DESCRIPTION

TITLE OF THE INVENTION

AUTONOMOUS MOBILE BODY AND SIGNAL CONTROL SYSTEM

TECHNICAL FIELD

[0001]

The present invention relates to an autonomous mobile body and a signal control system, and can be suitably applied to an autonomous mobile capable of safely crossing a crosswalk in the same manner as pedestrians and a signal control system which coordinates with such autonomous mobile body.

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]

From several years ago in certain areas, open experiments of robot movement of causing autonomous mobile robots to move in a real environment, such as on a promenade, as an endeavor of state-of-the-art technology for realizing a society in which humans and robots exist together are being conducted.

[0005]

Conventionally, a type, as described in PTL 1, in which an unmanned mobile device detects fixed obstacles and moving obstacles while moving, and resumes moving along a predetermined travel path while avoiding collision with such obstacles has been proposed.

[0006]
When an autonomous mobile robot is to travel on a public road, it is technically extremely difficult to autonomously cross a crosswalk, and, as the current process of causing an autonomous mobile robot to cross a crosswalk, the accompanying operator is required to stop the autonomous mobile robot by operating its switch or taking other measures.
[0007]
As a technology for verifying the safety of a crosswalk, as described in PTL 2, proposed is a type of extracting images of pedestrians waiting for a traffic light while capturing images within the monitoring area, including the crosswalk, and controlling the vehicle traffic light and the pedestrian traffic light based on the obtained information such as the number of pedestrians and the waiting time.

CITATION LIST
PATENT LITERATURE
[0008]
[PTL 1] Japanese Unexamined Patent Application Publication No. 2008-294934
[PTL 2] Japanese Unexamined Patent Application Publication No. H11-275562

SUMMARY OF THE INVENTION
PROBLEMS TO BE SOLVED BY THE INVENTION
[0009]
However, when an autonomous mobile robot is to autonomously cross a crosswalk, unlike the case of simply moving on a sidewalk, there is a possibility that the autonomous mobile robot may come into contact or collide with a vehicle driving on the road, or obstruct the passage of pedestrians walking across the crosswalk or walking on the roadside sidewalk.
[0010]
As measures for dealing with the foregoing possible dangers, it would be insufficient for the automobile mobile robot to simply avoid obstacles as with PTL 1, and it would also be insufficient to control traffic lights by recognizing pedestrians based on the camera imaging results in a traffic light control system as with PTL 2.
[0011]

In order to enable an autonomous mobile robot to autonomously cross a crosswalk in a safe manner without the accompaniment of an operator, there are strong demands for taking measures by considering the safety of vehicles driving on the road and the pedestrians crossing the crosswalk.

[0012]

The present invention was devised in view of the foregoing points, and an object of this invention is to propose an autonomous mobile body and a signal control system which enable an autonomous mobile body to travel while ensuring safety that is dramatically higher in comparison to conventional technologies.

MEANS TO SOLVE THE PROBLEMS

[0013]

In order to achieve the foregoing object, an aspect of the present invention provides an autonomous mobile body which moves freely within a designated area including a sidewalk, comprising: a SLAM function part which creates a planar or three-dimensional environmental map of the designated area simultaneously with estimating its own position relative to an external environment within the designated area; 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; an imaging unit which captures images of an outside world of a predetermined range in front of the travel path; a signal light color determination unit which recognizes a pedestrian traffic light within the designated area and determines a signal light color and lighting/flashing switching of the pedestrian traffic light based on an imaging result of the imaging unit; and a pedestrian recognition unit which, when the autonomous mobile body moving on the sidewalk reaches a crosswalk, recognizes a number and position of pedestrians waiting for a traffic light on an opposing side of the crosswalk based on the imaging result of the imaging unit, wherein the drive control unit is configured to predict a degree of congestion of pedestrians at the time of crossing before the pedestrian traffic light switches to a blue color lighting based on a determination result by the signal light color determination unit and the recognition result by the pedestrian recognition unit; and wherein the drive control unit causes the

autonomous mobile body to cross the crosswalk in synch with a timing of the signal light color of the pedestrian traffic light switching from a red color to the blue color, and causes the autonomous mobile body to avoid collision with a pedestrian based on a prediction result of the drive control unit.

[0014]

According to the autonomous mobile body described above, by causing the autonomous mobile body to start crossing the crosswalk from the sidewalk at a

timing of starting its movement to cross the crosswalk with plenty of time to spare, it is possible to prevent a situation where the autonomous mobile body is unable to cross the entire length of the crosswalk within the blue color lighting duration.

[0015]

Furthermore, a further aspect of the present invention additionally provides a signal control system which coordinates with an autonomous mobile body which moves freely within a designated area including a sidewalk, comprising: a signal light color control unit which controls a signal light color and lighting/flashing switching of a pedestrian traffic light within the designated area; and a signal transmission unit which transmits signals from the signal light color control unit, wherein the autonomous mobile body comprises: a SLAM function part which creates a planar or three-dimensional environmental map of the designated area simultaneously with estimating its own position relative to an external environment within the designated area; 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; a signal reception unit which receives control signals from the signal transmission unit; an imaging unit which captures images of an outside world of a predetermined range in front of the travel path; and a pedestrian recognition unit which, when the autonomous mobile body moving on the sidewalk reaches a crosswalk, recognizes a number and position of pedestrians waiting for a traffic light on an opposing side of the crosswalk based on the imaging result of the imaging unit; wherein the drive control unit is configured to predict a degree of congestion of pedestrians at the time of crossing before the pedestrian traffic light switches to a blue color lighting based on a determination result by the signal light color control unit and the recognition result by the pedestrian recognition unit; and wherein the drive control unit causes the autonomous mobile body to cross the crosswalk in synch with a timing of the signal light color of the pedestrian traffic light switching from a red color to the blue color, and causes the autonomous mobile body to avoid collision with a pedestrian based on a prediction result of the drive control unit.

[0016]

According to the signal control system described above, by causing the autonomous mobile body to start crossing the crosswalk from the sidewalk at a timing of starting its movement to cross the crosswalk with plenty of time to spare, it is possible to prevent a situation where the autonomous mobile body is unable to cross the entire length of the crosswalk within the blue color lighting duration.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0017]

According to the present invention, it is possible to realize an autonomous mobile body and a signal control system which enable an autonomous mobile body to travel on an outdoor sidewalk or the like while ensuring safety that is dramatically higher in comparison to conventional technologies.

BRIEF DESCRIPTION OF DRAWINGS

[0018]

[Fig. 1]

Fig. 1 is an external view showing the overall configuration of the autonomous mobile robot and the signal control 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 conceptual diagram explaining the pedestrian collision avoidance function during pedestrian crossing according to the same embodiment.

DESCRIPTION OF EMBODIMENTS

[0019]

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

[0020]

(1) Schematic configuration of signal control system

Fig. 1(A) and Fig. 1(B) show a signal control system 1 of the present invention, and, with a crosswalk 3 provided so as to traverse a road 2 as the reference, pedestrian traffic lights 4 (4A, 4B) are mounted to face each other at the upper part of a post installed at roadsides on either end of the crosswalk 3.

[0021]

A signal control unit 5 respectively controls the signal indication of the pedestrian traffic lights 4 (4A, 4B) at a specific intersection or on a specific road and the signal indication of the corresponding vehicle traffic lights 6 (6A, 6B) according to the system control from a traffic control system (not shown) of the corresponding city.

[0022]

When the signal control unit 5 of the present invention receives a request signal from an autonomous mobile robot 10 via wireless communication, the signal control unit 5 sends, in real time, the current state of indication of the pedestrian traffic light 4 (for instance, lighting of traffic lights, timing of starting and ending such lighting, and, in the case of a blue traffic light, timing of starting and ending the flashing thereof) in response to the request signal.

[0023]

Moreover, when the signal control unit 5 of the present invention receives an emergency signal from the autonomous mobile robot 10 via wireless communication, the signal control unit 5 adjusts the blue light flashing duration of the pedestrian traffic light 4 in response to the emergency signal.

[0024]

The autonomous mobile robot 10 of the present invention can move autonomously and freely, and, without limitation to moving on a general sidewalk 7, when it is necessary to cross the road to proceed to its destination, the autonomous mobile robot 10 can reach the nearest crosswalk 3, and cross the crosswalk 3 while observing traffic rules.

[0025]

(2) Configuration of autonomous mobile robot

As shown in Fig. 2(A) to Fig. 2(C), the autonomous mobile robot 10 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 11 in which the two drive wheels of the autonomous mobile robot 10 are mounted so as to form a diameter, and a substantial U-shaped sensor retaining part 12 which is erected from the upper part of the flat surface of the drive base part 11.

[0026]

The drive base part 11 comprises a pair of drive wheels 13a, 13b 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 14a and a rear caster 14b which are respectively provided at the front and back of the drive base part 11 and capable of oscillating freely according to the movement of the autonomous mobile robot 10. The left and right drive wheels 13a, 13b are each independently rotatably driven by drive motors 15a, 15b (Fig. 3), and the autonomous mobile robot 10 moves forward or backward based on the forward rotation or reverse rotation of the drive wheels 13a, 13b, and moves rightward or leftward while moving forward by applying a difference to the forward rotating speed of the drive wheels 13a, 13b. Moreover, the autonomous mobile robot 10 can spin; that is, turn about in its current position by rotatably driving the drive wheels 13a, 13b in mutually opposite directions.

[0027]

A laser range sensor 20 for detecting obstacles in the obliquely forward direction and crosswise direction is provided at a position that is anterior to the front caster 14a in the drive base part 11. Moreover, an RGB-D sensor 21 and a 3D range image sensor 22 capable of three-dimensional scanning are provided at the upper center of the sensor retaining part 12.

[0028]

Specifically, the laser range sensor 20 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 20 can obtain fan-like distance information on a plane in a range of up to 30 m and an angle of 240 degrees.

[0029]

Moreover, the RGB-D sensor 21 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.

[0030]

For example, when Kinect (brand name of Microsoft Corporation) is applied as the RGB-D sensor 21, 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.

[0031]

The reason why the RGB-D sensor 21 is mounted at the upper center of the sensor retaining part 12 is because it is not possible to secure a vertical field of view with the drive base part 11 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.

[0032]

The 3D range image sensor 22 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 22 has a detection capability of higher precision in comparison to the RGB-D sensor 21 described above and a field of view that is wider than the laser range sensor 20, it is required as a complementary sensor for outdoor use.

[0033]

For example, when Pixel Soleil (product name of Nippon Signal Co., Ltd.) is applied as the 3D range image sensor 22, 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.

[0034]

Furthermore, an imaging camera 23, a highly directional microphone 24 and a speaker 25 are mounted at the upper center of the sensor retaining part 12 of the autonomous mobile robot 10, and the autonomous mobile robot 10 is thereby able to collect sounds simultaneously with acquiring the video of the ambient environment, and output messages and warning sounds as needed.

[0035]

In addition, a pair of direction indicators 26a, 26b is mounted near the drive wheels 13a, 13b in the sensor retaining part 12 of the autonomous mobile robot 10 so that the direction indicators 26a, 26b adopt a symmetrical position relationship relative to the center plane of the autonomous mobile robot 10. The direction indicator 26 is configured from one or more LEDs capable of switching the emission color and

flashing in such emission color, and engages in lighting/flashing in accordance with the traveling state of the autonomous mobile robot 10 (including the advancing direction during its travel and a change in such advancing direction, as well as upon stopping).

[0036]

The direction indicators 26a, 26b are mounted at a predetermined position of the sensor retaining part 12 so that the spacing between the pair of left and right light-emitting parts will be 30 cm or more, and the height position from the ground will be 35 cm or more, and are thereby able to enable the pedestrians, who are positioned in the forward moving direction and the reverse moving direction, to visually recognize its direction indication based on flashing light.

[0037]

Note that the direction indicators 26a, 26b may also be configured so that they can be housed in a freely openable manner at a predetermined position of the sensor retaining part 12 so as long as they fit within a range of a diameter width of the drive base part 11, and the light-emitting parts may be respectively protruded on the outer left and right sides only when the autonomous mobile body 2 crosses a crosswalk.

[0038]

Moreover, the direction indicators 26a, 26b may also emit light in only one direction of either the forward moving direction or the reverse moving direction of the autonomous mobile robot 10, and, when light is emitted only in the reverse moving direction, it will suffice so as long as the spacing between the pair of left and right light-emitting parts is 15 cm or more.

[0039]

Furthermore, the configuration of the direction indicators 26a, 26b is not limited to a single light emitter, and the direction indicators 26a, 26b may also be configured as a group of plurality of light emitters arranged in a matrix. In the foregoing case, only the corresponding light emitters may be selectively caused to emit light while lighting/flashing in the shape of an arrow pattern indicating the traveling direction or an exclamation mark upon stopping. Consequently, the autonomous mobile robot 10 can move while indicating the scheduled traveling direction to pedestrians by emitting light in an arrow shape in addition to conventional directional indication by emitting a light pattern based on flashing.

[0040]

(3) Internal circuit configuration of autonomous mobile robot

Fig. 3 is a configuration diagram of the integrated control unit 30 mounted in the autonomous mobile robot 10. The integrated control unit 30 is basically configured from a microcomputer, and comprises a drive control unit 31 which governs the overall control thereof, a target travel path storage unit 32 which stores travel path information, and an operation control unit 33 which controls the drive system.

[0041]

The drive control unit 31 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 32, which stores pre-set travel path information, and the respective detection signals from the laser range sensor 20, the RGB-D sensor 21 and the 3D range image sensor 22, and creating an environmental map described later.

[0042]

For example, the drive control unit 31 determines whether the autonomous mobile robot 10 traveling on the road will come into contact with obstacles blocking the travel path such as the roadside curbstone, and once stops immediately before coming into contact with such obstacles and then changes the moving direction of the autonomous mobile robot 10 in a direction of following the user. The drive control unit 31 sends the determined travel path information to the operation control unit 33, and the operation control unit 33 controls the left and right motor drivers 34a, 34b and controls the rotation of the drive motors a, b according to the received travel path information.

[0043]

In effect, the autonomous mobile robot 10 utilizes the foregoing SLAM technology and automatically creates an environmental map of the target area where pedestrians can walk within an actual environment such as sidewalks within a predetermined area including the crosswalk.

[0044]

Specifically, the autonomous mobile robot 10 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 20 and the 3D range image sensor 22.

[0045]

Simultaneously, the autonomous mobile robot 10 calculates its travel distance based on the rotation angle read from an encoder (not shown) corresponding to the pair of drive wheels 13a, 13b of the autonomous mobile robot 10, 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.

[0046]

Moreover, the autonomous mobile robot 10 comprises a communication unit 35 which performs wireless communication with the signal control unit 5 of the signal control system 1 (Fig. 1(B)), and receives, from the signal control unit 5 of the signal control system 1, control signals for controlling the signal light color and the lighting/flashing switching of the pedestrian traffic light 4.

[0047]

Furthermore, the autonomous mobile robot 10 has a built-in drive battery 36 of a relatively large capacity configured from a secondary battery or a capacitor, and, by conductively connecting a charging terminal of the drive battery 36 to a power supply terminal provided to an external power supply board (not shown), power supplied from a commercial power supply can be supplied to the drive battery 36 via the power supply terminal so as to charge the drive battery 36.

[0048]

(4) Method of causing the autonomous mobile robot to cross the crosswalk safely

The autonomous mobile robot 10 of the present invention, upon reaching a crosswalk while moving on a sidewalk, can cross the entire length of the crosswalk within the allowed time limit for crossing the crosswalk and without coming into contact or colliding with pedestrians while recognizing the pedestrian traffic light 4.

[0049]

(4-1) Function of crossing the crosswalk within the time limit

The autonomous mobile robot 10 adjusts the timing of starting its movement to cross the crosswalk while recognizing the pedestrian traffic light 4. Specifically, the autonomous mobile robot 10 enters a stand-by state in front of the crosswalk 3, and

thereafter starts crossing the crosswalk in synch with the timing of the pedestrian traffic light 4 switching from a red color lighting to a blue color lighting. In other words, other than at the foregoing timing, the autonomous mobile robot 10 always stops so that it can cross the entire length of the crosswalk with plenty of time to spare even when the pedestrian traffic light 4 is a blue color lighting.

[0050]

As the method of determining the timing of switching the lighting indication of the pedestrian traffic light 4, considered may be, first, a method of the autonomous mobile robot 10 capturing the imaging range of the pedestrian traffic light 4 and determining the signal light color and the lighting/flashing switching of the pedestrian traffic light 4, and second, a method of notifying the signal control state of the pedestrian traffic light 4 to the autonomous mobile robot 10 via wireless communication from the signal control unit 5 in the signal control system 1.

[0051]

In the first method, the autonomous mobile robot 10 recognizes the pedestrian traffic light 4 based on distance (crosswalk width) and external shape (shape of traffic light) by using the laser range sensor 20 and the imaging camera 23, and thereafter detects brightness information and color information and simultaneously determines the signal indication pattern in a time series, and the autonomous mobile robot 10 can thereby comprehend, in real time, the signal light color and lighting/flashing status as well as the switching state thereof.

[0052]

In the second method, by sending the status of indication of the pedestrian traffic light 4 in the signal control system 1 to the autonomous mobile robot 10 via wireless communication in real time, the autonomous mobile robot 10 can comprehend the signal light color and lighting/flashing status as well as the switching state of the pedestrian traffic light.

[0053]

Note that, when the autonomous mobile robot 10 starts crossing the crosswalk in synch with the timing of the pedestrian traffic light 4 switching from a red color lighting to a blue color lighting and recognizes the existence of a vehicle entering the crosswalk area heedless of the red color lighting of the vehicle traffic light 6 based on the detection results of the laser range sensor 20, the imaging camera 23 and the

audio microphone 24, the autonomous mobile robot 10 stops without starting its movement until the corresponding vehicle passes through. When the duration of stoppage is relatively long and the autonomous mobile robot 10 determines that there is not enough time to cross the entire length of the crosswalk, the autonomous mobile robot 10 puts off crossing the crosswalk this time around, and stands by until the subsequent timing of starting its movement to cross the crosswalk.

[0054]

(4-2) Function of predicting congestion in advance

When the autonomous mobile robot 10 is in a stand-by state at the crosswalk 3, by recognizing, via image recognition, the number and position of pedestrians who are waiting for a traffic light on the opposing side of the crosswalk 3, the autonomous mobile robot 10 can thereby predict the level of congestion of pedestrians upon crossing the crosswalk before the pedestrian traffic light 4 switches to a blue color lighting.

[0055]

Specifically, the autonomous mobile robot 10 recognizes the number and position of pedestrians who are waiting for a traffic light on the opposing side of the crosswalk 3 based on distance (crosswalk width) and external shape (human recognition and facial recognition) by using the laser range sensor 20 and the imaging camera 23, and thereafter predicts the level of congestion of pedestrians upon actually crossing the crosswalk based on the recognition results.

[0056]

(4-3) Function of preventing collision with pedestrians during pedestrian crossing

When the autonomous mobile robot 10 starts crossing the crosswalk 3 (Fig. 4(A)) and recognizes an opposing pedestrian in a crossing direction (advancing head-on direction), the autonomous mobile robot 10 moves forward by shifting in a lateral direction or a diagonal direction so as to approach the lateral edge of the crosswalk 3 (when a bicycle-only lane is provided, then the lateral edge on the opposite side thereof), and thereafter crosses the road by moving along the lateral edge (Fig. 4(B)).

[0057]

At the time that a three-dimensional environmental map is created based on the SLAM technology, the autonomous mobile robot 10 has already identified the crosswalk 3 as the path planning by using the laser range sensor 20, the RGB-D

sensor 21 and the 3D range image sensor 22, but the autonomous mobile robot 10 may additionally use an imaging camera 23 to capture images of the crosswalk 3 during its actual travel, and thereby recognize the crosswalk 3 by using image processing technology such as edge detection and outline extraction.

[0058]

When the autonomous mobile robot 10 determines that it is likely to pass the pedestrian at or near the lateral edge of the crosswalk 3 upon crossing the crosswalk 3, the autonomous mobile robot 10 moves more outside than the lateral edge so as to prevent coming into contact with the pedestrian (Fig. 4(C)). By predicting the level of congestion of the crosswalk 3 based on the foregoing function of predicting congestion in advance, and the autonomous mobile robot 10 can promptly move to avoid collision with the pedestrian upon starting its movement to cross the crosswalk 3.

[0059]

By using the laser range sensor 20 and receiving the reflected light of the laser beam emitted to an area within with width of the crosswalk 3, and detecting pedestrians in which the positional information changes temporally based on the direction of the emitted light and the time difference between the emitted light and the reflected light, the autonomous mobile robot 10 can calculate the density of pedestrians based on the area occupied by such pedestrians.

[0060]

Moreover, when multiple pedestrians will cross the crosswalk 3, the autonomous mobile robot 10 can move along the gap between the pedestrians by respectively predicting the moving direction and speed of the multiple pedestrians, and can thereby prevent coming into contact or colliding with pedestrians.

[0061]

In other words, the autonomous mobile robot 10 uses the RGB-D sensor 21 and the 3D range image sensor 22 to sequentially detect, in a time series, the relative position of pedestrians relative to the autonomous mobile robot 10 as position data, calculates the position of the pedestrians in the real space based on a plurality of time-series position data of such pedestrians, and calculates the relative moving vector from the real space position. Based on the calculated relative moving vector, it

is possible to recognize the relative movement locus of pedestrians who are likely to collide or come into contact with the autonomous mobile robot 10.

[0062]

Moreover, in addition to the pedestrian recognition method based on the relative moving vector described above, the autonomous mobile robot 10 may use the laser range sensor 20 to measure a plurality of three-dimensional point groups and separate the three-dimensional object, and recognize pedestrians for each point group by clustering (grouping) the point groups of the three-dimensional object, and it will be possible to also predict the moving direction and moving speed of the approaching pedestrian (pedestrian walking across the crosswalk 3 from the opposite side) based on mobile information associated with the lapse of time.

[0063]

When the autonomous mobile robot 10 crosses the crosswalk 3, by the drive control unit 31 controlling the direction indicators 26a, 26b to flash/emit light in a predetermined color at a predetermined timing and in a predetermined pattern in accordance with the advancing direction, and any change to such advancing direction, while the autonomous mobile robot 10 is moving, it is possible to enable the pedestrians existing in front or behind the autonomous mobile robot 10 to visually recognize the advancing direction or path change of the autonomous mobile robot 10.

[0064]

Specifically, when the autonomous mobile robot 10 starts crossing the crosswalk 3, by causing the direction indicator 26b (26a) on the left side (right side) to flash in an orange color at a predetermined timing (for instance, at a fixed cycle of 60 times to 120 times or less per minute) immediately before the autonomous mobile robot 10 shifts leftward (rightward) or obliquely leftward (rightward) so as to approach the lateral edge of the crosswalk 3, pedestrians positioned in front of and behind the autonomous mobile robot 10, as well as in the diagonal direction thereof, will be able to visually recognize that the autonomous mobile robot 10 is changing its path. Here, the drive control unit 31 may also emit a message such as “moving leftward (rightward)” from the speaker 25 in synch with the timing of flashing the direction indicator 26b (26a).

[0065]

(4-4) Function of dealing with trouble while crossing the crosswalk

When the autonomous mobile robot 10 encounters a situation where normal movement becomes difficult while crossing the crosswalk (for instance, when surrounded by stray dogs or malicious pedestrians), the autonomous mobile robot 10 evacuates to the nearest sidewalk at the timing that the dogs or pedestrians move away from the autonomous mobile robot 10 upon the pedestrian traffic light 4 switching from a blue color lighting to a blue color flashing.

[0066]

When the autonomous mobile robot 10 actually makes an emergency stop or reduces speed when movement becomes difficult, the drive control unit 31 can control the direction indicators 26a, 26b to flash light in a red color (lighting of hazard lamp), and simultaneously emit a message or a siren from the speaker 25 to notify an emergency situation, and thereby warn the surrounding pedestrians.

[0067]

Here, by the drive control unit 31 sending an emergency signal via the communication unit 35 upon the pedestrian traffic light 4 switching to a blue color flashing, the signal control unit 5 of the signal control system 1 extends the blue color flashing duration of the corresponding pedestrian traffic light 4 for a predetermined time (up to 18 seconds), and simultaneously extends the red color lighting duration of the corresponding vehicle traffic light 5 for the same length of time. Consequently, it is possible to dramatically reduce the possibility of the autonomous mobile body 10 encountering a traffic accident on the crosswalk 3, and thereby ensure safety.

[0068]

(5) Effect of this embodiment

According to this embodiment described above, because the autonomous mobile robot 10 enters a stand-by state in front of the crosswalk 3 and thereafter starts crossing the crosswalk 3 in synch with the timing of the pedestrian traffic light 4 switching from the red color lighting to the blue color lighting, it is possible to minimize the risk of the pedestrian traffic light 4 switching to a red traffic light while the autonomous mobile robot 10 is crossing the crosswalk 3, and allow the autonomous mobile robot 10 to cross the crosswalk 3 with plenty of time to spare.

[0069]

Here, when the autonomous mobile robot 10 is in a stand-by state at the crosswalk 3, by the autonomous mobile robot 10 predicting the level of congestion of pedestrians

upon crossing the crosswalk 3, shifting to the lateral edge of the crosswalk 3 and crossing the road along the lateral edge upon starting to cross the crosswalk 3, and additionally predicting the density of pedestrians and the moving direction and speed of the respective pedestrians as needed, it is possible to prevent the autonomous mobile robot 10 from colliding or coming into contact with pedestrians.

[0070]

(6) Other embodiments

While this embodiment explained a case of applying the autonomous mobile robot 10 mainly to an autonomous transport robot which travels on the sidewalk 7, the present invention is not limited thereto, and may also be applied to an autonomous cleaning robot for use on office floors, a self-moving work robot for use at construction sites and for use in pesticide spraying, an automatic security robot, a walking guide robot for use in nursing care, and other various types of self-moving robots.

[0071]

Note that, while this embodiment explaining a case where the signal light color determination unit, the pedestrian recognition unit and the pedestrian prediction unit in the present invention are all executed by the drive control unit 31 in the integrated control unit 30, the present invention is not limited thereto, and corresponding circuits may also be separately provided within the integrated control unit 30.

[0072]

Moreover, while this embodiment explained a case where, in relation to the function of preventing collision with pedestrians while crossing the crosswalk and the function of dealing with troubles while moving, the autonomous mobile robot 10 recognizes the existence and approach of pedestrians existing in its periphery based on the detection results of the laser range sensor 20 and the imaging camera 23, the present invention is not limited thereto, and the autonomous mobile robot 10 may additionally also use an audio microphone 24 and recognize the existence and approach of pedestrians while collecting ambient sounds.

REFERENCE SIGNS LIST

[0073]

1..... signal control system, 2..... road, 3..... crosswalk, 4..... pedestrian traffic light, 5..... signal control unit, 6..... vehicle traffic light, 7..... sidewalk, 10..... autonomous

mobile robot, 11..... drive base part, 12..... sensor retaining part, 20..... laser range sensor, 21..... RGB-D sensor, 22..... 3D range image sensor, 23..... imaging camera, 24..... highly directional microphone, 25..... speaker, 26a, 26b..... direction indicator, 30..... integrated control unit, 31..... drive control unit, 32..... target travel path control unit, 33..... operation control unit, 35..... communication unit, 36..... drive battery.

CLAIMS

[Claim 1]

An autonomous mobile body which moves freely within a designated area including a sidewalk, comprising:

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

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;

an imaging unit which captures images of an outside world of a predetermined range in front of the travel path;

a signal light color determination unit which recognizes a pedestrian traffic light within the designated area and determines a signal light color and lighting/flashing switching of the pedestrian traffic light based on an imaging result of the imaging unit; and

a pedestrian recognition unit which, when the autonomous mobile body moving on the sidewalk reaches a crosswalk, recognizes a number and position of pedestrians waiting for a traffic light on an opposing side of the crosswalk based on the imaging result of the imaging unit;

wherein, the drive control unit is configured to predict a degree of congestion of pedestrians at the time of crossing before the pedestrian traffic light switches to a blue color lighting based on a determination result by the signal light color determination unit and the recognition result by the pedestrian recognition unit; and

wherein the drive control unit causes the autonomous mobile body to cross the crosswalk in synch with a timing of the signal light color of the pedestrian traffic light switching from a red color to the blue color, and causes the autonomous mobile body to avoid collision with a pedestrian based on a prediction result of the drive control unit.

[Claim 2]

The autonomous mobile body according to claim 1, further comprising:

an audio microphone which recognizes the presence or the approaching state of the pedestrian while collecting sound around the autonomous mobile body;

wherein the drive control unit recognizes the presence of a vehicle entering a vehicle traffic signal by ignoring the red lighting of the vehicle traffic signal based on the detection result of the SLAM function part, the imaging unit and the audio microphone when the autonomous mobile body starts to cross; and

wherein when it is determined there is insufficient time to cross the entire length of the crosswalk, the autonomous mobile body is kept in standby until a subsequent timing of starting its movement to cross the crosswalk.

[Claim 3]

The autonomous mobile body according to claim 2,

wherein, when the drive control unit recognizes the pedestrians on an opposing side of the crosswalk based on an output of the SLAM function part when the autonomous mobile body starts crossing the crosswalk, the drive control unit causes the

autonomous mobile body to move forward by shifting the autonomous mobile body in a lateral direction or a diagonal direction so as to approach a lateral edge of the crosswalk, and thereafter causes the autonomous mobile body to move along the lateral edge.

[Claim 4]

The autonomous mobile body according to claim 2 or claim 3, further comprising:

a walk prediction unit which respectively predicts a moving direction and speed of the plurality of pedestrians on the crosswalk based on an output of the SLAM function part,

wherein the drive control unit causes the autonomous mobile body to move along a gap between the pedestrians based on a prediction result of the walk prediction unit.

[Claim 5]

The autonomous mobile body according to any one of claims 1 to 4,

wherein, when it becomes difficult for the autonomous mobile body to move while crossing the crosswalk, the drive control unit causes the autonomous mobile body to evacuate to the nearest sidewalk when the pedestrian traffic light switches from blue color lighting to blue color flashing.

[Claim 6]

The autonomous mobile body according to any one of claims 3 to 5, further comprising:

a direction indication unit which is mounted at a predetermined position of the autonomous mobile body, and which is able to emit light in a forward moving direction and/or a reverse moving direction of the autonomous mobile body,

wherein the drive control unit causes the direction indication unit to emit light at a predetermined timing in accordance with a traveling state of the autonomous mobile body.

[Claim 7]

The autonomous mobile body according to claim 6, further comprising:

a speaker which is mounted at a predetermined position of the autonomous mobile body,

wherein the drive control unit causes the speaker to output sound in accordance with a light-emitting state of the direction indication unit.

[Claim 8]

A signal control system which coordinates with an autonomous mobile body which moves freely within a designated area including a sidewalk, comprising:

a signal light color control unit which controls a signal light color and lighting/flashing switching of a pedestrian traffic light within the designated area; and

a signal transmission unit which transmits signals from the signal light color control unit,

wherein the autonomous mobile body comprises:

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

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;

a signal reception unit which receives control signals from the signal transmission unit;

an imaging unit which captures images of an outside world of a predetermined range in front of the travel path; and

a pedestrian recognition unit which, when the autonomous mobile body moving on the sidewalk reaches a crosswalk, recognizes a number and position of pedestrians waiting for a traffic light on an opposing side of the crosswalk based on the imaging result of the imaging unit;

wherein, the drive control unit is configured to predict a degree of congestion of pedestrians at the time of crossing before the pedestrian traffic light switches to a blue color lighting based on a determination result by the signal light color control unit and the recognition result by the pedestrian recognition unit; and

wherein the drive control unit causes the autonomous mobile body to cross the crosswalk in synch with a timing of the signal light color of the pedestrian traffic light switching from a red color to the blue color, and causes the autonomous mobile body to avoid collision with a pedestrian based on a prediction result of the drive control unit.

[Claim 9]

The signal control system according to claim 8, further comprising:

an audio microphone which recognizes the presence or the approaching state of the pedestrian while collecting sound around the autonomous mobile body;

wherein the drive control unit recognizes the presence of a vehicle entering a vehicle traffic signal by ignoring the red lighting of the vehicle traffic signal based on the detection result of the SLAM function part, the imaging unit and the audio microphone when the autonomous mobile body starts to cross; and

wherein it is determined there is insufficient time to cross the entire length of the crosswalk, the autonomous mobile body is kept in standby until a subsequent timing of starting its movement to cross the crosswalk.

[Claim 10]

The signal control system according to claim 9,

wherein, when the drive control unit recognizes the pedestrians on an opposing side of the crosswalk based on an output of the SLAM function part when the autonomous mobile body starts crossing the crosswalk, the drive control unit causes the autonomous mobile body to move forward by shifting the autonomous mobile body in

a lateral direction or a diagonal direction so as to approach a lateral edge of the crosswalk, and thereafter causes the autonomous mobile body to move along the lateral edge.

[Claim 11]

The signal control system according to claim 9 or claim 10, further comprising:

a walk prediction unit which is provided to the autonomous mobile body and which respectively predicts a moving direction and speed of the plurality of pedestrians on the crosswalk based on an output of the SLAM function part,

wherein the drive control unit causes the autonomous mobile body to move along a gap between the pedestrians based on a prediction result of the walk prediction unit.

[Claim 12]

The drive control unit according to any one of claims 9 to 11,

wherein, when it becomes difficult for the autonomous mobile body to move while crossing the crosswalk, the drive control unit causes the autonomous mobile body to evacuate to the nearest sidewalk when the pedestrian traffic light switches from blue color lighting to blue color flashing.

[Claim 13]

The signal control system according to any one of claims 10 to 12, further comprising:

a direction indication unit which is mounted at a predetermined position of the autonomous mobile body, and which is able to emit light in a forward moving direction and/or a reverse moving direction of the autonomous mobile body,

wherein the drive control unit causes the direction indication unit to emit light at a predetermined timing in accordance with a traveling state of the autonomous mobile body.

[Claim 14]

The signal control system according to claim 13, further comprising:

a speaker which is mounted at a predetermined position of the autonomous mobile body,

wherein the drive control unit causes the speaker to output sound in accordance with a light-emitting state of the direction indication unit.

[Claim 15]

The signal control system according to claim 12,

wherein the drive control unit transmits an emergency signal via the signal reception unit when the pedestrian traffic light switches to blue color flashing, and

wherein the signal light color control unit extends a blue color flashing duration of the pedestrian traffic light for a predetermined time based on the emergency signal received via the signal transmission unit.