(19) Japan Patent Office (JP)

(12) **Japanese Unexamined Patent Application Publication** (A)

(11) Japanese Unexamined Patent Application Publication Number

H11-212642

(43) Publication Date August, 6 1999

(51) Int Cl[6]	ID Symbols	F1	
G05D 1/02		G05D 1/02	L
A47L 11/10		A47L 11/10	

Examination Claim Unexamined, Number of Claim Items 15 FD (Total pages 16)

(21) Patent Application No. Patent Application H10-23753
(22) Application Date January 21, 1998

(71) Applicant 00000[illeg] 326
Honda Motor Co. Ltd
2-1-1, Miyami-Aoyama, Minatoku, Tokyo

(72) Inventor Ichiro Ueno
c/o Honda R&D, 1-4-1 Chuo, Wako City, Saitama Pref.
(72) Inventor Kato Hironobu
c/o Honda R&D, 1-4-1 Chuo, Wako City, Saitama Pref.
(74) Agent Patent Attorney Koki Tanaka (one more)

(54) [Title of Invention] Method and Device for Controlling Self-propelled Robot

(57) [Abstract] (Revised)
[Challenge] It is designed for a robot traveling trajectory to fill up the entire region efficiently and exhaustively, based on the boundary detection signals of the travel planned region.

[Solution Means] By suitably combing the spiral travel (case a) that rotates and travels while the rotation radius from the position where robot 1 is located is made gradually larger, a boundary (border)-following travel that travels for a planned time along the boundary, and a random travel (case b) that rotates a planned angle in response to detecting the boundary, and after that, travels straight, it is executed as in the case (c). A combination sequence can be stored in a memory in advance.
[See Fig. 6 on page 11]

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[Claims]
[Claim 1] A control method of a self-propelled robot wherein a sensor to detect the boundary of a travel planned region is provided and the method allows the robot to travel to fill up the aforementioned travel planned region as exhaustively as possible,
The method for controlling a self-propelled robot wherein a rotation travel is started from an optional position in the aforementioned region until the aforementioned boundary (border) is

detected by the aforementioned sensor, and a spiral travel makes the rotation radius gradually larger; this spiral travel, and a border-following travel that travels along the aforementioned boundary are alternatively executed.

[Claim 2] The method for controlling a self-propelled robot according to claim 1 wherein when a boundary is detected during spiral travel, the aforementioned spiral travel is stopped and it is changed to a border-following travel.

[Claim 3] The method for controlling a self-propelled robot according to claim 1 wherein when a boundary is detected by the aforementioned sensor during spiral travel, the aforementioned spiral travel is stopped, and after repeating the random travel a planned number of times that includes the planned angle rotation in response to a boundary detection and a planned distance forward advance that follows this, the rotation traveling is executed.

[Claim 4] The method for controlling a self-propelled robot according to claim 1 wherein when a boundary is detected during spiral travel, it stops temporarily, and the planned angle rotation and forward advance until the boundary is again detected is repeated N times (N is an optional integer), and the border-following travel that travels along the boundary that was detected last is executed.

[Claim 5] The method for controlling the self-propelled robot according to claim 3 or 4 wherein before executing the rotation when the boundary was detected, a retreat of a planned distance is executed.

[Claim 6] The method for controlling a self-propelled robot according to any of the claim 1 through 5 wherein when a traveling is started, a spiral travel mode is executed

[Claim 7] The method for controlling a self-propelled robot wherein a sensor to detect the boundary of a travel planned region is provided and the method allows travelling to fill up the aforementioned travel planned region as exhaustively as possible,
the method for controlling a self-propelled robot wherein the rotation traveling is started from a certain position in the aforementioned region until the aforementioned boundary is detected by the aforementioned sensor, this spiral travel mode makes the rotation radius gradually larger;
the method comprises the spiral travel mode, the border-following travel mode that travels along the aforementioned boundary for a planned time, and a random travel mode wherein when the boundary is detected by aforementioned sensor, the aforementioned robot traveling is stopped, and the planned angle rotation in response to the boundary detection and planned distance forward advance that follows this are executed,
One of the aforementioned any 3 modes is selected and executed sequentially and at the time, before or after the random travel, at least one of spiral travel mode or border-following travel mode is executed.

[Claim 8] The method for controlling a self-propelled robot according to claim 7 wherein at the time to start traveling, the spiral travel mode is executed

[Claim 9] The method for controlling a self-propelled robot according to any of the claims 1 through 7 wherein the sequence of executing spiral travel, border-following travel and random travel is preset before traveling start.

[Claim 10] The method for controlling a self-propelled robot according to claim 8 or 9 wherein the aforementioned spiral travel mode, random travel mode, border-following travel mode and random travel mode is repeated in this sequence.

[Claim 11] The method for controlling a self-propelled robot according to any of the claims 1 through 10 wherein regarding the border-following travel, based on the boundary detection signal positioned on the side of robot main body, when the aforementioned boundary is detected, it advances straight, and when the aforementioned boundary is not detected, it is rotated to approach the boundary, and when it contacted the one side boundary or get too close, it is rotated to get away from the boundary.

[Claim 12] The method for controlling a self-propelled robot according to any of the claims 3 through 11 wherein the aforementioned rotation angle is somewhat 135° in the progress direction.

[Claim 13] The method for controlling a self-propelled robot according to any of the claims 3 through 12 wherein each continued time of the aforementioned border-following travel is preset.

[Claim 14] A device for controlling a self-propelled robot wherein the robot travels to fill up the travel planned region as exhaustively as possible,
the device for controlling a self-propelled robot wherein the device is provided with a plural number of sensors that are positioned at least in front of the robot main body and on one side thereof, and detects that the aforementioned robot approaches within the planned distance from the boundary of the aforementioned travel planned region and generates a proximity output;
a sensor that is positioned at the rim of the robot main body and generates a contact output when the aforementioned robot contacted the boundary of the aforementioned travel planned region;
execution mode setup means that sequentially selects and sets up the traveling mode that the robot should execute from among random travel, spiral travel and border-following travel mode;
Control means that controls the robot traveling according to the traveling mode selected and set up.
[Claim 15] The device for controlling a self-propelled robot according to claim 14 wherein the aforementioned execution mode setup means comprises the means that pre-stores the traveling mode that the robot should sequentially execute, and the means that reads from aforementioned memory means the travel mode the robot should execute next in response to the progress of traveling mode, and the aforementioned control means controls the robot traveling according to the traveling mode that was read.

[Detailed Explanation of Invention]
[0001]
[Technical Field of Invention] The present invention relates to a method and device for controlling a self-propelled robot, particularly relates to a method and device for controlling a

self-propelled robot that can travel the given region as in a short time and exhaustively as possible.

[0002]
[Prior Art] Self-propelled robots such as a sweeping robot, a lawn mowing robot, a field grade robot, and an agricultural dispersion robot etc are known that automatically travel a given region and executes pre-set work.

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For instance, regarding the sweeping robot described in Japanese Unexamined Patent Application H5-46246 Gazette, before starting cleanup, the robot circles inside the room, and detects the room size, shape and obstacles and does mapping of the traveling region, that is, the mapping of the cleanup region. After that, based on the coordinate information that was obtained by this mapping operation, the robot engages in a zigzag traveling and spiral traveling in which a circling travel radius is made smaller for each round, and the entire room is cleaned. This robot detects the wall surface by a contact sensor and ultrasonic sensor and decides the progress path, and also detects the finish of the circling by distance meter. Likewise, a robot that travels exhaustively the entire floor surface is also disclosed in Japanese Unexamined Patent Application H5-257533 Gazette.

[0003] Regarding the conventional robot described above, various drive system actuators such as a motor is controlled so that, based on the information detected by many sensors, traveling region conditions are sufficiently grasped and the robot fill ups and travels the travel region precisely and efficiently. Because of this, the control system gets quite complicated and high priced, and also, the processing speed slows down. Furthermore, there were problems such that due to mapping, teaching and various processing, it took a long time and training for initial settings such as threshold value settings etc, and obstacle avoidance operations were delayed etc.

[0004] The inventors involved herein previously proposed a method and device for controlling a robot (Japanese Unexamined Patent Application H9-29768) in which, regarding cleaning, lawn mowing robots etc, targeting the points in some cases in which it is not necessary to travel without missing the entire region of the target with high precision, and even if some unworked region remained, no big difficulty is generated, the robot can travels the given region somewhat exhaustively with a simpler configuration.

[0005] The aforementioned proposed self-propelled robot is equipped with various sensors that detect the work region boundary and obstacles, a wheel rotation number sensor etc, and it has the spiral travel mode (Fig. 6 a, c) in which centered on the optional point inside the aforementioned region, the rotation radius is gradually made larger, and a random travel mode (Fig. 6 b) in which when the distance to the boundary or obstacle gets to be within the preset values, a spiral travel is stopped and the robot rotates with a preset angle and advances straight so that it gets far away from the aforementioned region boundary, and thereafter furthermore, every time the aforementioned region boundary is detected, repeats the rotation and straight advance a preset number of times (fine tuning). In this case, it was found out as a result of simulations that in order to improve the efficiency (hereinafter called [work efficiency] that enables a robot to travel in the region exhaustively and faster, the optimum rotation angle α is 135º. Here, the traveling pattern that sets a rotation angle α to be 135º is called a fine tuning random travel.

[0006] During the operation, as shown in Fig. 6 (a) through (c), after doing spiral traveling, it moves to the random travel mode, and at the position of a planned distance straight advance from the last rotation, it starts the aforementioned spiral travel. The planned number of times of the aforementioned rotation and the last straight advance distance are predetermined by a simulation model so that the time to attain the desired coverage rate is minimal.

[0007] Fig. 16 is a block drawing showing a hardware configuration of the aforementioned self-propelled robot control device. The control devicen7 is equipped with CPU 8 and a drive circuit 16 controls input and output of an ultrasonic sensor 6. Based on the information from a pair of multiple ultrasonic sensors 6 positioned oriented toward front, right and left side surfaces and slanting -front direction etc, contact sensor 5A positioned on front end bumper etc, rotation number sensor 10 of right and left wheels, CPU 8 controls the operations of right and left wheel drive motors 14, 15, right and left brakes 12, 13 etc, enabling the robot to execute each operation of moving forward, retreat, stopping and ultra-pivot turn, pivot turn, rapid turn and slow turn. Slow turn and rapid turn are executed by making the rotation speed of right and left wheels different. As is evident, the rotation radius is decided by the left and right wheel rotation speed and its difference. A super pivot turn is a turn executed by making the left and right wheels mutually reverse-rotate, and a pivotal turn is a rotation such that one side of left and right wheels is stopped and only one side is rotated. The rotation angel in these cases is decided by the rotation amount of the wheel to be turned.

[0008] Regarding this robot, it is not that the action plan generated by each sensor status is immediately executed but based on the preset urgency degree, it is prioritized and the action plan with higher urgency is designed to be executed preemptively.

[0009] Fig. 17 is a block drawing showing the function of action decisions executed by the aforementioned robot. In case the action plan AP1, AP2, …, APn are generated based on the distance to the obstacle detected by each sensor 6, 5A, selection function 20 selects the action plan among action plans AP1 through AP n, that has the highest urgency operation when avoiding the collision with the wall surface, and energizes an actuator 19. According to this conventional example, when the retreat control is activated, this is regarded as the highest urgency operation and is set to have the first priority. Following this, the ultra-pivot turn control became the 2nd priority, and after that, the priority was given in order of pivot turn, rapid turn, slow turn. Moreover, prioritizing the action plan described above was decided according to the distance to the obstacle calculated based on the detection result by ultrasonic sensor 6, and the stop control when an obstacle was detected by aforementioned contact sensor 5A is not included.

[0010] Fig. 18 is a graph showing the result of a simulation of work time and work progress degree by the robot described above, and Y axis shows the ratio of the region area filled up by robot traveling in the given region and X axis shows the elapsed time from the traveling start. The flat area of the robot is represented by a circle of diameter 20 cm and the traveling speed is

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