

DESCRIPTION

TITLE OF THE INVENTION

AUTONOMOUS MOBILE BODY AND ON-SITE OPERATION MANAGEMENT SYSTEM

TECHNICAL FIELD

[0001]

The present invention relates to an autonomous mobile body and an on-site operation management system, and in particular relates to an autonomous mobile body and an on-site operation management system which are advantageous for improving the quality of services provided to airport users, alleviating the workload of workers, and improving the maintenance management in airports.

BACKGROUND ART

[0002]

In recent years, among autonomous mobile robots such as automatic cleaning robots, numerous types equipped with the SLAM (Simultaneous Localization and Mapping) technology of creating an environmental map simultaneously with estimating its own position relative to the external environment are being proposed.

[0003]

An autonomous mobile robot that utilizes this SLAM technology is able to identify its own travel path and autonomously move within the environment by dynamically creating an environmental map, which represents the three-dimensional positions of objects existing in the real space, while estimating its own position with high accuracy.

[0004]

Under circumstances where recent demands for air transportation continue to increase, introduction of the foregoing autonomous mobile robots is being promoted for improving the quality of airport services and enhancing the management and operation of airports. Specifically, the introduction of autonomous mobile robots are expected to contribute to (1) the provision of quality services based on the safety and convenience of airport users, (2) the creation of an environment where airport workers can work salubriously, and (3) the support of dynamic maintenance management in the airport.

[0005]

Mobile human interface robots have been proposed from the past, and, for instance, PTL 1 discloses a mobile robot that follows a person by adopting the method of person identification of obtaining a point group from a spatial volume based on a three-dimensional depth image sensor.

[0006]

Moreover, PTL 2 proposes a follow-up carriage system which moves by following a worker engaged in delivery tasks within a factory, and which is also capable of responding to the movement of the leader, who turns the corner of a building or a passage, by switching control according to the deviation point based on detection using electromagnetic waves or sound waves.

CITATION LIST

PATENT LITERATURE

[0007]

PTL 1: Japanese Unexamined Patent Application Publication No. 2014-195868

PTL 2: Japanese Unexamined Patent Application Publication No. 2014-92862

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0008]

Meanwhile, when introducing a plurality of autonomous mobile robots in an airport, the specific manner of utilization remains unclear; for instance, how it will contribute to the improvement in the quality of services provided to airport users, how it will be advantageous in alleviating the workload of airport workers, and how it can be coordinated with the airport management system, and various proposals and improvements can be listed.

[0009]

The present invention was devised in view of the foregoing points, and an object of this invention is to provide an autonomous mobile body and an on-site operation management system which are advantageous for improving the quality of services provided to users, alleviating the workload of workers, and improving the maintenance management in facilities.

MEANS TO SOLVE THE PROBLEMS

[0010]

In order to achieve the foregoing object, the present invention provides an autonomous mobile body which moves freely within a facility, comprising: a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; and a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit, wherein the drive control unit causes the autonomous mobile body to enter a standby state once the target object enters a specified area designated as being off limits within the facility, and thereafter causes the autonomous mobile body to enter a movable state of following the target object once again once the target object leaves the specified area and wireless signals from the beacon terminal become receivable.

[0011]

According to the autonomous mobile body described above, it is possible to follow the target object (user) while accurately comprehending the existence and position (access point) of the target object, and, by causing the autonomous mobile body to enter a standby state while the target object is within a specified area, it is possible to constantly follow the target object within the facility without losing sight of the target object.

[0012]

The present invention additionally provides an on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein the on-site operation management system comprises a plurality of imaging cameras installed within the facility, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or

three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; and a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit, wherein the integrated control unit, upon receiving wireless signals representing a request from the autonomous mobile body, recognizes a position of the autonomous mobile body within the facility, and captures images of the autonomous mobile body with at least one or more of the imaging cameras so that the autonomous mobile body is centered in the captured images.

[0013]

According to the on-site operation management system described above, it is possible to remarkably improve the efficiency of remote monitoring (security enhancement) by coordinating with a plurality of imaging cameras, which are used for remote monitoring, upon moving the autonomous mobile robots.

[0014]

The present invention additionally provides an on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein the on-site operation management system comprises a plurality of air conditioners installed for climate control, including heating and cooling, of the overall facility, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into

contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit; and a temperature humidity sensor which is mounted at a predetermined height position from a floor surface for measuring a temperature and a humidity of an ambient environment, wherein the integrated control unit, upon receiving wireless signals including a measurement result of the temperature humidity sensor from the autonomous mobile body, recognizes a position of the autonomous mobile body within the facility, and controls each of the corresponding air conditioners so as to maintain the ambient temperature and humidity of the autonomous mobile body in an optimal state.

[0015]

In the on-site operation management system described above, the autonomous mobile body can detect in real-time the sensible temperature/humidity at a location that is close to the perceived temperature of humans while it is moving even when the air conditioning within the facility is being managed collectively, and it is thereby possible to constantly maintain a comfortable environment for the target object (user) based on dynamic HVAC control.

[0016]

The present invention additionally provides an on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein an inspection area including a first inspection gate for inspecting luggage placed on the autonomous mobile body and a second inspection gate for inspecting the target object is provided, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; and a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to

move by following the target object based on a recognition result of the tracking recognition unit, wherein the integrated control unit: permits the target object to exit the inspection area only when inspection results of both the first and second inspection gates are determined as being all clear; and causes the autonomous mobile body to stand by at a predetermined standby position until the target object arrives when an inspection result of the first inspection gate is determined as being problematic.

[0017]

According to the on-site operation management system described above, as a result of the target object (user) and the autonomous mobile body separately undergoing inspections at separate inspection gates, it is possible to alleviate the burden (stress) of the target object having to wait in line until reaching the inspection gate while carrying one's luggage.

[0018]

The present invention additionally provides an on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part; and a highly directional microphone which collects sounds of an ambient environment, wherein the integrated control unit, upon receiving sound signals representing the collected sounds of the highly directional microphone from the autonomous mobile body and determining that it is a requisite state based on the collected sounds, recognizes a position of the autonomous mobile body within the facility.

[0019]

According to the on-site operation management system described above, remote monitoring based on sounds alone is enabled by determining a requisite state such as an emergency situation based on the collected sounds of the ambient environment and locating the position thereof upon moving the autonomous mobile robot. In

addition, by coordinating with a plurality of imaging cameras, it is possible to remarkably improve the efficiency of remote monitoring (security enhancement).

[0020]

Furthermore, the integrated control unit, upon determining that the collected sounds based on sound signals received from each of the plurality of autonomous mobile bodies are of a same sound source, estimates the sound source position, and captures images of the estimated sound source position with at least one or more of the imaging cameras so that the estimated sound source position is centered in the captured images. According to this on-site operation management system, it is possible to further improve the efficiency of remote monitoring by instantaneously identifying and capturing images of the position of the sound source that caused the requisite state.

[0021]

The present invention additionally provides an on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility; a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part; and a cartridge-type first battery which is detachably mounted as a driving source, wherein the on-site operation management system comprises: a power supply station which is installed within the facility and uses a commercial power source as its supply source; and a power supply mobile body which is disposed to move freely within the facility and equipped with a plurality of detachable cartridge-type second batteries configured in the same manner as the first battery, wherein, when the integrated control unit causes the power supply mobile body to reach the power supply station, the integrated control unit charges the power from the commercial power source in each of the second batteries via the power supply station, and, upon receiving wireless signals from the autonomous mobile body representing that a remaining charge amount of the first battery has fallen below a predetermined amount, moves and

positions the power supply mobile body to a position near the autonomous mobile body, thereafter removes the first battery mounted in the autonomous mobile body, and replaces the removed first battery with one among the plurality of second batteries mounted in the power supply mobile body.

[0022]

According to the on-site operation management system described above, even when the remaining power of the first battery mounted in the autonomous mobile body is low, the original state can be restored in a relatively short period simply by replacing the first battery with a second battery retained in the power supply mobile body, and it is thereby possible to avoid the considerable loss of time that results from having to return to the charging process as with conventional methods.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0023]

According to the present invention, by coordinating with at least one or more autonomous mobile bodies, it is possible to realize an autonomous mobile body and an on-site operation management system capable of performing various types of management and maintenance in facilities in a manner that is remarkably more efficient in comparison to conventional methods.

BRIEF DESCRIPTION OF DRAWINGS

[0024]

[Fig. 1]

Fig. 1 is a conceptual diagram showing the overall configuration of the airport operation management system according to an embodiment of the present invention.

[Fig. 2]

Fig. 2 is a perspective view and a side view showing the exterior configuration of the autonomous mobile robot according to the same embodiment.

[Fig. 3]

Fig. 3 is a block diagram showing the functional configuration of the autonomous mobile robot according to the same embodiment.

[Fig. 4]

Fig. 4 is a flowchart showing the processing routine of the user recognition function.

[Fig. 5]

Fig. 5 is a flowchart showing the processing routine of the remote monitoring function.

[Fig. 6]

Fig. 6 is a flowchart showing the processing routine of the mobile battery charge function.

[Fig. 7]

Fig. 7 is a flowchart showing the processing routine of the security check function.

[Fig. 8]

Fig. 8 is a flowchart showing the processing routine of the dynamic air-conditioning control function.

DESCRIPTION OF EMBODIMENTS

[0025]

An embodiment of the present invention is now explained in detail with reference to the appended drawings.

[0026]

(1) Schematic configuration of airport operation management system

Fig. 1 shows an airport operation management system 1 of the present invention, and a plurality of autonomous mobile robots 2 are disposed so that they can freely move on the respective floors from the entrance/exit area of buses and taxis within the airport facility to the check-in counter, security check point and boarding gate within the passenger terminal.

[0027]

Furthermore, a power supply station 3 is installed at predetermined positions within the airport facility and passenger terminal, and each autonomous mobile robot 2 is able to automatically charge or replace its battery, without manual intervention, by connecting to the power supply station 3 as needed while detecting its remaining battery charge.

[0028]

Furthermore, in the present invention, a power supply mobile robot 4 equipped with a plurality of drive batteries 4A is disposed to be freely movable within the facility, and, when positioned near each of the autonomous mobile robots 2, the power supply mobile robot 4 functions as a relay of the power supply station 3 by automatically replacing the battery of the autonomous mobile robot 2.

[0029]

Moreover, in the airport operation management system 1, a plurality of imaging cameras are installed at all locations of the airport facility and the passenger terminal where security management is required, and remote monitoring is performed by storing video data based on the imaging results of all imaging cameras 5.

[0030]

Moreover, in the airport operation management system 1, a plurality of air conditioners (climate control systems) 6 for heating/cooling the passenger terminal as well as purifying the air of the passenger terminal are respectively installed at predetermined positions so as to manage the temperature and air cleanliness of the entire passenger terminal.

[0031]

Furthermore, in the airport operation management system 1, a vast number of illumination apparatuses 7 are disposed within the passenger terminal and other airport facilities located outside the passenger terminal, and the illumination level thereof is adjusted according to the operating hours of the airport.

[0032]

The plurality of imaging cameras 5, the plurality of air conditioners 6, and the plurality of illumination apparatuses 7 described above are all collectively managed and controlled by a facility integrated control unit 8 which governs the control of the overall airport operation management system 1.

[0033]

The facility integrated control unit 8 fulfills the linkage function between the airport operation management system 1 and the respective autonomous mobile robots 2 by exchanging various types of information with the respective autonomous mobile robots 2 via wireless communication.

[0034]

Moreover, the facility integrated control unit 8 is also managing the power supply station 3 and the power supply mobile robot 4, and is able to control the charging process to the power supply station 3 and the guided movement and automatic battery replacement of the power supply mobile robot 4.

[0035]

(2) Configuration of autonomous mobile robot

As shown in Fig. 2(A) to Fig. 2(C), the autonomous mobile robot 2 is a two-wheel drive mobile body that can move autonomously or based on external operation, and

comprises a substantial disk-shaped drive base part 10 in which the two drive wheels of the autonomous mobile robot 2 are mounted so as to form a diameter, and a substantial U-shaped sensor retaining part 11 which is erected from the upper part of the flat surface of the drive base part 10.

[0036]

The drive base part 10 comprises a pair of drive wheels 12a, 12b provided at the lower part of the body and at either side of the center position in the front-back direction, and a front caster 13a and a rear caster 13b which are respectively provided at the front and back of the drive base part 10 and capable of oscillating freely according to the movement of the autonomous mobile robot 2. The left and right drive wheels 12a, 12b are each independently rotatably driven by drive motors 14a, 14b, and the autonomous mobile robot 2 moves forward or backward based on the forward rotation or reverse rotation of the drive wheels 12a, 12b, and moves rightward or leftward while moving forward by applying a difference to the forward rotating speed of the drive wheels 12a, 12b. Moreover, the autonomous mobile robot 2 can spin; that is, turn about in its current position by rotatably driving the drive wheels 12a, 12b in mutually opposite directions.

[0037]

A laser range sensor 15 for detecting obstacles in the obliquely forward direction and crosswise direction is provided at a position that is anterior to the front caster 13a in the drive base part 10. Moreover, an RGB-D sensor 16 and a 3D range image sensor 17 capable of three-dimensional scanning are provided at the upper center of the sensor retaining part 11.

[0038]

Specifically, the laser range sensor 15 emits light to the target (obstacle) viewed from its location, and receives the reflected light to calculate the distance to the target (obstacle). As a result of measuring the distance at given angular intervals, the laser range sensor 15 can obtain fan-like distance information on a plane in a range of up to 30 m and an angle of 240 degrees.

[0039]

Moreover, the RGB-D sensor 16 has a depth sensor capable of measuring the distance to the target (obstacle) viewed from the camera in addition to the RGB color camera function, and is able to three-dimensionally scan the target. The depth sensor is configured from an infrared sensor, and captures the image of the target in a state

where a single pattern of the structured light is projected onto the target, and calculates the depth of the respective points on the image based on triangulation by using its parameters.

[0040]

For example, when Kinect (brand name of Microsoft Corporation) is applied as the RGB-D sensor 16, it is possible to capture images in a horizontal field of view of 57 degrees, a vertical field of view of 43 degrees, and a sensor range of 1.2 m to 3.5 m, and the RGB image will be 640 × 480 pixels and the Depth image will be 320 × 240 pixels, and these can both be acquired at 30 frames/second.

[0041]

The reason why the RGB-D sensor 16 is mounted at the upper center of the sensor retaining part 11 is because it is not possible to secure a vertical field of view with the drive base part that is close to the floor surface, and a height of 0.6 m to 1.8 m from the floor surface needs to be secured.

[0042]

The 3D range image sensor 17 emits LED pulses and measures the arrival time of the reflected light from the target in pixel units and simultaneously superimposes the acquired image information, and thereby calculates the distance information to the target in pixel units. Because the 3D range image sensor 17 has a detection capability of higher precision in comparison to the RGB-D sensor 16 described above and a field of view that is wider than the laser range sensor 15, it is required as a complementary sensor for outdoor use. For example, when Pixel Soleil (product name of Nippon Signal Co., Ltd.) is applied as the 3D range image sensor 17, it is possible to capture images in a horizontal field of view of 72 degrees, a vertical field of view of 72 degrees, and a sensor range of 0.3 m to 4.0 m.

[0043]

(3) Internal circuit configuration of autonomous mobile robot

Fig. 3 is a configuration diagram of the integrated control unit 20 mounted in the autonomous mobile robot 2. The integrated control unit 20 is basically configured from a microcomputer, and comprises a drive control unit 11 which governs the overall control thereof, a target travel path storage unit 12 which stores travel path information, and an actuation control unit 13 which controls the drive system.

[0044]

The drive control unit 11 determines the suitability of the travel path or the necessity of

changing the travel path and determines the existence of obstacles blocking the travel path while simultaneously estimating its own position based on the travel path information from the target travel path storage unit 12, which stores pre-set travel path information, and the respective detection signals from the laser range sensor 15, the RGB-D sensor 16 and the 3D range image sensor 17, and creating an environmental map described later.

[0045]

For example, the drive control unit 11 determines whether the autonomous mobile robot 2 on the passenger terminal floor will come into contact with obstacles blocking the travel path such as the wall surface or location in front of the stairs upon moving while following the user, and once stops immediately before coming into contact with such obstacles and then changes the moving direction of the autonomous mobile robot 2 in a direction of following the user. The drive control unit 11 sends the determined travel path information to the actuation control unit 13, and the actuation control unit 13 controls the left and right motor drivers 24a, 24b and controls the rotation of the drive motors 14a, 14b according to the received travel path information.

[0046]

In effect, the autonomous mobile robot 2 utilizes the foregoing SLAM technology and automatically creates an environmental map of the target area where users or workers can walk within the airport facility and the passenger terminal.

[0047]

Specifically, the autonomous mobile robot 2 creates an environmental map which represents the overall intended target area while setting, as the area indicating the mobile environment, a local map on a grid that is partitioned with a two-dimensional lattice based on the distance information and angle information relative to the target obtained from the laser range sensor 15 and the 3D range image sensor 17.

[0048]

Simultaneously, the autonomous mobile robot 2 calculates its travel distance based on the rotation angle read from an encoder (not shown) corresponding to the pair of drive wheels 12a, 12b of the autonomous mobile robot 2, and estimates its own position based on the matching of the subsequent location map and the environmental map created up to such point in time, and its travel distance.

[0049]

Moreover, the autonomous mobile robot 2 comprises a communication unit 25 which

performs wireless communication, and sends the data of the foregoing environmental map according to the control of the integrated control unit 20, and receives various control data from the facility integrated control unit 8 (Fig. 1) of the airport operation management system 1.

[0050]

Moreover, a temperature/humidity sensor 30 is mounted at the upper center of the sensor retaining part 11 of the autonomous mobile robot 2, and the temperature/humidity sensor 30 can be used to measure the temperature and humidity of the ambient environment at a predetermined height position from the ground (height position corresponding to the waist of an adult).

[0051]

Furthermore, the autonomous mobile robot 2 is equipped with an illuminance sensor 31 configured from a photo IC having spectral sensitivity characteristics that are close to the visual sensitivity of humans, and the autonomous mobile robot 2 is thereby able to measure the illuminance level of the ambient environment.

[0052]

Furthermore, the autonomous mobile robot 2 is equipped with a microorganism sensor 32 that uses the heating fluorescence enhancement method (fluorescent detection method), and the autonomous mobile robot 2 is thereby able to measure the amount of microorganisms, such as bacteria and fungus, floating in the air in a relatively short period. For example, when BM-300C (product name of Sharp Corporation) is applied as the microorganism sensor 32, the amount of microorganisms can be measured, at minimum, in approximately 10 minutes.

[0053]

In addition, an infrared thermography 33 is mounted at the upper center of the sensor retaining part 11 of the autonomous mobile robot 2, and the autonomous mobile robot 2 is thereby able to comprehend the relationship between the environmental temperature and the user's body surface temperature, and estimate the skin temperature of a user whose body temperature is 38 degrees or higher.

[0054]

Moreover, a load sensor 34 is mounted on the drive base part 10 of the autonomous mobile robot 2, and the autonomous mobile robot 2 is thereby able to measure the weight of the hand luggage placed on the upper surface of the drive base part 10.

[0055]

Furthermore, two drive batteries 16 (16A, 16B) which are configured from a secondary battery or a capacitor and have a relatively large capacity are built into the autonomous mobile robot 2, and are used as the power supply source capable of being switched in parallel. These drive batteries 16 are configured from detachably loadable cartridges.

[0056]

When the autonomous mobile robot 2 determines that the remaining charge amount of either drive battery 16A, 16B is equal to or less than a predetermined amount in a standby state up to the next scheduled time of operation, the autonomous mobile robot 2 proceeds to an external power supply station 3 (Fig. 1), and becomes conductive with an internal commercial power source via the power supply station 3, and charges itself via contactless power supply.

[0057]

(4) User recognition method by autonomous mobile robot

The autonomous mobile robot 2 of the present invention has a communication unit 25 (Fig. 3) for a beacon adopting the communication standard of BLE (Bluetooth (registered trademark) Low Energy), and is thereby able to receive wireless signals emitted from a beacon terminal (not shown) in the possession of the user to receive the service, and follow the user while accurately comprehending the existence and position (access point) of the user.

[0058]

The beacon terminal is preferably lightweight, compact and of low power consumption in consideration of the convenience of the user to possess the beacon terminal. As the beacon terminal, particularly preferable is a thin and lightweight type having a thickness of 2.5 mm and a weight of 3 g which is flexible and deformable and which is free of maintenance, such as battery replacement, based on power supply control technology capable of applying a thin film solar cell and temporarily suspending power source monitoring.

[0059]

Moreover, a predetermined area outside the user's passage (for instance, restroom, lounge, or smoking room) within the airport passenger terminal is designated as the restricted area of the autonomous mobile robot 2, and the autonomous mobile robot 2 stores such predetermined area upon creating the environmental map by utilizing the foregoing SLAM technology.

[0060]

Fig. 4 shows the processing routine of the recognition function of the corresponding user by the autonomous mobile robot 2. The autonomous mobile robot 2, while following the user (SP0), determines whether or not the user has entered (stopped by) a restricted area (SP1), and causes itself (autonomous mobile robot 2) to enter a standby state once the user has entered the restricted area (SP2).

[0061]

Here, the autonomous mobile robot 2 determines whether or not a remote monitoring mode (Fig. 5) has been selected by the airport operation management system 1 (SP3), and, upon obtaining a positive result in the foregoing determination, proceeds to the processing routine of the remote monitoring function (SP10) shown in Fig. 5.

[0062]

In the processing routine (SP10) shown in Fig. 5, when the autonomous mobile robot 2 is in a standby state, the autonomous mobile robot 2 commences the detection of objects approaching within a predetermined distance (for instance, a radius of 50 cm) while rotating or oscillating so as to monitor all directions centered around the standby position (SP11). When the autonomous mobile robot 2 detects an object intruding within the predetermined distance (SP12), the autonomous mobile robot 2 emits a warning based on sound and/or light, and additionally commences video/audio recording of the object (SP13).

[0063]

Furthermore, in cases where the load sensor 34 reacts such as when someone attempts to steal the user's luggage or in cases where the object is in a non-contact state for a predetermined time or longer, the autonomous mobile robot 2 additionally determines whether there is an emergency situation (SP14), and sends wireless signals representing an emergency state to the facility integrated control unit 8.

[0064]

When the facility integrated control unit 8 receives wireless signals from the autonomous mobile robot 2, the facility integrated control unit 8 recognizes the position of the autonomous mobile robot 2 within the airport facility, and captures images of the autonomous mobile robot 2 with at least one or more imaging cameras 5 so that the autonomous mobile robot 2 is centered in the captured images (SP15).

[0065]

Subsequently, the autonomous mobile robot 2 returns to the processing routine (SP4)

shown in Fig. 4, and, upon detecting that the object has moved outside the predetermined distance, discontinues the warning based on sound/light, and additionally discontinues the video/audio recording operation.

[0066]

When the autonomous mobile robot 2 recognizes that the user has left the restricted area and wireless communication from the beacon terminal in the user's possession becomes receivable (SP5), the autonomous mobile robot 2 causes itself (autonomous mobile robot 2) to enter a movable state of following the user once again (SP6). Here, the autonomous mobile robot 2 discontinues its rotation or oscillation for monitoring and ends the detection of the objects. Subsequently, once the user returns to the passage and starts moving, the autonomous mobile robot 2 also moves by following the user (SP7).

[0067]

Note that an imaging camera and a highly directional microphone (both not shown) are mounted at the upper center of the sensor retaining part 11 of the autonomous mobile robot 2, and the autonomous mobile robot 2 is thereby able to collect sounds simultaneously with acquiring the video of the ambient environment, and record sounds and images if any trouble occurs around the autonomous mobile robot 2. Furthermore, it is possible to remarkably improve the efficiency of remote monitoring (security enhancement) by coordinating with a plurality of imaging cameras 5 which are used for remote monitoring.

[0068]

Furthermore, the autonomous mobile robot 2 is able to determine the existence of an emergency situation based on the user's spoken words or the recorded video/audio contents acquired by using the imaging camera and the highly directional microphone and send the data thereof to the facility integrated control unit 8 via the communication unit as needed, and thereby notify airport personnel of an emergency situation.

[0069]

(5) Drive battery charge method of autonomous mobile robot

In the airport operation management system 1 of the present invention, the external power supply station 3 (Fig. 1) is installed at a plurality of predetermined positions within the airport facility, and, when the autonomous mobile robot 2 is positioned with the commercial power source as the supply source, the drive batteries 16 can be

charged via contact or contactless power supply.

[0070]

Furthermore, the present invention is also configured such that, without the autonomous mobile robot 2 having to directly stop by the power supply station 3, the power supply mobile robot 4 equipped with a plurality of drive batteries 4A approaches the autonomous mobile robot 2 that made a charge request and replaces the drive battery 4A.

[0071]

The drive system and other components of the power supply mobile robot 4 are basically configured in the same manner as the autonomous mobile robot 2 described above, the power supply mobile robot 4 is loaded with a plurality (for instance, eight) cartridge-type drive batteries 4A having the same configuration as the drive batteries 16 loaded in the autonomous mobile robot 2, and the drive batteries 4A can be selectively mounted and dismounted according to the drive control of a mechanical system not shown. The power supply mobile robot 4 is positioned at the power supply station 3 in advance, and prepares the drive batteries 4A by charging them, via contact or contactless power supply, from the commercial power source via the power supply station 3.

[0072]

Fig. 6 shows the processing routine of the mobile battery charge function (SP20) based on the coordination of the autonomous mobile robot 2 and the power supply mobile robot 4. When the facility integrated control unit 8 receives wireless signals sent from the autonomous mobile robot 2 representing that the remaining charge amount of the drive battery 16 is equal to or less than a predetermined amount (SP21), the facility integrated control unit 8 moves and positions the power supply mobile robot 4 near the corresponding autonomous mobile robot 2 (SP22).

[0073]

Next, the power supply mobile robot 4 removes the drive battery 16 loaded in the autonomous mobile robot 2, and replaces the removed drive battery 16 with one of the plurality of drive batteries 4A loaded in the power supply mobile robot 4 (SP23).

[0074]

Here, the power supply mobile robot 4 preferentially replaces the removed drive battery 16 of the autonomous mobile robot 2 with the drive battery 4A having the largest remaining charge amount among the plurality of drive batteries 4A. This is

effective in that it is possible to prevent the trouble of having to once again replace the battery in cases where the removed battery is replaced with a drive battery having a low remaining charge amount.

[0075]

As described above, the autonomous mobile robot 2 manages the remaining power of the built-in drive battery 16 and, when the remaining power becomes a predetermined value or less, the autonomous mobile robot 2 determines, according to the current activity status, whether to switch to the other drive battery 16 (16A or 16B), or proceed to the nearest power supply station 3, or call the power supply mobile robot 4 via wireless communication.

[0076]

Consequently, even when the remaining power of the drive battery 16 is low, the autonomous mobile robot 2 can return to its original state in a relatively short period simply by replacing the drive battery 16, and it is thereby possible to avoid the considerable loss of time that results from having to return to the charging process as with conventional methods.

[0077]

Note that, without limitation to setting the power supply mobile robot 4 near the power supply station 3 as the standard setup location within the airport facility, the facility integrated control unit 8 may also suitably designate a different location where the power supply mobile robot 4 can most efficiently approach the corresponding autonomous mobile robot 2 while comprehending the operational status of a plurality of autonomous mobile robots 2.

[0078]

Moreover, because the power supply mobile robot 4 comprises a plurality of drive batteries 4A, the power supply mobile robot 4 can also be used as an emergency power source during emergency situations. In other words, a receptacle having the same standard as the receptacle (plug-in) of the commercial power source is provided at a predetermined position of the power supply mobile robot 4, and the receptacle is conductively connected with the plurality of built-in drive batteries. Consequently, by plugging an attachment plug of various types of general-purpose equipment into the receptacle provided at a predetermined position, power can be supplied in the same manner as a commercial power source.

[0079]

(6) Other additional equipment of autonomous mobile robot

The autonomous mobile robot 2 may also be equipped with an information input device (not shown) as needed for posting signs to users or displaying maps to workers.

[0080]

This information input device has a touch panel display mounted on the front face of the body, and a CPU, a graphic processor unit, a sound processor, a memory and other mechanisms required for various types of information processing are mounted, together with batteries, in the rear face thereof. The display is configured from a liquid crystal panel or an organic EL (Electric Luminescence) panel, and the top surface is covered, for instance, with a resistive or electrostatic capacitance touch panel. Moreover, the information input device additionally comprises a communication unit such as an infrared port or a wireless LAN for communicating with the autonomous mobile robots and other external devices.

[0081]

The display shows, according to the function, a menu screen, a screen with icons required for the user to perform input operations, and an environmental map image as the result of information processing. Furthermore, a GUI (Graphical User Interface) for the user to perform input operations is displayed on the screen. The user can perform input operations to the information input device by touching or sliding his/her finger on the touch panel in a manner of operating the GUI.

[0082]

Moreover, a laser pointer or a projector (both not shown) is mounted to the drive base part 10 or the sensor retaining part 11 of the autonomous mobile robot 2, and the autonomous mobile robot 2 is thereby able to emit light to display a mark (for instance, an arrow) showing its advancing direction on the floor surface that is approximately 1 m ahead of itself while moving so that the people around the autonomous mobile robot 2 can visually confirm the advancing direction of the autonomous mobile robot 2.

[0083]

Furthermore, in the present invention, the autonomous mobile robot 2 can also be applied as an automatic cleaning robot by mounting an external cleaning unit (not shown). Specifically, as a result of integrating the cleaning unit by mounting the cleaning unit on the upper part of the flat surface of the drive base part 10 while engaging it with the sensor retaining part 11 of the autonomous mobile robot 2, both

the transfer and cleaning functions can be utilized as an autonomous mobile cleaning robot substantially having an overall cylindrical shape.

[0084]

Furthermore, the autonomous mobile robot 2 may also be equipped with an AED (automated external defibrillator) and approach the corresponding user in an emergency (for instance, upon discovering a user who is laying flat on the floor), and thereafter emit sounds or light to convey the emergency situation to the people around the autonomous mobile robot 2.

[0085]

Note that, after placing the user's luggage or worker's goods on the disk-shaped surface of the drive base part 10 of the autonomous mobile robot 2, an antitheft net (for instance, mesh of 18 mm or 25 mm) made from a highly fire-resistant and tough material (polypropylene, polyester, nylon or the like) is used to cover such luggage or goods as needed. The ends of this antitheft net are provided with electronic or mechanical locks for engaging with the drive base part 10, and can be unlocked only by the person using the autonomous mobile robot 2 based on the beacon terminal or special key in the possession of the user or worker, or based on dial input.

[0086]

(7) Target-based functions of autonomous mobile robot and airport operation management system

(7-1) Functions of autonomous mobile robot for users

(7-1-1) From airport facility (entrance/exit area) to check-in counter within passenger terminal

The autonomous mobile robot 2 stands by at the entrance/exit area of the airport facility according to the user's call or advance reservation, and sets itself (autonomous mobile robot 2) to a movable state for following the user once the user turns on his/her beacon terminal.

[0087]

After the user places his/her luggage on the drive base part 10 of the autonomous mobile robot 2 and starts walking, the autonomous mobile robot 2 starts to move by following the user.

[0088]

The autonomous mobile robot 2 moves while following the user, and continues its movement from the entrance/exit area of the airport facility to the check-in counter of

the passenger terminal while maintaining a predetermined distance from the user and giving consideration so that it will not get in the way of other users.

[0089]

When the user enters a restricted area, such as the restroom, on his/her way to the check-in counter, the autonomous mobile robot 2 executes the processing routine shown in Fig. 4 and Fig. 5, and stands by until it once again receives wireless signals from the user's beacon terminal.

[0090]

Note that, by image-scanning the contents (including bar codes) indicated on the user's airline ticket and acquiring information from the airport operation management system via wireless communication, the autonomous mobile robot 2 can also identify the check-in counter corresponding to the airline ticket, and guide the user to the corresponding check-in counter.

[0091]

In the foregoing case, the user may also board the autonomous mobile robot 2 together with one's luggage to be carried to the check-in counter. The user may also deboard and stop by at one's intended location before reaching the check-in counter by designating the path using the touch panel of the information input device, and the autonomous mobile robot 2 constantly moves by positioning itself near the user.

[0092]

Otherwise, the user may also follow the autonomous mobile robot 2. In the foregoing case, when the user stops walking or enters a predetermined area, the autonomous mobile robot 2 also stops or stands by in accordance with the user's movement.

[0093]

When the user enters the passenger terminal and arrives at the check-in counter, the autonomous mobile robot 2 sends the weight of the luggage placed on the drive base part 10 to the input terminal of the counter clerk, and displays numerical figures on the input terminal. When the user only places checked luggage (luggage to be checked in) on the drive base part 10 upon excluding carry-on luggage, the user can determine whether the checked luggage is within the weight limit before the airport personnel loads such checked luggage onto the load measuring conveyer belt.

[0094]

Note that, while the user is in the passenger terminal, the autonomous mobile robot 2 measures the skin temperature of the user's facial surface by using infrared

thermography 33 and determines whether the user's body temperature is 38 degrees or higher. When the user's body temperature is consequently 38 degrees or higher, the autonomous mobile robot 2 determines that the user is of ill health and notifies the user to such effect based on voice notification, and simultaneously sends data to the airport personnel to such effect.

[0095]

(7-1-2) After check-in to security check point

Once the user places his/her carry-on luggage on the drive base part 10 and starts walking, the autonomous mobile robot 2 starts moving and follows the user.

[0096]

The autonomous mobile robot 2 moves while following the user, and continues its movement from the check-in counter to the security check point while maintaining a predetermined distance from the user and giving consideration so that it will not get in the way of other users.

[0097]

When the user enters a restricted area, such as the restroom, on his/her way to the security check point, the autonomous mobile robot 2 executes the processing routine shown in Fig. 4 and Fig. 5, and stands by until it once again receives wireless signals from the user's beacon terminal.

[0098]

Upon arriving at the security check point, the autonomous mobile robot 2 detects the waiting state of users at a plurality of entrances, and proceeds to the entrance with the fewest people waiting in line. Subsequently, the autonomous mobile robot 2 moves away from the user or, when the user boards the drive base part 10 together with one's luggage, the autonomous mobile robot 2 gets in line behind the preceding user, and proceeds by maintaining a predetermined clearance so that it will not collide with the preceding user.

[0099]

In the airport operation management system 1 of the present invention, the security check point is separated for independently inspecting the autonomous mobile robot 2 and the user, and the user is allowed to pass through the security check point only when both the autonomous mobile robot 2 and the user in possession of the corresponding beacon terminal are determined as being all clear.

[0100]

Specifically, at the entrance of the security check point, the user confirms that he/she is in possession of one's beacon terminal, and additionally confirms that his/her luggage is placed on the drive base part 10 of the autonomous mobile robot 2. Here, it is desirable for the user to also store his/her valuables including metal items among one's belongings in a safety tray (not shown) mounted on the autonomous mobile robot 2.

[0101]

Next, when the user enters the entrance of the security check point, the autonomous mobile robot 2 also enters the entrance of the same security check point, and the user proceeds to the human-only lane, and the autonomous mobile robot 2 proceeds to the robot-only lane, respectively. Fig. 7 shows the processing routine of the security check function (SP30).

[0102]

At the security check point (inspection area), only when the inspection results of both the inspection gate (second inspection gate) corresponding to the human-only lane and the inspection gate (first inspection gate) corresponding to the robot-only lane are determined as being all clear (SP31), the user is permitted to exit the security check point (SP34).

[0103]

When the inspection result of the hand luggage at the inspection gate of the robot-only lane is determined as being problematic (SP32), the autonomous mobile robot 2 leaves the robot-only lane and is moved to a predetermined standby location, and stands by until the corresponding user arrives (SP33).

[0104]

After the user's explanation to the inspection clerk is complete, the autonomous mobile robot 2 returns to the original robot-only lane, and once again passes through the inspection gate and undergoes inspection (SP31).

[0105]

Subsequently, after the user and the autonomous mobile robot 2 respectively pass through the inspection gates without any problem, they exit the security check point (SP35), and the autonomous mobile robot 2 approaches the user in possession of the corresponding beacon terminal and stands by in a movable state of following the user.

[0106]

As a result of separating the inspection gates and individually inspecting the user and

the autonomous mobile robot 2 at the security check point as described above, it is possible to alleviate the burden of the user having to wait in line until reaching the inspection gate while carrying one's hand luggage as with conventional methods. In particular, because the user can comfortably approach the inspection gate without regard to one's hand luggage, even when one's hand luggage arrives later, the user merely has to wait at the rear of the inspection gate, and it is possible to alleviate the user's stress because there is no mental burden of waiting in line to receive one's hand luggage.

[0107]

(7-1-3) From security check point to boarding gate

After the user, who passed through the security check point, places his/her carry-on luggage on the drive base part 10 of the autonomous mobile robot 2 and starts walking, the autonomous mobile robot 2 starts to move by following the user.

[0108]

The autonomous mobile robot 2 moves while following the user, and continues its movement from the security check point to the waiting lobby in front of the boarding gate while maintaining a predetermined distance from the user and giving consideration so that it will not get in the way of other users.

[0109]

When the user enters a restricted area, such as the restroom, on his/her way to the boarding gate, the autonomous mobile robot 2 executes the processing routine shown in Fig. 4 and Fig. 5, and stands by until it once again receives wireless signals from the user's beacon terminal.

[0110]

Note that, by image-scanning the contents (including bar codes) indicated on the user's airline ticket and acquiring information from the airport operation management system 1 via wireless communication, the autonomous mobile robot 2 can also identify the boarding gate corresponding to the airline ticket, and guide the user to the corresponding boarding gate.

[0111]

In the foregoing case, the user may also board the autonomous mobile robot 2 together with one's luggage to be carried to the boarding gate. The user may also deboard and stop by at one's intended location before reaching the boarding gate by designating the path using the touch panel of the information input device, and the

autonomous mobile robot 2 constantly moves by positioning itself near the user.

[0112]

Otherwise, the user may also follow the autonomous mobile robot 2. In the foregoing case, when the user stops walking or enters a predetermined area, the autonomous mobile robot 2 also stops or stands by in accordance with the user's movement.

[0113]

(7-2) Functions of autonomous mobile robot for workers

(7-2-1) Delivery support for replenishing goods for sale

The autonomous mobile robot 2 can also play the role of a delivery robot for replenishing goods to be sold in vending machines and shops within the airport.

[0114]

The autonomous mobile robot 2 sets itself (autonomous mobile robot 2) to a movable state for following the worker once the worker turns on his/her beacon terminal. After the worker places goods on the drive base part 10 of the autonomous mobile robot 2 and starts walking, the autonomous mobile robot 2 starts to move by following the worker.

[0115]

The autonomous mobile robot 2 moves while following the worker, and sequentially continues its movement from the storage location of goods of the airport facility to the predetermined locations of replenishing goods (vending machines and shops) while maintaining a predetermined distance from the worker and giving consideration so that it will not get in the way of general airport users.

[0116]

(7-2-2) Cooperative control with wearable motion assisting device

In recent years, wearable motion assisting devices capable of performing voluntary and autonomous feedback control based on biological signals are being proposed (Design Application No. 2014-5841, Design Application No. 2014-5842, Design Application No. 2014-5843, Design Registration No. 1515524 among others) in order to reduce the worker's lumbar stress during loading and unloading work.

[0117]

This kind of wearable motion assisting device is worn on the back of the worker's waist with cuffs during use, and has the function of analyzing the stress loading on the worker's lumbar spine and lumbar disc when the worker lifts heavy goods, and alleviating the burden on the worker's waist.

[0118]

A beacon terminal is built into the body of this wearable motion assisting device, and the autonomous mobile robot 2 follows the worker while accurately comprehending the existence and position (access point) of the worker based on the wireless signals transmitted from the beacon terminal.

[0119]

The autonomous mobile robot 2 moves while following the worker wearing the wearable motion assisting device, and once stops upon recognizing the worker's operation or verbal instruction.

[0120]

Moreover, when the autonomous mobile robot 2 is equipped with the information input device described above, it is also possible to display on the display screen, as stopping places, all locations of vending machines and shops that require the replenishment of goods, and set the delivery path and delivery order according to the worker's designation.

[0121]

When the stopping places have been designated by the worker in advance as described above, the autonomous mobile robot 2 proceeds to the next stopping place without following the worker while giving consideration so that it will not get in the way of general airport users.

[0122]

With the autonomous mobile robot 2, at each stopping place, the sensor retaining part 11 rotates so that it will not be positioned in front of the worker, and performs position control so that the luggage placed on the drive base part 10 will not get in the way of the protrusion of the sensor retaining part 11.

[0123]

Moreover, when the stopping place is a position that will hinder the worker's operation, such as right in front of the vending machine, the autonomous mobile robot 2 moves forward, backward, leftward or rightward in a distance of roughly 1 m toward a position that will not hinder the worker's operation based on the worker's verbal instruction or operation.

[0124]

(7-2-3) Collection of hand carts

After completing the user's transport support or the worker's work support, the

autonomous mobile robot 2 collects and tows the hand luggage carts left within the airport facility or passenger terminal, and thereby delivers such hand luggage carts to a predetermined parking location such as the security check point.

[0125]

In the foregoing case, the autonomous mobile robot determines whether or not there is any luggage on the hand luggage cart, and determines that only carts with no luggage are to be collected.

[0126]

(7-3) Functions of autonomous mobile robot for airport management and maintenance

(7-3-1) Dynamic air-conditioning control function

In the airport operation management system 1, while air conditioning within the passenger terminal is being collectively managed, when the autonomous mobile robot 2, while it is moving, determines that the temperature of a specific area where many visitors have gathered has increased and may be uncomfortable for the users, air conditioning is controlled so that cool air will reach only such specific area.

[0127]

In particular, as a result of setting the temperature/humidity sensor 30 mounted in the autonomous mobile robot 2 at a height position that is a predetermined height from the ground, it is possible to detect in real-time the sensible temperature/humidity at a location that is close to the perceived temperature of humans.

[0128]

Fig. 8 shows the processing routine of the dynamic air-conditioning control function (SP40). When the facility integrated control unit 8 of the airport operation management system 1 receives the temperature/humidity measurement result from one or more autonomous mobile robots 2 (SP41), the facility integrated control unit 8 recognizes the current position of each corresponding autonomous mobile robot 2 within the facility, and controls each of the corresponding air conditioners 6 so as to maintain the ambient temperature and humidity thereof in an optimal state (SP42).

[0129]

Consequently, with the airport operation management system 1, by collecting in real-time information related to the sensible temperature/humidity of the respective users from a plurality of autonomous mobile robots 2 and performing dynamic air conditioning control, it is possible to constantly maintain a comfortable environment for the respective users.

[0130]

(7-3-2) Illumination adjustment function

In the airport operation management system 1, while sunlight is being actively utilized during the day for illumination within the airport facility and passenger terminal to seek energy conservation, when the daylight becomes unstable on days which are cloudy with occasional patches of sunshine, collective illuminance adjustment with a plurality of illumination apparatuses is insufficient.

[0131]

In the present invention, as a result of setting the illuminance sensor 31 mounted in the autonomous mobile robot 2 at a height position that is a predetermined height from the ground, it is possible to detect in real-time the sensible illuminance at a location that is close to the perceived illuminance of humans.

[0132]

Consequently, with the airport operation management system 1, it is possible to collect in real-time the illuminance information of the respective users from a plurality of autonomous mobile robots 2, and adjust in real-time the hours of incorporating daylight and the brightness balance for each predetermined area.

[0133]

(7-3-3) Cleanliness detection function

In the airport operation management system 1, the cleanliness within the airport facility and passenger terminal can be detected in real-time with pinpoint accuracy by using a plurality of autonomous mobile robots 2.

[0134]

In the present invention, because the autonomous mobile robot 2 is equipped with a microorganism sensor 32, the autonomous mobile robot 2 is thereby able to measure the amount of microorganisms, such as bacteria and fungus, floating in the air in a relatively short period.

[0135]

Consequently, with the airport operation management system 1, it is possible to collect in real-time the microorganism measurement information from a plurality of autonomous mobile robots 2, and detect in real-time the cleanliness of air for each predetermined area.

[0136]

(7-3-4) Automatic cleaning function

In the airport operation management system 1, the autonomous mobile robot 2 cleans the floor surface within the passenger terminal by mounting an external cleaning unit during hours in which support requests are not received from users and workers.

[0137]

The travel path on the floor surface within the passenger terminal to be cleaned may be designated by the worker for each area by displaying a floor surface map on the touch panel of the information input device in advance. Consequently, so as long as the autonomous mobile robot 2 continues to replace its battery, the autonomous mobile robot 2 can be operated 24/7, and the work efficiency can be remarkably improved.

[0138]

(7-3-5) Security improvement function

In the airport operation management system 1, as a result of a plurality of autonomous mobile robots 2 moving within the airport facility and passenger terminal while operating their imaging cameras and highly directional microphones, it is possible to acquire the video/audio of the ambient environment which cannot be comprehended only with the imaging cameras 5 that are fixed within the facility.

[0139]

When an incident or the like occurs at a specific location within the facility, the circumstances of the incident can be comprehended in real-time by the nearest autonomous mobile robot 2 capturing images of such specific location to the extent that it will not cause trouble to users and workers.

[0140]

Furthermore, in the airport operation management system 1, when the facility integrated control unit 8 receives sound signals representing the collected sounds of the highly directional microphone from the autonomous mobile robot 2 and determines that it is a requisite state based on the collected sounds, remote monitoring based on sounds alone is enabled by recognizing the position of the corresponding autonomous mobile robot 2 within the facility. In addition, by coordinating with a plurality of imaging cameras 5 and capturing images of the autonomous mobile robot 2 with at least one or more imaging cameras 5 so that the autonomous mobile robot 2 is centered in the captured images, it is possible to remarkably improve the efficiency of remote monitoring (security enhancement).

[0141]

The determination of whether or not it is a requisite state may be made by the facility integrated control unit 8 analyzing the collected sounds based on the sound signals. In other words, the facility integrated control unit 8 calculates the content ratio (amplitude ratio) of the respective frequency components in the analysis period based on the frequency spectrum obtained by analyzing the sound signals, and recognizes sounds containing the features of vowels and consonants depending on whether or not a specific frequency spectrum exists at a certain intensity ratio or higher. Subsequently, the facility integrated control unit 8 determines whether the collected sounds are words or vocalized sounds that express heightened emotion such as human cries, screams or roars, or other sounds in which the occurrence of a problem within the facility is predicted such as explosion sounds, blasts and other impact noise.

[0142]

Furthermore, in the airport operation management system 1, the facility integrated control unit 8, upon determining that the collected sounds based on sound signals received from each of the plurality of autonomous mobile robots 2 are of a same sound source, estimates the sound source position, and captures images of the estimated sound source position with at least one or more of the imaging cameras 5 so that the estimated sound source position is centered in the captured images. According to this on-site operation management system 1, it is possible to further improve the efficiency of remote monitoring by instantaneously identifying and capturing images of the position of the sound source that caused the requisite state.

[0143]

As the method of estimating the sound source position, a general sound source localization method (that is, a method of using a plurality of microphones, and identifying the direction of the sound source based on the phase difference and intensity difference of the sound source data input from the respective microphones) may be applied, and, for instance, considered may be the sound source localization method of concurrently using Frequency Band Selection (FBS) after Delayed Sum Beam Forming (DSBF). Moreover, the point sound source detection method utilizing directional characteristics described in Japanese Patent No. 5007400 may also be applied. In other words, used may be the point sound source detection method of obtaining the flatness of the difference between the waveform of the spatial spectrum of the sound pressure distribution observed across all directions and the waveform of

the spatial spectrum of the point sound source that was created in advance, and determining whether or not it is within a predetermined threshold.

[0144]

(8) Effect of this embodiment

As described above, according to this embodiment, the autonomous mobile robot 2 which moves freely within a facility is able to follow the user while accurately comprehending the existence and position (access point) of the user, and, by causing the autonomous mobile body 2 to enter a standby state while the user is within a restricted area, it is possible to constantly follow the user within the facility without losing sight of the user.

[0145]

Moreover, according to this embodiment, in the airport operation management system 1 in which at least one or more autonomous mobile robots 2 which move freely within a facility are arranged, and which includes a facility integrated control unit 8 which sends and receives various types of information to and from the autonomous mobile robots 2 via wireless communication, it is possible to remarkably improve the efficiency of remote monitoring (security enhancement) by coordinating with a plurality of imaging cameras 5, which are used for remote monitoring, upon moving the autonomous mobile robots 2.

[0146]

Furthermore, according to this embodiment, in the airport operation management system 1, the autonomous mobile robot 2 can detect in real-time the sensible temperature/humidity at a location that is close to the perceived temperature of humans while it is moving even when the air conditioning within the facility is being managed collectively, and it is thereby possible to constantly maintain a comfortable environment for the user based on dynamic HVAC control.

[0147]

Furthermore, according to this embodiment, in the airport operation management system 1, as a result of the user and the autonomous mobile robot 2 separately undergoing inspections at separate inspection gates; specifically, an inspection gate (first inspection gate) corresponding to a robot-only lane and an inspection gate (second inspection gate) corresponding to a human-only lane, it is possible to alleviate the burden (stress) of the user having to wait in line until reaching the inspection gate while carrying one's luggage.

[0148]

Furthermore, according to this embodiment, in the airport operation management system 1, even when the remaining power of the drive battery (first battery) 16 mounted in the autonomous mobile robot 2 is low, the original state can be restored in a relatively short period simply by replacing the drive battery 16 with the drive battery (second battery) 4A retained in the power supply mobile robot 4, and it is thereby possible to avoid the considerable loss of time that results from having to return to the charging process as with conventional methods.

[0149]

(9) Other embodiments

While this embodiment explained a case of applying the autonomous mobile robot 2 mainly to an airport operation management system, the present invention is not limited thereto, and the present invention can also be broadly applied to various other facility operation management systems of large shopping malls and department stores, general hospitals, amusement parks and other amusement facilities.

REFERENCE SIGNS LIST

[0150]

1..... airport operation management system, 2..... autonomous mobile robot, 3..... power supply station, 4..... power supply mobile robot, 4A, 16 (16A, 16B)..... drive battery, 5..... imaging camera, 6..... air conditioner, 7..... illumination apparatus, 8..... facility integrated control unit, 10..... drive base part, 11..... sensor retaining part, 15..... laser range sensor, 16..... RGB-D sensor, 17..... 3D range image sensor, 20..... integrated control unit, 21..... drive control unit, 22..... target travel path control unit, 23..... actuation control unit, 30..... temperature humidity sensor, 31..... illuminance sensor, 32..... microorganism sensor, 33..... infrared thermography, 34..... load sensor.

CLAIMS

[Claim 1]

An autonomous mobile body which moves freely within a facility, comprising:
a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;

a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; and

a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit,

wherein the drive control unit causes the autonomous mobile body to enter a standby state once the target object enters a specified area designated as being off limits within the facility, and thereafter causes the autonomous mobile body to enter a movable state of following the target object once again once the target object leaves the specified area and wireless signals from the beacon terminal become receivable.

[Claim 2]

The autonomous mobile body according to claim 1,

wherein the drive control unit:

commences detection of objects approaching within a predetermined distance while rotating or oscillating the autonomous mobile body so as to monitor all directions centered around a standby position of the autonomous mobile body once the target object enters the specified area; and

discontinues the rotation or oscillation of the autonomous mobile body and ends the detection of the objects once the target object leaves the specified area and wireless signals from the beacon terminal become receivable.

[Claim 3]

The autonomous mobile body according to claim 2,

wherein the drive control unit:

emits a warning based on sound and/or light upon detecting the object intruding within the predetermined distance; and
discontinues the warning upon detecting that the object has moved outside the predetermined distance.

[Claim 4]

The autonomous mobile body according to claim 2 or claim 3,
wherein the drive control unit:
commences video/audio recording of the object upon detecting the object intruding within the predetermined distance; and
discontinues the video/audio recording upon detecting that the object has moved outside the predetermined distance.

[Claim 5]

An on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication,
wherein the on-site operation management system comprises a plurality of imaging cameras installed within the facility,
wherein the autonomous mobile body comprises:
a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;
a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal;
and
a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit,
wherein the integrated control unit, upon receiving wireless signals representing a request from the autonomous mobile body, recognizes a position of the autonomous mobile body within the facility, and captures images of the autonomous mobile body

with at least one or more of the imaging cameras so that the autonomous mobile body is centered in the captured images.

[Claim 6]

An on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication,

wherein the on-site operation management system comprises a plurality of air conditioners installed for climate control, including heating and cooling, of the overall facility,

wherein the autonomous mobile body comprises:

a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;

a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal;

a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit; and

a temperature humidity sensor which is mounted at a predetermined height position from a floor surface for measuring a temperature and a humidity of an ambient environment,

wherein the integrated control unit, upon receiving wireless signals including a measurement result of the temperature humidity sensor from the autonomous mobile body, recognizes a position of the autonomous mobile body within the facility, and controls each of the corresponding air conditioners so as to maintain the ambient temperature and humidity of the autonomous mobile body in an optimal state.

[Claim 7]

The on-site operation management system according to claim 5,

wherein the autonomous mobile body further comprises a microorganism sensor which measures an amount of microorganisms floating in the air, and

wherein the integrated control unit, upon receiving wireless signals including a measurement result of the microorganism sensor from the autonomous mobile body, recognizes a position of the autonomous mobile body within the facility, and controls each of the corresponding air conditioners so as to maintain an ambient air cleanliness of the autonomous mobile body in an optimal state.

[Claim 8]

An on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication,

wherein an inspection area including a first inspection gate for inspecting luggage placed on the autonomous mobile body and a second inspection gate for inspecting the target object is provided,

wherein the autonomous mobile body comprises:

a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;

a tracking recognition unit which retains a beacon terminal, which is unique to the autonomous mobile body, in a target object, and recognizes in real-time an existence and a position of the target object based on wireless signals from the beacon terminal; and

a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part while causing the autonomous mobile body to move by following the target object based on a recognition result of the tracking recognition unit,

wherein the integrated control unit:

permits the target object to exit the inspection area only when inspection results of both the first and second inspection gates are determined as being all clear; and causes the autonomous mobile body to stand by at a predetermined standby position until the target object arrives when an inspection result of the first inspection gate is determined as being problematic.

[Claim 9]

An on-site operation management system in which at least one or more autonomous

mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication,

wherein the autonomous mobile body comprises:

a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;

a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part; and

a highly directional microphone which collects sounds of an ambient environment, wherein the integrated control unit, upon receiving sound signals representing the collected sounds of the highly directional microphone from the autonomous mobile body and determining that it is a requisite state based on the collected sounds, recognizes a position of the autonomous mobile body within the facility.

[Claim 10]

The on-site operation management system according to claim 9, further comprising:

a plurality of imaging cameras installed within the facility,

wherein the integrated control unit captures images of the autonomous mobile body, in which the position was recognized, with at least one or more of the imaging cameras so that the autonomous mobile body is centered in the captured images.

[Claim 11]

The on-site operation management system according to claim 10,

wherein the integrated control unit, upon determining that the collected sounds based on sound signals received from each of the plurality of autonomous mobile bodies are of a same sound source, estimates the sound source position, and captures images of the estimated sound source position with at least one or more of the imaging cameras so that the estimated sound source position is centered in the captured images.

[Claim 12]

An on-site operation management system in which at least one or more autonomous mobile bodies which move freely within a facility are arranged, and which includes an integrated control unit which sends and receives various types of information to and from the autonomous mobile bodies via wireless communication, wherein the autonomous mobile body comprises:

a SLAM function part which creates a planar or three-dimensional environmental map simultaneously with estimating its own position relative to an external environment within the facility;

a drive control unit which suitably changes a travel path of the autonomous mobile body so that the autonomous mobile body does not come into contact with peripheral objects based on an output of the SLAM function part; and

a cartridge-type first battery which is detachably mounted as a driving source, wherein the on-site operation management system comprises:

a power supply station which is installed within the facility and uses a commercial power source as its supply source; and

a power supply mobile body which is disposed to move freely within the facility and equipped with a plurality of detachable cartridge-type second batteries configured in the same manner as the first battery,

wherein, when the integrated control unit causes the power supply mobile body to reach the power supply station, the integrated control unit charges the power from the commercial power source in each of the second batteries via the power supply station, and, upon receiving wireless signals from the autonomous mobile body representing that a remaining charge amount of the first battery has fallen below a predetermined amount, moves and positions the power supply mobile body to a position near the autonomous mobile body, thereafter removes the first battery mounted in the autonomous mobile body, and replaces the removed first battery with one among the plurality of second batteries mounted in the power supply mobile body.

[Claim 13]

The on-site operation management system according to claim 12, wherein the power supply mobile body preferentially replaces the removed first battery with the second battery having the largest remaining charge amount among the plurality of second batteries.

[Claim 14]

The on-site operation management system according to claim 12, wherein the power supply station charges the power from the commercial power source in the plurality of second batteries mounted in the power supply mobile body via contactless power supply.

[Claim 15]

The on-site operation management system according to claim 12,

wherein the integrated control unit designates the positioning of the power supply mobile body while comprehending an operational status of the plurality of autonomous mobile bodies.