

DESCRIPTION

Title of Invention

ROBOT MANAGEMENT SYSTEM AND RELOCALIZATION METHOD

Technical Field

[0001] The present disclosure generally relates to a robot management system and relocalization method, and more particularly relates to a robot management system and relocalization method for use in autonomous mobile robots.

Background Art

[0002] Patent Literature 1 discloses a robot localization controller designed to allow an autonomous mobile robot to recover from a localization error (i.e., relocalize the robot) by reading out location information from an RF ID tag located around the robot.

[0003] However, it is difficult for the robot localization controller of Patent Literature 1 to relocalize such a mislocalized robot if there are no RF ID tags around the robot (i.e., if the robot is currently located out of reach of radio waves emitted from RF ID tags).

Citation List

Patent Literature

[0004] Patent Literature 1: JP 2007-249735A

Summary of Invention

[0005] An object of the present disclosure is to provide a robot management system and relocalization method contributing to relocalizing an autonomous mobile robot more easily.

[0006] A robot management system according to an aspect of the present disclosure includes: an autonomous mobile robot including a camera; a positioning system; and a navigation system including a storage unit. The autonomous mobile robot moves autonomously while recognizing its own position and orientation within a predetermined area. The positioning system determines the current location of the autonomous mobile robot within the predetermined area. A marker, to which a code is attached, is provided at a predetermined location within the predetermined area. The code is associated with relocalization position information and relocalization orientation

information. The relocalization position information and relocalization orientation information are used to allow the autonomous mobile robot to recover from a mislocalized state to a relocalized state. The mislocalized state is a state where the autonomous mobile robot erroneously recognizes at least its own position. The relocalized state is a state where the autonomous mobile robot correctly recognizes its own position and orientation. The storage unit stores marker location information indicating the predetermined location. The navigation system navigates, when a decision is made that the autonomous mobile robot should be in the mislocalized state, the autonomous mobile robot toward the predetermined location in accordance with the marker location information and based on a result of positioning provided by the positioning system. The autonomous mobile robot includes a relocalizer. The relocalizer allows the autonomous mobile robot to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera after the autonomous mobile robot has been navigated by the navigation system, the relocalization position information and the relocalization orientation information associated with the code attached to the marker included in the captured image.

[0007] A relocalization method according to another aspect of the present disclosure is designed to allow an autonomous mobile robot including a camera to recover from a mislocalized state to a relocalized state. The autonomous mobile robot moves autonomously while recognizing its own position and orientation within a predetermined area. The mislocalized state is a state where the autonomous mobile robot erroneously recognizes at least its own position. The relocalized state is a state where the autonomous mobile robot correctly recognizes its own position and orientation. A marker, to which a code is attached, is provided at a predetermined location within the predetermined area. The code is associated with relocalization position information and relocalization orientation information used to allow the autonomous mobile robot to recover from the mislocalized state to the relocalized state. The relocalization method includes a navigation step and a relocalization step to be performed with respect to the marker. The navigation step includes navigating, when a decision is made that the autonomous mobile robot should be in the mislocalized state, the autonomous mobile robot toward the predetermined location in accordance with marker location information indicating the predetermined location and based on a result of positioning obtained about a current location of the autonomous mobile robot. The relocalization step includes allowing the autonomous mobile robot to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera after the autonomous mobile robot has been navigated by performing the navigation step, the relocalization position information and the relocalization orientation information associated with the code attached to the marker included in the captured image.

Brief Description of Drawings

[0008] [FIG. 1] FIG. 1 is a conceptual diagram of a robot management system according to an exemplary embodiment of the present disclosure;

[FIG. 2] FIG. 2 is a block diagram of the robot management system;

[FIG. 3] FIG. 3 is a flowchart showing a part of the processing to be performed by an autonomous mobile robot as a constituent element of the robot management system;

[FIG. 4] FIG. 4 is a flowchart showing another part of the processing;

[FIG. 5] FIG. 5 is a flowchart showing the procedure of relocalization processing included in the processing;

[FIG. 6] FIG. 6 is a flowchart showing the procedure of processing to be performed by a navigation system as another constituent element of the robot management system; and

[FIG. 7] FIG. 7A is a transparent view illustrating how the autonomous mobile robot performs an adjustment operation; and FIG. 7B is top view illustrating a state where the autonomous mobile robot faces a returning orientation at a returning position as a result of the adjustment operation.

Description of Embodiments

[0009] (1) Overview

In the following description of embodiments, a relocalization method which allows, in a robot management system 100 including: an autonomous mobile robot 1 with an onboard camera 11; and a positioning system 20 with a surveillance camera 3 as shown in FIGS. 1 and 2, the autonomous mobile robot 1 to recover from a mislocalized state to a relocalized state more easily and a robot management system 100 for performing such a relocalization method will be described.

[0010] As used herein, the “mislocalized state” refers to a state where the autonomous mobile robot 1 erroneously recognizes at least its own position. Note that in the mislocalized state, the autonomous mobile robot 1 often erroneously recognizes its own orientation as well. However, in the mislocalized state, the autonomous mobile robot 1 may recognize its own orientation correctly but its own position erroneously. On the other hand, the “relocalized state” as used herein refers to a state where the autonomous mobile robot 1 correctly recognizes its own position and orientation.

[0011] (1-1) Autonomous mobile robot

The autonomous mobile robot 1 moves autonomously while recognizing its own position and orientation (i.e., in the relocalized state) within a predetermined area (such as the area A1

shown in FIG. 1; which will be hereinafter simply referred to as an “area A1”).

[0012] Note that the area A1 is usually an indoor area. Alternatively, the area A1 may also be an outdoor lot or an area inside a facility including indoor and outdoor lots.

[0013] (1-2) Positioning system

The positioning system 20 determines the current location of the autonomous mobile robot 1 within the area A1. The positioning system 20 according to this embodiment performs positioning using an image (monitor image) provided by the surveillance camera 3.

[0014] (1-3) Marker and code

In this embodiment, a marker M1 is provided at a predetermined location (hereinafter referred to as a “marker location”) within the area A1. A code C1 is attached to the marker M1. The code C1 is associated with relocalization position information and relocalization orientation information. The relocalization position information and relocalization orientation information are pieces of information to be used to allow the autonomous mobile robot 1 to recover from the mislocalized state to the relocalized state.

[0015] The relocalization position information is a piece of information indicating, based on a captured image generated by shooting the autonomous mobile robot 1 using the onboard camera 11, the autonomous mobile robot’s 1 own position (such as the relocalization position Ps (to be described later) shown in FIGS. 7A and 7B) when the autonomous mobile robot 1 reads the code C1 attached to the marker M1. The relocalization orientation information is a piece of information indicating the orientation of the autonomous mobile robot 1 (such as the relocalization orientation Dr (to be described later) shown in FIG. 7B) when the autonomous mobile robot 1 reads the code C1.

[0016] (1-4) Navigation system

The robot management system 100 further includes a navigation system 30. The navigation system 30 includes a storage unit 22. The storage unit 22 stores marker location information indicating the predetermined location (marker location).

[0017] (1-5) Relocalizer

The autonomous mobile robot 1 includes a relocalizer 121. The relocalizer 121 performs the relocalization method using the marker M1 mainly in cooperation with the positioning system 20.

[0018] (1-6) Relocalization method

The relocalization method using the marker M1 includes Steps (navigation steps) S21–S27 shown in FIG. 6 and Step S11 shown in FIG. 4 (including Steps S111–S117 shown in FIG. 5: relocalization steps).

[0019] (1-6-1) Navigation step

The navigation steps (S21–S27) include making the navigation system 30 perform the processing of navigating the autonomous mobile robot 1 toward the marker location in accordance with the marker location information and based on the result of positioning made by the positioning system 20 when a decision is made that the autonomous mobile robot 1 should be in the mislocalized state.

[0020] Note that in this embodiment, it is the autonomous mobile robot 1 itself that determines whether the autonomous mobile robot 1 is in the mislocalized state. If the autonomous mobile robot 1 determines that the autonomous mobile robot 1 itself be in the mislocalized state, then the autonomous mobile robot 1 transmits a mislocalization signal, indicating that the autonomous mobile robot 1 has been mislocalized, to the navigation system 30. In response to the mislocalization signal that the navigation system 30 has received from the autonomous mobile robot 1, the navigation system 30 performs navigation processing.

[0021] Alternatively, the navigation system 30, for example, may determine whether the autonomous mobile robot 1 is in the mislocalized state (refer to the variations to be described later).

[0022] (1-6-2) Relocalization steps

The relocalization steps (S11, S111–S117) include making the relocalizer 121 perform the processing (relocalization processing) of allowing the autonomous mobile robot 1 to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera 11 after the autonomous mobile robot 1 has been navigated by the navigation system 30, the relocalization position information and the relocalization orientation information associated with the code attached to the marker M1.

[0023] (1-7) Advantages of robot management system and relocalization method

As can be seen from the foregoing description, in the robot management system and relocalization method according to this embodiment, if the autonomous mobile robot 1 has been mislocalized, then the navigation system 30 navigates the autonomous mobile robot 1 toward a predetermined location where the marker M1 is provided (i.e., the marker location). After having been navigated to the marker location, the autonomous mobile robot 1 reads a code C1 attached to the marker M1 to acquire relocalization position information and relocalization orientation information. This allows the autonomous mobile robot 1 to be relocalized more easily.

[0024] (2) Means of implementation

The robot management system 100 and relocalization method as described above may be implemented, for example, using the autonomous mobile robot 1, server 2, surveillance camera 3, communications device 4, and a plurality of markers M1 as shown in FIG. 1. That is to say, this

this embodiment allows the robot management system 100 and relocalization method to be implemented using existent equipment including the surveillance camera 3 and the communications device 4.

[0025] (2-1) Server

The server 2 is provided outside of the area A1 and connected to the surveillance camera 3 to be ready to communicate with the surveillance camera 3 via a wired LAN, for example, as shown in FIG. 1. However, this is only an example and should not be construed as limiting. Alternatively, the server 2 may also be provided inside the area A1 and may communicate wirelessly with the surveillance camera 3.

[0026] The server 2 is ready to communicate wirelessly, via the communications device 4, with the autonomous mobile robot 1 moving autonomously within the area A1.

[0027] The server 2 performs the functions of the positioning system 20 in cooperation with the surveillance camera 3. In addition, the server 2 also performs the functions of the navigation system 30 in cooperation with a communications unit 15 (to be described later) of the autonomous mobile robot 1.

[0028] (2-2) Surveillance camera and communications device

Each of the surveillance camera 3 and the communications device 4 is provided within the predetermined area A1. The respective locations of the surveillance camera 3 and the communications device 4 within the predetermined area A1 are known. The respective pieces of location information of the surveillance camera 3 and the communications device 4 may be stored, for example, in the storage unit 22 of the server 2.

[0029] The surveillance camera 3 according to this embodiment, as well as the onboard camera 11, is a stereoscopic camera and may perform positioning using a parallax. Alternatively, the surveillance camera 3 may also be each of a plurality of single-lens cameras arranged in the area A1. In that case, positioning may be performed based on a parallax between a plurality of monitor images corresponding to the plurality of single-lens cameras, respectively.

[0030] Note that the surveillance camera 3 may be a camera having a lower resolution and a lower frame rate than the onboard camera 11. That is to say, the resolution of the result of positioning provided by the positioning system 20 (i.e., the location information based on the monitor image captured by the surveillance camera 3) may be lower than the resolution of the position information based on the captured image generated by the onboard camera 11 (i.e., self-position information and self-orientation information for use to allow the autonomous mobile robot 1 to move autonomously).

[0031] The communications device 4 may be implemented as, for example, a repeater which

relays a wireless signal (radio waves) transmitted and received between the autonomous mobile robot 1 and the server 2 or a wireless LAN access point through which each of the autonomous mobile robot 1 and the server 2 is connected to a wireless LAN.

[0032] In this embodiment, positioning is performed by the positioning system 20 based on the monitor image captured by the surveillance camera 3. Alternatively or additionally, positioning may also be performed based on the received signal strength of the wireless signal transmitted and received between the autonomous mobile robot 1 and the communications device 4. In that case, the communications device 4 measures the received signal strength of the wireless signal that the communications device 4 has received from the autonomous mobile robot 1 and outputs the result of measurement to the positioning system 20. In response, the positioning system 20 may perform positioning based on either the result of measurement provided by the communications device 4 or the monitor image captured by the surveillance camera 3 and the result of measurement provided by the communications device 4.

[0033] (2-3) Onboard camera

The autonomous mobile robot 1 includes the onboard camera 11 as shown in FIG. 2. The onboard camera 11 is fixed on the head of the autonomous mobile robot 1 such that its optical axis faces the front of the autonomous mobile robot 1 (i.e., faces forward) as shown in FIGS. 1, 7A, and 7B. Thus, the onboard camera 11 shoots a subject falling within a predetermined angle of view which is centered around the front surface of the autonomous mobile robot 1 (i.e., the optical axis of the onboard camera 11).

[0034] The onboard camera 11 according to this embodiment is a stereoscopic camera having two lenses arranged on the right and left, respectively, which may serve as a rangefinder using a parallax between two captured images corresponding to the two lenses. In this case, the optical axis of the onboard camera 11 (i.e., the optical axis of the entire stereoscopic camera) is a straight line which passes through the midpoint between the two center points of the two lenses and which is parallel to the two optical axes of the two lenses. For example, in a situation where the onboard camera 11 confronts the marker M1 as shown in FIGS. 7A and 7B, a straight line aligned with the relocalization orientation D_r corresponds to the optical axis of the onboard camera 11.

[0035] As used herein, if something confronts something else, these two things preferably confront each other both horizontally and vertically. However, this is only an example and should not be construed as limiting. Rather, these two things have only to confront each other at least horizontally. That is to say, while the relocalization processing is being performed, the onboard camera 11 only needs to confront the marker M1 horizontally and does not have to confront the marker M1 vertically.

[0036] (2-4) Autonomous movement using onboard camera

The autonomous mobile robot 1 moves autonomously toward its destination based on at least the captured image generated by the onboard camera 11, the self-position information and self-orientation information, map information corresponding to the predetermined area A1, and location information (destination information) corresponding to the destination, for example.

[0037] The map information includes route information about a route within the predetermined area A1 and multiple pieces of location image information corresponding to multiple points along the route (i.e., a set of multiple pairs of location information and surrounding images).

[0038] (2-5) Self-position information and self-orientation information

The self-position information and the self-orientation information are acquired based on the captured image generated by the onboard camera 11 and the map information (such as the location image information, in particular). That is to say, the autonomous mobile robot 1 detects its own position and orientation based on the captured image generated by the onboard camera 11 and the location image information, for example, thereby acquiring self-position information and self-orientation information. Optionally, when the autonomous mobile robot 1 detects its own position and orientation, the result of positioning provided by the positioning system 20 using the monitor image captured by the surveillance camera 3 may be used as well, for example. The result of positioning provided by the positioning system 20 using the monitor image captured by the surveillance camera 3 has a lower resolution, but covers a broader range, than the position information based on the captured image generated by the onboard camera 11.

[0039] (2-6) Plurality of markers

The plurality of markers M1 are arranged at respectively different locations within the area A1. Note that the marker M1 that has been described in the “Overview” section corresponds to each of the plurality of markers M1. Also, the predetermined location (marker location) described above is any one of a plurality of predetermined locations (marker locations) corresponding to the plurality of markers M1, respectively. Furthermore, the marker location information described above is any one of multiple pieces of marker location information corresponding to the plurality of markers M1, respectively.

[0040] The navigation system 30 navigates the autonomous mobile robot 1 in the mislocalized state toward one of the plurality of predetermined locations which is nearest to the autonomous mobile robot 1. As a result, the autonomous mobile robot 1 that has been mislocalized is navigated toward the nearest marker M1 belonging to the plurality of markers M1. As used herein, the “nearest marker M1” refers to a marker M1 located closest the autonomous mobile robot 1 which belongs to the plurality of markers M1.

[0041] Navigating the autonomous mobile robot 1 toward the nearest marker M1 belonging to the plurality of markers M1 in this manner allows for shortening the amount of time it takes for the navigation system 30 to complete the navigation. Consequently, this contributes to broadening the range in which the autonomous mobile robot 1 is movable autonomously (among other things, the range in which even an autonomous mobile robot that has once been mislocalized is re-localizable).

[0042] (2-7) QR code (R) (hereinafter simply referred to as “QR code”) and adjustment image

In this embodiment, the code C1 described above is a QR code (hereinafter referred to as a “QR code C1”).

[0043] To each of the plurality of markers M1 (hereinafter simply referred to as the “marker M1”), attached are a QR code C1 and adjustment images F_i as shown in FIG. 1. The adjustment images F_i will be described later.

[0044] In this case, the QR code C1 and the adjustment images F_i (hereinafter referred to as “QR code C1 and other identifiers”) may be attached to the marker M1 by, for example, printing or engraving the QR code C1 and other identifiers directly on the marker M1 or affixing a sheet on which the QR code C1 and other identifiers are printed onto the marker M1, whichever is appropriate.

[0045] The marker M1 may be, for example, a thin rectangular plate as shown in FIG. 1. The QR code C1 and other identifiers are attached to one principal surface (surface) of the marker M1. The marker M1 is placed at a predetermined location (marker location) within the predetermined area A1 such that its surface is perpendicular to the floor surface and a normal to the surface faces the relocalization orientation D_r .

[0046] Alternatively, the marker M1 may also be attached to an appropriate place (such as on the external wall of a particular building) within the area A1. In that case, the location of the marker M1 thus attached may be defined as the predetermined location (marker location) and a direction aligned with a normal to the surface of the marker M1 may be defined as the relocalization orientation D_r , for example.

[0047] As used herein, the “relocalization position P_s ” refers to a position which is located at a predetermined distance d_C as measured along a normal to the surface of the marker M1 (i.e., in the direction aligned with the relocalization orientation D_r) from the center of the marker M1 (code C1) thus placed or attached.

[0048] Note that the marker M1 is preferably provided such that when measured from the floor surface, the QR code C1 and other identifiers attached to the marker M1 are level with the onboard camera 11 of the autonomous mobile robot 1. Nevertheless, the marker M1 does not have to be

level with the onboard camera 11 as long as the marker M1 may be captured by the onboard camera 11 and eventually, the adjustment operation may be performed based on the adjustment images Fi within the captured image and the QR code C1 within the captured image may be read.

[0049] (3) Details

The robot management system 100 includes the autonomous mobile robot 1, the positioning system 20, and the navigation system 30 as shown in FIG. 2.

[0050] (3-1) Autonomous mobile robot

The autonomous mobile robot 1 includes the onboard camera 11, a processing unit 12, a storage unit 13, a driving unit 14, and a communications unit 15 as shown in FIG. 2.

[0051] (3-1-1) Processing unit

The processing unit 12 performs various types of processing. Examples of the various types of processing include the processing to be performed by the relocalizer 121 (to be described later) (i.e., relocalization processing). Examples of the various types of processing further include the processing of detecting the self-position and self-orientation of the autonomous mobile robot 1 based on, for example, the captured image generated by the onboard camera 11 (hereinafter referred to as “position and orientation detection processing”) and the processing of controlling the driving unit 14 in accordance with the result of detection (i.e., self-position information and self-orientation information) of the position and orientation detection processing. The processing unit 12 further makes the various types of decisions to be described later with reference to flowcharts.

[0052] (3-1-2) Storage unit

The storage unit 13 stores various types of information. Examples of the various types of information include the self-position information and the self-orientation information. The self-position information and the self-orientation information are usually the results of detection of the position and orientation detection processing. That is to say, the processing unit 12 detects the position and orientation of the autonomous mobile robot 1. The storage unit 13 stores the self-position information indicating the position detected by the processing unit 12 and the self-orientation information indicating the orientation detected by the processing unit 12.

[0053] Note that the self-position information and self-orientation information stored in the storage unit 13 may be updated based on the result of scanning of the QR code C1 included in the captured image (i.e., the relocalization position information and the relocalization orientation information).

[0054] In addition, the storage unit 13 also stores, for example, the captured image, map information, destination information, and route information.

[0055] (3-1-3) Driving unit

The driving unit 14 includes, for example, a battery, a pair of motors, and right and left wheels. Under the control of the processing unit 12, the driving unit 14 supplies electric power from the battery to the pair of motors to drive the right and left wheels independently of each other. In this manner, the driving unit 14 allows the autonomous mobile robot 1 to move autonomously.

[0056] (3-1-4) Communications unit

The communications unit 15 communicates wirelessly, via the communications device 4, with the communications unit 23 on the server 2 end.

[0057] (3-1-5) Relocalizer

The processing unit 12 includes the relocalizer 121. The relocalizer 121 performs relocalization processing after the autonomous mobile robot 1 has been navigated by the navigation system 30.

[0058] (3-1-5a) Relocalization processing

As used herein, the “relocalization processing” refers to the processing of allowing the autonomous mobile robot 1 to recover from the mislocalized state to the relocalized state.

[0059] Specifically, the relocalization processing may be, for example, the processing of allowing the autonomous mobile robot 1 to recover from the mislocalized state to the relocalized state by acquiring, based on the captured image generated by the onboard camera 11, for example, relocalization position information and relocalization orientation information which are associated with the QR code C1 attached to the marker M1 included in the captured image. In this case, acquiring the relocalization position information and the relocalization orientation information may mean, for example, reading the relocalization position information and relocalization orientation information encrypted in the QR code C1.

[0060] Alternatively, identification information for use to identify the marker M1 may be encrypted in the QR code C1 or any other type of code such as a barcode and a set of two types of information, namely, the identification information and the relocalization position information and relocalization orientation information, may be stored in the storage unit 22 of the server 2. In that case, acquiring the relocalization position information and the relocalization orientation information means reading the identification information encrypted in the QR code C1 and acquiring, from the storage unit 22, relocalization position information and relocalization orientation information stored there in association with the identification information thus read.

[0061] (3-1-5b) Adjustment operation

The relocalizer 121 makes, after the autonomous mobile robot 1 has been navigated by the navigation system 30, the autonomous mobile robot 1 perform an adjustment operation based

on the captured image generated by the onboard camera 11. As used herein, the “adjustment operation” refers to the operation performed by the autonomous mobile robot 1 to adjust its own position and/or orientation so that the QR code C1 attached to the marker M1 included in the captured image is readable for the autonomous mobile robot 1. Having the autonomous mobile robot 1 adjust its own position and/or orientation using the captured image generated by the onboard camera 11 in this manner allows the QR code C1 included in the captured image to be read.

[0062] The adjustment operation according to this embodiment refers to the operation of having the position and orientation of the autonomous mobile robot 1 adjusted via the driving unit 14 so that the autonomous mobile robot 1 may face the relocalization orientation Dr corresponding to the relocalization orientation information at a relocalization position Ps corresponding to the relocalization position information. However, if the autonomous mobile robot 1 already faces the relocalization orientation Dr corresponding to the relocalization orientation information at the relocalization position Ps corresponding to the relocalization position information immediately after having been navigated by the navigation system 30, then there is no need to perform the adjustment operation.

[0063] The relocalizer 121 has the position and/or orientation of the autonomous mobile robot 1 adjusted via the driving unit 14 based on the captured image generated by the onboard camera 11 so that the autonomous mobile robot 1 may face the relocalization orientation Dr corresponding to the relocalization orientation information at the relocalization position Ps corresponding to the relocalization position information.

[0064] This allows the position and orientation of the autonomous mobile robot 1 to match the relocalization position information and relocalization orientation information more closely. In other words, this contributes to matching the position and orientation of the autonomous mobile robot 1 to the relocalization position Ps and relocalization orientation Dr corresponding to the relocalization position information and relocalization orientation information, respectively, or increasing the degree of matching between the position and orientation of the autonomous mobile robot 1 and the relocalization position Ps and the relocalization orientation Dr.

[0065] (3-1-5c) Adjustment images

The relocalizer 121 makes the autonomous mobile robot 1 perform the adjustment operation using adjustment images Fi included in the captured image generated by the onboard camera 11. As used herein, the “adjustment images Fi” refer to images for use to make the autonomous mobile robot 1 perform the adjustment operation.

[0066] The adjustment images Fi may be, for example, a pair of images FiL and FiR such as the

ones shown in FIG. 7A. The pair of images FiL and FiR are arranged on the surface of the marker M1 to be horizontally symmetric to each other with respect to the QR code C1. Each of the pair of images FiL and FiR has the shape of a square with the same dimension.

[0067] Note that the pair of images FiL and FiR do not have to be arranged perfectly horizontally symmetrically, but may also be arranged substantially horizontally symmetrically, to each other. The pair of images FiL and FiR may be regarded as being arranged horizontally symmetrically to each other if the difference between the distance from the QR code C1 to one (e.g., the image FiL) of the pair of images FiL and FiR and the distance from the QR code C1 to the other (e.g., the image FiR) of the pair of images FiL and FiR is equal to or less than a threshold value.

[0068] Note that each of the pair of images FiL and FiR may also have, for example, a circular, elliptical, rectangular, or any other polygonal shape without limitation. In addition, in this embodiment, the pair of images FiL and FiR may also have mutually different shapes or different dimensions because the distances dL and dR from the onboard camera 11 to the pair of images FiL and FiR have only to be measured.

[0069] As used herein, the distance from the onboard camera 11 to the image FiL refers to the distance from a midpoint between two center points corresponding to the two lenses to the center point of the image FiL. The same statement applies to the distance from the onboard camera 11 to the image FiR and the distance from the onboard camera 11 to the QR code C1.

[0070] As used herein, the “relocalization position Ps” refers to the position of the autonomous mobile robot 1 immediately after the relocalizer 121 has performed the relocalization processing, and the “relocalization orientation Dr” refers to the orientation of the autonomous mobile robot 1 immediately after the relocalizer 121 has performed the relocalization processing.

[0071] If the captured image includes the pair of images FiL and FiR that are arranged horizontally symmetrically to each other with the QR code C1 interposed between them in this manner, then the adjustment operation may be done even more easily. Optionally, the adjustment operation may also be performed based on the QR code C1 included in the captured image. Nevertheless, using the pair of images FiL and FiR that are horizontally spaced from each other more significantly than the QR code C1 contributes to having the adjustment operation done more easily.

[0072] (3-1-6) Specific method for acquiring relocalization position information and relocalization orientation information

The onboard camera 11 according to this embodiment outputs a moving picture. The captured image described above is any one of a plurality of still pictures that form the moving picture output by the onboard camera 11. The relocalizer 121 sequentially determines whether

each of the plurality of still pictures satisfies a predetermined condition. Then, the relocalizer 121 acquires the relocalization position information and relocalization orientation information based on a still picture corresponding to a point in time when the relocalizer 121 determines that the predetermined condition be satisfied.

[0073] (3-1-7) Predetermined condition

The predetermined condition is a condition on the positional relationship between the camera 11 and the marker M1. Reading, based on the moving picture provided by the camera 11, the QR code C1 using such a still picture that satisfies the predetermined condition in this manner contributes to matching the position and orientation of the autonomous mobile robot 1 to the relocalization position information and relocalization orientation information more closely.

[0074] (3-1-7a) Confronting condition

The predetermined condition includes a confronting condition. As used herein, the “confronting condition” refers to a condition that the camera 11 should directly confront the QR code C1 attached the marker M1.

[0075] The relocalizer 121 determines that a still picture corresponding to a point in time when the distances d_L and d_R (refer to FIG. 7A) from the onboard camera 11 to the pair of images Fi_L and Fi_R attached to the marker M1 are equal to each other (i.e., $d_L = d_R$) which belongs to a plurality of still pictures that form the moving picture (i.e., the plurality of still pictures sequentially output by the onboard camera 11) satisfy the confronting condition.

[0076] In this embodiment, the onboard camera 11 is a stereoscopic camera, and the distances d_L and d_R from the onboard camera 11 to the pair of images Fi_L and Fi_R on the surface of the marker M1 are calculated based on a parallax between two captured images corresponding to the lenses of the stereoscopic camera. Then, a still picture in which the two distances d_L and d_R thus calculated are equal to each other is determined to satisfy the confronting condition.

[0077] Using such a still picture satisfying the confronting condition which belongs to the plurality of still pictures that form the moving picture in this manner contributes to matching the orientation of the autonomous mobile robot 1 more closely to the relocalization orientation information.

[0078] (3-1-7b) Distance condition

The predetermined condition further includes a distance condition. As used herein, the “distance condition” refers to a condition that the (onboard camera 11 of the) autonomous mobile robot 1 should be currently located at a predetermined distance d_C from the QR code C1 attached to the marker M1.

[0079] As used herein, the “predetermined distance d_C ” refers to the distance from the (onboard

camera 11 of the) autonomous mobile robot 1 to the QR code C1 attached to the marker M1 immediately after the relocalizer 121 has performed the relocalization processing as shown in FIGS. 7A and 7B.

[0080] Note that the distance from the (onboard camera 11 of the) autonomous mobile robot 1 to the QR code C1 attached to the marker M1 refers to the distance from the position (i.e., self-position) of the autonomous mobile robot 1 as indicated by the self-position information to the location (marker location) of the marker M1 as indicated by the marker location information. The distance from the self-position to the marker location is calculated based on the self-position information and the marker location information.

[0081] The relocalizer 121 calculates, with respect to the still picture that has been determined to satisfy the confronting condition, the distance from the (onboard camera 11 of the) autonomous mobile robot 1 to the QR code C1 attached to the marker M1 based on at least one of the distances d_L and d_R from the (onboard camera 11 of the) autonomous mobile robot 1 to the pair of images Fi_L and Fi_R attached to the marker M1.

[0082] Note that the distances d_L and d_R from the onboard camera 11 to the pair of images Fi_L and Fi_R attached to the marker M1 may be calculated based on, for example, the distance between the two lenses that are constituent elements of the onboard camera 11 as a stereoscopic camera and a parallax between two captured images corresponding to the two lenses.

[0083] Also, the distance from the (onboard camera 11 of the) autonomous mobile robot 1 to the QR code C1 attached to the marker M1 may be calculated, for example, based on the angle defined by a direction pointing from a midpoint between two center points corresponding to the two lenses (i.e., a point corresponding to the relocalization position P_s in the example shown in FIGS. 7A and 7B) to one of the pair of images Fi_L and Fi_R (e.g., the image Fi_L) with respect to the optical axis of the onboard camera 11 and the distance d_L from the midpoint (P_s) to the image Fi_L . As used herein, the “direction pointing to the image Fi_L ” refers to a direction pointing toward the center point of the image Fi_L . The same statement applies to a direction pointing to the image Fi_R and a direction pointing to the QR code C1.

[0084] Then, the relocalizer 121 determines that if the difference between the distance thus calculated (i.e., the distance from the onboard camera 11 to the QR code C1) and the distance from the predetermined location (marker location) indicated by the marker location information to the relocalization position P_s indicated by the relocalization position information is equal to or less than a threshold value, the distance condition be further satisfied (i.e., that the onboard camera 11 be located at the predetermined distance d_C from the QR code C1).

[0085] Using such a still picture that satisfies the confronting condition and the distance

condition in this manner allows the position of the autonomous mobile robot 1 to be matched to the relocalization position information more closely.

[0086] (3-2) Positioning system and navigation system

As shown in FIG. 2, the positioning system 20 includes the server 2 and the surveillance camera 3. The navigation system 30 includes the server 2 and the communications unit 15.

[0087] (3-2-1) Server

The server 2 includes a processing unit 21, a storage unit 22, and a communications unit 23.

[0088] The storage unit 22 stores various types of information. Examples of the various types of information include the relocalization position information and the relocalization orientation information. The various types of information further include map information, for example. Note that the map information stored in the storage unit 22 on the server 2 end does not have to be the same as the map information stored in the storage unit 13 of the autonomous mobile robot 1 and does not have to include the position image information, for example.

[0089] The communications unit 23 communicates wirelessly, via the communications device 4, with the communications unit 15 of the autonomous mobile robot 1.

[0090] The processing unit 21 performs various types of processing. Examples of the various types of processing include positioning processing and navigation processing.

[0091] (3-2-1a) Positioning processing

The processing unit 21 performs positioning processing based on the monitor image provided by the surveillance camera 3. As used herein, the “positioning processing” refers to the processing of determining the current location of the autonomous mobile robot 1. Two captured images corresponding to the two lenses are output by the surveillance camera 3 as a stereoscopic camera. The processing unit 21 performs positioning processing using a parallax between the two captured images provided by the surveillance camera 3, thereby acquiring the location information of the autonomous mobile robot 1.

[0092] The processing unit 21 outputs the location information thus acquired to the navigation system 30. In this manner, the functions of the positioning system 20 described above are performed.

[0093] (3-2-1b) Navigation processing

In addition, the processing unit 21 also has navigation processing performed via the communications unit 23 and the communications unit 15 of the autonomous mobile robot 1 when the autonomous mobile robot 1 has fallen into the mislocalized state.

[0094] As used herein, the “navigation processing” refers to the processing of navigating the

autonomous mobile robot 1 in the mislocalized state toward a marker M1 (among other things, the nearest marker M1).

[0095] The processing unit 21 determines, when the communications unit 23 receives the mislocalization signal from the autonomous mobile robot 1, one piece of marker location information most closely matching the location information provided by the positioning system 20 which belongs to multiple pieces of marker location information corresponding to the plurality of markers M1 to generate a navigation signal instructing that the autonomous mobile robot 1 be navigated toward the marker location indicated by the marker location information. Then, the processing unit 21 transmits the navigation signal thus generated to the autonomous mobile robot 1 via the communications unit 23. In the autonomous mobile robot 1, the communications unit 15 receives the navigation signal and the processing unit 12 has the autonomous mobile robot 1 driven by the driving unit 14 in accordance with the navigation signal.

[0096] Furthermore, the processing unit 21 transmits, when determining, based on the location information provided by the positioning system 20 and the marker location information, that the autonomous mobile robot 1 not be approaching the marker M1 (e.g., going away from the marker M1), an orientation change instruction (e.g., an instruction that the traveling direction should be inverted) to the autonomous mobile robot 1 via the communications unit 23. In the autonomous mobile robot 1, the communications unit 15 receives the orientation change instruction and the processing unit 12 has the operation of changing (e.g., inverting) the traveling direction performed by the driving unit 14.

[0097] Furthermore, the processing unit 21 transmits, when determining, based on the location information provided by the positioning system 20 and the marker location information, that the autonomous mobile robot 1 have reached the vicinity of the marker M1, a relocalization instruction to the autonomous mobile robot 1 via the communications unit 23. In the autonomous mobile robot 1, the communications unit 15 receives the relocalization instruction and the relocalizer 121 performs the relocalization using the marker M1. In this manner, the functions of the navigation system 30 are performed.

[0098] (4) Exemplary operation

The autonomous mobile robot 1 operates following the procedures shown in the flowcharts of FIGS. 3 and 4. Note that the processing shown in FIGS. 3 and 4 is started when the robot management system 100 is activated and ended when the robot management system 100 is deactivated.

[0099] As shown in FIGS. 3 and 4, first, the processing unit 12 acquires an image (captured image) from the onboard camera 11 (in Step S1). Note that the onboard camera 11 outputs a

moving picture and a plurality of still pictures that form the moving picture are sequentially acquired one after another in Step S1.

[0100] Next, the processing unit 12 detects, based on the captured image acquired in Step S1 and the map information (position image information) stored in the storage unit 13, the self-position and self-orientation of the autonomous mobile robot 1 (i.e., performs position and orientation detection processing) (in Step S2). Subsequently, the processing unit 12 updates, based on the result of detection obtained in Step S2, the self-position information and self-orientation information that are stored in the storage unit 13 (in Step S3).

[0101] Thereafter, the processing unit 12 determines, based on the self-position information and self-orientation information that are stored in the storage unit 13 and the map information stored in the storage unit 13, whether the autonomous mobile robot 1 has been mislocalized (in Step S4). If a decision has been made that the autonomous mobile robot 1 should not have been mislocalized (if the answer is NO in Step S4), then the process proceeds to Step S12.

[0102] On the other hand, if a decision has been made in Step S4 that the autonomous mobile robot 1 should have been mislocalized (if the answer is YES in Step S4), then the processing unit 12 has the mislocalization signal transmitted to the (server 2 of the) navigation system 30 via the communications unit 15 (in Step S5).

[0103] Then, the processing unit 12 determines whether the communications unit 15 has received any navigation signal (in Step S6). If the communications unit 15 has received no navigation signals (if the answer is NO in Step S6), then the process proceeds to Step S8.

[0104] If a decision has been made in Step S6 that the communications unit 15 should have received any navigation signal (if the answer is YES in Step S6), then the processing unit 12 has the autonomous mobile robot 1 driven by the driving unit 14 in accordance with the navigation signal (in Step S7). Thereafter, the process returns to Step S6.

[0105] On the other hand, if a decision has been made in Step S6 that the communications unit 15 should have received no navigation signals (if the answer is NO in Step S6), then the processing unit 12 determines whether the communications unit 15 has received any orientation change instruction (in Step S8). If a decision has been made that the communications unit 15 should have received no orientation change instructions (if the answer is NO in Step S8), then the process proceeds to Step S10.

[0106] On the other hand, if a decision has been made in Step S8 that the communications unit 15 should have received any orientation change instruction (if the answer is YES in Step S8), then the processing unit 12 has the orientation changed via the driving unit 14 (in Step S9). As a result, the traveling direction of the autonomous mobile robot 1 is changed (i.e., inverted) into the

opposite direction, for example. Thereafter, the process returns to Step S6.

[0107] If a decision has been made in Step S8 that the communications unit 15 should have received no orientation change instructions (if the answer is NO in Step S8), then the processing unit 12 determines whether the communications unit 15 has received any relocation instructions (in Step S10). If a decision has been made in Step S10 that the communications unit 15 should have received no relocation instructions (if the answer is NO in Step S10), then the process returns to Step S6.

[0108] On the other hand, if a decision has been made in Step S10 that the communications unit 15 should have received any relocation instruction (if the answer is YES in Step S10), then the relocalizer 121 performs relocation processing using the marker M1 (in Step S11). The relocation processing will be described later. Thereafter, the process proceeds to Step S12.

[0109] In Step S12, the processing unit 12 has the autonomous mobile robot 1 driven autonomously by the driving unit 14 in accordance with, for example, the self-position information and self-orientation information stored in the storage unit 13 and the map information stored in the storage unit 13. Thereafter, the process returns to Step S6.

[0110] The relocation processing of Step S11 may be performed, for example, following the procedure of the flowchart shown in FIG. 5.

[0111] First, the relocalizer 121 acquires an image (captured image) from the onboard camera 11 (in Step S111). Note that in Step S111, the plurality of still pictures that form the moving picture output by the onboard camera 11 are sequentially acquired one after another.

[0112] Next, the relocalizer 121 determines whether the captured image acquired in Step S111 (hereinafter simply referred to as the “captured image”) includes the pair of images FiL and FiR (i.e., whether there are the pair of images FiL and FiR) (in Step S112). If a decision has been made that there should not be the pair of images FiL and FiR (if the answer is NO in Step S112), then the process proceeds to Step S115.

[0113] On the other hand, if a decision has been made in Step S112 that there should be the pair of images FiL and FiR (if the answer is YES in Step S112), then the relocalizer 121 determines, based on the pair of images FiL and FiR, whether the captured image satisfies the confronting condition (in Step S113). If a decision has been made that the captured image should not satisfy the confronting condition (if the answer is NO in Step S113), then the process proceeds to Step S115.

[0114] On the other hand, if a decision has been made in Step S113 that the captured image should satisfy the confronting condition (if the answer is YES in Step S113), then the relocalizer 121 determines whether the captured image satisfies the distance condition (in Step S114). If a

decision has been made that the captured image should not satisfy the distance condition (if the answer is NO in Step S114), then the process proceeds to Step S115. On the other hand, if a decision has been made that the captured image should satisfy the distance condition (if the answer is YES in Step S114), then the process proceeds to Step S116.

[0115] In Step S115, the relocalizer 121 has at least one of the position or the orientation adjusted via the driving unit 14. This allows the position of the autonomous mobile robot 1 to be adjusted closer toward the relocalization position Ps and/or the orientation of the autonomous mobile robot 1 to be adjusted closer toward the relocalization orientation Dr. Thereafter, the process returns to Step S111.

[0116] If a decision has been made in Step S114 that the captured image should satisfy the distance condition (if the answer is YES in Step S114), then the relocalizer 121 reads the QR code C1 using the captured image (in Step S116). In this manner, the relocalization position information and relocalization orientation information associated with the QR code C1 are read. At this time, the autonomous mobile robot 1 is located at the relocalization position Ps and facing the relocalization orientation Dr.

[0117] Next, the relocalizer 121 updates, based on the result of reading in Step S116, the self-position information and self-orientation information that are stored in the storage unit 13 (in Step S117). Updating the self-position information and self-orientation information into the relocalization position information and relocalization orientation information, respectively, in this manner allows the position and orientation of the autonomous mobile robot 1 to match the relocalization position information and relocalization orientation information, respectively. This contributes to relocalizing the autonomous mobile robot 1. Thereafter, the process returns to the high order flowchart (refer to FIGS. 3 and 4).

[0118] The (server 2 of the) navigation system 30 operates following the procedure shown in the flowchart of FIG. 6. Note that the processing shown in FIG. 6 is started when the robot management system 100 is activated and ended when the robot management system 100 is deactivated. It should also be noted that in the flowchart of FIG. 6, the result of positioning provided by the positioning system 20 is output as needed to the navigation system 30.

[0119] First, the navigation system 30 determines whether the communications unit 23 has received any mislocalization signal from the autonomous mobile robot 1 (in Step S21). If a decision has been made that the communications unit 23 should have received no mislocalization signals from the autonomous mobile robot 1 (if the answer is NO in Step S21), then process returns to Step S21.

[0120] On the other hand, if a decision has been made in Step S21 that the communications unit

23 should have received any mislocalization signal from the autonomous mobile robot 1 (if the answer is YES in Step S21), then the navigation system 30 determines which of the plurality of markers M1 is the nearest marker M1 for the autonomous mobile robot 1 (in Step S22). Specifically, the navigation system 30 determines a piece of marker location information most closely resembling the location information provided by the positioning system which belongs to multiple pieces of marker location information corresponding to the plurality of markers M1 to define the marker M1 corresponding to the piece of marker location information thus determined to be the nearest marker M1.

[0121] Next, the navigation system 30 generates a navigation signal that causes the autonomous mobile robot 1 to be navigated toward the nearest marker M1 determined in Step S22 (hereinafter simply referred to as the “marker M1”) and transmits the navigation signal thus generated to the autonomous mobile robot 1 (in Step S23).

[0122] Subsequently, the navigation system 30 determines, based on the result of positioning provided by the positioning system 20 and the marker location information corresponding to the marker M1, whether the autonomous mobile robot 1 has approached the vicinity of the marker M1 (in Step S24). If a decision has been made that the autonomous mobile robot 1 should not have approached the vicinity of the marker M1 (if the answer is NO in Step S24), then the navigation system 30 transmits an orientation change instruction to the autonomous mobile robot 1 (in Step S25). Thereafter, the process returns to Step S23.

[0123] On the other hand, if a decision has been made in Step S24 that the autonomous mobile robot 1 should have approached the vicinity of the marker M1 (if the answer is YES in Step S24), then the navigation system 30 determines whether the autonomous mobile robot 1 has reached the vicinity of the marker M1 (in Step S26). If a decision has been made that the autonomous mobile robot 1 should not have reached the vicinity of the marker M1 (if the answer is NO in Step S26), then the process returns to Step S23.

[0124] On the other hand, if a decision has been made in Step S26 that the autonomous mobile robot 1 should have reached the vicinity of the marker M1 (if the answer is YES in Step S26), then the navigation system 30 transmits a relocalization instruction to the autonomous mobile robot 1 (in Step S27). Thereafter, the process returns to Step S21.

[0125] (5) Variation

In one variation, the number of markers M1 provided in the area A1 may be one. If the number of markers M1 provided is one, then Step S22 may be omitted from the flowchart shown in FIG. 6.

[0126] The code C1 attached to the marker M1 does not have to be the QR code but may also be

a barcode or any other two-dimensional code. The code C1 may be any type of pattern (such as a uniquely identifiable pattern) which is uniquely identifiable within the area A1. For example, the code C1 may also be, for example, a sign such as a road sign or a logo mark of a company provided on a wall of a building.

[0127] Alternatively, the marker M1 may also be a landmark of a specific construction (such as a building) or a specific natural object (such as a tree). In that case, the unique shape of the landmark may serve as the code C1 included in the captured image.

[0128] The onboard camera 11 may be mounted pivotably onto the head or any other part of the autonomous mobile robot 1. The onboard camera 11 may be able to shoot the surroundings of the autonomous mobile robot 1 in front of, behind, and on the right or left of the autonomous mobile robot 1 in a state where the autonomous mobile robot 1 is at a stop, for example. Even in that case, when the autonomous mobile robot 1 is performing the adjustment operation, it is preferable to have the adjustment operation done easily that the optical axis of the onboard camera 11 face the front (surface) of the autonomous mobile robot 1. Nevertheless, as long as the onboard camera 11 directly confronts the marker M1, the body of the autonomous mobile robot 1 does not have to confront the marker M1.

[0129] The onboard camera 11 does not have to be the stereoscopic camera but may also be a single-lens camera having a single lens. In that case, the pair of images FiL and FiR are arranged horizontally symmetrically to each other with the QR code C1 interposed between them and have a mutually congruent shape. That is to say, the pair of images FiL and FiR have the same shape and the same size. In this case, the type of the same shape is not limited to any particular one. Also, if the sizes of the pair of images FiL and FiR included in the captured image are horizontally equal to each other (i.e., if the pair of images FiL and FiR are mutually congruent), then a decision may be made that the captured image should satisfy the confronting condition. Furthermore, if any one (e.g., the image FiL) of the pair of images FiL and FiR has a predetermined size in the captured image that has been determined to satisfy the confronting condition, then a decision may be made that the captured image should satisfy the distance condition as well.

[0130] Optionally, the autonomous mobile robot 1 may include a beacon transmitter and the communications device 4 may have the capability of a scanner for receiving an identification signal (as radio waves) from the beacon transmitter. Alternatively, the positioning system 20 may include a scanner instead of the surveillance camera 3. Still alternatively, the surveillance camera 3 may further have the scanner capability. In each of these cases, the positioning system 20 may receive, at the scanner, the identification signal (radio waves) from the beacon transmitter included in the autonomous mobile robot 1 and perform positioning in accordance with information such

as the received signal strength of the identification signal thus received.

[0131] The determination whether the autonomous mobile robot 1 is in the mislocalized state or not may be made by the (server 2 of the) navigation system 30. In that case, the autonomous mobile robot 1 may transmit the self-position information to the (server 2 of the) navigation system 30, and the (server 2 of the) navigation system 30 may determine, based on the self-position information provided by the autonomous mobile robot 1 and the result of positioning provided by the positioning system 20, whether the autonomous mobile robot 1 is in the mislocalized state.

[0132] Optionally, the autonomous mobile robot 1 may have a part of the positioning and navigation capabilities of the server 2. In that case, one (e.g., the communications unit 23) of the two communications units 15, 23 of the autonomous mobile robot 1 and the server 2 is omitted from the autonomous mobile robot 1 and the other communications unit (e.g., the communications unit 15) communicates wirelessly with the surveillance camera 3. In addition, the autonomous mobile robot 1 may include not only the onboard camera 11 but also a group of sensors including a motion sensor such as an acceleration sensor and a gyroscope and a geomagnetic sensor so that the majority of the positioning and navigation capabilities of the navigation system 30 may be performed by the autonomous mobile robot 1 without the server 2.

[0133] (6) Recapitulation

A robot management system (100) according to a first aspect includes: an autonomous mobile robot (1) including a camera (11); a positioning system (20); and a navigation system (30) including a storage unit (22). The autonomous mobile robot (1) moves autonomously while recognizing its own position and orientation within a predetermined area (A1). The positioning system (20) determines the current location of the autonomous mobile robot (1) within the predetermined area (A1). A marker (M1), to which a code (C1) is attached, is provided at a predetermined location within the predetermined area (A1). The code (C1) is associated with relocalization position information and relocalization orientation information. The relocalization position information and relocalization orientation information are used to allow the autonomous mobile robot (1) to recover from a mislocalized state to a relocalized state. The mislocalized state is a state where the autonomous mobile robot (1) erroneously recognizes at least its own position. The relocalized state is a state where the autonomous mobile robot (1) correctly recognizes its own position and orientation. The storage unit (22) stores marker location information indicating the predetermined location of the marker (M1). The navigation system (30) navigates, when a decision is made that the autonomous mobile robot (1) should be in the mislocalized state, the autonomous mobile robot (1) toward the predetermined location in accordance with the marker location information and based on a result of positioning provided by

the positioning system (20). The autonomous mobile robot (1) includes a relocalizer (121). The relocalizer (121) allows the autonomous mobile robot (1) to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera (11) after the autonomous mobile robot (1) has been navigated by the navigation system (30), the relocalization position information and the relocalization orientation information associated with the code (C1) attached to the marker (M1) included in the captured image.

[0134] According to this aspect, if the autonomous mobile robot (1) has been mislocalized, then the navigation system (30) navigates the autonomous mobile robot (1) toward a marker (M1) so that the autonomous mobile robot (1) may read a code (C1) attached to the marker (M1) to acquire relocalization position information and relocalization orientation information, thereby allowing the autonomous mobile robot (1) to be relocalized more easily.

[0135] In a robot management system (100) according to a second aspect, which may be implemented in conjunction with the first aspect, the relocalizer (121) makes the autonomous mobile robot (1) perform an adjustment operation based on the captured image generated by the camera (11) so that the code (C1) attached to the marker (M1) included in the captured image is readable for the autonomous mobile robot (1). The adjustment operation is the operation of adjusting at least one of the autonomous mobile robot's (1) own position or the autonomous mobile robot's (1) own orientation.

[0136] According to this aspect, having the autonomous mobile robot (1) adjust its own position and orientation using the captured image generated by the camera (11) allows the code (C1) to be read based on the image of the code (C1) included in the captured image.

[0137] In a robot management system (100) according to a third aspect, which may be implemented in conjunction with the first or second aspect, the relocalizer (121) makes the autonomous mobile robot (1) perform an adjustment operation based on the captured image generated by the camera (11) so that the autonomous mobile robot (1) faces a relocalization orientation (Dr) corresponding to the relocalization orientation information at a relocalization position (Ps) corresponding to the relocalization position information. The adjustment operation is the operation of adjusting at least one of the autonomous mobile robot's (1) own position or the autonomous mobile robot's (1) own orientation.

[0138] This aspect allows the position and orientation of the autonomous mobile robot (1) to match the relocalization position information and relocalization orientation information more closely.

[0139] In a robot management system (100) according to a fourth aspect, which may be implemented in conjunction with the third aspect, the marker (M1) further includes an adjustment

image (Fi). The adjustment image (Fi) is used to make the autonomous mobile robot (1) perform the adjustment operation. The relocalizer (121) makes the autonomous mobile robot (1) perform, based on the captured image generated by the camera (11), the adjustment operation using the adjustment image (Fi) included in the captured image.

[0140] According to this aspect, the captured image includes the adjustment image, thus allowing the adjustment operation to be performed more easily.

[0141] In a robot management system (100) according to a fifth aspect, which may be implemented in conjunction with the fourth aspect, the adjustment image (Fi) includes a pair of images (FiL and FiR). The pair of images (FiL and FiR) are arranged horizontally symmetrically to each other with the code (C1) interposed between the pair of images (FiL and FiR).

[0142] According to this aspect, the captured image includes the pair of images (FiL and FiR) arranged horizontally symmetrically to each other with the code (C1) interposed between them, thus contributing to having the adjustment operation done even more easily.

[0143] In a robot management system (100) according to a sixth aspect, which may be implemented in conjunction with the fifth aspect, the camera (11) outputs a moving picture. The captured image is any one of a plurality of still pictures that form the moving picture. The relocalizer (121) determines, one after another, whether each of the plurality of still pictures satisfies a predetermined condition and acquires the relocalization position information and the relocalization orientation information based on one of the plurality of still pictures which corresponds to a point in time when a decision is made that the predetermined condition should be satisfied. The predetermined condition is a condition about a positional relationship between the camera (11) and the marker (M1).

[0144] According to this aspect, reading the code (C1) using such a still picture that satisfies the predetermined condition based on the moving picture provided by the camera (11) allows the position and orientation of the autonomous mobile robot (1) to more closely match the relocalization position information and the relocalization orientation information, respectively.

[0145] In a robot management system (100) according to a seventh aspect, which may be implemented in conjunction with the sixth aspect, the predetermined condition includes a confronting condition. The confronting condition is a condition that the camera (11) should directly confront the code (C1) attached to the marker (M1). The relocalizer (121) determines that one of the plurality of still pictures which corresponds to a point in time when distances (dL and dR) from the camera (11) to the pair of images (FiL and FiR) included in the marker (M1) are equal to each other (i.e., $dL = dR$) should satisfy the confronting condition.

[0146] According to this aspect, using such a still picture that satisfies the confronting condition

allows the orientation of the autonomous mobile robot (1) to match the relocalization orientation information more closely.

[0147] In a robot management system (100) according to an eighth aspect, which may be implemented in conjunction with the seventh aspect, the predetermined condition further includes a distance condition. The distance condition is a condition that the camera (11) should be located at a predetermined distance from the code (C1) attached to the marker (M1). With respect to the still picture that has been determined to satisfy the confronting condition, the relocalizer (121) measures a distance from the camera (11) to the code (C1) attached to the marker (M1) based on at least one of respective distances (d_L and d_R) from the camera (11) to the pair of images (FiL and FiR) included in the marker (M1). The relocalizer (121) determines that the distance condition should be further satisfied when a difference between the distance thus measured and a distance from the predetermined location indicated by the marker location information to the relocalization position corresponding to the relocalization position information is equal to or less than a threshold value.

[0148] According to this aspect, using such a still picture that satisfies the distance condition allows the position of the autonomous mobile robot (1) to match the relocalization position information more closely.

[0149] In a robot management system (100) according to a ninth aspect, which may be implemented in conjunction with any one of the first to eighth aspects, a plurality of markers (M1) are provided within the predetermined area (A1). The marker (M1) is any one of the plurality of markers (M1). The predetermined location is any one of a plurality of predetermined locations corresponding to the plurality of markers (M1), respectively. The navigation system (30) navigates the autonomous mobile robot (1) in the mislocalized state toward one of the plurality of predetermined locations which is nearest to the autonomous mobile robot (1).

[0150] This aspect allows for shortening the amount of time it takes for the navigation system (30) to complete the navigation. In addition, this aspect also allows for expanding the range where the autonomous mobile robot (1) is movable autonomously (among other things, the range in which the autonomous mobile robot (1) is re-localizable even if the autonomous mobile robot (1) has been mislocalized once).

[0151] In a robot management system (100) according to a tenth aspect, which may be implemented in conjunction with any one of the first to ninth aspects, the camera (11) is an onboard camera (11). The positioning system (20) includes at least one of a surveillance camera (11) or a communications device (4). The surveillance camera (11) is installed within the predetermined area (A1). The communications device (4) is installed within the predetermined area and

transmits and/or receives radio waves to/from the autonomous mobile robot (1).

[0152] This aspect allows the positioning system (20) and the navigation system (30) to be implemented using existent equipment.

[0153] A relocalization method according to an eleventh aspect is designed to allow an autonomous mobile robot (1) including a camera (11) to recover from a mislocalized state to a relocalized state. The autonomous mobile robot (1) moves autonomously while recognizing its own position and orientation within a predetermined area (A1). The mislocalized state is a state where the autonomous mobile robot (1) erroneously recognizes at least its own position. The relocalized state is a state where the autonomous mobile robot (1) correctly recognizes its own position and orientation. A marker (M1), to which a code (C1) is attached, is provided at a predetermined location within the predetermined area (A1). The code (C1) is associated with relocalization position information and relocalization orientation information used to allow the autonomous mobile robot (1) to recover from the mislocalized state to the relocalized state. The relocalization method includes a navigation step (S21–S27) and a relocalization step (S11, S111–S117) to be performed with respect to the marker (M1). The navigation step (S21–S27) includes navigating, when a decision is made that the autonomous mobile robot (1) should be in the mislocalized state, the autonomous mobile robot (1) toward the predetermined location in accordance with marker location information indicating the predetermined location and based on a result of positioning obtained about a current location of the autonomous mobile robot (1). The relocalization step (S11, S111–S117) includes allowing the autonomous mobile robot (1) to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera (11) after the autonomous mobile robot (1) has been navigated by performing the navigation step (S21–S27), the relocalization position information and the relocalization orientation information associated with the code (C1) attached to the marker (M1) included in the captured image.

[0154] According to this aspect, if the autonomous mobile robot (1) has been mislocalized, then the autonomous mobile robot (1) is navigated toward a marker (M1) so that the autonomous mobile robot (1) may read a code (C1) attached to the marker (M1) to acquire relocalization position information and relocalization orientation information, thereby allowing the autonomous mobile robot (1) to be relocalized more easily.

Reference Signs List

[0155]	100	Robot Management System
	1	Autonomous Mobile Robot

11	Onboard Camera (Camera)
121	Relocalizer
22	Storage Unit
3	Surveillance Camera
4	Communications Device
20	Positioning System
30	Navigation System
M1	Marker
C1	Code
Fi	Adjustment Image
FiL and FiR	Pair of Images
Dr	Relocalization Orientation
Ps	Relocalization Position
dC	Predetermined Distance
dL and dR	Distances to Pair of Images

CLAIMS

[Claim 1] A robot management system comprising:

an autonomous mobile robot including a camera and configured to move autonomously while recognizing its own position and orientation within a predetermined area;

a positioning system configured to determine a current location of the autonomous mobile robot within the predetermined area; and

a navigation system including a storage unit configured to, with respect to a marker provided at a predetermined location within the predetermined area, store marker location information indicating the predetermined location, the marker including a code associated with relocalization position information and relocalization orientation information, the relocalization position information and the relocalization orientation information being used to allow the autonomous mobile robot to recover from a mislocalized state where the autonomous mobile robot erroneously recognizes at least its own position to a relocalized state where the autonomous mobile robot correctly recognizes its own position and orientation, the navigation system being configured to, when a decision is made that the autonomous mobile robot be in the mislocalized state, navigate the autonomous mobile robot toward the predetermined location in accordance with the marker location information and based on a result of positioning provided by the positioning system,

the autonomous mobile robot including a relocalizer, the relocalizer being configured to allow the autonomous mobile robot to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera after the autonomous mobile robot has been navigated by the navigation system, the relocalization position information and the relocalization orientation information associated with the code attached to the marker included in the captured image.

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

the relocalizer is configured to make the autonomous mobile robot perform an adjustment operation based on the captured image generated by the camera so that the code attached to the marker included in the captured image is readable for the autonomous mobile robot, the adjustment operation including adjusting at least one of the autonomous mobile robot's own position or the autonomous mobile robot's own orientation.

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

the relocalizer is configured to make the autonomous mobile robot perform an adjustment operation based on the captured image generated by the camera so that the autonomous mobile robot faces a relocalization orientation corresponding to the relocalization orientation information at a relocalization position corresponding to the relocalization position information, the adjustment operation including adjusting at least one of the autonomous mobile robot's own position or the autonomous mobile robot's own orientation.

[Claim 4] The robot management system of claim 3, wherein

the marker further includes an adjustment image for use to make the autonomous mobile robot perform the adjustment operation, and

the relocalizer is configured to make the autonomous mobile robot perform, based on the captured image generated by the camera, the adjustment operation using the adjustment image included in the captured image.

[Claim 5] The robot management system of claim 4, wherein

the adjustment image includes a pair of images arranged horizontally symmetrically to each other with the code interposed between the pair of images.

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

the camera is configured to output a moving picture,

the captured image is any one of a plurality of still pictures that form the moving picture, and

the relocalizer is configured to determine, one after another, whether each of the plurality of still pictures satisfies a predetermined condition about a positional relationship between the camera and the marker and acquire the relocalization position information and the relocalization orientation information based on one of the plurality of still pictures which corresponds to a point in time when a decision is made that the predetermined condition be satisfied.

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

the predetermined condition includes a confronting condition that the camera directly confront the code attached to the marker, and

the relocalizer is configured to determine that one of the plurality of still pictures which corresponds to a point in time when distances from the camera to the pair of images included in

the marker are equal to each other satisfy the confronting condition.

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

the predetermined condition further includes a distance condition that the camera be located at a predetermined distance from the code attached to the marker, and

the relocalizer is configured to, with respect to the still picture that has been determined to satisfy the confronting condition,

measure a distance from the camera to the code attached to the marker based on at least one of respective distances from the camera to the pair of images included in the marker, and

determine that the distance condition be further satisfied when a difference between the distance thus measured and a distance from the predetermined location indicated by the marker location information to the relocalization position corresponding to the relocalization position information is equal to or less than a threshold value.

[Claim 9] The robot management system of any one of claims 1 to 8, wherein

a plurality of markers are provided within the predetermined area,

the marker is any one of the plurality of markers,

the predetermined location is any one of a plurality of predetermined locations corresponding to the plurality of markers, respectively, and

the navigation system is configured to navigate the autonomous mobile robot in the mislocalized state toward one of the plurality of predetermined locations which is nearest to the autonomous mobile robot.

[Claim 10] The robot management system of any one of claims 1 to 9, wherein

the camera is an onboard camera, and

the positioning system includes at least one of: a surveillance camera installed within the predetermined area; or a communications device installed within the predetermined area and configured to transmit and/or receive radio waves to/from the autonomous mobile robot.

[Claim 11] A relocalization method designed to allow an autonomous mobile robot, including a camera and configured to move autonomously while recognizing its own position and orientation within a predetermined area, to recover from a mislocalized state where the autonomous mobile robot erroneously recognizes at least its own position to a relocalized state where the autonomous mobile robot correctly recognizes its own position and orientation,

the relocalization method comprising a navigation step and a relocalization step which are performed with respect to a marker, the marker being provided at a predetermined location within the predetermined area, the marker including a code associated with relocalization position information and relocalization orientation information, the relocalization position information and the relocalization orientation information being used to allow the autonomous mobile robot to recover from the mislocalized state to the relocalized state,

the navigation step including navigating, when a decision is made that the autonomous mobile robot be in the mislocalized state, the autonomous mobile robot toward the predetermined location in accordance with marker location information indicating the predetermined location and based on a result of positioning obtained about a current location of the autonomous mobile robot, and

the relocalization step including allowing the autonomous mobile robot to recover from the mislocalized state to the relocalized state by acquiring, based on a captured image generated by the camera after the autonomous mobile robot has been navigated by performing the navigation step, the relocalization position information and the relocalization orientation information associated with the code attached to the marker included in the captured image.