of the beacon signal thus received, identification information included in the beacon signal (i.e., the identification information of the robot 2 serving as a signal source of the beacon signal), and device's (each of the scanners' 3) own identification information.

[0034] In this embodiment, the plurality of scanners 3 are not constituent elements of the robot system 1. Alternatively, the plurality of scanners 3 may be constituent elements of the robot system 1.

[0035] (4) Camera

A plurality of cameras 4 are installed in the facility 6 (refer to FIG. 3). The plurality of cameras 4 are installed, for example, on a wall or ceiling of the facility 6. The plurality of cameras 4 generates image information by shooting the surrounding environment. The plurality of cameras 4 transmits the image information to the decision system 5.

[0036] The cameras 4 may be visible light cameras or may also be cameras (such as infrared cameras) other than visible light cameras.

[0037] The decision system 5 makes a decision about whether the robot 2 is able to pass through at least some area of the facility 6. More particularly, the facility 6 includes a single or a plurality of predetermined areas A1 defined in advance. When the robot 2 approaches any of the predetermined areas A1, the decision system 5 makes a decision about whether the robot 2 is able to pass through the predetermined area A1. In this manner, (the decider 513 of) the decision system 5 determines, based on the position information of the robot 2, a target predetermined area A1 in which a decision needs to be made about whether the robot 2 is able to pass through the predetermined area A1.

[0038] Also, the plurality of cameras 4 are installed at such locations as to be able to shoot at least the single or the plurality of predetermined areas A1. Naturally, the camera 4 may also be installed at a location, in the facility 6, other than those locations where the plurality of cameras 4 are arranged to shoot the single or the plurality of predetermined areas A1.

[0039] In this embodiment, the plurality of cameras 4 are not constituent elements of the robot system 1. Alternatively, the plurality of cameras 4 may also be constituent elements of the robot system 1.

[0040] (5) Decision system

As shown in FIG. 1, the decision system 5 includes a processing unit 51, the communications unit 52, and a storage unit 53.

[0041] The decision system 5 includes a computer system including one or more processors and a memory. At least some functions of the decision system 5 are performed by making the processor of the computer system execute a program stored in the memory of the computer system. The program may be stored in advance in the memory. Alternatively, the program may also be downloaded via a telecommunications line such as the Internet or distributed after having been stored in a non-transitory storage medium such as a memory card, which is readable for the computer system.

[0042] The processing unit 51 includes the one or more processors of the computer system. The processing unit 51 performs a predetermined function by executing the program. The processing

unit 51 controls the communications unit 52 and the storage unit 53.

[0043] Also, the processing unit 51 includes the first positioner 511, a second positioner 512, the decider 513, and the acquirer 514. Note that these constituent elements only represent functions to be performed by the processing unit 51 and do not necessarily have a substantive physical configuration.

[0044] The communications unit 52 includes a communication interface device. The decision system 5 is ready to communicate with the robot 2, the plurality of scanners 3, and the plurality of cameras 4 via the communications unit 52.

[0045] The storage unit 53 is a storage device implemented, for example, as a hard disk drive (HDD) or a solid state drive (SSD). The storage unit 53 stores information. For example, the storage unit 53 stores: location information of each of the plurality of scanners 3 and the plurality of cameras 4; identification information of each of the robot 2, the plurality of scanners 3, and the plurality of cameras 4; and map information (global map) of the facility 6 in which the robot 2 travels. Also, the storage unit 53 stores information that defines the single or the plurality of predetermined areas A1. The single or the plurality of predetermined areas A1 are defined by, for example, the user.

[0046] The first positioner 511 generates, based on the image information generated by the plurality of cameras 4, the location information of the one or more objects (e.g., persons H1, H2 and goods G1 shown in FIG. 3) present in the predetermined area A1 which would place obstacles in the way of the robot 2 on the move. That is to say, the first positioner 511 calculates the location information of the object(s) based on the location information of each of the plurality of cameras 4 and the location(s) of the object(s) shot in the image information.

[0047] The location information generated by the first positioner 511 is real-time location information.

[0048] Each of the one or more objects is an object of which information is not included in the map information (global map) of the facility 6 stored in the storage unit 53.

[0049] Also, each of the one or more objects is, for example, a movable object (a mobile object). The “movable object” includes not only an object that moves autonomously but also an object that can be carried by a human being or a machine.

[0050] As described above, each of the plurality of scanners 3 transmits, to the decision system 5, a signal including information about the received signal strength indicator of the beacon signal, identification information of the robot 2 serving as a signal source, and device's (each of the scanners' 3) own identification information. The decision system 5 receives the signal. The second positioner 512 obtains, based on the received signal strength indicator measured by three

or more scanners 3 belonging to the plurality of scanners 3, the distance between the robot 2 serving as the signal source and each of the three or more scanners 3. In addition, the second positioner 512 calculates, based on the distances, the position information of the robot 2 by the three-point positioning (trilateration) method. That is to say, the second positioner 512 generates the position information of the robot 2 based on the respective pieces of location information of the three or more scanners 3 and the distances.

[0051] The position information generated by the second positioner 512 is real-time position information.

[0052] The decider 513 makes a decision, by performing the first decision processing, second decision processing, and third decision processing as will be described in detail later, about whether or not the robot 2 is able to pass through the predetermined area A1.

[0053] The acquirer 514 acquires location information of the one or more objects (e.g., persons H1, H2 and goods G1 shown in FIG. 3) from the first positioner 511.

[0054] (6) Facility

An exemplary structure of the facility 6 in which the robot 2 travels is shown in FIGS. 3 and 4. The facility 6 includes the walls 61, 61, 62, and 62. The walls 61 and 61 face each other. The walls 62 and 62 are provided on the boundary between a room R1 and a room R2. When viewed in plan, the walls 62 and 62 protrude from the walls 61 and 61, respectively. As used herein, the phrase “when viewed in plan” refers to viewing from a direction (right over the floor surface) intersecting at right angles with the surface on which the robot 2 travels.

[0055] There is an opening 600 between the walls 62 and 62. The opening 600 is the doorway of the rooms R1 and R2. The robot 2 may go back and forth between the rooms R1 and R2 through the opening 600. Optionally, an automatic door or any other type of doors may be installed at the opening 600.

[0056] In each of the examples shown in FIGS. 3 and 4, the predetermined area A1 is defined in front of the opening 600 in the room R1. The boundary of the predetermined area A1 is located in the vicinity of the walls 61, 61, 62, and 62. In the following description, an exemplary process of making a decision about whether or not the robot 2 is able to pass through this predetermined area A1 will be described.

[0057] (7) Making decision about whether or not robot is able to pass through

The robot 2 autonomously travels, in the facility 6, along the traveling route plotted in advance (hereinafter referred to as a “first traveling route”). If the first traveling route overlaps with at least part of the predetermined area A1, the robot 2 will pass through the predetermined area A1.

[0058] The second positioner 512 generates position information of the robot 2. If the decider 513 decides, based on this position information, that the robot 2 have arrived at the vicinity of the opening 600 (i.e., the doorway) (if the answer is Yes in Step ST1 shown in FIG. 2), the decider 513 starts to make a decision about whether or not the robot 2 is able to pass through the predetermined area A1. More particularly, if the decider 513 decides that the robot 2 have arrived at the vicinity of the predetermined area A1 defined beside the opening 600, the decider 513 starts to make a decision about whether or not the robot 2 is able to pass through the predetermined area A1.

[0059] The decider 513 determines the occupancy rate of the one or more objects present in the predetermined area A1. As used herein, the “occupancy rate” refers to the number of the one or more objects present in the predetermined area A1. Therefore, the occupancy rate may be determined more easily and more quickly than in a situation where the occupancy rate is defined to be the ratio of the sum of the planar areas occupied by the one or more objects present in the predetermined area A1 to the overall planar area of the predetermined area A1.

[0060] For example, the decider 513 performs image processing to extract edges from the image information generated by the plurality of cameras 4. The decider 513 determines, based on the edges, the number of the one or more objects present in the predetermined area A1. As an algorithm for extracting the edges, a well-known algorithm such as the Sobel method or the Laplacian of Gaussian method may be adapted.

[0061] In each of the examples shown in FIGS. 3 and 4, there are three objects (namely, persons H1 and H2 and a single item of goods G1) in the predetermined area A1. Therefore, the occupancy rate is 3.

[0062] If the occupancy rate is equal to 0, the decision result in Step ST2 shown in FIG. 2 is “Yes” and the communications unit 52 of the decision system 5 transmits an instruction signal for instructing the robot 2 to pass through the predetermined area A1 (in Step ST3). The robot 2 passes through the predetermined area A1 on receiving the instruction signal. More particularly, the robot 2 passes through the predetermined area A1 along the first traveling route plotted in advance.

[0063] If the occupancy rate is not equal to 0, the decision result in Step ST2 shown in FIG. 2 is “No” and process proceeds to Step ST4. In Step ST4, the decider 513 makes a decision about whether or not the occupancy rate is equal to or greater than a threshold value. The threshold value is preferably a value equal to or greater than 2. In this embodiment, the threshold value is 4. Information about the size of the predetermined area A1 is included in the map information, stored in the storage unit 53, of the facility 6.

[0064] The threshold value may be a constant or may also be set at a value that increases as the size of the predetermined area A1 increases, whichever is appropriate. Also, the threshold value may also be set at a value that increases as the size of the robot 2 decreases.

[0065] In each of the examples shown in FIGS. 3 and 4, the occupancy rate is equal to 3. Therefore, the occupancy rate is less than the threshold value. Consequently, the decision result in Step ST4 is “No” and process proceeds to Step ST5. In Step ST5, the decider 513 defines a boundary box B1 (refer to FIGS. 3 and 4) based on the location information of two or more objects present in the predetermined area A1. Thereafter, in Step ST6, the decider 513 performs the second decision processing.

[0066] The boundary box B1 is a space surrounding the two or more objects which has a rectangular shape when viewed in plan. The number of the two or more objects is three in FIGS. 3 and 4. The boundary box B1 is a virtual space, and therefore, marks or any other indices that indicate the location of the boundary box B1 do not exist in the real space.

[0067] In this embodiment, an X-axis and a Y-axis that are perpendicular to each other are defined on the surface on which the robot 2 travels. Each set of an X-coordinate and a Y-coordinate indicating the location of a corresponding one of N objects is supposed to be represented by  $(X_1, Y_1)$ ,  $(X_2, Y_2)$ , ..., or  $(X_N, Y_N)$ . The four vertices of the boundary box B1 are  $(X_{\max}, Y_{\max})$ ,  $(X_{\max}, Y_{\min})$ ,  $(X_{\min}, Y_{\max})$ , and  $(X_{\min}, Y_{\min})$ , respectively. As used herein, “ $X_{\max}$ ” refers to the maximum number among  $X_1, X_2, \dots$ , and  $X_N$  and “ $Y_{\max}$ ” refers to the maximum number among  $Y_1, Y_2, \dots$ , and  $Y_N$ . As used herein, “ $X_{\min}$ ” refers to the minimum number among  $X_1, X_2, \dots$ , and  $X_N$  and “ $Y_{\min}$ ” refers to the minimum number among  $Y_1, Y_2, \dots$ , and  $Y_N$ .

[0068] Alternatively, a space having a rectangular shape when viewed in plan which surrounds a rectangle, of which the four vertices are  $(X_{\max}, Y_{\max})$ ,  $(X_{\max}, Y_{\min})$ ,  $(X_{\min}, Y_{\max})$ , and  $(X_{\min}, Y_{\min})$ , respectively, may also be defined as the boundary box B1. For example, supposing that  $\alpha$  is a positive constant, the four vertices of the boundary box B1 may also be  $(X_{\max} + \alpha, Y_{\max} + \alpha)$ ,  $(X_{\max} + \alpha, Y_{\min} - \alpha)$ ,  $(X_{\min} - \alpha, Y_{\max} + \alpha)$ , and  $(X_{\min} - \alpha, Y_{\min} - \alpha)$ , respectively.

[0069] Also, the decider 513 measures the width of the road outside the boundary box B1. More particularly, the width of the road outside the boundary box B1 is the distance between the boundary box B1 and any one of the walls 61, 61, 62, and 62. In FIG. 3, a distance W1 between the boundary box B1 and one of the walls 61 and a distance W2 between the boundary box B1 and one of the walls 62 are illustrated. In FIG. 4, a distance W3 between the boundary box B1 and one of the walls 61 is illustrated.

[0070] Furthermore, the decider 513 acquires information about the width of the robot 2. In this case, the actual width of the robot 2 may be used. Alternatively, as shown in FIGS. 3 and 4,

the width  $V1$  of a predetermined space  $C1$ , which is defined around the robot 2, may also be adopted as the width of the robot 2. The shape of the space  $C1$  shown in FIGS. 3 and 4 conforms with the shape of the robot 2. However, this should not be construed as limiting. Optionally, the shape of the space  $C1$  does not have to conform with the shape of the robot 2 but may also have, for example, the shape of a rectangle or a square.

[0071] The decider 513 makes a decision, based on the width of the road (i.e., the distances  $W1$  and  $W2$ ) outside the boundary box  $B1$  and the width  $V1$  of the robot 2, about whether or not the robot 2 is able to pass through the outside of the boundary box  $B1$  in the predetermined area  $A1$ .

[0072] In the example shown in FIG. 3, each of the widths of the road (namely, the distances  $W1$  and  $W2$ ) outside the boundary box  $B1$  is equal to or greater than the width  $V1$  of the robot 2 (the answer is Yes in Step ST6). Therefore, as indicated by the two-dot chain line and shading in FIG. 3, a traveling route for the robot 2 (hereinafter referred to as a “second traveling route”) on which the robot 2 travels to pass through the predetermined area  $A1$  may be plotted outside the boundary box  $B1$ . In that case, the decider 513 decides that the robot 2 be able to pass through the predetermined area  $A1$  (the second decision processing). That is to say, the decider 513 decides that the robot 2 be able to pass through the predetermined area  $A1$  following the second traveling route that passes outside of the boundary box  $B1$ . The communications unit 52 of the decision system 5 transmits an instruction signal instructing the robot 2 to pass through the outside of the boundary box  $B1$  (in Step ST7). The instruction signal includes information about the second traveling route. On receiving the instruction signal, the robot 2 passes through the predetermined area  $A1$  following the second traveling route. As indicated by the two-dot chain line and shading in FIG. 3, for example, the second traveling route is plotted outside the boundary box  $B1$ .

[0073] On the other hand, in the example shown in FIG. 4, the width of the road outside the boundary box  $B1$  (namely, the distance  $W3$ ) is narrower than the width  $V1$  of the robot 2 (the answer is No in Step ST6). Therefore, a traveling route for the robot 2 to pass through the predetermined area  $A1$  cannot be plotted outside the boundary box  $B1$ . In that case, the decider 513 performs the processing step ST8 next. Step ST8 corresponds to the third decision processing. The third decision processing is processing of making a decision about whether or not the robot 2 is able to pass through the predetermined area  $A1$  following the traveling route that passes inside the boundary box  $B1$ .

[0074] The traveling route determined in the third decision processing (hereinafter referred to as a “third traveling route”) allows the robot 2 to pass between two objects.

[0075] The third decision processing includes making a decision based on the global map of the boundary box  $B1$ . Also, the third decision processing uses a so-called “A\* algorithm” to make a

decision. In addition, the third decision processing includes making the decision based on the location information of the one or more objects (e.g., persons H1 and H2 and a single item of goods G1 shown in FIG. 4) present in the predetermined area A1 (refer to FIG. 4) which would place obstacles in the way of the robot 2 on the move.

[0076] The A\* algorithm is a type of algorithm for searching for the shortest path between two nodes, namely, a starting point and a goal. The global map includes information about the location and shape of the building frame of the facility 6 (e.g., walls 61, 61, 62, and 62 shown in FIG. 4). In the third decision processing, at least one piece of location information of the one or more objects is integrated into the global map. That is to say, the third decision processing includes calculating the location(s) of the one or more objects on the global map. Then, the third decision processing includes making a decision, by the A\* algorithm, about whether or not the global map includes any third traveling route which passes through the predetermined area A1 while circumventing the one or more objects and obstacles such as the building frame.

[0077] If the third traveling route is determined to be the route to follow as a result of the third decision processing (if the answer is Yes in Step ST8), the communications unit 52 of the decision system 5 transmits an instruction signal instructing the robot 2 to pass inside the boundary box B1 (in Step ST9). The instruction signal includes information about the third traveling route. On receiving the instruction signal, the robot 2 passes through the predetermined area A1 following the third traveling route. As indicated by the two-dot chain line and shading in FIG. 4, for example, the third traveling route that passes inside the boundary box B1 is plotted.

[0078] If no traveling route that passes inside the boundary box B1 is found as a result of the third decision processing (if the answer is No in Step ST8) and if the occupancy rate is less than the threshold value (which is equal to 4 in FIG. 2) (if the answer is No in Step ST4), the decider 513 decides that the robot 2 be unable to pass through the predetermined area A1. Then, the decider 513 searches for a new traveling route that bypasses the predetermined area A1 (in Step 10). More particularly, the decider 513 searches for a new traveling route based on the global map. The new traveling route is a traveling route that passes through the goal and transit point that have been set on the first traveling route.

[0079] When the decider 513 finds a new traveling route, the communications unit 52 of the decision system 5 transmits a notification signal to the robot 2 (in Step ST11). The notification signal is a signal for notifying the robot 2 of the new traveling route.

[0080] Note that if the decider 513 is unable to find any new traveling route in Step ST10, the robot 2 waits, for example. After a predetermined time has passed since the end of Step ST10, the decision system 5 will perform the series of processing steps from Step ST2 on all over again

based on the latest location information of the one or more objects present in the predetermined area A1.

[0081] (8) Advantages

The first decision processing and the second decision processing are simpler processing than the third decision processing. Therefore, the first decision processing and the second decision processing take a shorter time to make a decision than the third decision processing does.

[0082] Therefore, if a decision is made in the first decision processing that the robot 2 be unable to pass through the predetermined area A1 (if the decision result in Step ST4 is “Yes”), the decision may be made more quickly than when the third decision processing is performed instead of the first decision processing. Also, if a decision is made in the second decision processing that the robot 2 be able to pass through the predetermined area A1 (if the decision result in Step ST6 is “Yes”), the traveling route may be determined more quickly than when the third decision processing is performed instead of the second decision processing.

[0083] Only if no decision has been made in the first decision processing or the second decision processing about whether or not the robot 2 is able to pass through, the third decision processing is performed. When no decision has been made in the first decision processing or the second decision processing about whether or not the robot 2 is able to pass through, the decision system 5 does not necessarily decide that the robot 2 be unable to pass through. Instead, the decision system 5 may make a decision, by the third decision processing, about whether or not a traveling route that passes inside the boundary box B1 should be followed.

[0084] In this manner, the decision system 5 contributes to making a quicker decision by performing the first, second, and third decision processing in combination and increasing the chances of finding a traveling route, compared to when the decision system 5 does not perform the third decision processing.

[0085] Also, if there is any obstacle (e.g., a human being, goods, or the building frame of the facility 6) which is undetectable from the current position of the robot 2, the first, second, and third decision processing allows for making a decision about whether or not the robot 2 is able to pass through even without having the robot 2 reach a point where the robot 2 is able to detect the obstacle.

[0086] (Variations of exemplary embodiment)

Next, variations of the exemplary embodiment will be enumerated one after another. Note that the variations to be described below may be adopted in combination as appropriate. In the following description, the configuration of the exemplary embodiment described above will be hereinafter referred to as a “basic example.”

[0087] The second positioner 512 may determine the position of the robot 2 serving as a signal source of the beacon signal based on the phase of the beacon signal instead of the received signal strength indicator of the beacon signal.

[0088] In the basic example, the occupancy rate is defined to be the number of the one or more objects present in the predetermined area A1. Alternatively, the occupancy rate may also be defined to be the ratio of the sum of the surface areas occupied by the one or more objects present in the predetermined area A1 to the overall surface area of the predetermined area, for example.

[0089] The second positioner 512 does not have to be configured to generate the position information of the robot 2 based on the beacon signal. Alternatively, the second positioner 512 may also generate the position information of the robot 2 based on the image information generated by the camera 4, for example.

[0090] In the basic example, the first positioner 511 generates the location information of the one or more objects based on the image information generated by the positioning system P1 including the plurality of cameras 4. However, the means used by the first positioner 511 for generating the location information of the one or more objects should not be limited to this. For example, suppose the object is a person and the positioning system P1 includes the plurality of scanners 3. In that case, the plurality of scanners 3 receive the beacon signal transmitted by a beacon carried by the person, and then the first positioner 511 may also generate location information of the person based on the information (e.g., the received signal strength indicator) generated by the plurality of scanners 3 based on the beacon signal.

[0091] The first positioner 511 may also be provided outside of the decision system 5. In that case, the acquirer 514 of the decision system 5 may acquire the location information of the one or more objects (e.g., persons H1, H2 and goods G1 shown in FIGS. 3 and 4) from the first positioner 511 via the communications unit 52.

[0092] In the basic example, the persons H1, H2 and goods G1 are cited as exemplary objects present in the predetermined area A1. However, this should not be construed as limiting. Alternatively, the object may also be, for example, another robot.

[0093] The boundary of the predetermined area A1 in the basic example is located in the vicinity of the walls 61, 61, 62, and 62 of the facility 6. Alternatively, the boundary may also be spaced apart from the walls of the facility 6.

[0094] Note that the flowchart shown in FIG. 2 is only an exemplary procedure of the decision method according to the present disclosure and should not be construed as limiting. Optionally, the processing steps shown in FIG. 2 may be performed in a different order as appropriate from the illustrated one, some of the processing steps shown in FIG. 2 may be omitted as appropriate,

and/or an additional processing step may be performed as needed.

[0095] The robot system 1 according to the present disclosure or the agent that performs the decision method according to the present disclosure includes a computer system. The computer system includes a processor and a memory as principal hardware components thereof. The computer system performs at least some functions of the robot system 1 according to the present disclosure or serves as the agent that performs the decision method according to the present disclosure by making the processor execute a program stored in the memory of the computer system. The program may be stored in advance in the memory of the computer system. Alternatively, the program may also be downloaded through a telecommunications line or be distributed after having been stored in some non-transitory storage medium such as a memory card, an optical disc, or a hard disk drive, any of which is readable for the computer system. The processor of the computer system may be made up of a single or a plurality of electronic circuits including a semiconductor integrated circuit (IC) or a large-scale integrated circuit (LSI). As used herein, the “integrated circuit” such as an IC or an LSI is called by a different name depending on the degree of integration thereof. Examples of the integrated circuits such as an IC or an LSI include integrated circuits called a “system LSI,” a “very-large-scale integrated circuit (VLSI),” and an “ultra-large-scale integrated circuit (ULSI).” Optionally, a field-programmable gate array (FPGA) to be programmed after an LSI has been fabricated or a reconfigurable logic device allowing the connections or circuit sections inside of an LSI to be reconfigured may also be adopted as the processor. Those electronic circuits may be either integrated together on a single chip or distributed on multiple chips, whichever is appropriate. Those multiple chips may be aggregated together in a single device or distributed in multiple devices without limitation. As used herein, the “computer system” includes a microcontroller including one or more processors and one or more memories. Thus, the microcontroller may also be implemented as a single or a plurality of electronic circuits including a semiconductor integrated circuit or a large-scale integrated circuit.

[0096] In the embodiment described above, the plurality of functions are integrated together in a single device. Alternatively, those functions may be distributed in multiple different devices. Still alternatively, at least some functions of the robot system 1 (e.g., some functions of the processing unit 51 of the decision system 5) may be implemented as, for example, either a server or a cloud computing system as well.

[0097] (Recapitulation)

The exemplary embodiment and its variations described above provide specific implementations for the following aspects of the present disclosure.

[0098] A robot system (1) according to a first aspect makes a decision when determining a traveling route for a robot (2) configured to travel autonomously in a facility (6). The robot system (1) includes the robot (2), a positioner (511), a decider (513), and a communications unit (52). The positioner (511) generates, based on a piece of information generated by a positioning system (P1) installed in the facility (6), location information of one or more objects present in a predetermined area (A1) which place obstacles in the way of the robot (2) that is moving. The decider (513) makes a decision about whether or not the robot (2) is able to pass through the predetermined area (A1). The communications unit (52) transmits, to the robot (2), a communication signal including a result of the decision made by the decider (513). The decider (513) performs first decision processing. The first decision processing includes determining an occupancy rate of the one or more objects present in the predetermined area (A1) based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot (2) be unable to pass through the predetermined area (A1).

[0099] This configuration allows the decider (513) to make a decision, by performing simple processing of comparing the occupancy rate with the threshold value, that circumstances would not permit the robot (2) to pass through.

[0100] In a robot system (1) according to a second aspect, which may be implemented in conjunction with the first aspect, the occupancy rate of the one or more objects present in the predetermined area (A1) is the number of the one or more objects present in the predetermined area (A1). The threshold value is equal to or greater than 2.

[0101] This configuration allows for determining the occupancy rate easily.

[0102] In a robot system (1) according to a third aspect, which may be implemented in conjunction with the first or second aspect, the decider (513) searches, when deciding that the robot (2) be unable to pass through the predetermined area (A1), for a traveling route that bypasses the predetermined area (A1).

[0103] This configuration allows the robot (2) to move while bypassing the predetermined area (A1) that is congested.

[0104] In a robot system (1) according to a fourth aspect, which may be implemented in conjunction with any one of the first to third aspects, the positioner (511) serves as a first positioner (511). The robot system (1) further includes a second positioner (512) for generating position information of the robot (2). The decider (513) determines the predetermined area (A1) based on the position information of the robot (2). The predetermined area (A1) is a target in which the decision needs to be made about whether the robot (2) is able to pass through the predetermined

area.

[0105] This configuration allows the decider (513) to determine the predetermined area (A1) appropriately by reference to the position information of the robot (2).

[0106] In a robot system (1) according to a fifth aspect, which may be implemented in conjunction with any one of the first to fourth aspects, the one or more objects are two or more objects. The decider (513) defines a boundary box (B1) based on the location information of the two or more objects present in the predetermined area (A1). The boundary box (B1) surrounds the two or more objects and has a rectangular shape when viewed in plan. The decider (513) performs second decision processing when the occupancy rate turns out to be less than the threshold value as a result of the first decision processing. The second decision processing includes deciding, when width of a road outside the boundary box (B1) is equal to or greater than width of the robot (2), that the robot (2) be able to pass through the predetermined area (A1).

[0107] This configuration allows the decider (513) to decide, by performing simple processing of comparing the width of the road outside the boundary box (B1) with the width of the robot (2), that circumstances would permit the robot (2) to pass through.

[0108] In a robot system (1) according to a sixth aspect, which may be implemented in conjunction with the fifth aspect, the decider (513) performs third decision processing, when the width of the road outside the boundary box (B1) turns out to be narrower than the width of the robot (2) as a result of the second decision processing. The third decision processing includes making a decision about whether or not the robot (2) is able to pass through the predetermined area (A1) following a traveling route that passes inside the boundary box (B1).

[0109] This configuration increases the chances that the robot (2) is able to pass through the predetermined area (A1) compared to deciding, without exception, when the width of a road outside the boundary box (B1) turns out to be narrower than the width of the robot (2), that the robot (2) be unable to pass through.

[0110] In a robot system (1) according to a seventh aspect, which may be implemented in conjunction with the sixth aspect, the third decision processing includes making the decision based on a global map of the boundary box (B1).

[0111] According to this configuration, in the third decision processing, the robot (2) does not have to generate a local map, thus reducing the load placed on the robot (2).

[0112] In a robot system (1) according to an eighth aspect, which may be implemented in conjunction with the sixth or seventh aspect, the third decision processing includes using an A\* algorithm to make the decision.

[0113] This configuration allows for improving the accuracy of the third decision processing.

[0114] Note that the constituent elements according to the second to eighth aspects are not essential constituent elements for the robot system (1) but may be omitted as appropriate.

[0115] A decision system according to a ninth aspect makes a decision when determining a traveling route for a robot (2) configured to travel autonomously in a facility (6). The decision system includes an acquirer (514), a decider (513), and a communications unit (52). The acquirer (514) acquires location information of one or more objects present in a predetermined area (A1) which place obstacles in the way of the robot (2) that is moving. The location information is based on a piece of information generated by a positioning system (P1) installed in the facility (6). The decider (513) makes a decision about whether or not the robot (2) is able to pass through the predetermined area (A1). The communications unit (52) transmits, to the robot (2), a communication signal including a result of the decision made by the decider (513). The decider (513) performs first decision processing. The first decision processing includes determining an occupancy rate of the one or more objects present in the predetermined area (A1) based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot (2) be unable to pass through the predetermined area (A1).

[0116] This configuration allows the decider (513) to make a decision, by performing simple processing of comparing the occupancy rate with the threshold value, that circumstances would not permit the robot (2) to pass through.

[0117] A decision method according to a tenth aspect is performed by a decision system to make a decision when determining a traveling route for a robot (2) configured to travel autonomously in a facility (6). The decision method includes an acquiring step, a deciding step, and a communicating step. The acquiring step includes acquiring location information of one or more objects present in a predetermined area (A1) which place obstacles in the way of the robot (2) that is moving. The location information is based on a piece of information generated by a positioning system (P1) installed in the facility (6). The deciding step includes making a decision about whether or not the robot (2) is able to pass through the predetermined area (A1). The communicating step includes transmitting, to the robot (2), a communication signal including a result of the decision made in the deciding step. The deciding step includes first decision processing. The first decision processing includes determining an occupancy rate of the one or more objects present in the predetermined area (A1) based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot (2) be unable to pass through the predetermined area (A1).

[0118] This method allows for making a decision, by performing simple processing of comparing the occupancy rate with the threshold value in the deciding step, that circumstances would not permit the robot (2) to pass through.

[0119] A program according to an eleventh aspect is designed to cause one or more processors of a computer system to perform the decision method according to the tenth aspect.

[0120] This program allows for making a decision, by performing simple processing of comparing the occupancy rate with the threshold value in the deciding step, that circumstances would not permit the robot (2) to pass through.

[0121] Note that these are not the only aspects of the present disclosure but various configurations (including variations) of the robot system (1) according to the exemplary embodiment described above may also be implemented as, for example, a decision method, a (computer) program, or a non-transitory storage medium on which the program is stored.

## Reference Signs List

|        |     |                               |
|--------|-----|-------------------------------|
| [0122] | 1   | Robot System                  |
|        | 2   | Robot                         |
|        | 6   | Facility                      |
|        | 52  | Communications Unit           |
|        | 511 | Positioner (First Positioner) |
|        | 512 | Second Positioner             |
|        | 513 | Decider                       |
|        | 514 | Acquirer                      |
|        | A1  | Predetermined Area            |
|        | B1  | Boundary Box                  |
|        | P1  | Positioning System            |

## CLAIMS

[Claim 1] A robot system configured to make a decision when determining a traveling route for a robot, the robot being configured to travel autonomously in a facility, the robot system comprising:

the robot;

a positioner configured to generate, based on a piece of information generated by a positioning system installed in the facility, location information of one or more objects present in a predetermined area which place obstacles in a way of the robot that is moving;

a decider configured to make a decision about whether or not the robot is able to pass through the predetermined area; and

a communications unit configured to transmit, to the robot, a communication signal including a result of the decision made by the decider,

the decider being configured to perform first decision processing, and

the first decision processing including determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[Claim 2] The robot system of claim 1, wherein

the occupancy rate of the one or more objects present in the predetermined area is a numerical number of the one or more objects present in the predetermined area, and

the threshold value is equal to or greater than 2.

[Claim 3] The robot system of claim 1 or 2, wherein

the decider is configured to, when deciding that the robot be unable to pass through the predetermined area, search for a traveling route that bypasses through the predetermined area.

[Claim 4] The robot system of any one of claims 1 to 3, wherein

the positioner is configured to serve as a first positioner,

the robot system further comprises a second positioner configured to generate position information of the robot, and

the decider is configured to determine the predetermined area based on the position information of the robot, the predetermined area being a target in which the decision needs to be made about whether the robot is able to pass through the predetermined area.

[Claim 5] The robot system of any one of claims 1 to 4, wherein

the one or more objects are two or more objects,

the decider is configured to define a boundary box based on the location information of the two or more objects present in the predetermined area, the boundary box surrounding the two or more objects and having a rectangular shape when viewed in plan,

the decider is configured to perform second decision processing when the occupancy rate turns out to be less than the threshold value as a result of the first decision processing, and

the second decision processing includes deciding, when width of a road outside the boundary box is equal to or greater than width of the robot, that the robot be able to pass through the predetermined area.

[Claim 6] The robot system of claim 5, wherein

the decider is configured to perform third decision processing when the width of the road outside the boundary box turns out to be narrower than the width of the robot as a result of the second decision processing, and

the third decision processing includes making a decision about whether or not the robot is able to pass through the predetermined area following a traveling route that passes inside the boundary box.

[Claim 7] The robot system of claim 6, wherein

the third decision processing includes making the decision based on a global map of the boundary box.

[Claim 8] The robot system of claim 6 or 7, wherein

the third decision processing includes using an A\* algorithm to make the decision.

[Claim 9] A decision system configured to make a decision when determining a traveling route for a robot, the robot being configured to travel autonomously in a facility, the decision system comprising:

an acquirer configured to acquire location information of one or more objects present in

a predetermined area which place obstacles in a way of the robot that is moving, the location information being based on a piece of information generated by a positioning system installed in the facility;

a decider configured to make a decision about whether or not the robot is able to pass through the predetermined area; and

a communications unit configured to transmit, to the robot, a communication signal including a result of the decision made by the decider,

the decider being configured to perform first decision processing, and

the first decision processing including determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[Claim 10] A decision method designed to be performed by a decision system to make a decision when determining a traveling route for a robot, the robot being configured to travel autonomously in a facility, the decision method comprising:

an acquiring step including acquiring location information of one or more objects present in a predetermined area which place obstacles in a way of the robot that is moving, the location information being based on a piece of information generated by a positioning system installed in the facility;

a deciding step including making a decision about whether or not the robot is able to pass through the predetermined area; and

a communicating step including transmitting, to the robot, a communication signal including a result of the decision made in the deciding step,

the deciding step including first decision processing, and

the first decision processing including determining an occupancy rate of the one or more objects present in the predetermined area based on the location information of the one or more objects and deciding, when the occupancy rate of the one or more objects is equal to or greater than a threshold value, that the robot be unable to pass through the predetermined area.

[Claim 11] A program designed to cause one or more processors of a computer system to perform the decision method of claim 10.