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Leinauer

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[45] **July 10, 1973**

[54] **AUTOMATICALLY STEERED SELF-PROPELLED VEHICLE**

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[73] Assignee: **Robert Bosch GmbH,** Stuttgart, Germany

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[30] **Foreign Application Priority Data**

Oct. 7, 1970 Germany .... P 20 49 136.5

[52] **U.S. Cl.** .... **180/79.1,** 180/98, 250/202, 340/282, 343/7 ED

[51] **Int. Cl.** **B62d 1/24**

[58] **Field of Search** .... 180/79.1, 98; 318/587; 340/282; 250/202; 343/7 ED

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[57] **ABSTRACT**

A self-propelled vehicle is automatically reversed and steered to a new path if sensors thereon sense an obstruction surrounding an area, or an obstacle in the area so that the vehicle moves forward, rearward and laterally over the entire unobstructed area for treating the same with a tool, such as a brush or agricultural implement. The forward and rearward movements are maintained along straight paths independently of irregularities prevelant in the area, tolerances in the steering control system of the vehicle or other such influences.

11 Claims, 7 Drawing Figures

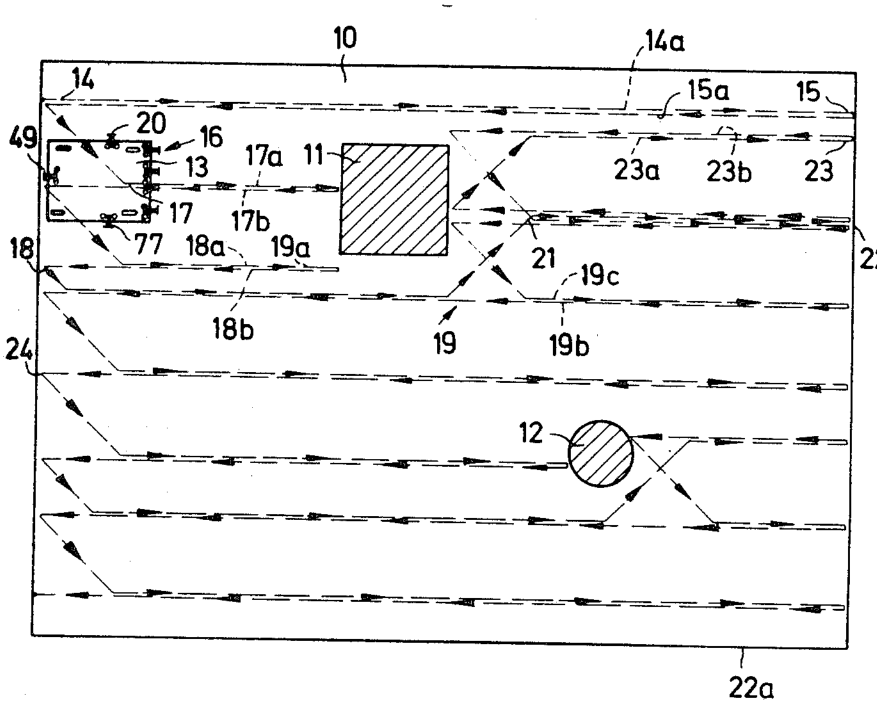

Fig. 1

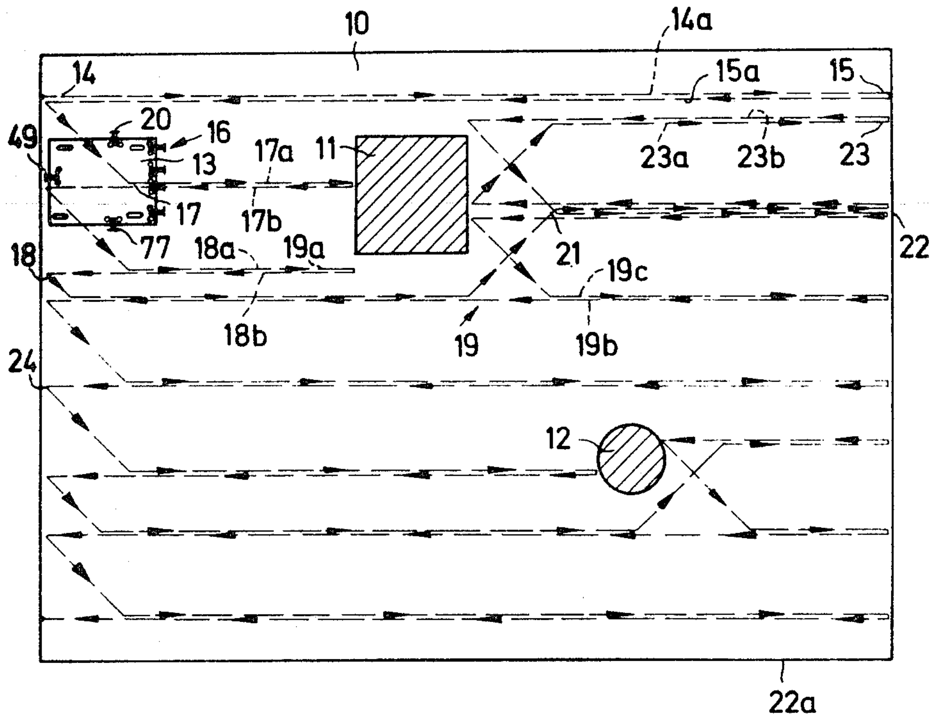
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Fig. 2

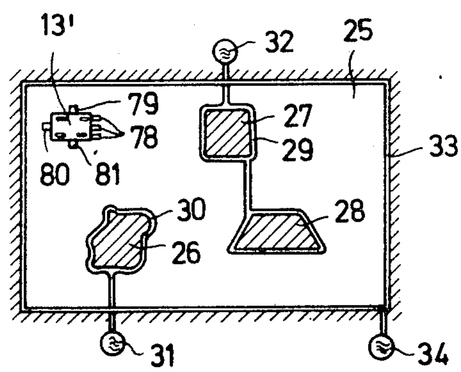
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Fig. 3

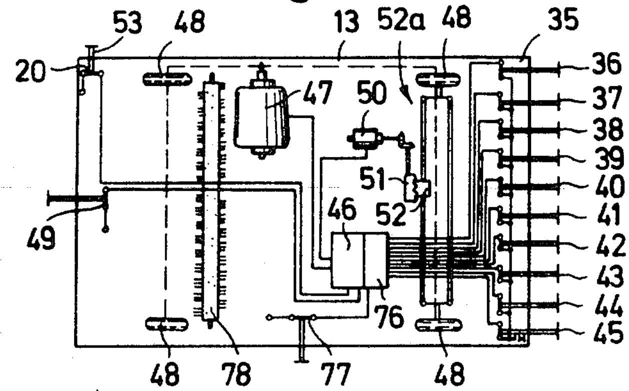

Fig. 4

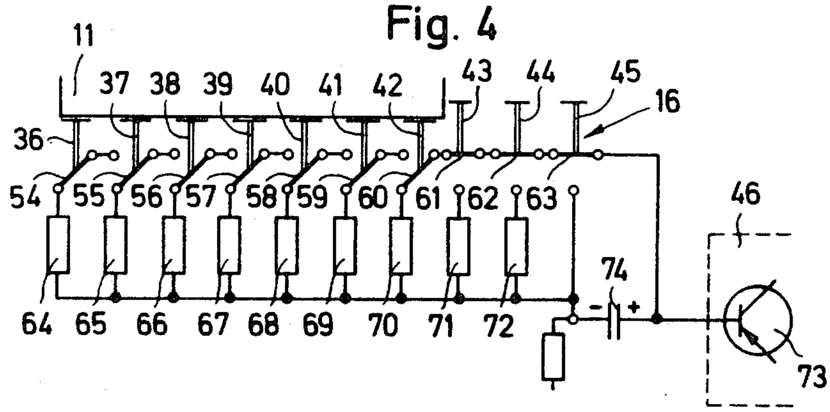

Fig. 5

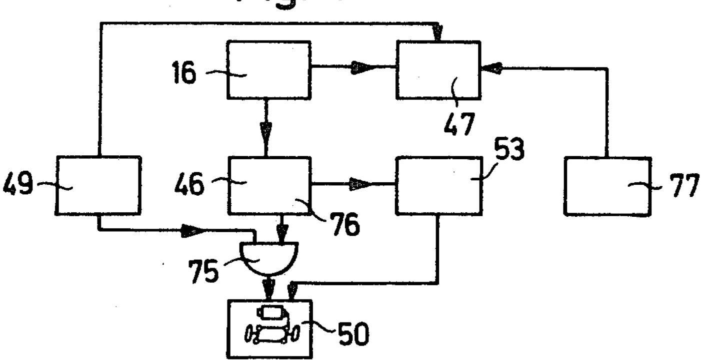

Fig. 6

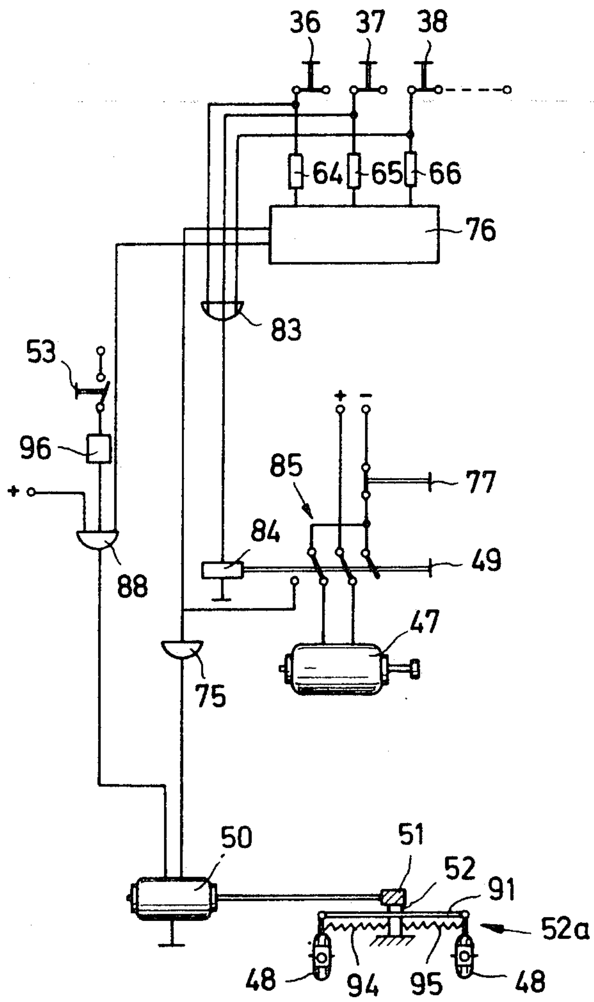
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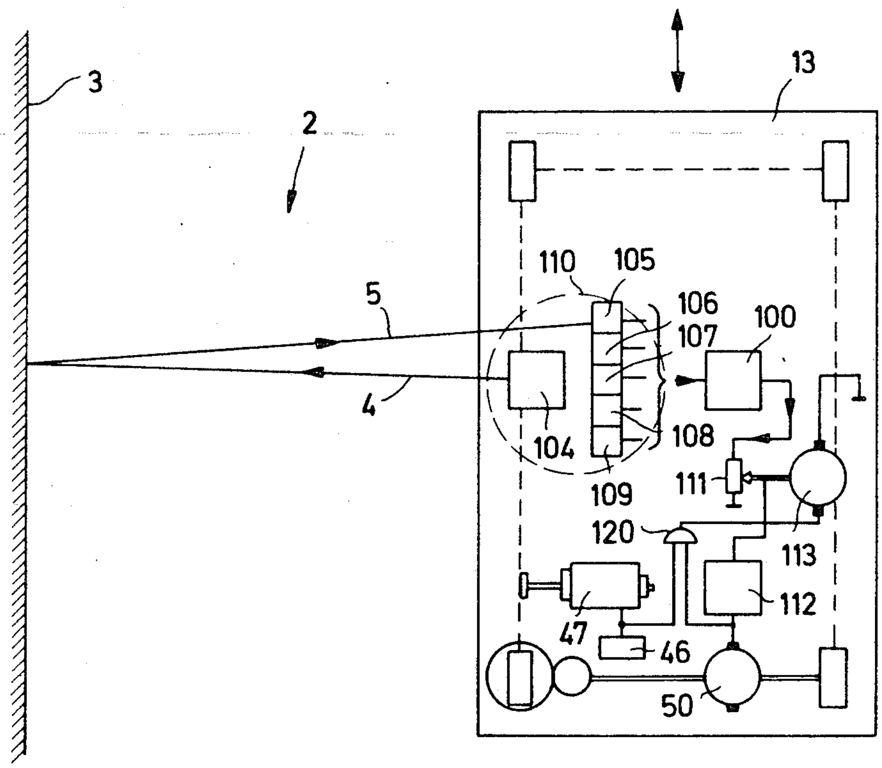
Fig. 7



AUTOMATICALLY STEERED SELF-PROPELLED VEHICLE

CROSS-REFERENCE TO RELATED APPLICATION

The apparatus of the present invention constitutes an improvement over and a further development of apparatus disclosed in the copending application Ser. No. 137,354 filed by Wolfram Müller on Apr. 26, 1971 and owned by the assignee of the present case.

BACKGROUND OF THE INVENTION

The present invention relates to an unmanned vehicle for treating the unobstructed part of an area having obstructions preventing continued movement of the vehicle.

Vehicles of this type are known which move along guiding conductors generating an alternating field. The actual path of the vehicle is determined by the guiding conductors, and the vehicle is incapable of recognizing obstructions which are 'ocated in the path of movement determined by a conductor, which was placed there after the operation of the vehicle was started. Since the guiding conductors are usually under the floor, a changing of the path is not easily possible. The arrangement of the prior art is unsuitable under conditions where loads are deposited at varying and different places, as may occur in storage areas and warehouses. It may occur, that a truck deposits its load on a conductor, so that the vehicle, moving along the guiding conductor, would ram the load.

An apparatus which solves the above-mentioned problems is disclosed and claimed in U.S. Pat. application Ser. No. 137,354 filed by Wolfram Müller on Apr. 26, 1971 and assigned to the assignee of the present invention. The apparatus disclosed in this referenced application is not limited or dependent in the provision of guiding conductors which are usually placed under the ground. As described in that application, once that apparatus has selected a straight path to traverse, it proceeds essentially along said straight path. However, because of irregularities in the ground over which the vehicle passes, tolerances in the steering mechanism and/or other such influences, it is possible that the vehicle deviate off its selected straight path.

SUMMARY OF THE INVENTION

It is one object of the invention to provide an automatically steered self-propelled vehicle which does not have the disadvantages of the vehicles known in the prior art.

Another object of the invention is to provide an automatically steered self-propelled vehicle which will in a simple and effective way maintain the course of the vehicle in substantial parallelism with a reference surface.

Another object of the invention is to provide an automatically steered self-propelled vehicle which can maintain its course in substantial parallelism with a reference surface independently of the distance that said vehicle is from said reference surface.

According to the present invention, and with these objects in view, the present invention can be utilized with a wheeled vehicle having a frame and motor means on said frame for propelling the vehicle at least in one direction. Steering means on the frame is provided for steering said vehicle so that the course of the vehicle is normally at least substantially parallel to a reference surface. At least one transmitter is provided for transmitting a signal in the direction of the reference surface and at least one receiver is provided for receiving the reflected signal from the reflecting surface when the vehicle deviates from its normal course. Regulating means are connected to the receiver and to the steering means for generating a control signal in response to said reflected signal for activating said steering means when said reflected signal is received by said receiver means to thereby alter the course of the vehicle and to cause the vehicle to resume its movement in substantial parallelism with said reference surface.

According to a presently preferred embodiment, the receiver includes a plurality of receiver sensors arranged in a determined order with respect to the transmitted signal. Each sensor is positioned to receive the reflected signal for different relative orientations of the vehicle with respect to the reference surface. The sensors are calibrated to generate output sensor signals which are a function of the degree by which said vehicle alters its course from its normal course. The output sensing signals generated by the sensors appear in quantized form and these are converted in a digital-to-analog converter which is connected to said sensors for converting said output sensing signals into an analog output signal. A variable gain amplifier is provided which has means for changing its gain. The amplifier is connected to the digital-to-analog converter and to the steering means for amplifying said analog output signal to yeild a control signal for appropriately activating, at a predetermined distance of said vehicle from said reference surface, said steering means. To make the control signals independent of the distance of the vehicle from the reference surface, the means for changing the gain includes a potentiometer having a movable portion, said analog output signal being applied across the potentiometer and said amplifier input being connected to said movable portion. Position changing means are provided for changing the position of the movable portion as a function of and proportional to the distance between the vehicle and the reference surface, whereby said control signal is substantially independent of the latter distance. In order to change the distance of the vehicle from the reference surface, the wheels of the vehicle are rotatable 90° from the normal position. The position changing means comprise a servo motor operatively connected to the movable portion to move its position when the servo motor is energized. An AND control switch has an output and two input points and generates an output at said output point only when appropriate signals are applied to both input points to energize said servo motor. One input point of said control switch is connected to the steering control means to sense the presence of the appropriate control signal. The other input point is connected to a control device connected to the wheels to sense when the wheels are rotated 90° from their normal position and the vehicle is changing its distance with respect to the reference surface. In this manner, the movable portion position and the gain of the amplifier is changed only in relation to changes in distance of said vehicle from said reference surface.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic plan view illustrating an area having obstructions, and a vehicle on the unobstructed portion of the area;

FIG. 2 is a schematic view illustrating an area having obstructions surrounded by conductors, and a vehicle on the unobstructed portion of the area;

FIG. 3 is a schematic plan view of an automatically steered self-propelled vehicle;

FIG. 4 is a diagram illustrating an electric circuit for the sensing means with which the vehicle of FIG. 3 is provided;

FIG. 5 is a diagram illustrating schematically the interconnection between elements of the control device of the vehicle;

FIG. 6 is a diagram schematically illustrating the control of the steering means of the vehicle; and

FIG. 7 is a schematic plan view of an automatically steered self-propelled vehicle incorporating the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, an area 10 has obstructions 11 and 12. A self-propelled vehicle 13, shown in greater detail in FIG. 3, may carry rotary-sweeping brushes for cleaning the unobstructed portion of the area 10. The obstructions 11 and 12 project above the surface of the area, and would obstruct the movement of vehicle 13. The area 10 is surrounded by a suitable obstruction by which vehicle 13 is prevented from moving out of and beyond the area.

The vehicle 13 is placed at the region 14 of the surrounding obstruction, and is driven by a motor 47 driving wheels 48, to move along a substantially straight path 14*a* shown with broken lines and arrowheads, until reaching the region 15 of the surrounding obstruction or boundary 22, which is recognized by front sensor means 16 of vehicle 13. The front sensor means generate a reversing signal which causes reversing of motor 47 so that the vehicle 13 moves in a rearward direction along the path 15*a* back to the region 14 of the surrounding obstruction 22. The rear sensor 49 senses the position of the vehicle, and causes again reversing of motor 48, so that the vehicle is again driven to move in forward direction toward the other end of the area 10. The vehicle 13 includes a control device 46 in which the signals generated by the sensing means 16 and 49 are evaluated for initiating required operations. In the region 14, the steering means of the vehicle are operated under the control of the control device 46 to turn the wheels 48 a suitable angle, for example 90° or 45°, to a new path starting at point 17. The distance between the first paths 14*a* and 15*a* and a new path may correspond to the width of vehicle 13 so that the entire area 10 would be successively swept by vehicle 13, if no obstructions 11 and 12 were found in area 10. The return of wheels 48 to the normal position for forward and rearward movement, is effected by resilient means when the steering motor 50 is de-energized. The steering motor 50 drives, when energized, a spindle 51 by which a gear 52 is displaced for operating a linkage 52*a* by which the wheels 48 are angularly displaced, as shown in FIG. 3. Resilient means 94,95 connected with linkage 91 straighten wheels 48 out when steering motor 50 is de-energized, see FIG. 6.

Vehicle 13 moves now along a path 17*a* until the sensing means 16 sense the obstruction 11, which causes reversal of motor 47 by the control device 46 so that vehicle 13 moves along the path 17*b* in a rearward direction toward point 17 where rear sensor 49 recognizes the boundary 24, and causes reversal of motor 47. The steering means 50,51,52,48 are again operated to steer the vehicle to a new path 18*a* on which the vehicle moves in forward direction toward the obstruction 11. Upon approaching the obstruction 11, the sensing means 16, which includes a row of sensors, recognizes that the obstruction 11 only partially projects into the new path 18*a*. Since only a part of the row of sensors 16 engage the obstruction, the row of front sensors 16 recognizes how far obstruction 11 projects into the new path 18*a*. The motor of the vehicle 47 is reversed, the vehicle moves back in reverse direction along the path 18*b*, and is automatically steered, in accordance with the information derived from the row of sensors 16, a smaller transverse distance to the new path 19*a* where the vehicle moves forward to the point 19 just bypassing the lateral surface of obstructionn 11. A lateral sensor 20 having a projecting actuator 53, as shown in FIG. 3, preferably constructed as a microswitch, engages the lateral surface of the obstruction 11 and is closed, but when vehicle 13 has passed the obstruction 11, the sensor switch 20,53 is again released by the lateral surface of obstruction 11 and the actuator 53 moves again transversely to open switch 20. In this manner, information is transmitted to the control device 46 that the obstruction 11 has been passed, and the control device 46 energizes the steering motor 50 to steer the vehicle 13 to a new path located between the obstruction 11 and the surrounding obstruction 22, and the steering means is controlled to straighten out the wheels 48 at the point 21 so that the vehicle moves in the initial forward direction, until the motor 47 is reversed at the boundary obstruction, and vehicle 13 moves back until the rear sensor, also a microswitch 49, again senses the obstruction 11 during rearward movement of vehicle 13.

As described above, motor 47 is again reversed and the steering means operated so that vehicle 13 moves along path 23*a* to the point 23 where motor 47 is reversed so that the vehicle moves rearward along path 23*b* until the rear sensor 49 senses the obstruction 11, and causes steering of vehicle 13 back to point 21, rearward toward obstruction 11, where the vehicle is steered again to move onto the track 19*c* where it moves forwardly until reversed by the boundary obstruction 22 and moves along the path 19*b* to the other end of the area 10, where the movements of the vehicle 13 are controlled as described above, and as shown in broken lines provided with arrowheads in FIG. 1. When vehicle 13 approaches the lateral boundary obstruction 22*a*, an end sensor 77 senses the obstruction 22*a*, and causes de-energization of motor 47 so that the vehicle stops, when the front sensor means 16 engages the other end of the boundary obstruction.

The embodiment of FIG. 1 operates due to mechanical operation of sensor switches. However, if the obstructions are recesses in the surface of the area, as shown at 26,27, and 28, in FIG. 2, wire loops 29 and 30 are placed on the surface of the area around the obstructions 26,27,28, and are connected to alternating current generators 31 and 32, as shown in FIG. 2. The corresponding loop 33 of a conductor may form the boundary obstruction around the area 25, and is supplied by alternating current generator 34 with a required current, so that the currents flowing in the wire loops create alternating fields. The vehicle 13' is provided with front sensors 78, lateral sensor 79, stop sensor 81, and rear sensor 80, each of which includes a coil responsive to the alternating fields and controlling the reversing and steering operations of vehicle 13'. The pattern according to which the area 25 is swept by the vehicle 13', is the same as described with reference to FIG. 1.

Referring now particularly to FIG. 3, the forward end of the supporting frame 35 of vehicle 13, carried 10 microswitches 36 to 45 arranged in a horizontal row, which either in the actuated condition, or in the normal position, generate a signal for the control device 46, which includes a storage device 76, as shown in the schematic diagram of FIG. 5. The storage device 76 may consist of bistable multivibrators which store the width of the portion of the vehicle 13 which is stopped by an obstruction. Each microswitch 36 to 45 is correlated with a certain information which is introduced into the control device 46 and the storage device 76, so that the width of an obstruction can also be determined by the sensing means 36 to 45 when the obstruction is narrow, so that only one microswitch 41, for example, engages the obstruction, while the other microswitches 36–40 and 42–45 are free. In accordance with the signals from the sensing means, which indicate that an obstruction or obstacle is located in the path of movement of the vehicle 13, the electromotor 47, which is the drive motor of the vehicle 13, is reversed. As explained above, the wheels 48 are then driven in a reverse direction of rotation, and the movement of the vehicle 13 takes place opposite to the intial forward direction. This rearward movement is maintained until the microswitch 49 at the rear end of frame 35 senses an obstruction, and generates a signal which indicates that the vehicle 13 has arrived at the start of the respective path of movement. In accordance with the width of the obstacle determined by the front sensor microswitches 36 to 45, vehicle 13 is moved laterally the distance determined by the microswitches 36 to 45.

If the sensed obstruction is wider than the vehicle 13, which is the case when the front sensor microswitches 36 to 45 engage the boundary obstruction 22 at the end of a forward movement, the control device 46 controls the steering means to move the vehicle in transverse direction its entire width.

When the lateral sensor 53 senses the end of a passed obstruction 11, it generates a signal to the control device 46, which causes a transverse steering of the vehicle 13 for its entire width in the same transverse direction in which sensor 53 projects, so that the vehicle can move between the front face of obstruction 11 and the boundary obstruction 22 so that no part of the surface area is skipped.

FIG. 4 illustrates an electric circuit for the sensor microswitches 36 to 45. Each microswitch 35 to 45 has a shiftable contact 54 to 63. Shiftable contacts of sensor switches, which are not actuated by an obstruction, are connected in series as shown for the shiftable contacts 61,62,63 of the sensor switches 43,44,45. The series-connected contacts 61,62,63 are connected to the positive terminal of a capacitor 74, which is also connected to the base of an input transistor 73 of the control device 46. The microswitches, which engage an obstruction, for example the microswitches 37 to 42 in FIG. 4, displace the respective shiftable contacts 54 to 60 to positions connected with the resistors 64 to 72, respectively, which have different resistances, which differ by the same amount. One free contact of microswitch 45, which is open, is connected to the interconnected ends of resistors 64 to 72, and to the negative terminal of capacitor 74. Consequently, the input electrode of the input transistor 73 receives an input signal corresponding to the charge of capacitor 74, and representing the width of the sensed obstruction 11.

Referring now to the schematic diagram of FIG. 5, the steering means, represented by reference numeral 50, are connected with the storage device 76 by an AND gate 75 which permits passage of a signal only when an output signal is generated by rear sensor switch 49 together with a signal from storage means 76 for causing operation of the steering means 50. The storage device 76, which may consist of multivibrators respectively correlated with the front microswitches 37, 35 is constructed so that the multivibrators switch to one or the other position depending on the condition of the microswitches 36 to 45, and remain in the shifted condition until the vehicle 13 has been steered into the next path. Storage device 76 is connected with the front sensing means 16 for recognizing the obstructions, which include the electromechanical microswitches 36 to 45.

In accordance with the determined value corresponding to the width of the obstruction 11 or 12, drive motor 47 is reversed so that the vehicle moves in the opposite direction until rear sensor switch 53 generates a signal which causes again reversal of drive motor 47 without energization of the same, as will be explained hereinafter. First, the steering motor 50 is operated so that when drive motor 47 is again energized, the vehicle 13 is steered laterally to the next following path. After the lateral displacement of vehicle 13, the wheels 46 are automatically straightened so that vehicle 13 drives in a substantially forward direction until sensing another obstruction in its path, or until arriving at the boundary obstruction 22.

By passing of an obstruction 11 or 12, the lateral sensor 53 generates a signal which influences the steering motor 50 to cause movement of the vehicle in the lateral direction into the omitted part of the area. The end switch 77 on the other side of the vehicle 13 is actuated when engaging the lateral portion 22*a* of the boundary obstruction, and disconnects drive motor 47 from the voltage source.

The storage 76 may be constituted by a capacitor, but it is also possible to provide a counting storage, as shown in FIG. 6. Such a storage 76 counts the actuated front sensor switches 36 to 45, and the counted number of operated front sensing switches in stored, until no longer required. Storage means of this type are well known to those skilled in the art.

Referring now to FIG. 6, three microswitches 36,37,38 are shown, respectively connected with resistors 64,65,66,as also shown in FIG. 4. Microswitches 36 to 45 can be connected by resistors 64 to 72 with storage device 76 of the control device 46.

Switches 36 to 38, for example, are connected by a OR gate 83 with the winding 84 of a relay. Relay 84 operates a reversing switch 85 which is also operable by the rear sensor 49. Reversing switch 85 is connected with drive motor 47 for reversing the same, so that the motor 47 is reversed when front sensor switches 36,37,38 simultaneously abut the obstruction during forward movement, or when rear sensor 49 abuts the boundary obstruction during rearward movement of the vehicle 13. The stop switch 77 is connected into the circuit of drive motor 47, so that the same is disconnected from the voltage source when the lateral boundary obstruction *22a* is sensed by the sensor 77.

The storage means 76 is connected with the first input of an AND gate 75 whose second input is connected with a contact of the reversing switch 85. The output of the AND gate 75 is connected with the steering motor 50. Storage means 76 is also connected with the first input of an AND gate 88 at whose second input a voltage is applied, and whose third input receives a signal from the lateral sensor switch 53. A differential element 96 connects lateral sensor switch 53 with the AND gate 88, and has the effect that only when a signal is generated by the lateral sensor switch 53, a pulse opens the AND gate 88. The output of the AND gate 88 is connected with the steering motor 50 which, as explained above, operates a worm spindle 85 and a gear segment 90 for displacing a steering link 91 by which the wheels 48 of the vehicle 13 can be angularly displaced. The two springs 94 and 95 are acting on linkage 91 to turn wheels 48 to a straight position when motor 50 does not operate.

When the vehicle 13 senses an obstruction during forward movement, at least one of the front switches 36 to 45 is actuated, so that a pulse reaches the winding 84 of the relay of the reversing switch 83 to the OR gate 83 so that drive motor 47 is reversed, causing the vehicle 13 to move along the same path as before in the reverse opposite direction. The width of the obstruction is determined in the storage means 76 by the number and position of the actuated front sensor switches 36 to 45. When vehicle 13 has arrived in its initial position, the rear sensor 49 is operated by the boundary obstruction, so that the reversing switch 85 is shifted and the drive motor 47 is set to forward movement. At the moment in which the rear sensor 49 responds, and reversing switch 85 is shifted, the voltage source of motor 47 is connected with the AND gate 75 so that steering motor 50 is energized during a certain time in accordance with the electric charge stored in storage means 76, for example in a capacitor, the charge representing the width of the obstruction in the path of movement of the vehicle 13. The time during which steering motor 50 is energized and turn wheels 48, is so determined that the wheels are turned 90°, and the vehicle moves in a direction transverse to its previous direction of movement until, in accordance with the amount of electricity stored in storage means 76, the AND gate 75 closes again so that steering motor 50 is reset, and springs 94,95 turn wheels 48 back to the initial straight position.

During the following movement of vehicle 13, the lateral sensor switch 53 is depressed, and nothing happens because the differential element 97 blocks the generated signal. When vehicle 13 has passed the obstruction, the actuator of the lateral sensor switch 53 is urged by a spring to move outward again so that a pulse is transmitted through the differential element 96 to the AND gate 88 and opens the same so that steering motor 50 is then connected with the voltage, but in a different polarity, as compared with the operation when rear sensor 49 sensed the rear portion of boundary obstructiOn 22. Consequently, wheels 48 are again turned 90°, but in the opposite direction, so that the vehicle 13 moves laterally, as viewed in FIG. 1 from the point 19 to the point 21 of its path. After the vehicle 13 has moved transversely a distance corresponding to the width of the obstruction 11, the AND gate 88 closes, and steering motor 50 is no longer operated, so that springs 94 and 95 turn wheels 48 back to a straight position for forward and rearward movement. At the same time when steering motor 50 is disconnected, a signal may be transmitted to storage means 76 which causes clearing of storage means 76 since the signal stored in the same is no longer required.

Paths *14a*, *15a*, *17a* and so on have been shown in FIG. 1 to be straight paths. As has been described, referring to FIG. 6, springs 94,95 are provided which act on linkage 91 to turn the wheels 48 to a straight position when motor 50 does not operate. This, at least to a first approximation, steers vehicle 13 in the substantially straight paths shown in FIG. 1. However, as a practical matter, unevenness of the ground over which vehicle 13 traverses, tolerances in the steering linkages and wheels of the vehicle and other prevailing influences sometimes have the tendency to cause vehicle 13 to move off of its predetermined straight course despite the action of resilient means 94,95.

Accordingly, the present invention is shown embodied on vehicle 13, where some of the details shown in FIG. 3 have been deleted for clarity. It should be noted, however, that the components shown in FIG. 3 are not necessarily replaced by the apparatus to be described in relation to FIG. 7. This latter apparatus merely serves to assist or enhance the operation of the vehicle 13 in substantial parallelism to a reference surface as will hereinafter be described. Referring to FIG. 7, the reference surface 3 is shown from which vehicle 13 is spaced a predetermined amount, leaving a space 2 therebetween. On vehicle 13 is mounted transmitter means 104 and receiver means comprising of sensors 105 through 109. The transmitter 104 transmits a signal 4 in the direction of the reference surface 3, the signal reflected 5 being received by one of the sensors 104 through 109. The type of signal transmitted by transmitter 104 is not critical for the purposes of the present invention, any suitable signal commonly used for such purposes being equally suitable. The only requirement, is that the reference surface 3 be at least partially reflecting of the type of signal which is transmitted by 104 so as to give rise to a reflected signal 5. Thus, transmitted signal 4 can consist of electromagnetic radiation, such as a light beam. In such an instance, transmitter 104 would consist of a light source and sensors 104 through 109 would consist of photodetecting devices. Another possibility is that transmitted signal 4 be an acoustic signal, in which case transmitter 104 can be in the form of a loudspeaker while sensors 104 through 109 can be selected to be a plurality of microphones.

As shown in FIG. 7, the transmitter 104 and the receiver sensors 105 through 109 are mounted on a rotatable deck 110. By such mounting, it is possible to rotate the direction of transmission of the transmitter 104 and the receiver sensors 105 through 109 in such a way as to utilize any surface surrounding vehicle 13 as a reference surface. As described above, space 2 can contain obstacles and as such, where appropriate, the elevation of the transmitter 104 and the sensors 105 through 109, should be such that these obstacles would not interfere or obstruct the transmitted signal 4 or the reflected signal 5.

The sensors 105 through 109 are arranged in a predetermined order with respect to the transmitted signal, each sensor being positioned to receive the reflected signal for a different relative orientation of the vehicle with respect to the reference surface. Normally, when the vehicle 13 is progressing along one of the straight paths depicted in FIG. 1 and substantially parallel to a reference surface such as surface 22, the transmitted signal 4 is transmitted perpendicularly to the reference surface 4 and, therefore, the angle of incidence is zero. Since the angle of incidence is zero, the reflected signal returns along the same path as the transmitted signal traversed, and the reflected signal is detected by a neutral sensor, such as sensor 107. The effect of this will hereinafter be described. Now, should the vehicle 13 deviate off its course of substantial parallelism with the surface 3, then, transmitter 104 being fixed to the frame of the vehicle 13, the transmitted signal 4 will now impinge on the reference surface 3 at a predetermined incidence angle. Accordingly, the reflected signal 5 will no longer impinge on sensor 107 but on another sensor, such as sensor 105, as shown in FIG. 7. The more the vehicle 13 deviates off its course of substantial parallelism with the surface 3, the greater is the angle of incidence and said beam accordingly impinges on sensors further from sensor 107. If the deviation of the vehicle 13 is in opposite direction, then the reflected signal 5 will impinge on a sensor on the other side of neutral sensor 107, such a sensor 108 or 109. The sensors 105 through 109 are calibrated to generate output sensing signals which are a function of the relative position of the individual sensors in relation to sensor 107. Thus, according to one arrangement, the output sensing signals of sensors 105 through 109 could increase in ascending order. However, the specific nature of the output sensing signals is not critical as long as they contain the information regarding the deviation of the vehicle.

Since the sensor 105 through 109 are shown to be individual sensors, each sensor will, in response to impingement of the reflected signal 5 on said sensor, generate a discrete output sensing signal. Stated another way, the outputs of sensors 105 through 109 are quantized in amplitude, phase, or some other variable. According to the embodiment presently shown in FIG. 7, the output sensing signals are quantized in amplitude and the quantized output sensing signals are fed to a digital-to-analog converter 100 for converting the output signals from a quantized signal to an analog signal. The analog output signal from digital-to-analog converter 100 is placed across potentiometer 111. The potentiometer 111 has a movable portion or a slidable contact which is mechanically connected to servomotor 113. The sliding contact of the potentiometer 111 is electrically connected to the input of a variable gain amplifier 112, whose output is connected to the steering motor 50.

When the vehicle 13 is travelling at a predetermined distance from the reference surface 3, the transmitter 104 is intermittently or continuously transmitting the signal 4 at the reference surface 3. As long as the vehicle 13 progresses in substantial parallelism with the reference surface 3, the reflected signal 5 impinges on the sensor 107. The output sensing signal of the sensor 107 and the digital-to-analog converter 100 are so adjusted that when the reflected signal 5 impinges on the neutral sensor 107, no control signal is supplied at the output of amplifier 112 which energizes steering motor means 50 to modify the course of vehicle 13. However, should the vehicle 13 now deviate from its course of substantial parallelism with the surface 3, the reflected signal will now impinge on a sensor other than the neutral sensor 107. Assuming that the reflected signal impinges on the sensor 106, a control signal will be generated at the output of the amplifier 112 to correct the course of the vehicle 13. The amplitude of the control signal is a function of the angle of incidence of the reflected signal, and therefore upon which sensor the reflected signal impinges on. For example, should the reflected signal 5 impinge on the sensor 105 instead of the sensor 106, then the control signal which energizes the steering motor 50 would be correspondingly greater, since the course of the vehicle 13 must be modified to a greater extent in order to maintain its normally defined course.

The calibration of the sensors 104 through 109 results in a set of control signals which are most appropriate for a predetermined distance between the vehicle 13 and the reference surface 3. It is clear from the geometry that even for equal angles of incidence of the transmitted and reflected signals, the reflected signal 5 may impinge on a sensor closer or further from the neutral sensor 107 depending on the distance of the vehicle 13 from the reference surface 3. In order to maintain the control signals only a function of the angle of incidence of the reflected signal 5 and not a function of the absolute distance of the vehicle 13 from the reference surface 3, means are provided for adjusting the gain of the amplifier 112 as a function of the distance of the vehicle 13 from the reference surface 3, so as to compensate for the above-described fact. Thus, an AND control device, here shown as an AND gate 120, is shown to have one output and two input points. The output point of AND gate 120 is connected to the servomotor 113 for energizing the same under specified conditions. One input point of the AND gate 120 is connected to the output of amplifier 112 to sense the presence of a control signal. The other input point of the AND gate 120 is connected to the junction point between the motor 47 and the control device 46. With this arrangement, the output of AND gate 120 will energize servomotor 113 only when both the wheels of the vehicle have turned 90° to their normal direction and they are in fact turning. This condition signifies that the vehicle 13 is moving in a direction perpendicular to the reference surface 3 in a way as to modify the distance between the reference surface 3 and the vehicle 13. For the duration of time that the wheels of the vehicle 13 are 90° from their normal position and these wheels are turning, the output of AND gate 120 energizes the servomotor 113 which is operatively connected to the movable portion or sliding contact of the potentiometer 111. Thus, by ensuring that the vehicle 13 moves towards or away from the reference surface 3 at a constant velocity, and by ensuring that the servomotor 113 moves the sliding contact at a correspondingly constant velocity, the position of a sliding contact, and, therefore, the effective gain of amplifier 112 can be proportionally changed. Now, the impingement of the reflected signal on one of the sensors 105 through 109, may not produce a control signal as large or as significant as they did at another prior distance. Although the output sensing signals of the sensors 105 through 109 in response to impingement thereon of the reflected signal 5 remains substantially constant, a greater or lesser portion of the converted analog output signal is fed to the amplifier 112. In a sense, the gain adjusting means above described is not unlike a weighing factor which weighs the output sensing signals from the respective sensors to take into account the distance of the vehicle 13 from the reference surface 3. By using such an arrangement, the control signals which energize the steering motor to modify slight deviations of the vehicle off its course of substantial parallelism, is substantially independent of the distance of the vehicle 13 from the reference surface 3 and almost entirely dependent on the degree of deviation from the desired course.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of vehicles for automatically following an obstructed surface differing from the types described above.

While the invention has been described as embodied in an automatically steered self-propelled vehicle following its direction of movement automatically in substantial parallelism with a reference surface, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

I claim:

1. An apparatus for maintaining a substantially fixed relative orientation between at least one partially reflecting reference surface and a steered self-propelled vehicle, particularly a vehicle for movement over the unobstructed portion of an area having obstructions, comprising a vehicle frame; motor means on said frame for propelling said vehicle at least in one direction; steering means on said frame for steering said vehicle so that the course of the vehicle is normally at least substantially parallel to said reference surface; at least one transmitter means for transmitting a signal in the direction of said reference surface; at least one receiver means for receiving the reflected signal from said reflecting surface when said vehicle deviates from said course; and regulating means connected to said receiver means and to said steering means for generating a control signal in response to said reflected signal for activating said steering means when said reflected signal is received by said receiver means to alter the course of the vehicle and cause the vehicle to resume its movement in substantial parallelism with said reference surface, wherein said receiver means includes a plurality of receiver sensors arranged in a predetermined order with respect to the transmitted signal, each sensor of said receiver means being positioned to receive said reflected signal for different relative orientations of said vehicle with respect to said reference surface and being calibrated to generate output sensing signals which are a function of the degree by which said vehicle deviates from its normal course.

2. An apparatus as defined in claim 1, further comprising sensing means on said frame for generating a signal when sensing an obstruction during movement in said direction; and a control device including steering control means responsive to said latter signal of said sensing means to operate said steering means to change the direction of movement of said vehicle so that said vehicle continues to move on said unobstructed portion of said area.

3. An apparatus as defined in claim 1, further including rotatable means for supporting said transmitter and receiver means and for rotating said transmitter and receiver means in equal amounts in relation to said vehicle frame, whereby any surface surrounding said vehicle can be chosen to be said reference surface.

4. An apparatus as defined in claim 1, wherein two transmitter means and two corresponding receiver means are arranged on said frame, each transmitter means transmitting a signal towards a corresponding reference surface.

5. An apparatus as defined in claim 1, wherein said transmitter and receiver means comprise a light source and photo-electric means respectively, and said transmitter and reflected signals comprise light beams.

6. An apparatus as defined in claim 1, wherein said transmitter and receiver means comprise acoustic transmitter and acoustic receiver means respectively, and said transmitted and reflected signals comprise acoustic signals.

7. An apparatus as defined in claim 1, wherein said output sensing signals generated by said sensors appear in quantized form, and wherein said regulating means includes a digital-to-analog converter which is connected to said sensors for converting said output sensing signals into an analog output signal.

8. An apparatus as defined in claim 7, wherein said regulating means includes a variable gain amplifier, having means for changing its gain, which is connected to said digital-to-analog converter and to said steering means for amplifying said analog output signal to yield said control signal for appropriately activating, at a predetermined distance of said vehicle from said reference surface, said steering means.

9. An apparatus as defined in claim 8, wherein said means for changing the gain includes a potentiometer having a movable portion, said analog output signal being applied across the potentiometer and said amplifier input being connected to said movable portion.

10. An apparatus as defined in claim 9, further comprising position changing means for changing the position of said movable portion as a function of and proportional to the distance between said vehicle and said reference surface, whereby said control signal is substantially independent of the latter distance.

11. An apparatus as defined in claim 10, wherein said wheels of said vehicle are rotatable 90° from their normal position in response to an appropriate control signal to thereby enable the vehicle to move in a direction perpendicular to said reference surface to thereby change its distance relative to said surface, and wherein said position changing means comprises a servomotor operatively connected to said movable portion to move

its position when said servomotor is energized; an AND control switch having an output and two input points and which generates an output at said output point only when appropriate signals are applied to both input points to energize said servomotor, one input point of said control switch being connected to said steering control means to sense the presence of said appropriate control signal, the other input point being connected to a control device and said motor means to sense when the wheels are energized to thereby detect when the vehicle is changing its distance with respect to said reference surface, whereby said movable portion position and the gain of the amplifier is changed only in relation to changes in distance of said vehicle from said reference surface.

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