

DESCRIPTION

TITLE OF THE INVENTION

SELF-PROPELLED ROBOT AND SELF-PROPELLED ROBOT CONTROL METHOD

TECHNICAL FIELD

[0001]

The present invention is suited for use in a self-propelled robot that is autonomously movable within facilities such as an airport.

BACKGROUND ART

[0002]

In recent years, there have been proposed many autonomously movable robots, such as automatic cleaning robots, which are equipped with a SLAM (Simultaneous Localization and Mapping) technique that estimates their own position relative to an external environment and, at the same time, creates an environmental map.

[0003]

A common type of the autonomous mobile robot using this SLAM technique is a robot that identifies its moving route and autonomously moves within the environment by dynamically generating an environmental map which expresses three-dimensional positions of objects existing in a real space, while estimating its own position with high accuracy by using a distance measurement sensor such as a laser range sensor (see PTL 1).

[0004]

Moreover, there has been proposed, as a method of determining obstacles along a traveling route without using the distance measurement sensor, a method of detecting obstacles existing in front of its own vehicle on the basis of the width in a height direction of a lightness change area at an upper end or lower end of a radiation area in a captured image (see PTL 2).

[0005]

Furthermore, there has been described, as a distance calculation method without using the distance measurement sensor, a method of casting a pulsed light so that its

upper end will be placed over a target, demodulating the then-captured image and detecting its upper-end edge, also detecting a shape edge of the target from an image captured in a specified light emitting state, and calculating the distance between the moving body and the target by using the principles of triangulation based on the upper-end edge and the shape edge (see PTL 3).

CITATION LIST

PATENT LITERATURE

[0006]

PTL 1: WO2017/030188

PTL 2: Japanese Patent Application Laid-Open (Kokai) Publication No. 2013-101432

PTL 3: Japanese Patent Application Laid-Open (Kokai) Publication No. 2013-24636

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007]

Regarding PTL 1, since a laser range sensor or an ultrasonic sensor which is used to detect obstacles is very expensive as compared with other internal components of the autonomous mobile robot, it is desirable that the laser range sensor or the ultrasonic sensor should not be mounted to the extent possible for the purpose of mass production.

[0008]

Moreover, since the obstacle judging method of PTL 2 does not use the distance measurement sensors, but is targeted at moving body with a relatively fast traveling speed like an automobile, it is inappropriate to apply this obstacle judging method to an autonomous mobile robot with rough obstacle detection accuracy and a relatively slow traveling speed to detect surrounding minute border lines.

[0009]

Furthermore, the distance calculation method of PTL 3 can calculate the distance between the moving body and the target with high accuracy even when a relative positional relationship between the moving body and the target changes; however, in a case of distance measurement by means of the triangulation with reference to the edges detected during traveling at a relatively high speed like an automobile, this

distance calculation method becomes troublesome because its measurement accuracy is rough and synchronous detection and the pulsed light are required.

[0010]

The present invention was devised in consideration of the above-described circumstances and proposes a self-propelled robot and its control method capable of detecting obstacles and wall surfaces on a real-time basis simply by capturing images of the radiated light when roaming around a crowded place such as an airport.

MEANS TO SOLVE THE PROBLEMS

[0011]

In order to solve the above-described problems, provided according to the present invention is a self-propelled robot traveling on a floor face autonomously or according to an external operation, wherein the self-propelled robot includes: a light radiation unit that radiates light to the floor face including at least a traveling direction among a plurality of orientations around a robot body so that the light forms a radiation area of a specified shape with a defined distance from the robot body to an external border line of the radiation area; a floor face imaging unit that is provided at a specified height position from the floor face, sets a focusing position so as to cause the external border line of the radiation area radiated on the floor face to be located within a depth of field and captures images of the floor face around the robot body at a position centered around the radiation area; a border line detection unit that detects a shape change of the external border line of the radiation area on the basis of the images captured chronologically continuously by the floor face imaging unit; an environment detection unit that detects an ambient environment along a traveling route of the robot body on the basis of the shape change of the external border line of the radiation area; and a traveling control unit that controls a traveling state while securing the traveling route of the robot body on a real-time basis on the basis of a result of the detection by the environment detection unit.

[0012]

As a result of this, the self-propelled robot according to the present invention can detect obstacles and wall surfaces with high accuracy on a real-time basis simply by capturing images of the radiated light without being equipped with a laser range sensor and/or an ultrasonic sensor which are relatively expensive.

[0013]

Moreover, a traveling route imaging unit that captures images of the traveling direction of the robot body including the floor face is further included according to the present invention, wherein the environment detection unit detects the ambient environment along the traveling route of the robot body by detecting a vibration state which occurs to the robot body and a road surface condition on the traveling route of the robot body on the basis of content of the images captured by the traveling route imaging unit and also correcting a detected error which will influence a normal traveling state among a result of the detection.

[0014]

As a result of this, with the self-propelled robot according to the present invention, when the traveling route of the robot body has slopes or becomes tortuous or when the robot body is receiving vibrations due to, for example, an external impact, there is a possibility that the external border line of the radiation area on the floor face may become out of the depth of field. So, if that is corrected by capturing images, the detection accuracy can be maintained.

[0015]

Furthermore, a light control unit that controls a light quantity of the light radiated from the light radiation unit is further included in according to the present invention, wherein when it is difficult for the border line detection unit to detect the shape change of the external border line of the radiation area from an imaging result of the floor face imaging unit, the light control unit controls the light quantity of the light radiation unit so as to enhance intensity of the light radiated from the light radiation unit.

[0016]

As a result of this, the self-propelled robot according to the present invention can enhance the light intensity of the radiated light to the level enabling image recognition of the external border line of the radiation area when the ambient environment along the traveling route of the robot body is relatively bright.

[0017]

Furthermore, according to the present invention, the light control unit controls an illuminating angle of the light radiated from the light radiation unit so that the distance from the robot body to the external border line of the radiation area becomes longer as a traveling speed of the robot body becomes faster.

[0018]

As a result of this, when any obstacles or wall surfaces exist on the traveling route of the robot body, the self-propelled robot according to the present invention can prevent the situation where it becomes difficult to stop or avoid the obstacles or the wall surfaces because of a fast traveling speed.

[0019]

Furthermore, provided according to the present invention is a method for controlling a self-propelled robot traveling on a floor face autonomously or according to an external operation, wherein the self-propelled robot control method includes: a first step of radiating light to the floor face including at least a traveling direction among a plurality of orientations around a robot body so that the light forms a radiation area of a specified shape with a defined distance from the robot body to an external border line of the radiation area; a second step of setting a focusing position so as to cause the external border line of the radiation area radiated on the floor face to be located within a depth of field and capturing images of the floor face around the robot body at a position centered around the radiation area; a third step of detecting a shape change of the external border line of the radiation area on the basis of the images captured chronologically continuously by the second step; a fourth step of detecting an ambient environment along the traveling route of the robot body on the basis of the shape change of the external border line of the radiation area; and a fifth step of controlling a traveling state while securing the traveling route of the robot body on a real-time basis on the basis of a result of the detection by the fourth step.

[0020]

As a result of this, the self-propelled robot according to the present invention can detect obstacles and wall surfaces on a real-time basis with the high accuracy simply by capturing images of the radiated light without being equipped with the laser range sensor and/or the ultrasonic sensor which are relatively expensive.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0021]

The self-propelled robot and its control method capable of detecting obstacles and wall surfaces simply by capturing images of the radiated light when roaming around a crowded place such as an airport can be implemented according to the present

invention.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

Fig. 1 is perspective views illustrating an appearance configuration of a self-propelled robot;

Fig. 2 is a block diagram illustrating a functional configuration of the self-propelled robot;

Fig. 3 is a diagram illustrating other examples of a radiation area;

Fig. 4 is a flowchart illustrating a processing sequence of an integrated control unit;

Fig. 5 is a flowchart illustrating a processing sequence for border line detection; and

Fig. 6 is a diagram illustrating the status of the border line detection.

DESCRIPTION OF EMBODIMENTS

[0023]

(1) Configuration of Self-propelled Robot According to This Embodiment

An embodiment of the present invention will be explained below with reference to the drawings. Fig. 1A and Fig. 1B are perspective views illustrating an appearance configuration of a self-propelled robot 1.

[0024]

The self-propelled robot 1 may be a carrier robot, a cleaning robot, or an alter ego robot; however, in this embodiment, an explanation will be provided by taking a communication robot (staff robot) as an example. The self-propelled robot 1 travels along its own moving route autonomously or according to an external operation.

[0025]

A pair of driving wheels 11a, 11b are provided on the right and left of a center position relative to a front-back direction in a lower part of a main body of the self-propelled robot 1; and there are also provided omni wheels 12a, 12b which can freely rotate in a traveling direction as the self-propelled robot 1 travels or in a direction intersecting with the traveling direction. Each of the right and left driving wheels 11a, 11b is rotated and driven independently by each of drive motors 13a, 13b (see Fig. 2); and the self-propelled robot 1 moves forwards or backwards by forward-moving rotations or backward-moving rotations of the driving wheels 11a, 11b and moves forwards to the

right or left by allowing differences between forward-moving rotation speeds of the driving wheels 11a, 11b. Moreover, the self-propelled robot 1 spins, that is, turns to a different direction at the same position by rotating and driving the driving wheels 11a, 11b in mutually opposite directions.

[0026]

A display unit 14 and a tray 15 are provided at the upper end of the main body of the self-propelled robot 1. The display unit 14 displays, for example, a screen which is necessary for a user to input operations, such as a menu screen and icons, and an environmental map image which is a result of information processing according to functions. A touch panel is further provided and placed over the screen for the user to input the operations and displays a GUI (Graphical User Interface) on its screen. The user performs the operation to input information by touching the touch panel with their finger or sliding their finger over the touch panel in order to operate the GUI. The tray 15 is used to place baggage or the user's personal belongs on it.

[0027]

A light radiation unit 16 is provided at an upper part of the main body of the self-propelled robot 1. The light radiation unit 16 radiates light so as to form a radiation area 17 of a circular ring shape around the self-propelled robot 1 on a floor face where the self-propelled robot 1 travels. The distance between the self-propelled robot 1 and an external border line of the radiation area 17 is defined in advance.

[0028]

The radiation area 17 is not limited to the circular ring shape around the self-propelled robot 1 and the radiation area 17 may be formed, for example, in an arc shape only in an advancing direction of the self-propelled robot 1 as illustrated in Fig. 3A. Furthermore, the radiation area 17 may be formed in a linear shape perpendicularly to, and in the advancing direction of, the self-propelled robot 1 as illustrated in Fig. 3B. The light radiated from the light radiation unit 16 is a combination of infrared light and visible light in this embodiment; however, the invention is not limited to this example and a certain level of light intensity is required, but only the visible light may be used or a laser beam or the like may be used.

[0029]

In this embodiment, images of the radiation area 17 are captured and any shape change of an edge image of the external border line of the image-captured radiation

area 17 is detected, thereby detecting any obstacles existing in the traveling direction of the self-propelled robot 1 on a real-time basis.

[0030]

Fig. 2 is a block diagram illustrating a functional configuration of the self-propelled robot 1. An integrated control unit 20 is composed of a computer as its main body and controls the entire self-propelled robot 1. The display unit 14, the light radiation unit 16, an infrared sensor 21, an imaging camera 22, an RGB-D sensor 23, a speaker 24, an information communication unit 25, a target traveling route storage unit 26, and a traveling control unit 27 are coupled to the integrated control unit 20.

[0031]

The infrared sensor 21 receives the light of an infrared region (infrared rays), converts it into an electric signal, and takes out necessary information. When the light radiated from the light radiation unit 16 is the infrared light, the infrared sensor 21 is used to capture images of the floor face around the self-propelled robot 1 at a position centered around the radiation area 17.

[0032]

The imaging camera 22 is provided at a specified height position from the floor face; its focusing position is set so that the external border line of the radiation area 17 radiated on the floor face will be located within the depth of field; and the imaging camera 22 captures images of the floor face around the self-propelled robot 1 at the position centered around the radiation area 17. The imaging camera 22 includes, for example, a CCD image sensor and a CMOS image sensor as solid-state imaging devices.

[0033]

The RGB-D sensor 23 has a depth sensor capable of measuring the distance to a target in addition to an RGB color camera function and can perform a three-dimensional scan of the target. The speaker 24 outputs various kinds of guide information and warning information by sounds.

[0034]

The information communication unit 25 wirelessly transmits/receives environmental map data and various kinds of control data to/from a center system (which is omitted in the drawing) under the control of the integrated control unit 20. The target traveling route storage unit 26 stores traveling route information which is set in advance.

[0035]

The traveling control unit 27 controls a traveling state while securing the traveling route of the self-propelled robot 1 on a real-time basis on the basis of the processing result by the integrated control unit 20. the drive motors 13a, 13b are coupled via motor drivers 28a, 28b to the traveling control unit 27. The traveling control unit 27 controls the rotations of the drive motors 13a, 13b and drives the right and left driving wheels 11a, 11b in accordance with traveling route information.

[0036]

(2) Traveling Control of Self-propelled Robot According to This Embodiment

Fig. 4 is a flowchart illustrating a processing sequence of the integrated control unit 20. Incidentally, a program illustrated in this flowchart can be executed by a computer equipped with a CPU, a memory, and so on. The entire processing or part of the processing may be implemented by a hard logic circuit. Furthermore, this program can be stored and provided in a storage medium of the self-propelled robot 1 in advance. Alternatively, the program can be stored and provided in an independent storage medium or can be recorded and stored in a storage medium of the self-propelled robot 1 by a network circuit via the information communication unit 25. The program may be supplied as a computer-readable computer program product of various forms such as a data signal (carrier wave).

[0037]

In step S31 in Fig. 4, the integrated control unit 20 causes the light radiation unit 16 to radiate the light to the floor face including at least the traveling direction among a plurality of orientations around the main body of the self-propelled robot 1 so as to form the circular-ring-shaped radiation area 17 with the defined distance from the main body of the self-propelled robot 1 to the external border line of the radiation area 17. Then, the integrated control unit 20 adjusts an illuminating angle of the light radiated from the light radiation unit 16 so that the distance from the self-propelled robot 1 to the external border line of the radiation area 17 becomes longer as a traveling speed of the self-propelled robot 1 becomes faster. Next, the processing proceeds to step S32.

[0038]

In step S32, the integrated control unit 20 causes the imaging camera 22 to chronologically continuously captures images of the floor face around the self-propelled robot 1 at a position centered around the radiation area 17. The imaging

camera 22 is provided at a specified height position from the floor face and a focusing position is set so that the external border line of the radiation area 17 radiated on the floor face will be positioned within the depth of field. Next, the processing proceeds to step S33.

[0039]

In step S33, the integrated control unit 20 executes border line detection processing for detecting a shape change of the external border line of the radiation area 17 on the basis of the images captured chronologically continuously by the imaging camera 22. The details of this border line detection processing will be explained later with reference to Fig. 5. If it is difficult for this border line detection processing to detect the shape change of the external border line of the radiation area 17 due to any problem such as the light quantity, the processing proceeds to step S34.

[0040]

In step S34, the integrated control unit 20 controls the light quantity of the light radiation unit 16 so as to enhance the intensity of the light radiated from the light radiation unit 16. Subsequently, the processing returns to the processing in step S31.

[0041]

If the shape change of the external border line of the radiation area 17 can be detected by the border line detection processing in step S33, the processing proceeds to step S35.

[0042]

In step S35, the integrated control unit 20 causes the RGB-D sensor 23 to capture images of the floor face in the traveling direction of the self-propelled robot 1. Next, the processing proceeds to step S36.

[0043]

In step S36, the integrated control unit 20 detects an ambient environment along a traveling route of the self-propelled robot 1 by detecting a vibration state which occurs to the self-propelled robot 1 and a road surface condition of the traveling route of the self-propelled robot 1 on the basis of the content of the captured images of the floor face in the traveling direction and also correcting a detected error which will influence a normal traveling state among the result of this detection. Specifically speaking, if the traveling route of the robot body has slopes or becomes tortuous and the robot body receives vibrations due to an external impact or the like, the focusing position of the

imaging camera 22 is set so that the external border line of the radiation area 17 on the floor face will not be out of the depth of field. Next, the processing proceeds to step S37.

[0044]

In step S37, the traveling control unit 27 controls the traveling state while securing the traveling route of the self-propelled robot 1 on a real-time basis on the basis of the processing result by the integrated control unit 20.

Subsequently, traveling of the self-propelled robot 1 is controlled by repeating the processing from step S31 to step S37.

[0045]

Next, the border line detection processing will be explained with reference to Fig. 5. Incidentally, a program illustrated in this flowchart can be executed by a computer equipped with a CPU, a memory, and so on. The entire processing or part of the processing may be implemented by a hard logic circuit. Furthermore, this program can be stored and provided in a storage medium of the self-propelled robot 1 in advance. Alternatively, the program can be stored and provided in an independent storage medium or can be recorded and stored in a storage medium of the self-propelled robot 1 by a network circuit via the information communication unit 25. The program may be supplied as a computer-readable computer program product of various forms such as a data signal (carrier wave).

[0046]

In step S331 in Fig. 5, the integrated control unit 20 detects the shape change of the external border line of the radiation area 17 on the basis of the images chronologically continuously captured by the imaging camera 22. Specifically speaking, the integrated control unit 20 detects whether or not a light shape change of X cm or more in the time series in a height direction from the floor face exists in an edge image of the external border line. For example, X cm is 1 cm; and if the shape change of X cm or more exists, it is determined that an obstacle (an object or a wall surface) exists on the traveling route of the self-propelled robot 1. If there is the shape change of X cm or more, the processing proceeds to step S332. Incidentally, if it is difficult to detect the shape change of the external border line of the radiation area 17 due to a problem such as the light quantity, the processing proceeds to step S34.

[0047]

In step S332, the integrated control unit 20 judges whether there is a possibility that the wheels (the driving wheels 11a, 11b and the omni wheels 12a, 12b) of the self-propelled robot 1 might run over the obstacle. Specifically speaking, if some obstacle exists on the traveling route of the self-propelled robot 1 and the self-propelled robot 1 continues to travel, the integrated control unit 20 judges whether the wheels of the self-propelled robot 1 may possibly match the position of the obstacle. If it is determined that the wheels of the self-propelled robot 1 may possibly run over the obstacle, the processing proceeds to step S333. If there is no such possibility, the processing proceeds to step S334.

[0048]

In step S333, the integrated control unit 20 issues an instruction to the traveling control unit 27 to stop the self-propelled robot 1 or circumvent the obstacle and travel. Incidentally, if the self-propelled robot 1 is stopped, the self-propelled robot 1 will resume traveling autonomously after the obstacle is removed or after the traveling direction is changed by the external operation.

[0049]

In step S334, the integrated control unit 20 detects the shape change of the external border line of the radiation area 17 on the basis of the images chronologically continuously captured by the imaging camera 22. Specifically speaking, the integrated control unit 20 detects whether or not a light shape change of Y cm or more in the time series in a height direction from the floor face exists in the edge image of the external border line. For example, Y cm is 2 cm and is a threshold value for the height of the obstacle which the self-propelled robot 1 can run over. If the shape change of Y cm or more exists, the processing proceeds to step S335. Incidentally, if it is difficult to detect the shape change of the external border line of the radiation area 17 due to a problem such as the light quantity, the processing proceeds to step S34.

[0050]

In step S335, the integrated control unit 20 advances Z cm in the advancing direction from the position where the light shape change was started to be detected. For example, Z cm is 10cm and is the distance to approach to the obstacle. When the self-propelled robot 1 has approached to the obstacle, the processing proceeds to step S333.

[0051]

If the light shape change in the height direction from the floor face is not X cm or more in step S331 or if the light shape change in the height direction from the floor face is not Y cm or more in step S334, this means that no obstacle has been detected; and therefore, the border line detection processing is terminated.

[0052]

Fig. 6A to Fig. 6D are diagrams illustrating the status of the border line detection. In the respective diagrams, (a1) to (d1) illustrate the positional relationship between the radiation area 17 and an obstacle 18 and (a2) to (d2) illustrate a shape change detection status in the external border line of the radiation area 17.

[0053]

Referring to Fig. 6A, at the stage where the radiation area 17 has not reached the obstacle 18, no shape change is recognized. Referring to Fig. 6B, at the stage where the radiation area 17 is reaching the obstacle 18, a shape change (approximately 0.5 cm) is detected as time t1 proceeds. Referring to Fig. 6C, at the stage where the radiation area 17 has completely reached the obstacle 18, the shape change in excess of a threshold value (approximately 2.0 cm or more) is detected as time t2 proceeds. Referring to Fig. 6D, when the radiation area 17 has passed beyond the obstacle 18, the shape change is no longer detected as time t3 proceeds.

[0054]

(3) Motions and Effects of Self-propelled Robot According to This Embodiment

According to the embodiment described above, the self-propelled robot 1 which travels on the floor face autonomously or according to the external operation radiates the light to the floor face including at least the traveling direction among a plurality of orientations around the robot body by using the light radiation unit 16 so that the radiation area 17 of a specified shape will be formed with the defined distance from the robot body to the external border line of the radiation area 17.

[0055]

At the same time, the self-propelled robot 1 captures images of the floor face around the robot body at a position centered around the radiation area 17 by using the floor face imaging unit (the imaging camera 22; step S32) which is provided at a specified height position from the floor face and for which the focusing position is set so that the external border line of the radiation area 17 radiated on the floor face will be located within the depth of field.

[0056]

Accordingly, the self-propelled robot 1: causes the border line detection unit (the imaging camera 22; step S33) to detect the shape change of the external border line of the radiation area 17 on the basis of the images captured chronologically continuously by the floor face imaging unit (the imaging camera 22; step S32); and then causes the environment detection unit (the imaging camera 22 and the RGB-D sensor 23; step S36) to detect the ambient environment on the traveling route of the robot body on the basis of the shape change of the external border line of the radiation area 17.

[0057]

Then, the self-propelled robot 1 causes the traveling control unit 27 to control the traveling state while securing the traveling route of the robot body on a real-time basis on the basis of the detection result by the environment detection unit (the imaging camera 22 and the RGB-D sensor 23; step S36).

[0058]

As a result, the self-propelled robot 1 can detect obstacles and wall surfaces on a real-time basis with high accuracy simply by capturing images of the radiated light without being equipped with any laser range sensor or ultrasonic sensor which is relatively expensive.

[0059]

Moreover, with the self-propelled robot 1, the environment detection unit (the imaging camera 22 and the RGB-D sensor 23; step S36) detects the ambient environment on the traveling route of the robot body by detecting the vibration state which occurs to the robot body and the road surface condition of the traveling route of the robot body and correcting the detected error which will influence a normal traveling state among the detection result on the basis of the content of the images captured by the traveling route imaging unit (the RGB-D sensor 23; step S35) which captures images of the traveling direction of the robot body including the floor face.

Consequently, with the self-propelled robot 1, when the traveling route of the robot body has slopes or becomes tortuous and the robot body is receiving vibrations due to, for example, an external impact, there is a possibility that the external border line of the radiation area on the floor face may become out of the depth of field. So, if that is corrected, the detection accuracy can be maintained.

[0060]

Furthermore, with the self-propelled robot 1, when it is difficult for the light control unit (step S34), which controls the light quantity of the light radiated from the light radiation unit 16, to detect the shape change of the external border line of the radiation area 17 from the imaging result of the floor face imaging unit (the imaging camera 22; step S32), the light quantity of the light radiation unit 16 is controlled so as to enhance the intensity of the light radiated from the light radiation unit 16. Consequently, when the ambient environment on the traveling route of the robot body is a relatively bright place, the light intensity of the radiated light can be enhanced to the level enabling image recognition of the external border line of the radiation area 17.

[0061]

Furthermore, with the self-propelled robot 1, the light control unit (step S31) controls an illuminating angle of the light radiated from the light radiation unit 16 so that the distance from the robot body to the external border line of the radiation area 17 becomes longer as a traveling speed of the robot body becomes faster. As a result of this, when any obstacles (objects or wall surfaces) exist on the traveling route of the robot body, it is possible to prevent the situation where it becomes difficult to stop or avoid the obstacles because of a fast traveling speed.

[0062]

(4) Other Embodiments

The present invention is not limited to the aforementioned embodiment and other embodiments which are conceivable within the scope of technological thoughts of the present invention are also included within the scope of the present invention unless they impair the features of the present invention.

[0063]

The type of the light radiated from the light radiation unit 16 may be a combination of infrared light and visible light; and although a certain level of light intensity is required, only the visible light may be applied. Alternatively, the light may be a laser beam. Accordingly, in a case of the infrared light, an infrared sensor may be applied as the floor face imaging unit; and in a case of the visible light, an imaging camera (a CMOS sensor and/or a CCD sensor) may be applied as the floor face imaging unit.

[0064]

Regarding a line width of the light radiated from the light radiation unit 16, a narrow width is preferred as long as the shape change of the border line can be read. This is

because it becomes difficult to recognize the shape change, for example, when a small object(s) such as small stones enter within the light line width. During the border line detection processing, the external border line is extracted to judge the shape change in the time series of the edge image (the border line). In this case, for example, 2 cm from the floor face is a threshold value and 2 cm is a standard reference for traveling judgment.

[0065]

The environment detection unit and the traveling control unit may recognize the size (largeness and shape) of an obstacle from the shape change of the border line and the traveling speed and direction of the robot body.

[0066]

The RGB-D sensor 23 may detect the vibration state which occurs to the robot body, and the road surface condition of the traveling route of the robot body on the basis of the content of the images captured by the traveling route imaging unit.

REFERENCE SIGNS LIST

[0067]

- 1: self-propelled robot
- 11a, 11b: driving wheels
- 12a, 12b: omni wheels
- 13a, 13b: drive motors
- 14: display unit
- 15: tray
- 16: light radiation unit
- 17: radiation area
- 18: obstacle
- 20: integrated control unit
- 21: infrared sensor
- 22: imaging camera
- 23: RGB-D sensor
- 24: speaker
- 25: information communication unit
- 26: target traveling route storage unit

27: traveling control unit

CLAIMS

[Claim 1]

A self-propelled robot traveling on a floor face autonomously or according to an external operation,

the self-propelled robot comprising:

a light radiation unit that radiates light to the floor face including at least a traveling direction among a plurality of orientations around a robot body so that the light forms a radiation area of a specified shape with a defined distance from the robot body to an external border line of the radiation area;

a floor face imaging unit that is provided at a specified height position from the floor face, sets a focusing position so as to cause the external border line of the radiation area radiated on the floor face to be located within a depth of field, and captures images of the floor face around the robot body at a position centered around the radiation area;

a border line detection unit that detects a shape change of the external border line of the radiation area on the basis of the images captured chronologically continuously by the floor face imaging unit;

an environment detection unit that detects an ambient environment along a traveling route of the robot body on the basis of the shape change of the external border line of the radiation area; and

a traveling control unit that controls a traveling state while securing the traveling route of the robot body on a real-time basis on the basis of a result of the detection by the environment detection unit.

[Claim 2]

The self-propelled robot according to claim 1,

further comprising a traveling route imaging unit that captures images of the traveling direction of the robot body including the floor face,

wherein the environment detection unit detects the ambient environment along the traveling route of the robot body by detecting a vibration state which occurs to the robot body and a road surface condition on the traveling route of the robot body on the basis of content of the images captured by the traveling route imaging unit and also correcting a detected error which will influence a normal traveling state among a result

of the detection.

[Claim 3]

The self-propelled robot according to claim 1 or 2,
further comprising a light control unit that controls a light quantity of the light radiated from the light radiation unit,

wherein when it is difficult for the border line detection unit to detect the shape change of the external border line of the radiation area from an imaging result of the floor face imaging unit, the light control unit controls the light quantity of the light radiation unit so as to enhance intensity of the light radiated from the light radiation unit.

[Claim 4]

The self-propelled robot according to claim 3,
wherein the light control unit controls an illuminating angle of the light radiated from the light radiation unit so that the distance from the robot body to the external border line of the radiation area becomes longer as a traveling speed of the robot body becomes faster.

[Claim 5]

A method for controlling a self-propelled robot traveling on a floor face autonomously or according to an external operation,

the self-propelled robot control method comprising:

a first step of radiating light to the floor face including at least a traveling direction among a plurality of orientations around a robot body so that the light forms a radiation area of a specified shape with a defined distance from the robot body to an external border line of the radiation area;

a second step of setting a focusing position so as to cause the external border line of the radiation area radiated on the floor face to be located within a depth of field and capturing images of the floor face around the robot body at a position centered around the radiation area;

a third step of detecting a shape change of the external border line of the radiation area on the basis of the images captured chronologically continuously by the second step;

a fourth step of detecting an ambient environment along a traveling route of the robot body on the basis of the shape change of the external border line of the radiation area;
and

a fifth step of controlling a traveling state while securing the traveling route of the robot body on a real-time basis on the basis of a result of the detection by the fourth step.

[Claim 6]

The self-propelled robot control method according to claim 5, wherein in the fourth step, the ambient environment along the traveling route of the robot body is detected by detecting a vibration state which occurs to the robot body and a road surface condition on the traveling route of the robot body on the basis of content of the images captured by the traveling route imaging unit on the basis of content of captured images of the traveling direction of the robot body including the floor face and also correcting a detected error which will influence a normal traveling state among a result of the detection.

[Claim 7]

The self-propelled robot control method according to claim 5 or 6, further comprising a sixth step of controlling a light quantity of the light so as to enhance intensity of the light radiated when it is difficult in the third step to detect the shape change of the external border line of the radiation area from an imaging result of the second step.

[Claim 8]

The self-propelled robot control method according to claim 7, wherein in the sixth step, an illuminating angle of the light radiated is controlled so that the distance from the robot body to the external border line of the radiation area becomes longer as a traveling speed of the robot body becomes faster.