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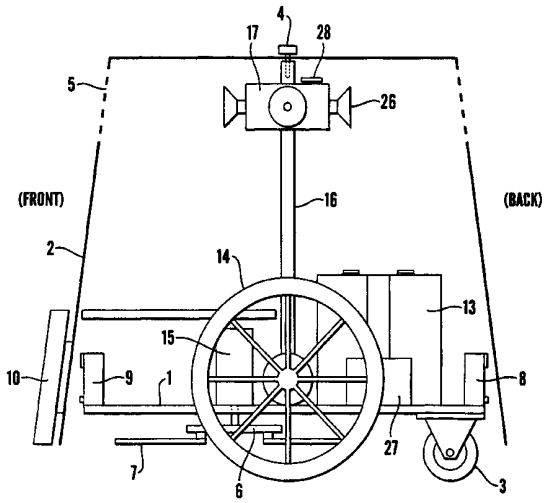
(54) Title: AUTOMATED MOWING APPARATUS



(57) **Abstract:** Mowing apparatus has cutting means (6, 7, 15) and drive means (12) for propelling the apparatus along a route (20). Navigation means (17) determines the position of the apparatus and obstacle detection means (8, 9, 10) detects obstacles in the route (20). Control means (11), in response to information from the navigation means (17) and obstacle detection means (8, 9, 10), controls the operation of the drive means (12) thereby to propel the apparatus along the route (20) with the deviations necessary to circumnavigate detected obstacles. The navigation means (17) includes signal detectors (26) responsive to a beacon signal emitted from a base station (18). The obstacle detection means includes mechanical obstruction detectors (8, 9) and detectors (10) responsive to colour changes in the terrain beneath or adjacent the apparatus, indicative of an obstruction.

WO 00/74465 A1

AUTOMATED MOWING APPARATUS

The invention relates to mowing apparatus and, in particular, to self-propelled and self-guided mowing apparatus.

Mowers, of the type commonly used for cutting domestic lawns, generally comprises a cutting arrangement, typically a rotary blade, driven by an electric motor or internal combustion engine. Sometimes, power from the motor or engine is also used to assist in the propulsion of the mower, say, by driving a roller. Generally, however, the user has to exert at least some work to push the mower forward. Nevertheless, irrespective of the manner of propulsion, most currently available mowers rely on the user to guide and operate them, which can make mowing a moderately arduous and time-consuming task for the user.

Automatic or robot mowers, that is, self-propelled and self-guided mowers, are well known. The guidance systems of such mowers need to be able, in combination with the propulsion system, to negotiate the mower around obstacles without user attention. The obstacles could be obstructions such as walls, boulders or posts or could be the edge of a depression such as the boundary of the lawn. European patent application number [94303668.1] discloses an automated grass cutter having a power supply, drive wheels, cutter mechanism and a collision obstacle detection means to guide the cutter around an area in a pre-programmed or pseudo random path. Other types of automated devices are known to follow a pre-programmed path or may be mechanically guided, for example, along rails buried in a lawn. Such devices are very limited in application, particularly since they are in effect dedicated to a specific lawn. US patent number 5444965 discloses a solar powered self-propelled mower, but such mowers are limited in power and by climatic conditions.

What is required is mowing apparatus which is capable of unattended operation yet versatile enough to adapt readily to use in a number of different locations.

The invention provides mowing apparatus comprising cutting means, drive means for propelling the apparatus along a route, navigation means for determining the position of the apparatus, obstacle detection means for detecting an obstacle in the route, and control means which, in response to information from the navigation means and obstacle detection means, controls the operation of the drive means thereby to propel the apparatus along the route with the deviations necessary to circumnavigate detected obstacles.

The process of circumnavigation on encountering an obstacle my involve, initially, ceasing further forward movement, reversing, turning away from the obstacle and again moving forward. This process of deviation continues until the obstruction has been circumnavigated and the primary route has been resumed.

The control means preferably comprises a microcontroller, microprocessor or semiconductor gate array or similar apparatus or device. A microcontroller system may have interface ports and random (RAM) and read only (ROM) memory space. Such a system is available in the UK from Microchip Technology Inc under their designation PIC 16C56. The system may supply control signals to the drive means in accordance with information input from the navigation means and obstacle detection means, the working data extracted from the information being held in the memory space and processed according to the device programming sequence, also held in the memory space. In addition, the system may effect various control algorithms. For example, if adverse weather is detected, the system may cause the drive means to direct the apparatus back to a base station.

The navigation means may comprise at least one signal detector responsive to a beacon signal emitted from a base station. The beacon signal may be emitted omni-directionally to enable the apparatus to determine its position across a wide area, for example, a lawn. Alternatively, the beacon signal may be emitted uni-directionally as a narrow homing beam to enable the apparatus to guide itself back to the base station in the event of, say, adverse weather conditions.

The at least one signal detector may provide information enabling the apparatus to be propelled along a route comprising a concentric circle search pattern. Such a pattern may have a plurality of evenly spaced arcuate paths each centred on the base station.

The apparatus may comprise four signal detectors. In such a case each detector may be responsive to the beacon signal in each of four directions: front, back, left, right, thereby determining the orientation of the apparatus. Alternatively, any number of detectors could be used, or a rotating detector arrangement and angular encoder could be used. The detectors may also have the facility to transmit to the base station thereby establishing a two-way communications link with the base station.

The beacon signal may be in the infra-red region of the electromagnetic spectrum.

The obstacle detection means may comprise at least one mechanical obstacle detection device. The obstacle detection device may comprise a switch.

The obstacle detection means may comprise at least one optical detection device. The at least one optical detection device may detect the colour of the terrain beneath or adjacent the apparatus. Thus, a change in colour may indicate, for example, an absence of grass or a change of terrain, either of which may necessitate a deviation in the route and/or de-activation of the cutting means. The colour optical detection device may comprise at least one light sensitive means and an associated at least one filter. The at least one filter may be green so that in the absence of ambient light reflected from green grass, that is, in the absence of grass, little if any light may reach the light sensitive means. Alternatively, two light sensitive means may be used, each with a different colour of filter, say green and red, so that a comparison can be performed of the light reaching each light sensitive means. The light sensitive means could comprise at least one phototransistor, photoresistor or photodiode or similar device. Alternatively, the light sensitive means could comprise an array of active pixel sensors using charged couple devices. Optical detection devices can be used

also to detect, say yellow weeds, or other specific colours of vegetation that may require cutting, removal or leaving in the ground. Also, the optical detection means can be used to de-activate the cutting means from use other than when absolutely necessary.

The drive means may comprise an electric motor or internal combustion engine. In the case of electric motor drive means, the apparatus may be further provided with a battery, which may be rechargeable at the base station. Solar power may be used to recharge the battery or to supplement power derived from the battery.

The invention further comprises motion detector means.

The cutter means may be of any suitable form, for example, a rotary cutter, a flail cutter or a reciprocating bar cutter. Preferably, a rotary cutter is used.

In an alternative embodiment of the invention, the beacon signal and detectors enable the microcontroller to navigate the apparatus in an optimum path across the lawn avoiding obstacles such as trees. Navigation is achieved by aligning the device with the base station beacon signal and fixing reference point on the cutting area. The alignment of the beacon signal in the apparatus permits a bi-directional communications link to be set up permitting information to be transferred so that the control means can be at either end of the link. Preferably, the control means is located in the base station in order to reduce power consumption, weight and the cost of the cutting device.

A specific embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic side view of mowing apparatus according to the invention;

Figure 2 is an underside plan view of the apparatus shown in figure 1;

Figure 3 is a plan view of the apparatus shown in figure 1 with the cowling and navigation means removed;

Figure 4 illustrates the use of a beacon signal to navigate the apparatus shown in figure 1;

Figure 5 illustrates the four beacon signals detectors (forward, backwards, left and right) incorporated in the apparatus shown in figure 1;

Figure 6 is a plan view of the primary control route of the apparatus shown in figure 1 on a cutting area; and

Figure 7 is a schematic block diagram of the colour change detectors incorporated in the apparatus shown in figure 1.

Referring in detail to Figures 1, 2 and 3, mowing apparatus according to the invention has a chassis formed from aluminium sheet folded to form a generally circular base plate 1. A protective cowling 2, of generally frusto-conical shape, fits over the chassis 1 and is secured on a pivot point by a screw 4 on to a main supporting shaft 16 centrally upstanding from the base plate 1. The cowling 2 provides a number of functions apart from protection against adverse weather and mechanical mistreatment.

The apparatus runs on a pair of co-axial drive wheels 14 and a rear castor 3. The castor 3 is not powered. The drive wheels 14 are individually driven by separate electric motors 12 each incorporating a reduction gearbox, the wheels are mounted on top of the base plate 1 and protrude downwards therethrough. The forward and reverse motion of the drive wheels 14 is detected by the detection switches 27, also mounted on the base plate 1 adjacent the wheels 14, which change state and phase as the wheels 14 rotate. A controller 11 uses information from the rate of change of

switches 27 to determine velocity and/or distance travelled while the phase of the output from the switches 27 indicates the direction of travel.

Power for each electric motor 12 is provided by a 12-volt rechargeable battery pack 13 mounted on the base plate 1, above the castor 3, to provide ballast and mechanical stability for the apparatus. The motion of the apparatus is performed under the control of the controller 11, described in detail below.

The controller 11 may also provide for under-voltage protection e.g. automatically switching the power off if the battery voltage falls to a predetermined minimum level. This prevents over discharge of the batteries 13 as well as ensuring sufficient power available to enable the apparatus to return to a base station (not shown) for recharging. When recharging, timers and over voltage circuitry protect the batteries from being overcharged.

Also supported on the base plate 1 is a rotary cutter mechanism comprising a motor 15 and a support plate 6 on which the replaceable rotary blade cutters 7 are attached. The height of the blade cutters 7 above the grass can be set by adjusting the support plate 6 position on the shaft of the motor 15. Power for the cutter mechanism motor 15 is also powered by the battery pack 13.

At the front and rear of the apparatus, mechanical obstacle detection devices in the form of obstacle detectors 9 and 8 respectively are provided. The protective cowling 2 is mounted on a pivot on top of the support shaft 16 and secured by screw 4 to provide the mechanical linkage to either obstacle detector 9, 8. In the event of an obstacle being encountered during the movement of the apparatus, the cowling 2 tilts to contact and actuate the appropriate detector 9 or 8, which are in effect switches.

Movement of the apparatus over the edge of a lawn is prevented by the edge detection mechanism comprising optical detection devices in the form of two colour detectors 10 mounted spaced apart on the front of the cowling 2. In the event that the

apparatus encounters the edge of a lawn or a damaged patch of grass, the colour change away from a background colour level is detected. The manner of operation of the colour detectors 10 is described in more detail hereinafter.

In the event that the controller 11 receives information from the obstacle detectors 9, 8 that an obstruction has been encountered or from a colour detector 10 that a lawn edge has been encountered, the controller 11 will effect changes to the drive command signals. In other words, the controller 11 will control the operation of the motors 12. This will result in the apparatus, initially, ceasing further forward movement, reversing, turning away from the obstruction and again moving forward. This process of deviation continues until the obstruction has been circumnavigated and the primary route has been resumed. The cutter arrangement motor 15 may also be stopped in the event that a colour detector 10 identifies a patch of dead grass.

Referring to Figures 4, 5 and 6 which depict various aspects of the navigation means in normal use. Situated to one edge of a lawn 22 is a base station 18. Omni-directionally emitted from the base station 18 is an infra red beacon signal. If switched on at the main power switch 24, the apparatus moves on to and around the lawn 22 from the base station 18 according to the primary route control algorithm. The algorithm executed in the controller 11 causes the apparatus to be driven in the predetermined primary route 20 across the lawn 22. The apparatus is kept to the route 20 by monitoring the direction and strength of the beacon's signal at the detector head 17, and thereby determining the position of the apparatus. The individually driven drive wheels 14 are adjusted by the control circuit 11 to obtain the maximum beacon signal 23 strength through a slit 5 in the protective cowling 2 to a detector head 17. In other words, the apparatus is maintained on a path which is the same radial distance 21 from the base station 18, until the edge of the lawn 22 is reached whereupon the apparatus moves to a path at a new radial distance. The alignment provides a useful reference point and a serial, two-way communications link can be established using the detectors 26 for transmitting as well as detecting between the device and the base station. This is the primary navigation mechanism

employed by the controller 11 and used in conjunction with the motion detection switches 27 on the drive wheels 14.

In the preferred embodiment the detector head 17 contains four beacon signal detector/transmitter means 26 at right angles to each other. In an alternative embodiment any number of detector means could be used to sense the orientation of the apparatus with respect to the base station. This could for example even involve a rotating detector/transmitter head and angular encoder mechanism at either end to achieve the same means. In the preferred embodiment four infra-red detectors/transmitters 26 are used to align the apparatus for either forward, backward, left or right motion relative to the beacon signal from the base station 18. Each detector means 26 is capable of not only receiving the beacon signal for the purpose of position, determining, orientation and alignment, but also transmission to the base station 18 to establish a two-way communication link.

The primary route 20 of the apparatus is normally in a sequence of arcuate paths using either of the side detectors 26 aligned through the slots 5 in the cowling 2 at 90° to the direction of emission of the beacon signal 23. A modulated and coded beacon signal 23 from the docking station 18 is used so that possible interference with a neighbouring device is limited.

The controller 11 incorporates a PIC 16C56 microcontroller system from Microchip Technology Inc. The microcontroller contains interface ports and both random (RAM) and read only memory (ROM) to contain both device program sequence and working data. Various control algorithms are employed depending on the status of the incoming detector means and for sensors. If for example an under-voltage battery signal or adverse weather signal is present then the beacon signal 23 could be used to directly guide the robot on the cutting area 22 back to the docking station for recharging. This is achieved by ensuring that the front infra-red detector 26 is aligned with the beacon signal 23 in the primary route control algorithm until it returns to the base station 18.

In the under-voltage battery status, adverse weather condition or at inappropriate time of day, the radius distance 21 between the apparatus position 19 and the base station 18 is measured so that the apparatus can return to the same area when instructed. Alternatively, if an obstacle or change in background colour is detected, evasive actions in a controlled retreating fashion or a random sequence are employed.

In Figure 6 the primary control route 20 of the device is in a concentric circle search pattern so that the cutting area 22 is covered. Once the radius distance 21 reaches a maximum permissible the apparatus returns towards the centre to repeat the primary control route 20 again. The repetition rate of the primary control route 20 is selectable and may be conditional and dependent on the date, time or weather conditions. Similarly, if the radius distance 21 becomes too large and or the beacon signal is lost, an external boundary condition is set before the primary control path 20 is repeated. Failure to maintain a regular communications, alignment link between the device and the docking/recharging station results in an alarm condition being activated.

In another embodiment of the invention the lawn surface may be digitally mapped in the microcontroller system memory either in the apparatus or in the base station. This embodiment and mode of operation allows the primary control route 20 to follow an optimised route to ensure the lawn surface 22 is covered more efficiently. In this embodiment the primary navigation system contained within the microcontroller system uses the beacon and motion detection signals as reference points and plots an optimised course across the lawn. Tall obstacles such as trees in the middle of a lawn potentially block the beacon signal 23 from the base station 18 and cast an invisible shadow on the surface. In this embodiment, the primary control path 20 derived from the control program could be in a straight line and permit the device to navigate around such obstacles by re-establishing the link.

In yet another embodiment of the invention the beacon signal may also provide a bi-directional communication link between the device and the base station. In this embodiment some of the expensive and or bulky control circuitry is contained within the base station that can also interface with other computer systems.

With reference to figure 7, each colour detector 10 incorporates a set of two matched photodiodes 71 and colour filters 72 to detect green vegetation. Thus, there are four photodiodes and filters in all. The photodiodes 71 constitute light sensitive means and each pair of photodiodes 71 and filters 72 constitutes a red and green light sensitive circuit: each pair of photodiodes 71 is the same, but the input to one is via a green filter 72 and the input to the other is via a red filter 72. The amplified output from each light sensitive circuit is fed to a comparator circuit 73 in the microcontroller. Each red and green light sensitive circuit is housed in a tube (not shown). Ambient light is reflected from the lawn/boundary surface and direct comparisons between each red and green light sensitive circuit of each of the detectors 10 is performed by the comparator circuit. When green vegetation is present in the field of view of the detector 10 each photodiode 71 monitors the amount of reflected light and the green light sensitive circuit response is greater than the red light sensitive circuit response. When the apparatus enters close to a green lawn border or dead patch of grass, where there is no green vegetation, the red and green light sensitive circuit responses become more similar and the colour change is detected by the comparator circuit 73. The amount of light and lawn area detected is controlled by the size, position and length of the mechanical tube housing the two detector assemblies.

Claims

1. Mowing apparatus comprising cutting means, drive means for propelling the apparatus along a route, navigation means for determining the position of the apparatus, obstacle detection means for detecting an obstacle in the route, and control means which, in response to information from the navigation means and obstacle detection means, controls the operation of the drive means thereby to propel the apparatus along the route with the deviations necessary to circumnavigate detected obstacles.

2. Mowing apparatus according to claim 1 wherein the control means comprises a microcontroller, microprocessor or semiconductor gate array.

3. Mowing apparatus according to claim 1 or claim 2 wherein the navigation means comprises at least one signal detector responsive to a beacon signal emitted from a base station.

4. Mowing apparatus according to claim 3 wherein the beacon signal is emitted omni-directionally.

5. Mowing apparatus according to claim 3 wherein the beacon signal is emitted uni-directionally.

6. Mowing apparatus according to claim 3 or claim 4 wherein the at least one signal detector provides information enabling the apparatus to be propelled along a route comprising a concentric circle search pattern.

7. Mowing apparatus according to any of claims 3 to 6 comprising four beacon signal detectors.

8. Mowing apparatus according to any of claims 3 to 7 comprising a rotating signal detector arrangement and angular encoder.

9. Mowing apparatus according to any of claims 3 to 8 wherein the beacon signal is in the infra-red region of the electromagnetic spectrum.

10. Mowing apparatus according to any of claims 3 to 9 wherein the signal detectors also transmit signals thereby to establish a two-way communications link with the base station.

11. Mowing apparatus according to any preceding claim wherein the obstacle detection means comprises at least one mechanical obstacle detection device.

12. Mowing apparatus according to claim 11 wherein the obstacle detection device comprises a switch.

13. Mowing apparatus according to any preceding claim wherein the obstacle detection means comprises at least one optical detection device.

14. Mowing apparatus according to claim 13 wherein the at least one optical detection device detects the colour of the terrain beneath or adjacent the apparatus.

15. Mowing apparatus according to claim 14 wherein the colour optical detection device comprises at least one light sensitive means and an associated at least one filter.

16. Mowing apparatus according to claim 15 wherein the at least one filter is green.

17. Mowing apparatus according to claim 14 comprising two light sensitive means, each with a different colour of filter.

18. Mowing apparatus according to claim 17 wherein one light sensitive means has a green filter and the second light sensitive means has another colour filter.

19. Mowing apparatus according to claim 17 comprising comparator means for comparing the responses from the two light sensitive means.

20. Mowing apparatus according to any of claims 15 to 19 wherein the at least one light sensitive means comprises at least one phototransistor, photoresistor or photodiode.

21. Mowing apparatus according to any of claims 15 to 19 wherein the light sensitive means comprises an array of active pixel sensors using charged couple devices.

22. Mowing apparatus according to claim any preceding claim wherein the drive means comprises an electric motor or internal combustion engine.

23. Mowing apparatus according to any preceding claims further comprising motion detector means.

24. Mowing apparatus according to any preceding claim wherein the cutter means comprises a rotary cutter, a flail cutter or a reciprocating bar cutter.

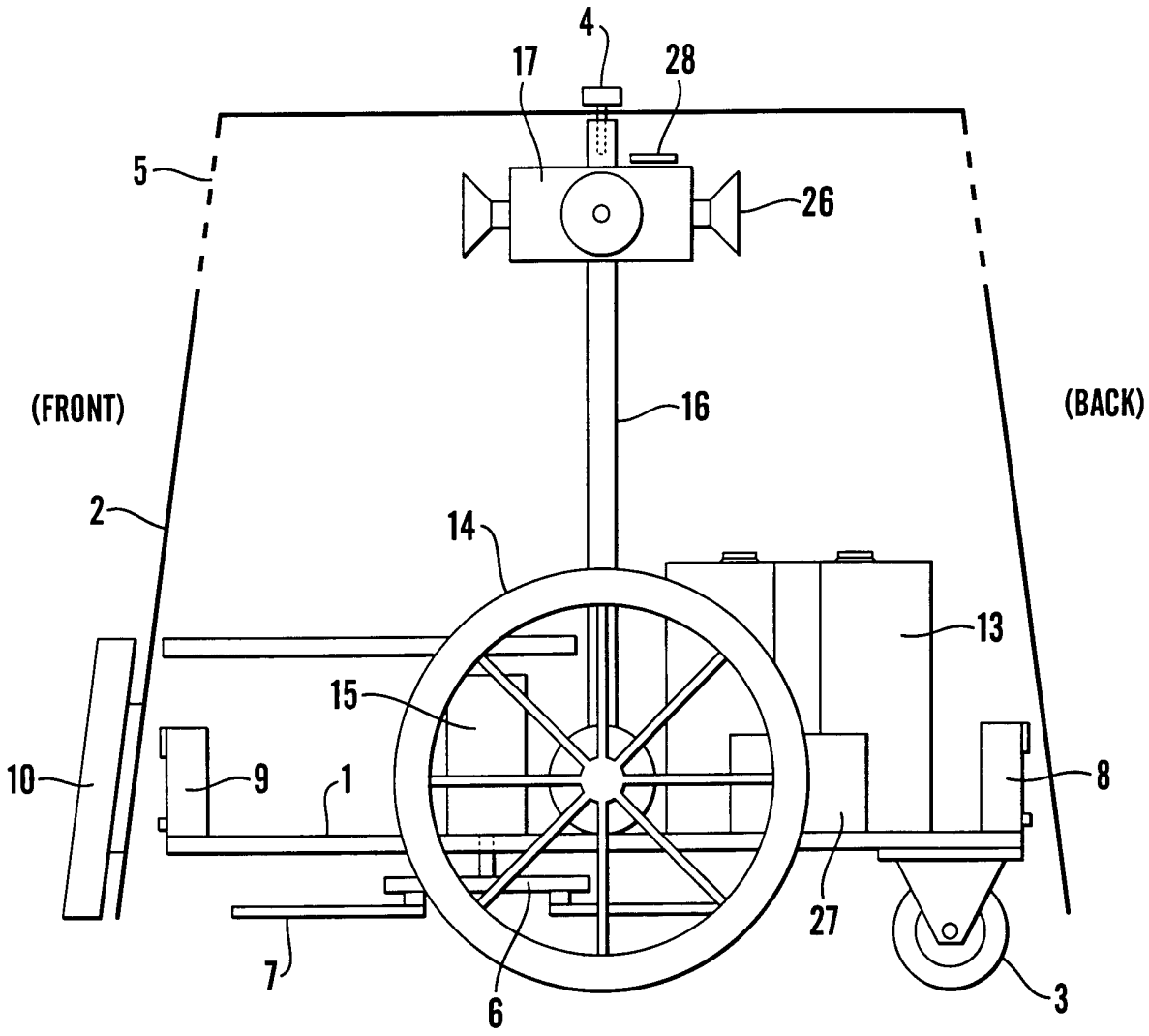
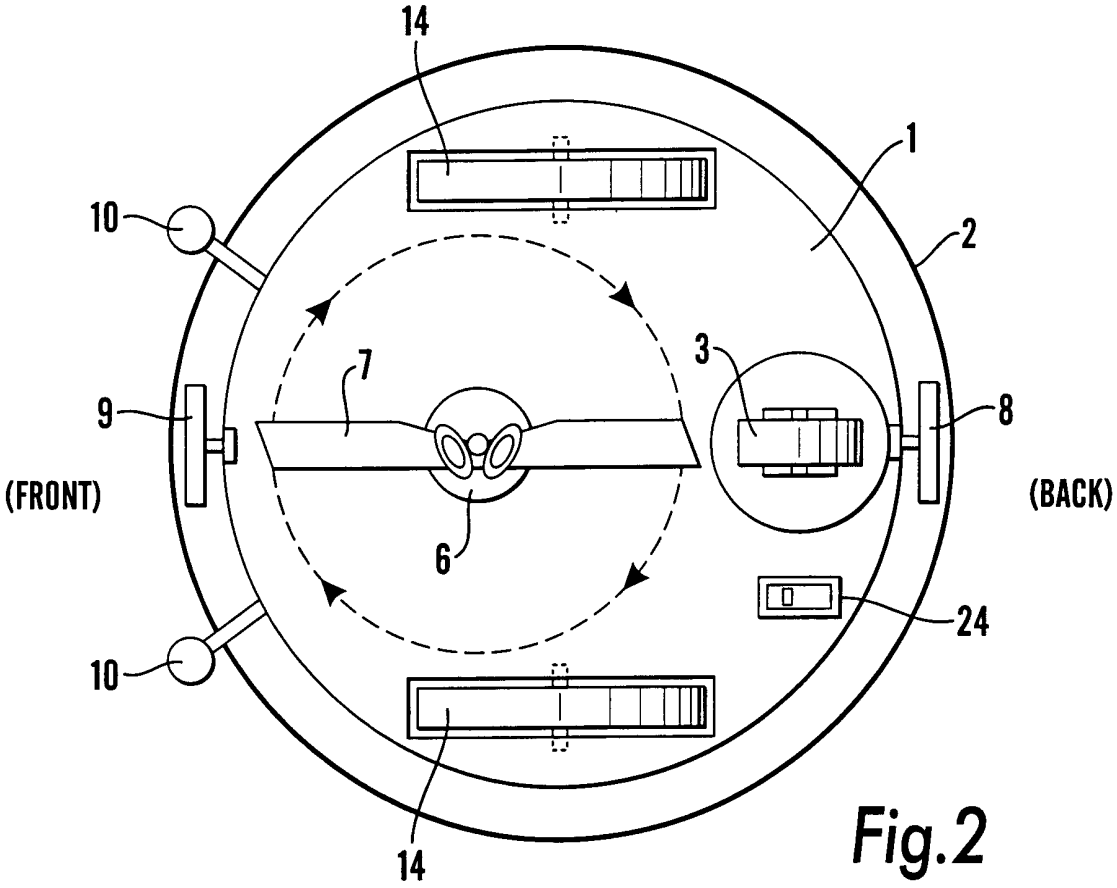


Fig. 1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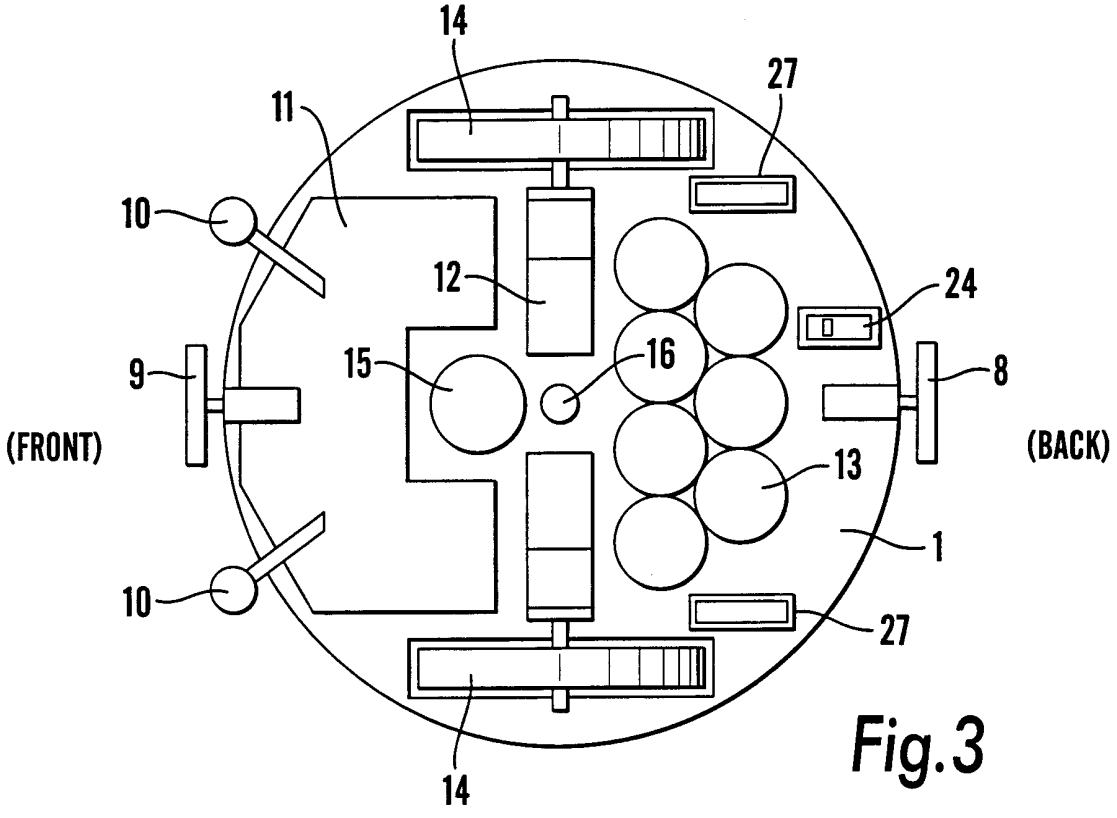
24
10
14

Fig.2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14

Fig.3

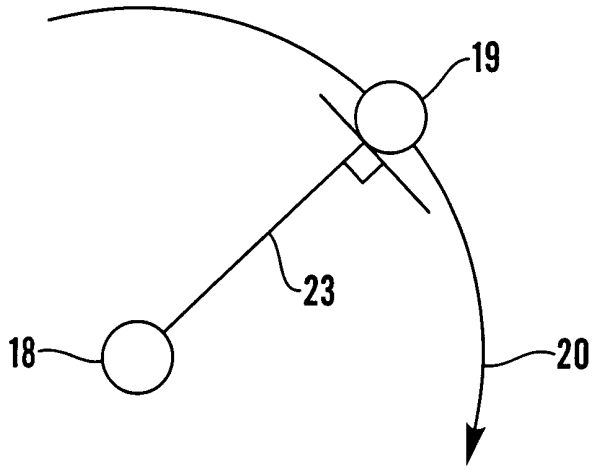


Fig.4

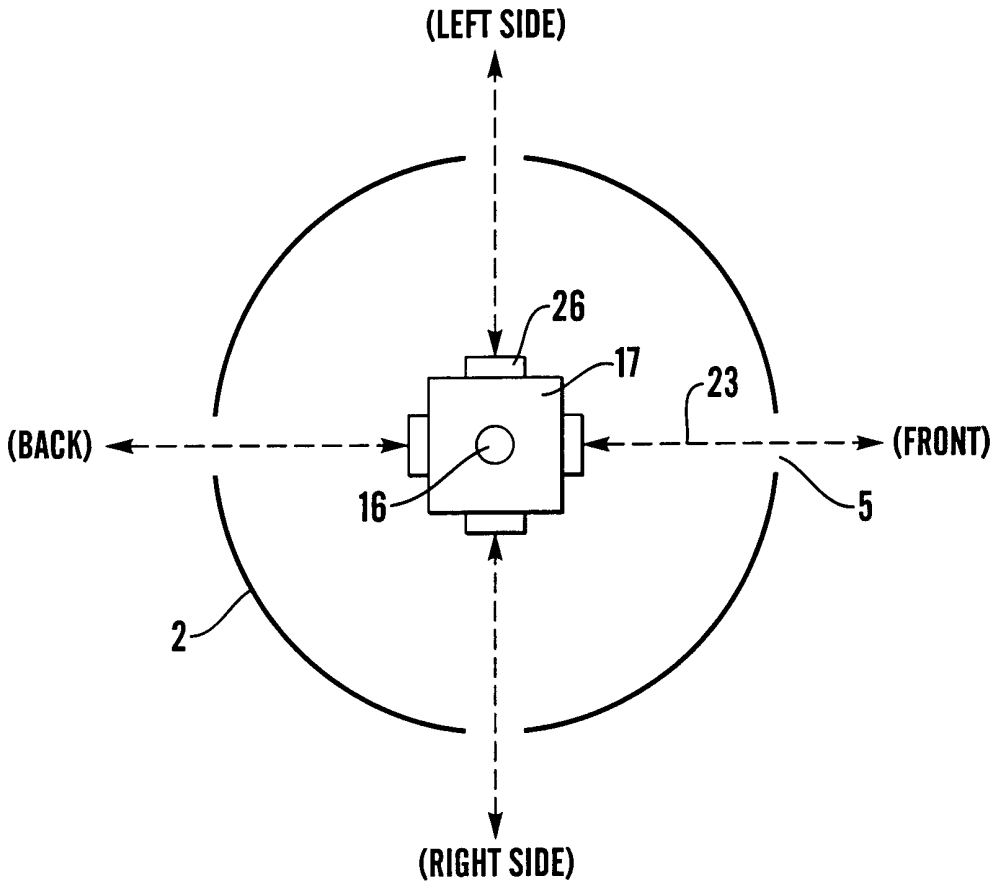


Fig.5

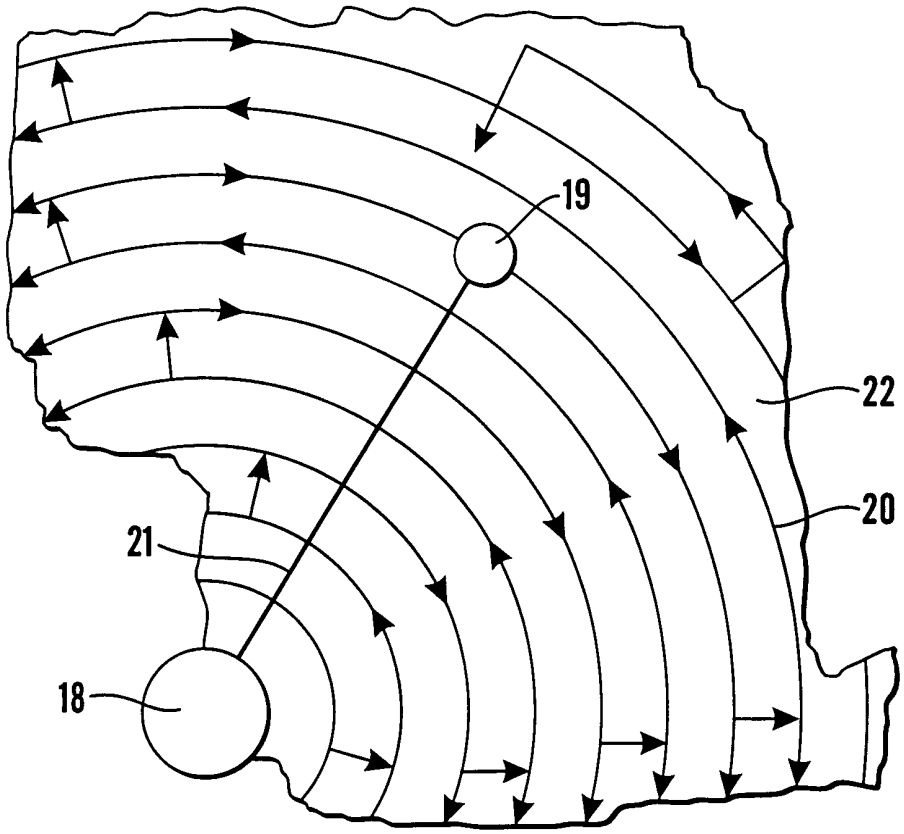
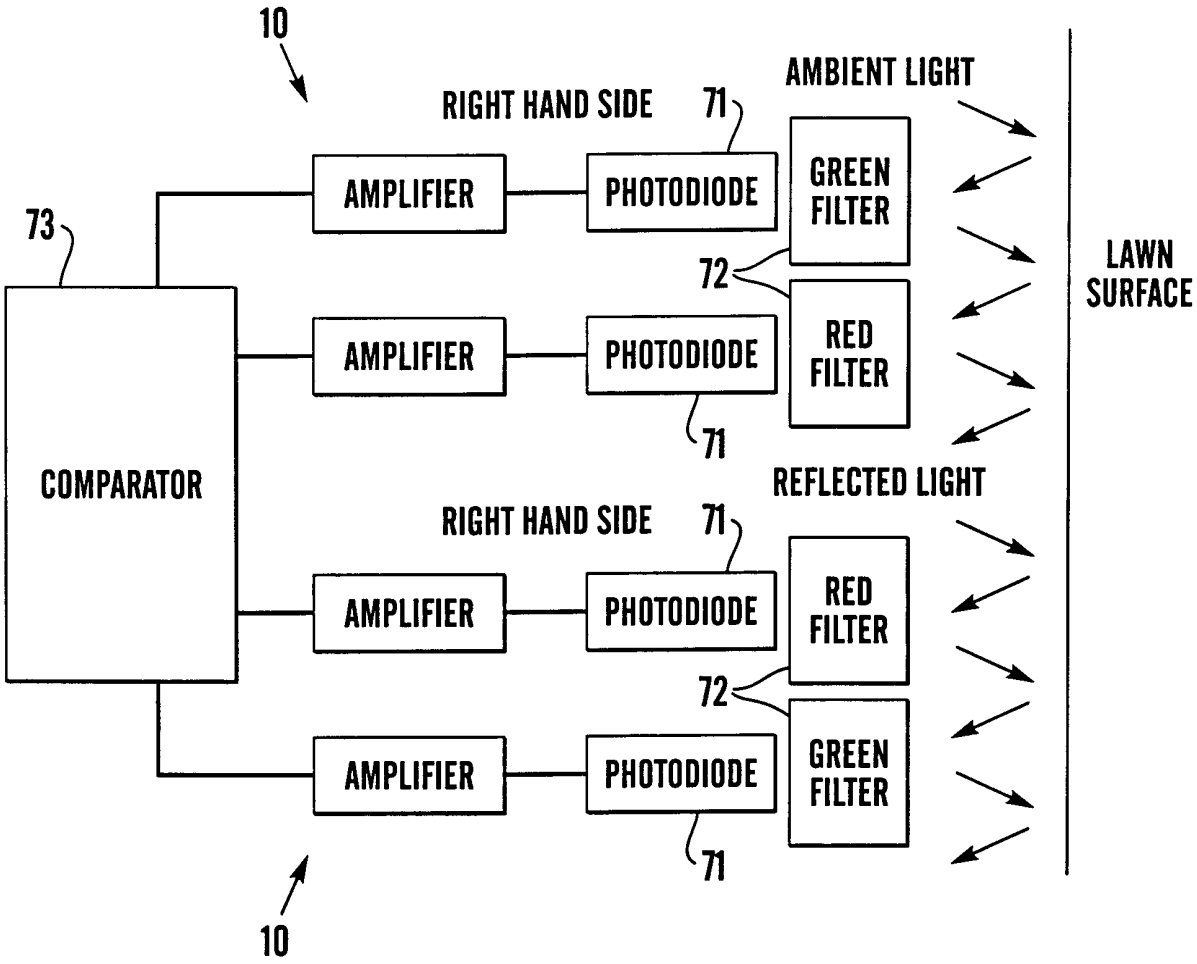


Fig.6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AMBIENT LIGHT
RIGHT HAND SIDE
71
AMPLIFIER
PHOTODIODE
GREEN FILTER
73
72
AMPLIFIER
PHOTODIODE
RED FILTER
LAWN SURFACE
71
COMPARATOR
REFLECTED LIGHT
RIGHT HAND SIDE
71
AMPLIFIER
PHOTODIODE
RED FILTER
72
AMPLIFIER
PHOTODIODE
GREEN FILTER
71
10

Fig.7

INTERNATIONAL SEARCH REPORT

Inter. .onal Application No
PCT/GB 00/02083

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A01D34/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 628 239 A (BLACK & DECKER INC) 14 December 1994 (1994-12-14) cited in the application the whole document	1,11,12, 22-24
A	DE 28 07 482 A (FRIELINGSDORF WERKZEUGMASCHINE) 23 August 1979 (1979-08-23) page 16, last paragraph	1,11
A	FR 2 687 808 A (HONDA MOTOR CO LTD) 27 August 1993 (1993-08-27)	

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 July 2000	19/07/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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PCT/GB 00/02083

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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