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(54) ELECTRIC VEHICLE, CONTROL METHOD FOR SAME, AND CONTROL PROGRAM FOR SAME

(57) Provided is an electric vehicle capable of highly accurately detecting whether the electric vehicle touches a step and accomplishing an operation intended by the user. The electric vehicle includes one or more driving units for driving one or more wheels, where the one or more wheels include one or more front wheels, one or more rear wheels, or the front and rear wheels, a control unit for controlling the one or more driving units to perform a step overcoming control, a measuring unit for measuring at least one of speed or acceleration imparted to a vehicle body having the one or more wheels provided thereon, and a determining unit for determining, based on a value measured by the measuring unit, whether to perform the step overcoming control.

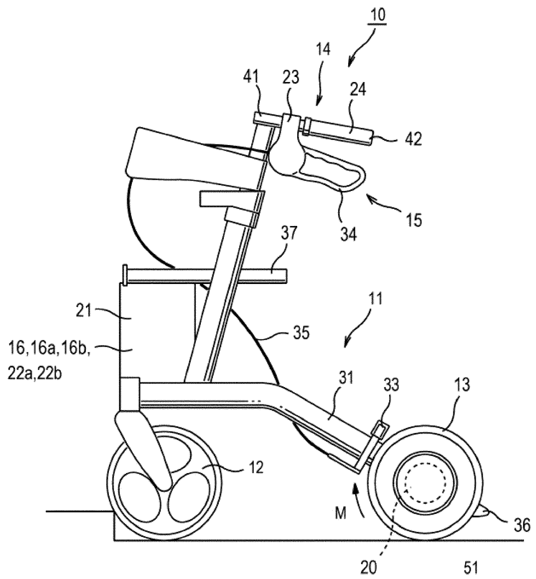

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an electric vehicle configured to assist elderly people, disabled people, patients and others with a gait impairment in walking, and a control method of the electric vehicle, and a control program of the electric vehicle.

BACKGROUND

[0002] There have been used walking aids including a wheeled walker (a rollator, a rolling walker) that assists the elderly's outing, and a walker that assists disabled people or patients in walking. For example, Patent Literature 1 discloses a walking aid that does not require the user to perform a burdensome operation to cause the front wheel that run onto a step.

[0003] Patent Literature 1 discloses a walking aid (electric vehicle) including a frame, at least one front wheel and at least one rear wheel provided on the frame, a drive unit configured to produce a driving force to lift the front wheel relative to the rear wheel, and a control unit connected to the drive unit and configured to control the drive unit. The walking aid is characterized in that, when the control unit determines that the front wheel has struck a step while a user is trying to move the electric vehicle forward, the control unit controls the drive unit to lift the front wheel relative to the rear wheel.

RELEVANT REFERENCES

LIST OF RELEVANT PATENT LITERATURE

[0004] Patent Literature 1: Japanese Patent Application Publication No. 2018-61819

SUMMARY

[0005] The conventional walking aids achieve only limited success in accurately detecting whether it touches a step. Since the conventional walking aids can not perform sufficiently fine control, they may not be able to overcome a step as intended by the user. For example, the step detecting and overcoming capabilities of the existing walking aids have been based on the assumption that the walking aids face almost directly the step while moving toward it (move toward the step almost perpendicularly). Therefore, the walking aids face difficulties in overcoming the step if their right and left front wheels touch the step at different times. In order to properly determine the need of performing a step overcoming operation, the walking aids need to distinguish a case where the walking aids touch a step from a case where the users stop the walking aids or a case where the walking aids touch an object other than a step.

[0006] The present disclosure provides an electric vehicle capable of highly accurately detecting whether the electric vehicle touches a step and accomplishing an operation intended by the user, a control method of the electric vehicle, and a control program of the electric vehicle.

[0007] An electric vehicle relating to the present disclosure is characterized by including one or more driving units for driving one or more wheels, where the one or more wheels include one or more front wheels provided on a vehicle body, one or more rear wheels provided on the vehicle body, or the front and rear wheels, a control unit for performing a step overcoming control on the one or more driving units so that the one or more wheels overcome a step, a measuring unit for measuring at least one of speed or acceleration imparted to the vehicle body having the one or more wheels provided thereon, and a determining unit for determining, based on a value measured by the measuring unit, whether to cause the control unit to perform the step overcoming control.

[0008] In the electric vehicle relating to the present disclosure, the determining unit may determine that the step overcoming control is to be performed if the one or more front wheels are estimated to have touched a step based on the value measured by the measuring unit.

[0009] In the electric vehicle relating to the present disclosure, the step overcoming control may include increasing a driving force applied by the one or more driving units to drive the one or more wheels.

[0010] In the electric vehicle relating to the present disclosure, the step overcoming control may include turning the vehicle body.

[0011] In the electric vehicle relating to the present disclosure, the step overcoming control may include increasing a driving force while turning the vehicle body.

[0012] In the electric vehicle relating to the present disclosure, the one or more front wheels may include left and right front wheels spaced away from each other in a width direction of the vehicle body, and the determining unit may estimate, based on the value measured by the measuring unit, which one of the left and right front wheels has touched the step.

[0013] In the electric vehicle relating to the present disclosure, the measuring unit may at least measure (i) acceleration in the width direction of the vehicle body and (ii) acceleration directed to reduce a speed of the vehicle body or acceleration in a front-rear direction of the vehicle body.

[0014] In the electric vehicle relating to the present disclosure, the one or more rear wheels may include left and right rear wheels spaced away from each other in the width direction of the vehicle body, and the measuring unit may at least calculate (i) an average value between acceleration of the left rear wheel in a rotational direction and acceleration of the right rear wheel in a rotational direction, or (ii) a difference between acceleration of the left rear wheel in a rotational direction and acceleration of the right rear wheel in a rotational direction.

[0015] In the electric vehicle relating to the present disclosure, the measuring unit may at least calculate (i) an average value between acceleration of the left front wheel in a rotational direction and acceleration of the right front wheel in a rotational direction, or (ii) a difference between acceleration of the left front wheel in a rotational direction and acceleration of the right front wheel in a rotational direction.

[0016] In the electric vehicle relating to the present disclosure, the measuring unit may measure (i) at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and (ii) acceleration in the width direction of the vehicle body, and the determining unit may estimate which one of the left and right front wheels has touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a first threshold value.

[0017] In the electric vehicle relating to the present disclosure, the measuring unit may measure (i) at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and (ii) acceleration in the width direction of the vehicle body, and the determining unit may estimate which one of the left and right front wheels has touched a step when a largest absolute value of the acceleration in the width direction of the vehicle body measured within a predetermined period of time after at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a first threshold value becomes equal to or greater than a second threshold value.

[0018] In the electric vehicle relating to the present disclosure, the measuring unit may measure at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and the determining unit may estimate that the left and right front wheels have touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a third threshold value that is less than the first threshold value.

[0019] In the electric vehicle relating to the present disclosure, the control unit may control the one or more driving units such that only a driving unit of a rear wheel located on a same side in the width direction of the vehicle body as one of the front wheels that is estimated to have touched the step generates a driving force.

[0020] In the electric vehicle relating to the present disclosure, the control unit may control the one or more driving units such that only a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step generates a driving force.

[0021] In the electric vehicle relating to the present disclosure, the control unit may control the one or more driving units such that a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step generates a higher driving force than a driving unit of at least one of (i) the front wheel estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

[0022] In the electric vehicle relating to the present disclosure, the control unit may control the one or more driving units such that a driving unit of at least one of (i) one of the front wheels that is estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step generates a higher driving force than a driving unit of at least one of (i) one of the front wheels that is estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

[0023] In the electric vehicle relating to the present disclosure, the control unit may gradually increase, until a fourth threshold value, (i) a driving force applied by a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step and (ii) a driving force applied by a driving unit of at least one of the front wheel estimated to have touched the step or a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

[0024] In the electric vehicle relating to the present disclosure,(i) the driving force applied by the driving unit of at least one of the front wheel or the rear wheel located on the opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step may be greater than (ii) the driving force applied by the driving unit of at least one of the front wheel estimated to have touched the step or the rear wheel located on the same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

[0025] In the electric vehicle relating to the present disclosure, the control unit may control the one or more driving units such that, when the determining unit estimates based on the value measured by the measuring unit that both of the front wheels have touched a step, (i) driving units of the front wheels on respective sides in the width direction of the vehicle body, (ii) driving units of the rear wheels on the respective sides in the width direction of the vehicle body, or (iii) driving units of the front and rear wheels generate equal driving forces.

[0026] In the electric vehicle relating to the present disclosure, when a largest absolute value of acceleration in the width direction of the vehicle body measured by the measuring unit becomes equal to or greater than a second threshold value, the control unit may lower a fifth threshold value for the acceleration based on which whether or not to perform the step overcoming operation is determined.

[0027] In the electric vehicle relating to the present disclosure, the control unit may increase a sixth threshold value for an absolute value of the acceleration based on which whether or not to perform the step overcoming operation is determined, as the speed of the vehicle body measured by the measuring unit increases.

[0028] In the electric vehicle relating to the present disclosure, the measuring unit may measure at least one of acceleration directed to reduce the speed of the vehicle body or rearward acceleration of the vehicle body, and the determining unit may estimate that the one or more front wheels have touched a step if at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is greater than a seventh threshold value.

[0029] In the electric vehicle relating to the present disclosure, the determining unit may not estimate that the one or more front wheels have touched a step if at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than the seventh threshold value.

[0030] In the electric vehicle relating to the present disclosure, the measuring unit may measure a frequency spectrum of vibration of the vehicle body, and the determining unit may estimate that the one or more front wheels have touched a step if a representative value of values measured by the measuring unit is greater than an eighth threshold value.

[0031] In the electric vehicle relating to the present disclosure, the determining unit may not estimate that the one or more front wheels have touched a step if the representative value of the values measured by the measuring unit is equal to or less than the eighth threshold value.

[0032] The electric vehicle relating to the present disclosure may include a memory unit for storing the value measured by the measuring unit, and the determining unit may adjust the seventh threshold value based on the measured value stored on the memory unit.

[0033] In the electric vehicle relating to the present disclosure, after the control unit performs a step overcoming operation for the one or more front wheels, the determining unit may lower the seventh threshold value if acceleration that is lower than the seventh threshold value is detected within a predetermined period of time before the control unit performs the step overcoming control for the one or more front wheels.

[0034] In the electric vehicle relating to the present disclosure, the determining unit may increase the seventh threshold value if the acceleration measured by the measuring unit when the control unit performs the step overcoming operation for the one or more front wheels is greater than the seventh threshold value and a difference between the measured acceleration and the seventh threshold value is greater than a predetermined value.

[0035] In the electric vehicle relating to the present disclosure, the vibration of the vehicle body may include vibration of the vehicle body in the front-rear direction.

[0036] The electric vehicle relating to the present disclosure may include a buffer member covering at least part of a front portion of the vehicle body or respective side surfaces of the vehicle body that face each other in the width direction.

[0037] In the electric vehicle relating to the present disclosure, the one or more front wheels may be one or more turnable twin-wheel casters.

[0038] An electric vehicle relating to the present disclosure is characterized by including a driving unit for driving a wheel, where the wheel includes at least one of a front wheel or a rear wheel, a control unit for controlling the driving unit to perform a step overcoming control, a measuring unit for measuring at least one of speed or acceleration imparted to a vehicle body having the wheel provided thereon, and a determining unit for determining whether to cause the control unit to perform the step overcoming control, based on a value measured by the measuring unit. The electric vehicle is characterized in that the control unit increases a driving force applied by the driving unit to drive the wheel or turns the vehicle body if the determining unit determines, based on the value measured by the measuring unit, that the front wheel has touched a step.

[0039] A control method of an electric vehicle relating to the present disclosure is characterized by including steps of measuring at least one of speed or acceleration imparted to a vehicle body, and determining whether to perform a step overcoming control based on at least one of the speed or the acceleration.

[0040] The control method of an electric vehicle relating to the present disclosure may include steps of determining whether a front wheel has touched a step based on at least one of the speed or the acceleration, and performing the step overcoming control when the front wheel is estimated to have touched a step.

[0041] According to the control method of an electric vehicle relating to the present disclosure, the step overcoming control may include at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body.

[0042] A control program of an electric vehicle relating to the present disclosure is characterized by including steps of measuring at least one of speed or acceleration imparted to a vehicle body, determining whether a front wheel has touched a step based on at least one of the speed or the acceleration, and performing the step overcoming control when the front wheel is estimated to have touched a step.

[0043] According to the control program of an electric vehicle relating to the present disclosure, the step overcoming control may include at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body.

[0044] The present disclosure can provide an electric vehicle capable of highly accurately detecting whether it touches a step and accomplishing an operation intended by the user.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045]

Fig. 1 is a perspective view of a power-assisted rollator according to a first embodiment of the disclosure.
Fig. 2 is a side view of the power-assisted rollator according to the first embodiment of the disclosure.
Fig. 3 schematically shows a leg sensor.
Fig. 4 schematically shows a grip sensor.
Fig. 5 schematically shows a modification example of the grip sensor.
Fig. 6 is a flowchart illustrating an example of how a control unit works.
Fig. 7 is a graph showing how a driving force changes as time elapses after a front wheel strikes a step.
Fig. 8 is a graph showing, as an example, values of acceleration detected when the power-assisted rollator strikes a step and when it is stopped and also showing threshold values.
Fig. 9 is a graph showing, as an example, acceleration detected when the power-assisted rollator strikes a soft object and acceleration detected when it strikes a step.
Fig. 10 schematically shows an example configuration with a buffer member being provided at a front portion of a vehicle body.
Fig. 11 is a plan view showing, as an example, acceleration applied to the vehicle body when the power-assisted rollator strikes a step.
Fig. 12 is a graph showing how the detected values of acceleration differ depending on which of the front wheels collide.
Fig. 13 is a graph showing, as an example, the values of acceleration detected when the power-assisted rollator moves toward a step while turning and when it moves toward a step perpendicularly.
Fig. 14 is a graph showing, as an example, the temporal waveform of the acceleration measured when the power-assisted rollator strikes a step.
Fig. 15 is a plan view illustrating a first example of the power-assisted rollator running toward a step at an angle.
Fig. 16 is a plan view illustrating a second example of the power-assisted rollator running toward a step at an angle.
Fig. 17 is a plan view illustrating the second example of the power-assisted rollator running toward a step at an angle.
Fig. 18 is a graph showing, as an example, a control performed to turn the electric vehicle after detecting one of the front wheels touches a step.
Fig. 19 is a graph showing, as an example, a control performed to turn the electric vehicle after detecting one of the front wheels touches a step.
Fig. 20 is a plan view showing a first example of a case where the front wheels are directed at an angle relative to the direction in which the vehicle body runs.
Fig. 21 is a plan view showing a second example of the case where the front wheels are directed at an angle relative to the direction in which the vehicle body runs.
Fig. 22 is a plan view showing, as an example, how the power-assisted rollator strikes a step.
Fig. 23 is a plan view showing, as an example, how the power-assisted rollator strikes a step.
Fig. 24 is a perspective view of a power-assisted rollator according to a second embodiment of the disclosure.
Fig. 25 is a side view of the power-assisted rollator according to the second embodiment of the disclosure.
Fig. 26 is a side view of a rear wheel of the power-assisted rollator according to the second embodiment of the disclosure.
Fig. 27 is a sectional view of the rear wheel of the power-assisted rollator according to the second embodiment of the present disclosure (a sectional view along the XI-XI line in Fig. 25).
Fig. 28 is a perspective sectional view of the rear wheel of the power-assisted rollator according to the second

embodiment of the present disclosure.

Fig. 29 schematically shows a modification example of the power-assisted rollator (running under normal circumstances).

Fig. 30 schematically shows the modification example of the power-assisted rollator (the front wheel being locked).

Fig. 31a schematically shows a power-assisted rollator according to a third embodiment of the present disclosure.

Fig. 31b schematically shows the power-assisted rollator according to the third embodiment of the present invention.

Fig. 32a schematically shows a power-assisted rollator according to a modification example of the third embodiment of the present disclosure.

Fig. 32b schematically shows the power-assisted rollator according to the modification example of the third embodiment of the present disclosure.

Fig. 33 is a perspective view of a power-assisted rollator according to a fourth embodiment of the disclosure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

<First Embodiment

[0046] A first embodiment of the present disclosure will now be described with reference to Figs. 1 to 23. In the following description, common constituents are assigned with common reference numbers. The common constituents are named and configured in the same manner. The constituents assigned with the common reference numbers are described in detail only once.

[0047] Figs. 1 and 2 show an electric rollator (hereunder referred to as a power-assisted rollator) as an example of an electric vehicle. Fig. 1 is a schematic perspective exterior view showing, as an example, a power-assisted rollator 10 according to the first embodiment, and Fig. 2 is a side view of the power-assisted rollator 10 of Fig. 1.

<Configuration of Power-Assisted Rollator>

[0048] Referring to Figs. 1 and 2, the power-assisted rollator 10 includes a frame 11, a pair of front wheels (wheels) 12 and a pair of rear wheels (wheels) 13 provided on the frame 11, and a pair of handles (operation units) 14 connected to the frame 11. The pair of rear wheels 13 includes two rear wheels spaced away from each other in the width direction of the vehicle body. Similarly, the pair of front wheels 12 includes two front wheels 12 spaced away from each other in the width direction of the vehicle body. The following description is made mainly with reference to an example case where the electric vehicle is a four-wheel vehicle with two front wheels and two rear wheels. This configuration, however, is a mere example. For example, the electric vehicle may be a tricycle having a vehicle body, one front wheel provided on the vehicle body, and a pair of (two) rear wheels spaced away from each other in the width direction of the vehicle body. Alternatively, three or more front wheels may be spaced away from each other in the width direction. The terms "right front wheel" and "left front wheel" respectively refer to the far right front wheel and the far left front wheel provided on the front portion of the vehicle body. In other words, the front wheels include the left and right front wheels spaced away from each other in the width direction of the vehicle body. Furthermore, three or more rear wheels may be spaced away from each other in the width direction. The terms "right rear wheel" and "left rear wheel" respectively refer to the far right rear wheel and the far left rear wheel provided on the front portion of the vehicle body. In other words, the rear wheels include the left and right rear wheels spaced away from each other in the width direction of the vehicle body. The number of wheels of the electric vehicle is not limited to any particular number. The electric vehicle may include different numbers of wheels from those mentioned above.

[0049] A brake unit 15 is further provided at each handle 14 to manually put a brake on the power-assisted rollator 10. In the following, the vehicle body of the power-assisted rollator 10 indicates the frame 11 and the entire structure supported by the frame 11.

[0050] Each of the rear wheels 13 has a motor 20 coupled thereto for assisting the rear wheel 13 in moving. The power-assisted rollator may have motors coupled to the front wheels 12 for assisting the respective front wheels 12 in moving. Every one of the front and rear wheels 12 and 13 may be coupled to motors, or only the front wheels 12 may be coupled to motors. A battery 21 and a control unit 16 are mounted to the frame 11.

[0051] The control unit 16 includes an acceleration sensor 22a and a speed sensor 22b. Furthermore, each of the handles 14 has an inclination sensor 23 and a grip sensor (an operation force sensor) 24. A leg sensor 25 for detecting a leg of a user is provided on the frame 11 at a position below the pair of handles 14.

[0052] Next, the components of the power-assisted rollator 10 will be further described.

[0053] The frame 11 includes a pair of right and left pipe frames 31 and a connecting frame 32 that connects together the pipe frames 31 in the horizontal direction.

[0054] On the front ends of the left and right pipe frames 31, the front wheels 12 are provided, respectively. In other words, the two front wheels are spaced away from each other in the width direction of the vehicle body of the power-assisted rollator 10. Of the front wheels 12, the one on the R side is referred to as the right front wheel, and the one on the L side is referred to as the right front wheel. The front wheels 12 are each rotatable in the front-rear direction and also turnable about vertical axes.

[0055] Furthermore, the two rear wheels 13 are respectively provided on the rear ends of the left and right pipe frames 31. Of the rear wheels 13, the one on the R side is referred to as the right rear wheel, and the one on the L side is referred to as the right rear wheel. The rear wheels 13 are rotatable in the front-rear direction. Accordingly, the power-assisted rollator 10 can easily move forward and backward and, moreover, easily move in the left-right direction or change its direction (turn around).

[0056] Near the periphery of each rear wheel 13, a brake shoe 33 is provided that is configured to mechanically touch the rear wheel 13. The brake shoes 33 are connected to brake levers 34 of the brake units 15 via wires 35. Therefore, when the user manually operates the brake levers 34, the brake shoes 33 may be accordingly actuated to brake the rear wheels 13. The mechanical brakes are not limited to such, and can be configured in any manner.

[0057] A fall prevention member 36 is provided on the rear end of each of the left and right pipe frames 31. The fall prevention member 36 is configured to prevent the power-assisted rollator 10 from being toppled in the rear direction when the pair of front wheel 12 is lifted off the ground.

[0058] On the upper ends of the left and right pipe frames 31, the handles 14 are provided. The handles 14 are designed to be gripped by hands of a user. The handles 14 each include a pole 41. The pole 41 is provided with a grip 42. The pole 41 is also provided with the brake lever 34. The configuration of the handle 14 is not limited to the above-described one. For example, a bar handle extending in the horizontal direction may be provided so as to connect the right and left pipe frames 31, and the grips 42 may be provided as the left and right handles 14 on the bar handle.

[0059] In the embodiment, the motors 20 may be any motors such as servomotors, stepper motors, AC motors, and DC motors. Alternatively, the motors 20 may be integrated with a speed reducer. The motors 20 assist the rear wheels 13 in moving by driving the rear wheels 13 in the forward direction, so that the power-assisted rollator 10 can run. In the embodiment, the motors 20 also serve as driving units for lifting the front wheels 12 relative to the rear wheels 13. More specifically, the motors 20 (driving units) produce a driving force for applying to the power-assisted rollator 10 a moment directed to lift the front wheels 12.

[0060] Furthermore, the motors 20 may also serve as dynamic brakes. In this case, the motors 20 further serve as brake units for braking the rear wheels 13. When the motors 20 are configured to brake the rear wheels 13, the motors 20 work as power generators, and the resistance produced by the power generators is used to apply a brake. When the motors 20 serve as brake units, the motors 20 may be used as reverse brakes for driving the motors 20 reversely. The brake units for braking the rear wheels 13 may be different components than the motors 20. Such brake units are, for example, electromagnetic or mechanical brakes.

[0061] The left and right motors 20 may be controlled by the control unit 16 independently of each other. If there is no need to establish a difference in speed or acceleration between the wheel on the right side of the vehicle body and the wheel on the left side of the vehicle body, the control unit 16 may collectively control the left and right motors 20.

[0062] In the present embodiment, the motors 20 are respectively coupled with the rear wheels (left and right rear wheels) 13. Note that, however, the single motor may be coupled to all of the front and rear wheels 12 and 13.

[0063] The control unit 16 controls the driving units of the power-assisted rollator 10 (e.g., the motors 20 described above), so that a step overcoming control is performed. The term "step overcoming control" means controlling the power-assisted rollator 10 such that the front wheels on the vehicle body can climb a step. A determining unit 16a is configured to determine whether or not a step overcoming control is to be performed, based on the values measured by a measuring unit. For example, the determining unit 16a determines that a step overcoming control is to be performed if the values measured by the measuring unit suggest that the front wheels 12 have touched a step. Examples of the measuring unit include acceleration sensors 22a, 81r to 821 and a speed sensor 22b, which will be described later. For example, the measuring unit may be configured to measure (i) at least one of acceleration directed to reduce the speed of the vehicle body or acceleration in the front-rear direction of the vehicle body, and (ii) acceleration in the width direction of the vehicle body. These measurements can be used to distinguish a case where one of the left and right front wheels has touched a step (the power-assisted rollator 10 has touched a step on one side) from a case where both of the left and right front wheels have touched a step (the power-assisted rollator 10 has touched a step on both sides).

[0064] For example, the control unit 16 and determining unit 16a are provided adjacently to the battery 21. The control unit 16 and determining unit 16a may be equipped with a processor capable of executing various instructions or programs. The control unit 16 and determining unit 16a execute, for example, a control program of the power-assisted rollator 10 (electric vehicle). The control unit 16 and determining unit 16a may include, for example, ASICs, FPGAs, PLDs, and other hardware circuits. In addition, the power-assisted rollator 10 may include a memory unit 16b. The control unit 16 and determining unit 16a can read and write data to and from the memory unit 16b. The memory unit 16b stores thereon the instructions and programs to be executed by the control unit 16 and determining unit 16a, the data to be used when the instructions and programs are executed, and the values measured by the various sensors (measuring unit). The control unit 16 and determining unit 16a may be implemented using a common hardware circuit. The control unit 16 and determining unit 16a may be implemented using a common program. The control unit 16 and determining unit 16a may be implemented using different hardware circuits or programs.

[0065] The step overcoming control, which is performed by the driving units, may include increasing the driving force produced by the driving units and designed to drive the wheels. In addition, the step overcoming control may include turning the vehicle body. The step overcoming control may include increasing the driving force while turning the vehicle body. The operations performed by the control unit 16 and determining unit 16a will be described in detail below.

[0066] The memory unit 16b provides a storage area where various types of data can be stored. The memory unit 16b may be located near the control unit 16 or may be part of the control unit 16. The memory unit 16b may be a volatile memory such as SRAM and DRAM, or non-volatile memory such as NAND, MRAM, or FRAM. Alternatively, the memory unit 16b may be a storage such as a hard disk and SSD, or an external storage device. There are no particular limitations on the type of the memory unit 16b. The memory unit 16b may be a combination of two or more types of memory and storage devices.

[0067] The acceleration sensor 22a is configured to measure the acceleration in the front-rear direction of the vehicle body and the acceleration in the width direction of the vehicle body. Here, the acceleration in the front-rear direction of the vehicle body refers to the acceleration in the direction FB identified in Fig. 1. The acceleration in the width direction of the vehicle body refers to the acceleration in the directions L and R identified in Fig. 1. As will be described below, the acceleration sensor 22a may be configured to measure, in addition to the acceleration in the front-rear direction of the vehicle body, the acceleration directed to reduce the speed of the vehicle body. Alternatively, the acceleration sensor 22a may be configured to measure, in place of the acceleration in the front-rear direction of the vehicle body, the acceleration directed to reduce the speed of the vehicle body. The control unit 16 can acquire the acceleration measured by the acceleration sensor 22a. The acceleration applied to the vehicle body can be measured by a sensor such as a MEMS sensor, but devices of any types may be used.

[0068] Alternatively, a piezoelectric sensor, a strain gauge, an operating force sensor (for example, a grip sensor) and the like may be used to measure the force applied to the power-assisted rollator 10 or any of the components of the power-assisted rollator 10, so that the acceleration can be estimated.

[0069] The acceleration sensor may measure the acceleration applied to each of the wheels of the power-assisted rollator 10 in the rotating direction. For example, the acceleration sensors 81r to 821 shown in Fig. 1 are configured to measure the acceleration of the respective wheels in the rotating direction. Specifically, the acceleration sensor 81r is configured to measure the acceleration of the right front wheel (the front wheel 12 on the R side). The acceleration sensor 811 is configured to measure the acceleration of the right front wheel (the front wheel 12 on the L side). The acceleration sensor 82r is configured to measure the acceleration of the right rear wheel (the rear wheel 13 on the R side). The acceleration sensor 821 is configured to measure the acceleration of the right rear wheel (the rear wheel 13 on the L side).

[0070] The acceleration sensors 81r to 821 may directly measure the acceleration of the respective wheels, or measure the acceleration of the motors 20 and estimate the acceleration of the wheels. Alternatively, the acceleration sensors 81r to 821 may measure the speed of the wheels or motors 20 and estimate the acceleration. Furthermore, the acceleration sensors 81r to 821 may measure the number of rotations per unit time of the motors 20 or wheels and calculate the time derivative of the number of rotations to estimate the acceleration. The control unit 16 can acquire the acceleration measured by the acceleration sensors 81r to 82l.

[0071] The speed sensor 22b senses the number of rotations or speed of the rear wheels 13 and transmits a signal representing the number of rotations or speed to the control unit 16. The speed sensor 22b may be provided adjacently to, for example, the control unit 16. The speed sensor 22b may be embedded in the rear wheels 13 of the power-assisted rollator 10. Alternatively, the speed sensor 22b may be embedded only in the front wheels 12, or in all of the front and rear wheels 12 and 13. The speed sensor can be, for example, a gyro sensor for measuring an angular velocity. Using a gyro sensor makes it possible to detect which one of the left and right wheels has struck an object such as a step.

[0072] When the motors 20 are brushless motors, the speed sensor 22b may use the Hall elements embedded in the motors 20 to calculate the number of rotations or speed of the wheels, or the speed of the power-assisted rollator 10.

[0073] When the speed can be detected based on the counter electromotive force of the motors 20, the speed sensor 22b can be configured to calculate the number of rotations or speed of the wheels, or the speed of the power-assisted rollator 10 based on the counter electromotive force of the motors 20. When the angular velocities of the rear or front wheels 13 or 12 can be detected, the speed sensor 22b can be configured to calculate the number of rotations or speed of the wheels, or the speed of the power-assisted rollator 10 based on the angular velocities.

[0074] The speed sensor 22b may not be necessarily embedded in the front and rear wheels 12 and 13, but can be attached to the frame 11, the handles 14 or any other components. The speed may be calculated by integrating the acceleration measured by the acceleration sensors. When a Global Positioning System (GPS) is used, the speed may be calculated based on the displacement of the coordinates per unit time.

[0075] The speed sensor 22b and the acceleration sensors 81r to 821 may be used to measure the acceleration directed to reduce the speed of the vehicle body (negative acceleration). Specifically, the value measured by the speed sensor 22b is consulted in order to identify the direction in which the vehicle body runs. In addition, the directions of the accelerations measured by the acceleration sensors 81r to 82l are identified. If the measured accelerations include a component directed oppositely to the direction in which the vehicle body runs, the component can be deemed as the acceleration directed to reduce the speed of the vehicle body.

[0076] The inclination sensor 23 is configured to sense the inclination of the power-assisted rollator 10, or sense, for example, whether the power-assisted rollator 10 is on a flat or inclined surface, and send to the determining unit 16a a signal related to the inclination of the power-assisted rollator 10. The determining unit 16a may estimate whether or not the power-assisted rollator 10 has successfully overcome a step, based on the value measured by the inclination sensor 23. The inclination sensor 23 is provided in the upper portion of the power-assisted rollator 10, for example, in each of the handles 14. Alternatively, the inclination sensor 23 may be provided in the lower portion of the power-assisted rollator 10. If the inclination sensor 23 is provided in the upper portion, however, the attitude of the power-assisted rollator 10 can be more accurately sensed than if the inclination sensor 23 is provided in the lower portion. The inclination sensor 23 may be a gyro sensor. Alternatively, the acceleration sensors may be used to sense the inclination of the power-assisted rollator 10.

[0077] Fig. 3 is a schematic view of an example of the leg sensor 25. Referring to Fig. 3, the leg sensor 25 is mounted on the connecting frame 32. The leg sensor 25 is an image sensor, an infrared sensor, or the like, for example. The leg sensor 25 can detect how the user's leg moves by measuring the distance from the foot of the user of the power-assisted rollator 10.

[0078] More specifically, the leg sensor 25 shown in Fig. 3 may determine whether, in the area AR, the user's leg is moving or stays still, or whether it is moving away or closer, or whether or not it is turned around since the user is about to sit on a seat 37.

[0079] Figs. 4 and 5 are schematic views of the grip sensor 24.

[0080] The grips 42 of the handles 14 each have the grip sensor 24 for sensing the operation force (the grip force) applied by the user to manually push or pull the power-assisted rollator 10. The grip sensors 24 are restricted by not-shown elastic members (for example, springs), from being displaced in one or both of the pushing and pulling directions with respect to the poles 41. The grip sensors 24 further include potentiometers to detect the displacement.

[0081] As mentioned above, the grips 42 can be displaced in the front-rear direction with respect to the poles 41. When the grips 42 are displaced in the direction indicated by the arrow in Figs. 4 and 5 (frontward), it may be determined that the power-assisted rollator 10 is pushed by the user. When the grips 42 are displaced in the direction opposite to the direction indicated by the arrow in Figs. 4 and 5 (rearward), it may be determined that the power-assisted rollator 10 is pulled by the user. When the grips 42 are displaced in neither of the directions, it may be determined that the rollator 10 is neither pushed nor pulled.

[0082] In this manner, it is possible to determine whether the user is trying to move the power-assisted rollator 10 forward or backward, or whether the user does not have the intention to change the state of the power-assisted rollator 10.

[0083] The left and right handles 14 have separate grip sensors 24. The grip sensors 24 are configured to sense the operation forces (grip forces) applied to the respective handles 14 independently from each other and send the sensed operation forces to at least one of the control unit 16 or the determining unit 16a. Thus, at least one of the control unit 16 or determining unit 16a can recognize whether the user grips only one of the handles 14 (the one-hand gripping state), grips neither of the handles 14 (the non-hand gripping state), or grips both the handles 14 (the two-hand gripping state).

[0084] Referring again to Fig. 5, strain sensors 38 (for example, strain gauges) may be provided on the grips 42 to sense the moments applied to the grips 42 or the pipe frames 31, and serve as the grip sensors 24. In this case, the grips 42 are fixedly attached onto the poles 41, so that the grips 42 can be simplified. Alternatively, joy sticks, push buttons, or proximity sensors for sensing a hand of the user may be provided on the grips 42 and may be used as the grip sensors 24. In other words, "to determine that the user is trying to move the electric vehicle forward via the operation units (that the user is performing a forward operation on the electric vehicle)," the operation force applied by the user to the operation units when the user pushes or pulls the operation units by hand or other part of his/her body may be sensed, or the operation made by the user may be sensed by means of a switch such as a joystick or a push button.

<Overview of Power-Assisted Rollator>

[0085] The power-assisted rollator 10 (electric vehicle) includes driving units for driving wheels, where the wheels include front wheels provided on a vehicle body, rear wheels provided on the vehicle body, or the front and rear wheels, a control unit 16 for performing a step overcoming control on the driving units so that the wheels overcome a step, a measuring unit for measuring at least one of speed or acceleration imparted to the vehicle body having the wheels provided thereon, and a determining unit 16a for determining, based on a value measured by the measuring unit, whether to perform the step overcoming control. The control unit of the power-assisted rollator 10 may increase the driving force produced by the driving unit to drive the wheel or turn the vehicle body if the determining unit 16a determines, based on the value measured by the measuring unit, that the front wheel has touched a step. In this manner, the power-assisted rollator 10 can detect whether it collides with (touches) a step and also determine how it touches a step. In addition, the power-assisted rollator 10 can perform an appropriate step overcoming operation in a timely manner.

[0086] The following description is made with reference to an example case where the control unit 16 sends instructions based on a step overcoming control algorithm to the driving unit and the driving unit operates accordingly. The operations, however, may be assigned to the components in different manners. For example, the control unit 16 may send to the driving unit an instruction to start a step overcoming control, and the driving unit may start an operation based on a step overcoming control algorithm configured on itself.

[0087] Based on the values (including at least one of the speed or acceleration) measured by the measuring unit, the determining unit 16a distinguishes between a case where the power-assisted rollator touches a step, a case where the user stops the power-assisted rollator 10, and a case where the power-assisted rollator 10 collides with an object other than a step. The determining unit 16a can also refer to the measured values to estimate the direction in which the power-assisted rollator runs relative to the step (the angle formed by the power-assisted rollator relative to the step).

[0088] When detecting that the power-assisted rollator 10 has touched a step, the control unit 16 performs a step overcoming operation determined by the estimated direction (angle) in which the power-assisted rollator 10 runs relative to the step. The step overcoming operation includes, for example, turning the vehicle body, allowing the driving units coupled to the front wheels to assist the step overcoming operation, and combination of turning the vehicle body and allowing the driving unit coupled to the front wheels to assist the step overcoming operation.

[0089] A control method of a power-assisted rollator (an electric vehicle) may include steps of measuring at least one of speed or acceleration imparted to a vehicle body, determining whether there is a step based on at least one of the speed or the acceleration, and performing a step overcoming operation when it is determined that there is a step.

[0090] The power-assisted rollator (electric vehicle) may be controlled through programs installed on the power-assisted rollator, hardware such as processors and electronic circuits, or combinations thereof. The power-assisted rollator may be configured to receive wireless signals from outside, and controlled based on control signals sent from an external controller (information processor).

<Advantageous Effects of Embodiment

[0091] The following describes the advantageous effects of the above-described embodiment. Fig. 6 is a flowchart for explaining one example of how the control unit 16 operates.

[0092] To begin with, the control unit 16 determines whether the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward. More specifically, the control unit 16 determines whether the left and right handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time (e.g., one second or more), based on the signals detected by the grip sensors 24 provided on the left and right handles 14 (step S101).

[0093] The control unit 16 may use the rate of change of the operation force (the absolute value) in addition to the value of the operation force (the absolute value) so as to determine whether the handles 14 are pushed by the hands of the user with more than a predetermined amount of force. This may enable the control unit 16 to more accurately determine whether the handles 14 are pushed by the hands of the user with more than a predetermined amount of force. For example, when the absolute value of the operation force is equal to or less than a predetermined value and the absolute value of the rate of change of the operation force (the differentiation value of the operation force) is equal to or less than a predetermined value, the control unit 16 may determine that the handles 14 are not pushed by the hands of the user with more than a predetermined amount of force, and otherwise, the control unit 16 may determine that the handles 14 are pushed by the hands of the user with more than a predetermined amount of force. Further, when the operation force and the rate of change of the operation force reside within an oval region internally touching a rectangular numerical region defined by the predetermined values, the control unit 16 may determine that the handles 14 are not gripped by the hands of the user. In this case, the control unit 16 can make determination even more accurately.

[0094] When the handles 14 are not pushed with more than a predetermined amount of force ("NO" in step S101), the control unit 16 determines that the user is not trying to move the power-assisted rollator 10 forward and does not run to the subsequent steps. In this case, the control unit 16 may use the motors 20 as dynamic brakes to brake the rear wheels 13.

[0095] On the other hand, when the handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time ("YES" in step S101), the control unit 16 determines that the user is trying to move the power-assisted rollator 10 forward. Then, the control unit 16 determines whether the front wheels 12 have struck a step (step S102).

[0096] More specifically, the speed sensor 22b senses the number of rotations or the speed of the rear wheels 13 and sends signals representing the number of rotations or the speed to the control unit 16. The control unit 16 calculates the speed of the rear wheels 13 based on the received signals and compares the calculated speed with a predetermined speed (threshold value) V.

[0097] When the rear wheels 13 are driven, that is, the rear wheels 13 are moving at a speed higher than the predetermined speed V ("YES" in step S102), the control unit 16 determines that the power-assisted rollator 10 is moving under normal circumstances and allows the motors 20 to continue to assist the rear wheels 13 in moving.

[0098] On the other hand, when the rear wheels 13 stop rotating and the speed is zero (the power-assisted rollator 10 is stationary) or when the rear wheels 13 are moving at a speed equal to or lower than the predetermined speed V (the power-assisted rollator 10 is moving at a speed equal to or lower than the predetermined speed) ("NO" in step S102), the control unit 16 estimates, based on the value (including at least one of the speed or acceleration) measured by the measuring unit, whether the power-assisted rollator has struck a step, the user stops the power-assisted rollator, or the power-assisted rollator encounters other events such as colliding with an object other than a step.

[0099] When determining that the power-assisted rollator has struck a step ("YES" in step S103), the control unit 16 estimates, based on the value (including at least one of the speed or acceleration) measured by the measuring unit, the direction in which (the angle at which) the power-assisted rollator runs relative to the step (step S104). The control unit 16 then performs a step overcoming operation determined by the estimated direction in which (the estimated angle at which) the power-assisted rollator 10 moves with respect to the step (step S105). The step overcoming operation includes, for example, turning the vehicle body, allowing the driving units coupled to the front wheels to assist the step overcoming operation, and combination of turning the vehicle body and allowing the driving units coupled to the front wheels to assist the step overcoming operation. The step overcoming operation may include lifting the front wheels.

[0100] Note that how the control unit 16 detects whether the power-assisted rollator strikes a step (step S103), how the control unit 16 estimates the direction in which the power-assisted rollator runs with respect to the step (step S104), and how the control unit 16 performs the step overcoming operation in a variety of manners (step S105) will be described in detail below. As will be described below, what matters in the steps S103 to S105 is that the left and right components are controlled differently and how the detected speed and acceleration is directed. The following first describes, as an example, how to lift the front wheels, while how the left and right components are controlled differently will be described afterwards.

[0101] To lift the front wheels, the control unit 16 controls the motors 20 (the driving units) so as to increase or reduce the driving forces of the motors 20 in accordance with, e.g., the force applied to push the handles 14 (the operation force applied to the handles 14). Since the front wheels 12 have struck a step and thus the power-assisted rollator 10 cannot move forward, the driving force applied to the rear wheels 13 in the forward direction may produce a moment on the power-assisted rollator 10 that is directed to lift the front wheels 12. As a result, the front wheels 12 can be lifted relative to the rear wheels 13.

[0102] The control unit 16 determines whether the user is trying to move the power-assisted rollator 10 forward (the user intends to move the power-assisted rollator 10 forward) by referring to the amount of time spent and the amount of force exerted to push the handles 14, as described above. This enables the control unit 16 to accurately determine whether the user is trying to move forward and to avoid making a determination inconsistent with the intention of the user. Therefore, the user may feel safer in using the power-assisted rollator 10. The determination can be made only based on the amount of force exerted to push the handles 14. For example, when the handles 14 are pushed with more than a predetermined amount of force, the control unit 16 determines that the user is trying to move the power-assisted rollator 10 forward. In this case, the control unit 16 can quickly determine that the user is trying to move forward, and the user thus does not need to reduce the walking speed significantly to lift the front wheels 12.

[0103] Alternatively, the control unit 16 may use the acceleration of the rear wheels 13, in addition to the speed of the rear wheels 13, to determine whether the front wheels 12 have struck a step. This may result in more accurate determination as to whether or not the power-assisted rollator 10 is moving. For example, when the speed of the rear wheels 13 is equal to or lower than the predetermined speed V and the acceleration of the rear wheels 13 is equal to or lower than a predetermined acceleration, the control unit 16 may determine that the power-assisted rollator 10 has struck a step, and in other cases, the control unit 16 may determine that the power-assisted rollator 10 has not struck a step.

[0104] Alternatively, when the speed of the rear wheels 13 is equal to or lower than the predetermined speed V that is approximately zero, and the deceleration (negative acceleration) of the power-assisted rollator 10, that is, the deceleration (negative acceleration) of the rear wheels 13 is equal to or greater than a predetermined threshold value (a threshold value), the control unit 16 may determine that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward (the user intends to move the rollator 10 forward). When the speed of the rear wheels 13 is approximately zero and the deceleration of the rear wheels 13 is equal to or greater than a predetermined value, it seems that the front wheels 12 have struck a step and the power-assisted rollator 10 stops suddenly. In this case, the information from the grip sensors 24 may not necessarily be used to determine that the front wheels 12 have struck a step. For this reason, the power-assisted rollator 10 may not necessarily include the grip sensors 24. It should be noted that, as described above, a deceleration is a negative acceleration. A deceleration has a positive value when the power-assisted rollator 10 is decelerated and has a negative value when the power-assisted rollator 10 is accelerated.

[0105] When the handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time and the deceleration (negative acceleration) of the rear wheels 13 is equal to or greater than a predetermined threshold value, the control unit 16 may determine that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward (the user intends to move the rollator 10 forward). This may result in accurate determination as to whether or not the power-assisted rollator 10 is moving. As described above, whether the handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time can be determined based on the signals from the grip sensors 24. The control unit 16 may refer to the rearward acceleration of the vehicle body, instead of the negative acceleration, to determine whether the steps 12 have struck a step.

[0106] When the step is relatively low, the above-described driving forces applied to the rear wheels 13 can lift the front wheels 12, so that the front wheels 12 can run onto the step. If the front wheels 12 are not lifted, the user then reduces the force to push the handles 14. This can lower the moment applied to the power-assisted rollator 10 and directed to press down the front wheels 12 (the moment opposed to lifting of the front wheels 12). The control unit 16 maintains the driving force applied to the rear wheels 13 in the forward direction for more than a predetermined period of time, to drive the rear wheels 13 forward (see Fig. 7). Consequently, the moment directed to raise the front wheels 12 increases and acts to lift the front wheels 12.

[0107] If the front wheels 12 are still not lifted, the user then pulls the handles 14 backward. In this case, the force applied to pull the handles 14 backward produces moment directed to raise the front wheels 12 about the rear wheels 13, and the produced moment acts to lift the front wheels 12 in cooperation with the driving force applied to the rear wheels 13. Since the motors 20 apply the driving forces and, additionally, the user operates the handles 14 as described above, a moment directed to raise the front wheels 12 is produced on the power-assisted rollator 10 (see the arrow M in Fig. 2), so that the front wheels 12 are more definitely lifted (the power-assisted rollator 10 is put into wheelie). Alternatively, the front wheels 12 may be lifted by the user treading a pedal (not shown) fixed behind the axis of rotation of the rear wheels 13, instead of pulling the handles 14 backward.

[0108] As the front wheels 12 are lifted relative to the rear wheels 13, a gap is produced between the front wheels 12 and the step. Since the rear wheels 13 are driven in the forward direction, the power-assisted rollator 10 can move forward to narrow the gap until the front wheels 12 touch the top portion of the step. Thus, the front wheels 12 can run onto the step smoothly.

[0109] After the front wheels 12 are lifted, the control unit 16 gradually reduces the driving force applied to move the rear wheels 13 in the forward direction at a first reduction rate. In this manner, the rear wheels 13 are not accelerated too much after the front wheels 12 move beyond the step. Therefore, the front wheels 12 can run over the step smoothly. Reducing the driving force starts when a predetermined condition is no longer satisfied. The predetermined condition (the condition based on which the front wheels 12 are determined to have struck a step while the user intends to move the power-assisted rollator 10 forward) is used by the control unit 16 to determine whether to control the driving units to lift the front wheels 12. For example, reducing the driving force may start when the handles 14 are no longer pushed with more than a predetermined amount of force (when the user reduces the force to push the handles 14 or pulls the handles 14 backward), or when the rear wheels 13 rotate in the forward direction at a speed higher than a predetermined speed.

[0110] The user then pushes the handles 14 while the front wheels 12 are lifted up relative to the rear wheels 13. Thus, the user can move the power-assisted rollator 10 forward, and the front wheels 12 can run over the step.

[0111] As described above, when the user pulls the handles 14 backward, a moment around the rear wheels 13 can be produced. When combined with the driving force from the motors 20, this moment can easily lift the front wheels 12. Thus, the user is not required to raise the power-assisted rollator 10 to allow the front wheels 12 to run over the step smoothly. As described above, the front wheels 12 may be lifted only by increasing the driving force from the motors 20 (driving units) without requiring the user to pull the handles 14 backward, for example, when the step is low.

[0112] If the output of the motors 20 remain increased after the front wheels 12 have run over the step, the power-assisted rollator 10 may be accelerated too much. To avoid this, when any one of the following conditions (1) to (3) is satisfied after the front wheels 12 are lifted relative to the rear wheels 13, the control unit 16 may determine that the front wheels 12 have run over the step and restrain further acceleration of the power-assisted rollator 10. In this case, the control unit 16 may control the motors 20 such that the driving force applied by the motors 20 to the rear wheels 13 is reduced at a higher rate. More specifically, the driving force applied to the rear wheels 13 in the forward direction is reduced at a second reduction rate higher than the first reduction rate described above (see the two-dot chain line in Fig. 7). The control unit 16 may alternatively set the driving force applied to the rear wheels 13 in the forward direction at zero.

[0113] Condition (1): The inclination angle of the power-assisted rollator 10 sensed by the inclination sensor 23 is equal to or greater than a predetermined value (when the front wheels 12 run onto the step, the power-assisted rollator 10 is inclined).

[0114] Condition (2) The rotation speed of the rear wheels 13 sensed by the speed sensor 22b satisfies a predetermined condition. For example, the rotation speed of the rear wheels 13 is equal to or greater than a predetermined value. (As soon as the front wheels 12 run over the step, the speed of the rear wheels 13 increases, and when the rear wheels 13 rotate idly, the rotation speed of the rear wheels 13 increases.)

[0115] Condition (3): The distance between the user and the power-assisted rollator 10 sensed by the leg sensor 25 is equal to or greater than a predetermined value. (As soon as the front wheels 12 run over the step, the speed of the rear wheels 13 increases, so that the power-assisted rollator 10 moves away from the user.)

[0116] The conditions used to determine whether the user is trying to move the electric vehicle forward (the user intends to move the electric vehicle forward) may not be limited to the above, but may include one or more variable selected from, e.g., (i) the amount of rotation of the front or rear wheels 12 or 13, (ii) the output from a strain gauge provided on the power-assisted rollator 10, (iii) the air pressure of the tires of the front or rear wheels 12 or 13, (iv) the acceleration of the power-assisted rollator 10 in the front-rear direction, (v) the output from a pressure sensor provided on the handles 14 or the like, (vi) the output from an electromyography sensor provided on the handles 14 or the like, and (vii) the movement of the feet of the user.

<How to Detect Step>

[0117] The following describes in detail how to detect whether the power-assisted rollator (electric vehicle) strikes a step.

[0118] A conventional power-assisted rollator (electric vehicle) detects a step based on, for example, acceleration. The power-assisted rollator, however, detects acceleration when it experiences other events than collision with a step. For example, the power-assisted rollator also detects acceleration when the user stops the power-assisted rollator and when the power-assisted rollator strikes an object other than a step. In order to detect a step more accurately, the power-assisted rollator must distinguish acceleration detected when the power-assisted rollator has struck a step from acceleration detected when the user stops the power-assisted rollator. Similarly, the power-assisted rollator must take into consideration different accelerations to be detected when the power-assisted rollator strikes different types of objects.

[0119] Fig. 8 is a graph showing, as an example, the accelerations detected when the power-assisted rollator has struck a step and when the power-assisted rollator is stopped by the user, and a threshold for the accelerations. In Fig. 8, the horizontal axis represents the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle), and the vertical axis represents the negative acceleration. The negative acceleration refers to acceleration directed to reduce the speed of the power-assisted rollator 10 (electric vehicle) (deceleration).

[0120] Fig. 8 shows how the speed measured when the power-assisted rollator strikes a step and when the user stops the power-assisted rollator is related to the negative acceleration. Fig. 8 reveals that the detected acceleration is higher when the power-assisted rollator 10 strikes a step than when the user stops the power-assisted rollator 10. This is because, when the power-assisted rollator 10 strikes a step, the power-assisted rollator 10 experiences an impact. This means that the measuring unit may be required to measure at least one of the acceleration directed to reduce the speed of the vehicle or the rearward acceleration of the vehicle body. In this case, the determining unit 16a may estimate that the front wheels 12 have touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is greater than a threshold value (seventh threshold value). The determining unit 16a may estimate that the front wheels 12 have not touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than the threshold value. In this manner, the determining unit 16a can determine whether the front wheels 12 have touched a step.

[0121] For example, before a step overcoming control is performed (i.e., before it is determined that the front wheels 12 have touched a step), the detected acceleration may remain less than the threshold value for a certain period of time. If such is the case, the threshold value may be too high, as a result of which the determining unit 16a may possibly determine that the power-assisted rollator has not touched a step even if the front wheels 12 have actually touched a step. To avoid this, the determining unit 16a may lower the threshold value (the seventh threshold value) after the control unit 16 have successfully performed a step overcoming control for the front wheels 12, if the detected acceleration remains less than the threshold value (the seventh threshold value) for a certain period of time before the control unit 16 performs the step overcoming control for the front wheels 12. On the other hand, the threshold value may be set too low if the detected acceleration is higher than the threshold value before the step overcoming control is performed (i.e., before it is determined that the front wheels 12 have touched a step) and the difference between the detected acceleration and the threshold value is greater than a predetermined value. To deal with this, the determining unit 16a may increase the threshold value (the seventh threshold value) if the acceleration measured by the measuring unit when the control unit 16 performs the step overcoming control for the front wheels 12 is greater than the threshold value (the seventh threshold value) and the difference between the measured acceleration and the threshold value (the seventh threshold value) is greater than a predetermined value. In this way, when the front wheels 12 have successfully overcome a step, the threshold value used to determine whether the front wheels 12 have touched a step is adjusted. This can contribute to detect whether the front wheels 12 have touched a step more accurately.

[0122] As described above, the power-assisted rollator 10 may include the memory unit 16b for storing thereon the values measured by the measuring unit. In this case, the determining unit 16a may adjust the threshold value (the seventh threshold value) based on the measured values stored on the memory unit 16b. Since the values measured for the last several step overcoming controls and stored on the memory unit 16b are used, the threshold value can be more accurately adjusted. In addition to the seventh threshold value, other threshold values described herein may be adjusted based on the measured values stored in the memory unit 16b.

[0123] Fig. 8 reveals such a tendency that the detected acceleration increases as the speed of the power-assisted rollator 10 increases irrespective of when the power-assisted rollator 10 strikes a step or when the user stops the power-assisted rollator 10. Note that a graph plotting the speed measured in each of these cases and the rearward acceleration of the vehicle body will reveal the same correlation as shown in Fig. 8.

[0124] The power-assisted rollator 10 can increase, in accordance with the speed of the power-assisted rollator 10, the threshold used to detect whether the power-assisted rollator 10 has struck a step, instead of constantly using the same threshold value. When the measured acceleration is greater than the threshold value, the power-assisted rollator 10 can perform a step overcoming operation. The control unit 16 may increase the threshold value (sixth threshold value) to be compared against the absolute value of the acceleration in order to determine whether to perform the step overcoming operation, as the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured by the measuring unit increases. The dotted line in Fig. 8 shows an example of the threshold (the fourth threshold). This provides for improved accuracy for the step detection.

[0125] The threshold may follow a function represented as $T=\Sigma(\alpha_n v^\wedge\beta_n)+\gamma$, but may follow different functions. Here, v denotes the speed of the vehicle body, and α_n and β_n are coefficients greater than zero (positive real numbers). In addition, y is any coefficient, and can be a positive real number, zero, or a negative real number. If the respective side surfaces of the power-assisted rollator 10 are differently structured or made of different materials, the threshold or threshold function may depend on the direction. For example, if the front and rear wheels are different from each other in terms of at least one of the material, structure or size, different coefficients may be used for the front and rear wheels in order to detect whether they strike a step.

[0126] Fig. 9 is a graph showing, as an example, the acceleration detected when the power-assisted rollator 10 has struck a soft object and the acceleration detected when it has struck a step. Here, a soft object means an object having less repulsive hardness than a step. Such an object is a human body, for example. In Fig. 9, the horizontal axis represents the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) and the vertical axis represents the negative acceleration (deceleration).

[0127] Fig. 9 plots how the negative acceleration is related to the speed measured when the power-assisted rollator 10 has struck a soft object and the speed measured when the power-assisted rollator 10 has struck a step. Referring to Fig. 9, with the speed of the power-assisted rollator 10 being approximately the same, the detected acceleration is greater when the power-assisted rollator 10 has struck a step than when the power-assisted rollator 10 has struck a soft object. This result shows that the repulsive hardness of the object struck by the power-assisted rollator 10 can be estimated based on the acceleration detected when the power-assisted rollator 10 has struck the object. For example, whether the power-assisted rollator 10 has struck a step or a human body can be determined by comparing the detected acceleration against the threshold value. Although Fig. 9 plots the negative acceleration (acceleration directed to reduce the speed of the vehicle body), the same correlation can be presented even in a graph plotting the rearward acceleration of the vehicle body, instead of the negative acceleration.

[0128] In the example shown in Fig. 9, the detected acceleration tends to increase as the speed of the power-assisted rollator 10 increases.

[0129] The determining unit 16a of the power-assisted rollator 10 compares the measured acceleration against the threshold value, thereby determining whether to perform the step overcoming operation. For example, the determining unit 16a may estimate that the front wheels 12 have touched an object other than a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than a predetermined threshold value. The determining unit 16a may not instruct the driving unit to perform the step overcoming operation if at least one of the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than the threshold value (fourth threshold value). In this way, if there is a possibility that the user may stop the power-assisted rollator 10 or the power-assisted rollator 10 may have touched a human, the step overcoming operation is less likely to be performed. This can improve the safety of the power-assisted rollator 10.

[0130] The determining unit 16a may instruct the driving units to perform a step overcoming operation if the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit is greater than the threshold value (fourth threshold value). Generally, when the acceleration directed to reduce the speed of the electric vehicle (deceleration) or the rearward acceleration of the vehicle body is greater than a threshold value, this may indicate that the electric vehicle has touched a step. For example, the measuring unit may measure at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body, and the determining unit 16a may estimate that the front wheels 12 have touched a step when at least one of the acceleration directed to reduce the sped of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is greater than a predetermined threshold value (fifth threshold value). In this manner, only when determining that the power-assisted rollator 10 have struck a step, the determining unit 16a allows the driving unit to perform a step overcoming operation.

[0131] The control method of the power-assisted rollator (electric vehicle) may include steps of measuring at least one of speed or acceleration imparted to a vehicle body, and determining whether to perform a step overcoming control based on at least one of the speed or the acceleration. The control method of the power-assisted rollator (electric vehicle) may further include steps of determining whether the front wheels 12 have touched a step based on at least one of the speed or the acceleration, and performing the step overcoming control when the front wheels 12 are estimated to have touched a step. The step overcoming control may include at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body.

[0132] The control program of the power-assisted rollator (electric vehicle) may include steps of measuring at least one of speed or acceleration imparted to a vehicle body, determining whether the front wheels 12 have touched a step based on at least one of the speed or the acceleration, and performing the step overcoming control when the front wheels 12 are estimated to have touched a step. The step overcoming control may include at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body. The control program may be executed by the control unit 16 or determining unit 16a, or by an external controller or server.

[0133] In order to calculate the negative acceleration (deceleration) indicating the acceleration directed to reduce the speed of the power-assisted rollator 10 (electric vehicle), it is necessary to identify the direction in which the power-assisted rollator 10 runs. The direction in which the power-assisted rollator 10 runs can be estimated based on the values measured by the speed sensor 22b, for example.

[0134] Note that the acceleration based on which whether or not the power-assisted rollator 10 is to overcome a step is determined is not limited to the negative acceleration (deceleration). For example, the determining unit 16a may determine whether to instruct the control unit 16 to perform the step overcoming control based on the rearward acceleration applied to the power-assisted rollator 10 (electric vehicle) measured by the measuring unit. When the determination is made based on the rearward acceleration applied to the power-assisted rollator 10, it may not be necessary to identify the direction in which the vehicle body runs.

[0135] For example, the determining unit 16a may not instruct the control unit 16 to perform the step overcoming control if at least one of the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than the fifth threshold value. The determining unit 16a may instruct the control unit 16 to perform the step overcoming control if at least one of the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit is greater than the fifth threshold value.

[0136] The determining unit 16a of the power-assisted rollator 10 (electric vehicle) may determine whether to instruct the control unit 16 to perform the step overcoming control based on vibration detected by the measuring unit.

[0137] The determining unit 16a may not instruct the control unit 16 to perform the step overcoming control if the representative value of the frequency spectrum of the vibration of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured by the measuring unit is equal to or less than a sixth threshold value. The determining unit 16a may instruct the control unit 16 to perform the step overcoming control if the representative value of the frequency spectrum of the vibration of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured by the measuring unit is greater than the sixth threshold value. In other words, the measuring unit may measure the frequency spectrum of the vibration of the vehicle body, and the determining unit 16a may estimate that the front wheels 12 have touched a step if the representative value of the values (of the frequency spectrum) measured by the measuring unit is greater than the threshold value (eighth threshold value). The determining unit 16a may estimate that the front wheels 12 have not touched a step if the representative value of the values (of the frequency spectrum) measured by the measuring unit is equal to or less than the threshold value (eighth threshold value). The representative value will be described below specifically.

[0138] When objects collide with each other, vibration is generated. It is commonly known that the vibration depends on the repulsive hardness of the objects. As the repulsive hardness of the objects increases, the frequency of the vibration generated by the collision between them increases. Therefore, if the frequency of the detected vibration is greater than the threshold value, this can indicate that the power-assisted rollator 10 (electric vehicle) has struck a step. If the frequency of the detected vibration is equal to or below the threshold value, this can indicate that the power-assisted rollator 10 has struck an object other than a step, or the user has stopped the power-assisted rollator 10. When the power-assisted rollator 10 (electric vehicle) strikes (or touches) an object other than a step, this may mean that any of the parts of the power-assisted rollator 10 (electric vehicle) may collide with a third person’s foot or belongings, for example. The object is not limited to any particular type.

[0139] The representative value of the frequency spectrum may be the frequency at which the highest peak of the frequency spectrum appears, or a weighted average value of the frequencies of a plurality of peaks of the frequency spectrum. The representative value of the frequency spectrum may be the intermediate or average frequency. In other words, the representative value can be calculated in any manners.

[0140] When the front portion of the power-assisted rollator 10 strikes an object such as a step, a force is applied to the vehicle body in the front-rear direction. For this reason, the vibration of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured by the measuring unit may contain vibration in the front-rear direction of the vehicle body. Note that the measuring unit of the power-assisted rollator 10 may measure the vibration of the vehicle body of the power-assisted rollator 10 (electric vehicle) in any directions.

[0141] The power-assisted rollator 10 (electric vehicle) may include a buffer member covering at least part of the front portion of the vehicle body or the side surfaces of the vehicle body that face each other in the width direction. If the frame of the power-assisted rollator 10 (electric vehicle) strikes a part of a human body that is relatively hard and close to the bone, such as the shin, this may generate high deceleration, which in turn result in the determining unit 16a falsely detecting a step. To avoid this issue, a first buffer member is provided on at least part of the front portion of the power-assisted rollator 10 (electric vehicle) or the side surfaces of the rollator 10 that face each other in the width direction. This can prevent the power-assisted rollator 10 from detecting high deceleration when striking a human body.

[0142] Fig. 10 schematically shows an example configuration with a buffer member being provided at the front portion of the vehicle body. As shown in Fig. 10, the pipe frame 31 of the power-assisted rollator 10 protrudes frontward beyond the vehicle body. A buffer member 81 is provided on the front end of the frontward protruding portion of the pipe frame 31. The buffer member 81 can be formed by, for example, rubber, urethane foam, foamed resin, and various types of springs, but can be of any types. Fig. 10 shows the left pipe frame 31 of the power-assisted rollator 10 and the buffer member 81. Like the left one, the right pipe frame 31 of the power-assisted rollator 10 may have a buffer member 81 at the front end of the frontward protruding portion. The configuration shown in Fig. 10 is merely an example. The buffer member may constitute a part of a single piece, or may be attached to the power-assisted rollator in a different manner than shown in Fig. 10. Alternatively, the buffer member may be provided on at least part of the side surfaces of the power-assisted rollator that face each other in the width direction.

[0143] Conventional walking aids are configured to detect a step and overcome the step on the assumption that the walking aids face almost directly the step while running toward the step (run toward the step almost perpendicularly). Therefore, when the walking aids run toward a step at an angle and the right and left front wheels touch the step at different times, the walking aids face difficulties in overcoming the step. The following describes how to detect a step when the walking aids run toward the step at an angle.

[0144] Fig. 11 is a plan view showing the power-assisted rollator 10 (electric vehicle) from above. In the plan view of Fig. 11, the power-assisted rollator 10 moves in the direction indicated by the dotted line P (toward the upper left corner of Fig. 11) relative to a step 80. The dotted line P thus shows the direction in which the power-assisted rollator 10 runs. Referring to Fig. 11, the dotted line P leads to the step 80. This means that the power-assisted rollator 10 runs toward the step 80. If the power-assisted rollator 10 is turning, the direction in which the power-assisted rollator 10 runs changes as time elapses. Accordingly, the dotted line P may indicate the direction of the speed vector of the power-assisted rollator 10 at a certain time.

[0145] The dotted line S in Fig. 11 is a perpendicular line to the step 80, and indicates the direction that directly faces (that is perpendicular to) the step 80. The dotted line P indicating the direction in which the power-assisted rollator 10 runs forms an angle θ relative to the perpendicular line S to the step 80. As shown, the power-assisted rollator 10 may run toward the step not in the perpendicular direction, but at an angle relative to the perpendicular direction. The step 80 is not necessarily shaped like a straight line as shown in the example of Fig. 11. For example, the step is curved, in which case the perpendicular line can be defined as being perpendicular to the tangent of the curved step.

[0146] As shown in Fig. 11, when the power-assisted rollator 10 runs toward the step 80 at an angle, one of the right and left front wheels collides with the step 80 earlier than the other. In the example of Fig. 11, the right front wheel of the power-assisted rollator 10 has collided with the step 80. The arrow a shows the vector representing the acceleration applied to the vehicle body by the collision between the right front wheel and the step 80. The arrows I and w shown on the power-assisted rollator 10 respectively indicate the front-rear and width directions of the vehicle body. Referring to Fig. 11, the vector a of the acceleration has components in the front-rear and width directions I and w of the vehicle body.

[0147] The following describes, as an example, the accelerations in the front-rear and width directions of the vehicle body detected by the power-assisted rollator 10.

[0148] Fig. 12 a graph showing how the detected values of acceleration differ depending on which of the front wheels collide. In Fig. 12, while the horizontal axis represents the acceleration in the front-rear direction of the vehicle body, the vertical axis represents the acceleration in the width direction of the vehicle body. In the example shown in Fig. 12, the positive and negative values of the acceleration in the front-rear direction of the vehicle body respectively denote the frontward and frontward acceleration. Similarly, the positive and negative values of the acceleration in the width direction of the vehicle body respectively denote the rightward and leftward acceleration. These correspondences between the directions of the acceleration and the positive and negative values are merely mentioned as an example, and different correspondences may be used.

[0149] The graph in Fig. 12 shows that, when one of the front wheels collides with a step, the acceleration occurs not only in the front-rear direction of the vehicle body, but also in the width direction of the vehicle body. When the right front wheel collides with a step, leftward acceleration is detected. On the other hand, when the left front wheel collides with a step, rightward acceleration is detected. The values of the acceleration measured when both of the front wheels collide with a step presented in the graph in Fig. 12 reveal that the rearward acceleration of the vehicle body tends to be higher than when one of the front wheels collides with a step. When both of the front wheels collide with a step, acceleration in the width direction is also detected. The graph shown in Fig. 12 shows that most of the values of the acceleration in the width direction detected when both of the front wheels collide with a step are found in the rightward acceleration domain. This is probably because the left front wheel collides with a step earlier than the right front where in many of the cases when the acceleration is measured.

[0150] The results in Fig. 12 show that which one of the right and left front wheels collides with a step can be estimated based on the direction of the detected acceleration in the width direction. More specifically, the acceleration measured by the measuring unit may include (i) at least one of the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the acceleration in the front-rear direction of the vehicle body and (ii) the acceleration in the width direction of the vehicle body of the power-assisted rollator 10 (electric vehicle). The determining unit 16a can estimate which one of the left and right wheels has touched a step based on the acceleration in the width direction of the vehicle body of the power-assisted rollator 10 (electric vehicle). In other words, the determining unit 16a may estimate, based on the values measured by the measuring unit, which one of the front wheels has touched a step.

[0151] The determining unit 16a can distinguish, based on the values measured by the measuring unit, a case where one of the left and right front wheels has touched a step (single-side contact) and a case where both of the left and right front wheels have touched a step (both-side contact). This enables the power-assisted rollator 10 to control the vehicle body, for example, to perform a step overcoming operation, in an appropriate manner determined by how the power-assisted rollator 10 has touched a step (the single-side or both-side contact). For example, the determining unit 16a can distinguish the single-side contact and the both-side contact, based on the acceleration in the width and front-rear directions of the vehicle body. For example, the determining unit 16a can determine that the power-assisted rollator 10 has touched a step on one side if the acceleration in the width direction of the vehicle body is greater than a threshold value th_w. The determining unit 16a can determine that the power-assisted rollator 10 has touched a step on both wheels if the acceleration in the front-rear direction of the vehicle body is greater than a threshold value th_{fb}. Furthermore, the determining unit 16a can determine that the power-assisted rollator 10 has touched a step on both wheels if the acceleration in the width direction of the vehicle body is less than the threshold value th_w and the acceleration in the front-rear direction of the vehicle body is greater than the threshold value th_{fb}.

[0152] The measuring unit may measure at least one of the acceleration directed to reduce the speed of the vehicle body, the rearward acceleration of the vehicle body, or the acceleration in the width direction of the vehicle body. The determining unit 16a estimates which one of the left and right front wheels has touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a predetermined threshold value (first threshold value). The determining unit 16a may estimate which one of the left and right front wheels has touched a step when the largest absolute value of the acceleration in the width direction of the vehicle body measured within a predetermined period of time after at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than the predetermined threshold value (first threshold value) becomes equal to or greater than a predetermined threshold value (second threshold value). In this manner, the power-assisted rollator 10 can distinguish when it touches a step with the left front wheel and when it touches a step with the right front wheel.

[0153] The determination may be made by referring to (i) the value of the acceleration in the width direction of the vehicle body measured at the same time as when the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body becomes equal to or greater than the threshold value (first threshold value), or (ii) the value of the acceleration in the width direction of the vehicle body measured at a different time. The control unit 16 can perform a step overcoming operation in accordance with the determination.

[0154] The control method of the power-assisted rollator 10 (electric vehicle) may include steps of measuring at least first acceleration and second acceleration, where the first acceleration is (i) the acceleration directed to reduce the speed of the vehicle body or (ii) the acceleration in the front-rear direction of the vehicle body, and the second acceleration is the acceleration in the width direction of the vehicle body, estimating which one of the left and right wheels has touched a step based on the measured first acceleration and second acceleration, and performing a step overcoming operation in accordance with the wheel estimated to have touched the step.

[0155] The control program of the power-assisted rollator 10 (electric vehicle) may include steps of measuring at least first acceleration and second acceleration, where the first acceleration is (i) the acceleration directed to reduce the speed of the vehicle body or (ii) the acceleration in the front-rear direction of the vehicle body, and the second acceleration is the acceleration in the width direction of the vehicle body, estimating which one of the left and right wheels has touched a step based on the measured first acceleration and second acceleration, and performing a step overcoming operation in accordance with the wheel estimated to have touched the step.

[0156] According to the foregoing method, the acceleration sensor 22a measures acceleration in more than one direction, and the measurement is referred to in order to estimate which one of the wheels has touched a step. The values of the speed measured by the speed sensor 22b may be alternatively referred to. For example, if the rate of reduction in speed within a given period of time is equal to or greater than a threshold value, the power-assisted rollator 10 can estimate that it has touched a step. The speed sensor 22b may be used to measure speed in more than one direction, or both speed and acceleration. In other words, the determining unit 16a may estimate, based on at least one of speed or acceleration, which one of the front wheels has touched a step. The power-assisted rollator 10 may touch a step only with the left front wheel, only with the right front wheel, or with both of the left and right front wheels.

[0157] The graph in Fig. 13 shows acceleration measured when the power-assisted rollator 10 collides with a step while turning, and acceleration measured when the power-assisted rollator 10 collides with a step while moving straight. In Fig. 13, the vertical axis represents the acceleration in the width direction of the vehicle body, and the horizontal axis represents the acceleration in the front-rear direction of the vehicle body.

[0158] Referring to the graph in Fig. 13, whether the power-assisted rollator 10 collides with a step while moving straight or while turning cannot be clearly determined if the acceleration in the front-rear direction of the vehicle body and the acceleration in the width direction of the vehicle body are the only factors consulted to make the determination.

[0159] To deal with this issue, information related to the rotation of the wheels is also considered to distinguish the former from the latter. For example, if the speed sensor 22b measures the rotational speed of the rear wheels, the rotational speed is differentiated by time and signed negatively. The resulting value can be used as the deceleration (negative acceleration) of the rear wheels. When the right front wheel collides with a step, the deceleration of the right rear wheel tends to be greater than that of the left rear wheel. Considering this, not only the acceleration in the front-rear direction of the vehicle body and the acceleration in the width direction of the vehicle body, but also the deceleration of the right rear wheel and the deceleration of the left rear wheel are referred to, so that it can be estimated whether the power-assisted rollator 10 collides with a step while moving straight or while turning.

[0160] For example, when the rear wheels 13 include left and right rear wheels spaced away from each other in the width direction of the vehicle body, the measuring unit may calculate at least (i) an average value between acceleration of the left rear wheel in a rotational direction and acceleration of the right rear wheel in a rotational direction, or (ii) a difference between the acceleration of the left rear wheel in the rotational direction and the acceleration of the right rear wheel in the rotational direction. When the front wheels 12 include left and right rear wheels spaced away from each other in the width direction of the vehicle body, the measuring unit may calculate at least (i) an average value between acceleration of the left front wheel in a rotational direction and acceleration of the right front wheel in a rotational direction, or (ii) a difference between the acceleration of the left front wheel in the rotational direction and the acceleration of the right front wheel in the rotational direction. In this manner, the power-assisted rollator 10 can distinguish when it touches a step with the right front wheel and when it touches a step with the left front wheel.

[0161] The measuring unit can calculate, as first acceleration, (i) an average value between the acceleration of the left front wheel in the rotational direction and the acceleration of the right front wheel in the rotational direction, or (ii) an average value between the acceleration of the left rear wheel in the rotational direction and the acceleration of the right rear wheel in the rotational direction. The measuring unit may calculate, as second acceleration, (i) a difference between the acceleration of the left front wheel in the rotational direction and the acceleration of the right front wheel in the rotational direction, or (ii) a difference between the acceleration in the rotational direction of the left rear wheel and the acceleration in the rotational direction of the right rear wheel. If the second acceleration is greater than a threshold value, it may be estimated that the power-assisted rollator 10 (electric vehicle) is turning. In this manner, the power-assisted rollator 10 can also distinguish when it touches a step with the right front wheel and when it touches a step with the left front wheel.

[0162] Here, the threshold value may depend on the first acceleration. For example, the threshold value can increase as the first acceleration increases. The threshold value may follow a function represented as, for example, $T=\Sigma(\alpha_n a\text{^}\beta_n)+\gamma$, but may be defined differently. Here, a denotes the acceleration of the vehicle body (first acceleration), and α_n and β_n are coefficients greater than zero (positive real numbers). In addition, γ is any coefficient, and can be a positive real number, zero, or a negative real number.

[0163] Fig. 14 is a graph showing, as an example, the temporal waveform of the acceleration measured when the power-assisted rollator 10 collides with a step. In Fig. 14, the horizontal axis represents the time, and the vertical axis represents the detected acceleration. The graph in Fig. 14 shows the values of the acceleration measured when the power-assisted rollator 10 is moved in more than one pattern. Fig. 14 shows a waveform 90 measured when the power-assisted rollator 10 collides with a step perpendicularly, a waveform 91 measured when the front wheels of the power-assisted rollator 10 collide with a step at different times, and a waveform 92 measured when the user stops the power-assisted rollator 10.

[0164] Referring to the waveform 90, the power-assisted rollator 10 collides with a step at a time 0.0 (seconds). The collision causes a greater impact than those found in the other waveforms, and the detected acceleration is high. According to the waveform 91, on the other hand, the front wheels collide with a step at different times, which can cause a plurality of lighter shocks. The peaks of the detected acceleration are lower than those found in the waveform 90. The waveform 92 represents the case where the power-assisted rollator 10 does not collide with a step, and the user manually stops the power-assisted rollator 10. Therefore, the peaks of the detected acceleration in the waveform 92 are even lower than those found in the waveform 91.

[0165] In order to detect whether the power-assisted rollator 10 collides with a step, the threshold value needs to be determined taking into consideration the values of acceleration detected when the power-assisted rollator 10 is moved in the respective patterns shown in Fig. 14. For example, if the threshold value may be set based on the peak value of the acceleration detected when the power-assisted rollator 10 collides with a step perpendicularly (e.g., the waveform 90), the threshold value is too high. The power-assisted rollator 10 thus may not be able to detect a step when the front wheels of the power-assisted rollator 10 collide with a step at different times (for example, the waveform 91). If the threshold value is set too low, on the other hand, the power-assisted rollator 10 may possibly falsely detect a step when the user manually stops the power-assisted rollator 10.

[0166] The threshold value can be conditionally set at different values in order to allow the power-assisted rollator 10 to detect a step more accurately. For example, it is estimated whether the power-assisted rollator 10 is turning in the above-described manner. If it is estimated that the power-assisted rollator 10 is turning, the threshold value may be set at a different value or follows a different function from when the power-assisted rollator 10 is moving straight. More specifically, when the largest absolute value of the acceleration in the width direction of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured by the measuring unit is equal to or greater than a predetermined threshold value (second threshold value), the determining unit 16a may lower the threshold value (fifth threshold value) of the acceleration based on which whether or not to perform a step overcoming operation is performed is determined. The acceleration is, for example, the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit. Whether or not to perform the step overcoming operation may be determined based on other types of accelerations. The threshold value may be selected from several fixed values, or follow a function whose parameter is the speed of the vehicle body.

[0167] Referring to the waveform 91 in Fig. 14, which shows the acceleration measured when the respective front wheels of the power-assisted rollator 10 collide with a step at different times, the acceleration peaks at times 0.0 (seconds) and 0.6 (seconds). The acceleration is higher at the earlier peak (the time 0.0 (seconds)) than at the later peak (the time 0.6 (seconds)). It is estimated that the front wheels on the different sides collide with the step at the respective peaks. The acceleration detected when the power-assisted rollator 10 touches the step the second time is lower since the kinetic energy of the power-assisted rollator 10 drops when the power-assisted rollator 10 touches the step for the first time. Considering this, when the front wheels of the power-assisted rollator 10 collide with a step at different times, the threshold value can depend on how many times the power-assisted rollator 10 have collided.

[0168] An example case is assumed where the power-assisted rollator 10 moves toward a step at an angle so that the right and left front wheels touch the step at different times. After detecting that one of the right and left front wheels has touched the step, the power-assisted rollator 10 sets the threshold value to be used to detect whether the other front wheel touches the step lower than the threshold value used to detect the initial collision with the step. More specifically, the measuring unit may measure at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body, and the determining unit 16a may estimate that the left and right front wheels have touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a threshold value (third threshold value) that is less than the first threshold value.

[0169] If the threshold value is set too low, the power-assisted rollator 10 may falsely detect a step when the power-assisted rollator 10 does not actually collide with a step, for example, when it is manually stopped. The present embodiment can avoid this false step detection.

[0170] When the power-assisted rollator 10 collides with a step, the peak of the acceleration in the width direction of the vehicle body may be measured later than the peak of the acceleration in the front-rear direction of the vehicle body. Based on this, the determining unit 16a may estimate which one of the left and right wheels has touched the step when the largest absolute value of the acceleration in the width direction of the vehicle body of the power-assisted rollator 10 (electric vehicle) measured within a predetermined period of time after the acceleration directed to reduce the speed of the vehicle body of the power-assisted rollator 10 (electric vehicle) or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than the first threshold value becomes equal to or greater than a second threshold value. The predetermined period of time may be 10 milliseconds, but not limited thereto.

<Step Overcoming Operation>

[0171] The following describes how a power-assisted rollator (electric vehicle) overcomes a step.

[0172] Fig. 15 is a plan view illustrating a first example where a power-assisted rollator moves toward a step at an angle. The following describes how the power-assisted rollator 10 overcomes a step 80 when the power-assisted rollator 10 moves toward the step 80 at an angle, with reference to Fig. 15. When the vector (the dotted line P) representing the direction in which the power-assisted rollator 10 moves makes an angle of 0 degrees or more with respect to the perpendicular line (the dotted line S) to the step 80, this case is described as the power-assisted rollator 10 moving toward the step 80 at an angle. In Fig. 15, the right front wheel of the power-assisted rollator 10 has collided with the step 80. It is assumed that the determining unit 16a detects that the right front wheel has collided with a step based on the values measured by the measuring unit.

[0173] The white arrows in Fig. 15 respectively indicate the driving forces d_{pl} and d_{pr} of the left and right rear wheels. In the example of Fig. 15, on the assumption that the driving forces d_{pl} and d_{pr} of the left and right rear wheels are equal to each other, the force directed perpendicularly to the step 80 is equal to the result of multiplying the resultant force of the driving forces d_{pl} and d_{pr} by $\sin(90-\theta)$. This means that an increase in the angle θ results in more difficulties faced by the power-assisted rollator 10 in overcoming the step 80. Accordingly, the vehicle body of the power-assisted rollator 10 is turned, so that a greater force can be applied perpendicularly to the step 80 when attempts are made to overcome the step 80.

[0174] For example, as shown in the example of Fig. 15, the control unit 16 can control the driving units such that the driving force d_{pl} of the left rear wheel can be made greater than the driving force d_{pr} of the right rear wheel. This creates a force acting to turn the vehicle body of the power-assisted rollator 10 in the rightward direction, so that the power-assisted rollator 10 can overcome the step 80 with a smaller angle θ. In this way, the control unit 16 may control the driving units such that the driving unit of at least one of the front and rear wheels 12 and 13 located on the opposite side in the width direction of the vehicle body to the front wheel 12 estimated to have touched the step can produce a greater driving force than the driving unit of at least one of the front wheel 12 estimated to have touched the step or the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12.

[0175] The control unit 16 may control the driving units such that only at least one of the driving units of the front and rear wheels 12 and 13 located on the opposite side in the width direction of the vehicle body to the front wheel 12 estimated to have touched the step can generate a driving force. In other words, the driving force of the driving unit of at least one of the front and rear wheels 12 and 13 located on the opposite side in the width direction of the vehicle body to the front wheel 12 estimated to have touched the step may be greater than the driving force of the driving unit of at least one of the front wheel 12 estimated to have touched the step or the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12. In this manner, the power-assisted rollator 10 can perpendicularly face the step after one of the left and right front wheels touch the step. The wheels that have touched a step can be estimated in the manner described above in relation to how to detect a step.

[0176] When the power-assisted rollator 10 moves toward the step 80 at an angle, the driving force to turn the vehicle body of the power-assisted rollator 10 may not be necessarily generated. For example, the control unit 16 may control the driving units such that only the driving unit of the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12 estimated to have touched the step can generate a driving force. In addition, the control unit 16 may control the driving units such that the driving force of the driving unit of at least one of the front wheel 12 estimated to have touched the step or the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12 estimated to have touched the step is greater than the driving force of the driving unit of at least one of the front wheel 12 estimated to have touched the step or the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12 estimated to have touched the step. In this manner, the power-assisted rollator 10 can also face the step perpendicularly after one of the left and right front wheels touches the step. For example, if the step to overcome is not high, or the step is in the form of a ramp, the step can be overcome without requiring a high driving force. In such cases, it is not necessary to turn the power-assisted rollator 10 before performing a step overcoming control, or to perform a step overcoming control involving turning the power-assisted rollator 10. This simplifies the control and allows the user to move the power-assisted rollator 10 onto the step within a shorter period of time.

[0177] Figs. 16 and 17 are plan views illustrating a second example where the power-assisted rollator moves toward the step at an angle. Figs. 16 and 17 show the steps of how to operate the power-assisted rollator 10. The following describes how the power-assisted rollator 10 operates with reference to Figs. 16 and 17.

[0178] The power-assisted rollator 10 is moving toward the step 80 at an angle θ greater than 0 degrees (step S1). In the step S1, it is assumed that the driving force d_{pl} applied to the left rear wheel and the driving force d_{pr} applied to the right rear wheel are equal. In this case, the relations $d_{pl} > 0$, $d_{pr} > 0$ may hold true, or the relation $d_{pl} = d_{pr} = 0$ may be established. In the case of $d_{pl} = d_{pr} = 0$, the user is moving the power-assisted rollator 10 forward without any assisting force.

[0179] As the power-assisted rollator 10 moves further forward from the step S1, the right front wheel collides with the step 80 (step S2). The determining unit 16a detects that the right front wheel has collided with the step 80 based on the values measured by the measuring unit. The control unit 16 controls the driving units such that the forward driving force d_{pr} of the right rear wheel, which is the wheel located on the same side as the wheel estimated to have touched the step 80, is set to zero. The control unit 16 may control the braking unit so that the right rear wheel is braked. Here, the driving force d_{pl} of the left rear wheel, which is the wheel on the side estimated not to have touched the step 80, is set greater than zero. This causes the power-assisted rollator 10 to start turning in the rightward direction (to changing its direction).

[0180] As described above, the control unit 16 may control the driving units such that a driving force is only generated by the driving unit of one of the front and rear wheels located on the opposite side in the width direction of the vehicle body to the front wheel estimated to have touched the step. In this manner, after one of the front wheels touches the step, the vehicle body can be turned swiftly.

[0181] Since the power-assisted rollator 10 is turned in the rightward direction, the left front wheel or the other front wheel 12 touches the step 80 (step S3). As a result, the power-assisted rollator 10 faces the step 80 almost perpendicularly. In other words, the angle θ mentioned above is almost equal to zero degrees. As the angle θ decreases, the driving force required to cause the power-assisted rollator 10 to overcome the step 80 decreases. Therefore, the power-assisted rollator 10 may start a step overcoming operation for the step 80 in the step S3. Stated differently, once it is estimated that both of the front wheels have touched a step, the control unit 16 can perform the step overcoming operation. Since the power-assisted rollator 10 can assume a more stable attitude, the power-assisted rollator 10 can successfully overcome the step 80 without requiring complicated control.

[0182] For example, once the determining unit 16a estimates based on the values measured by the measuring unit that both of the front wheels 12 have touched a step, the control unit 16 may control the driving units such that the driving forces of the driving units of at least one of (i) the front wheels or (ii) the rear wheels on the respective sides in the width direction of the vehicle body of the power-assisted rollator 10 (electric vehicle) become equal. This can adjust the driving forces of the driving units such that the power-assisted rollator 10 is not turned too much. The power-assisted rollator 10 is assisted by the driving forces only after the front portion of the power-assisted rollator 10 has faced the step 80 almost perpendicularly. The power-assisted rollator 10 can thus advantageously overcome the step 80 in a more reliable manner.

[0183] There are no particular limitations on the times when the left and right front wheels (both of the front wheels) touch a step. For example, the left and right front wheels may touch a step almost simultaneously, or one of the left and right front wheels may touch a step before the other does. How to control the driving forces after the power-assisted rollator 10 starts the step overcoming operation for the step 80 will be described below.

[0184] In the step S4, the power-assisted rollator 10 performs the step overcoming operation for the step 80. In the step S4, to assist the power-assisted rollator 10 in overcoming the step 80, the driving force d_{pr} of the right rear wheel and the driving force d_{pl} of the left rear wheel are greater than in the steps preceding the step S3.

[0185] The following describes, as an example, how to control the wheels when the power-assisted rollator 10 moves toward a step at an angle. Figs. 18 and 19 show the graphs presenting an example of how to control the wheels of the power-assisted rollator 10 (electric vehicle). In Figs. 18 and 19, the horizontal axis represents the time, and the vertical axis represents the driving force applied to the wheels.

[0186] The dotted line c1 in Fig. 18 shows the driving force of the driving unit connected to the other wheel on the side estimated to have touched the step. On the other hand, the dotted line c2 shows the driving force of the driving unit connected to the wheel on the side estimated not to have touched the step. For example, assuming that the power-assisted rollator 10 configured as shown in Figs. 1 and 2 is used and that the right front wheel first touches a step, the dotted line c1 corresponds to the driving unit of the driving unit connected to the right rear wheel. On the other hand, the dotted line c2 corresponds to the driving unit of the driving unit connected to the left rear wheel. The following describes the control shown in Fig. 18 with reference to an example case where the right front wheel first touches a step.

[0187] Prior to the time t1, the power-assisted rollator 10 is moving forward, and the driving force d_{pl} applied to the left rear wheel and the driving force d_{pr} applied to the right rear wheel are set equal. Note that, in the example in Fig. 18, the relations $d_{pl} > 0$, $d_{pr} > 0$ hold true prior to the time t1, but the relations $d_{pl} = 0$, $d_{pr} = 0$ may be alternatively established.

[0188] At a time t1, the right front wheel of the power-assisted rollator 10 collides with a step. The determining unit 16a estimates that the right front wheel has collided with a step based on the values measured by the measuring unit. The control unit 16 determines that a step is detected at the time t1, and gradually increases the driving force d_{pl} applied to the left rear wheel and the driving force d_{pr} applied to the right rear wheel after the time t1. The rate of increase per unit time of the driving force d_{pl} of the driving unit coupled to the wheel on the side estimated to have touched the step (in the present example, the left rear wheel) is greater than the rate of increase per unit time of the driving force d_{pr} of the driving unit coupled to the wheel on the side estimated not to have touched the step (in the present example, the right rear wheel).

[0189] At a time t2, the driving force d_{pl} of the left rear wheel, which has a higher rate of increase per unit time, reaches a target value. The target value may or may not be the maximum driving force of the driving unit. The control unit 16 maintains the driving force d_{pl} of the left front wheel at the target value after the time t2. On the other hand, the driving force d_{pr} of the right rear wheel, which has a lower rate of increase per unit time, has not yet reached the target value at the time t2. The control unit 16 continues to gradually increase the driving force d_{pr} of the right rear wheel after the time t2.

[0190] At a time t3, the driving force d_{pr} of the right rear wheel, which has a lower rate of increase per unit time, has also reached the target value. The control unit 16 maintains the driving force d_{pl} of the left front wheel at the target value after the time t3.

[0191] For example, until determining that the power-assisted rollator 10 has successfully overcome the step, the control unit 16 keeps the driving force d_{pl} of the left front wheel and the driving force d_{pr} of the right rear wheel at the target value. The control unit 16 can determine whether or not the power-assisted rollator 10 has successfully overcome the step, for example, based on the value measured by the inclination sensor 23, but can make the determination in any other manner. As described with reference to Fig. 7, once the control unit 16 determines that the power-assisted rollator 10 has successfully overcome the step, the control unit 16 may lower the driving force d_{pl} of the left front wheel and the driving force d_{pr} of the right rear wheel.

[0192] Fig. 18 shows that, between the time t1 and the time t3, the relation $d_{pl} > d_{pr}$ is established, which means that the driving force of the left front wheel remains greater than that of the right rear wheel. Accordingly, while the vehicle body of the power-assisted rollator 10 is climbing up the step, the vehicle body can be turned in the rightward direction. This corrects the direction (angle θ) of the vehicle body of the power-assisted rollator 10 after the rollator 10 overcomes the step, thereby allowing the user to assume a safer attitude when moving forward after running onto the step.

[0193] The dotted line c3 in Fig. 19 shows the driving force of the driving unit connected to the other wheel on the side estimated to have touched a step. On the other hand, the dotted line c4 shows the driving force of the driving unit connected to the wheel on the side estimated not to have touched a step. For example, assuming that the power-assisted rollator 10 configured as shown in Figs. 1 and 2 is used, and that the right front wheel first touches a step, the dotted line c3 corresponds to the driving unit of the driving unit connected to the right rear wheel. On the other hand, the dotted line c4 corresponds to the driving unit of the driving unit connected to the left rear wheel. The following describes the control shown in Fig. 19 with reference to an example case where the right front wheel first touches a step.

[0194] At a time t1, the right front wheel of the power-assisted rollator 10 collides with a step. The determining unit 16a estimates that the right front wheel has collided with a step based on the values measured by the measuring unit. The control unit 16 determines that a step is detected at the time t1, and gradually increases the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel after the time t1. In this case, the rate of increase per unit time of the driving force d_{pl} of the driving unit coupled to the wheel on the side estimated to have touched the step (in the present example, the left rear wheel) is also greater than the rate of increase per unit time of the driving force d_{pr} of the driving unit coupled to the wheel on the side estimated not to have touched the step (in the present example, the right rear wheel).

[0195] While the rate of increase per unit time of the driving force d_{pr} of the right rear wheel is kept constant, the rate of increase per unit time of the driving force d_{pl} of the left rear wheel decreases as the time elapses. Accordingly, the dotted line c4 is gently inclined after the time t1.

[0196] At a time t3, both the driving force d_{pr} of the right rear wheel and the driving force d_{pl} of the left rear wheel reach a target value. The target value may or may not be the maximum driving force of the driving unit. The control unit 16 maintains the driving force d_{pr} of the right rear wheel and the driving force d_{pl} of the left rear wheel at the target value after the time t3.

[0197] For example, until determining that the power-assisted rollator 10 has successfully overcome the step, the control unit 16 keeps the driving force d_{pl} of the left front wheel and the driving force d_{pr} of the right rear wheel at the target value. The control unit 16 can determine whether or not the power-assisted rollator 10 has successfully overcome the step, for example, based on the value measured by the inclination sensor 23, but can make the determination in any other manner. As described with reference to Fig. 7, once the control unit 16 determines that the power-assisted rollator 10 has successfully overcome the step, the control unit 16 may lower the driving force d_{pl} of the left front wheel and the driving force d_{pr} of the right rear wheel.

[0198] Fig. 19 shows that, between the time t1 and the time t3, the relation $d_{pl} > d_{pr}$ is established, which means that the driving force of the left front wheel remains greater than that of the right rear wheel. Accordingly, while the vehicle body of the power-assisted rollator 10 is climbing up the step, the vehicle body can be turned in the rightward direction. This corrects the direction (angle θ) of the vehicle body of the power-assisted rollator 10 after the rollator 10 overcomes the step, thereby allowing the user to assume a safer attitude when moving forward after running onto the step.

[0199] As described as an example with reference to the controls shown in Figs. 18 and 19, the control unit 16 may gradually increase, until they reach a predetermined threshold value (fourth threshold value or the target value), (i) the driving force of the driving unit of at least one of the front and rear wheels 12 and 13 located on the opposite side in the width direction of the vehicle body to the front wheel 12 estimated to have touched the step and (ii) the driving force of the driving unit of at least one of the front wheel 12 estimated to have touched the step or the rear wheel 13 located on the same side in the width direction of the vehicle body as the front wheel 12. This can prevent the vehicle body from turning excessively.

[0200] According to the methods shown in Figs. 18 and 19, between the time t1 and the time t3, a driving force is also applied to the rear wheel on the side estimated to have collided with the step (the side closer to the step). Thus, the power-assisted rollator 10 can climb the step with both of the rear wheels while the vehicle body of the power-assisted rollator 10 is turning. According to the methods shown in Figs. 18 and 19, the driving force differs between the left and right rear wheels during the transition period (from the time t1 to the time t3) or until the driving forces of the respective rear wheels reach the target value. This can contribute to smoothly correct the direction of the vehicle body of the power-assisted rollator 10.

[0201] In the methods shown in Figs. 18 and 19, the driving forces of the respective rear wheels may be set equal after it is detected that the other front wheel has touched the step. In this way, once the left and right front wheels have touched the step, a high driving force (for example, the driving force at the above-described target value) can be applied to the power-assisted rollator 10, so that it can successfully climb the step.

[0202] As described above, the overcoming operation performed by the control unit 16 may include any one of controlling the driving units to increase the driving forces applied to the wheels while turning the vehicle body of the power-assisted rollator 10 (electric vehicle), controlling the driving units to increase the driving forces applied to the wheels after turning the vehicle body of the power-assisted rollator 10 (electric vehicle), or controlling the driving units to increase the driving forces applied to the wheels.

<Use of Twin Wheel Caster>

[0203] As shown in the plan view in Fig. 20, the power-assisted rollator 10 (electric vehicle) may move toward the step 80 with the front and rear wheels 12 and 13 rotating in different directions. For example, if the power-assisted rollator 10 changes its direction (turns) while moving, the front wheels 12 may be directed differently than the direction in which the vehicle body of the power-assisted rollator 10 runs.

[0204] Fig. 20 is a plan view showing a first example of the case where the front wheels are directed at an angle relative to the direction in which the vehicle moves forward. In a step S10 of Fig. 20, both of the front wheels 12 (the left and right front wheels) of the power-assisted rollator 10 collide with the step 80. The front wheels 12 are subjected to reaction forces F_{nl} and F_{nr} from the step 80 as a reaction to the driving force (d_{pl} + d_{pr}) applied to the rear wheels 13. The reaction forces F_{nl} and F_{nr} serve as moment centered on the center of rotation 12r of the respective front wheels 12 and cause the respective front wheels 12 to rotate counterclockwise (leftward).

[0205] As a result of the rotation, the side surface of the front wheels 12 are oriented almost parallel to the step 80 (step S11). In the step S11, the front wheels 12 are directed such that they are rotatable in a direction that is approximately parallel to the step 80. Since the front wheels 12 cannot rotate in the direction toward the step 80, the power-assisted rollator 10 faces serious difficulties in overcoming the step 80 even if it is assisted by the driving forces (d_{pl}, d_{pr}) applied to the rear wheels 13.

[0206] Although the vehicle body of the power-assisted rollator 10 moves in the direction approximately perpendicular to the step 80 in the example shown in Fig. 20, the above-mentioned problem may arise in a case where the vector indicating the movement of the vehicle body of the power-assisted rollator 10 forms an angle θ (θ > 0 degrees) relative to the perpendicular line to the step 80.

[0207] The wheels of the power-assisted rollator described in the above all have single-wheel tires. The wheels of the power-assisted rollator, however, may not be necessarily single-wheel tires. For example, the front wheels 12 (right and left front wheels) of a power-assisted rollator 10a in Fig. 21 are turnable twin-wheel casters 12a.

[0208] Fig. 21 is a plan view showing a second example of the case where the front wheels are directed at an angle relative to the direction in which the vehicle body moves forward. In a step S20 of Fig. 21, both of the twin-wheel casters 12a provided at the respective sides of the front portion of the power-assisted rollator 10a collide with the step 80. The twin-wheel casters 12a are subject to reactions forces F_{nl} and F_{nr} from the step 80 as a reaction to the driving force (d_{pl} + d_{pr}) applied to the rear wheels 13. The reaction forces F_{nl} and F_{nr} serve as moment centered on the center of rotation 12r of the respective twin-wheel casters 12a and cause the respective twin-wheel casters 12a to rotate clockwise (rightward).

[0209] The twin-wheel casters 12a have a greater overall wheel width than the front wheels 12 shown in Fig. 20. For this reason, as a result of the rotation, the contact surface of the twin-wheel casters 12a is oriented almost parallel to the step 80 (step S21). Accordingly, the power-assisted rollator 10a can overcome the step 80 by being assisted by the driving forces (d_{pl}, d_{pr}) applied to the rear wheels 13.

[0210] As shown in the example in Fig. 21, the front wheels of the power-assisted rollator (electric vehicle) may be twin-wheel casters configured to rotate about a vertical axis. The front wheels of the power-assisted rollator (electric vehicle), however, may not be necessarily twin-wheel casters. For example, the front wheels may be tires having a larger width than the rear wheels, which can avoid the difficulties faced by the power-assisted rollator in moving forward shown in Fig. 20.

<How to Detect Step when Twin-Wheel Casters Are Used>

[0211] When the front wheels of the power-assisted rollator (electric vehicle) are twin-wheel casters, the wheels may collide with a step in more than one stage. Figs. 22 and 23 are plan views showing, as an example, how the power-assisted rollator 10a collides with a step. The following describes how the rollator 10a collides with a step in more than one stage with reference to Figs. 22 and 23.

[0212] According to the example shown in Figs. 22 and 23, the power-assisted rollator 10a is moving toward the step 80 at an angle θ (θ > 0 degrees). In other words, the angle θ is formed between the perpendicular line to the step 80 and the direction in which the power-assisted rollator 10a runs. The twin-wheel casters 12a mounted on the front portion of the power-assisted rollator 10a both form an angle with respect to the direction in which the power-assisted rollator 10a runs. The left and right twin-wheel casters 12a are directed differently.

[0213] In a step S30, as for the angle relative to the direction in which the power-assisted rollator 10a runs, the right twin-wheel caster 12a forms a larger angle than the left twin-wheel caster 12a. First, in the step S30, the right twin-wheel caster 12a collides with the step 80 at one end thereof. The determining unit 16a detects that the right twin-wheel caster 12a collides with the step based on the values measured by the measuring unit. This results in the control unit 16 determining that the power-assisted rollator 10a needs to be turned in the rightward direction. The control unit 16 then controls the driving units such that the driving force d_{pl} of the left rear wheel can be made greater than the driving force d_{pr} of the right rear wheel. This causes the power-assisted rollator 10a to start turning in the rightward direction in the step S30.

[0214] In the next step S31, the left twin-wheel caster 12a collides with the step 80 at one end thereof. The determining unit 16a may detect that the left twin-wheel caster 12a has collided with the step based on the values measured by the measuring unit. If such a collision is detected, the control unit 16 determines that the vehicle body has been changing its direction. As a result, the control unit 16 may reduce the difference between the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel. In the step S31, the control unit 16 may not necessarily change the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel. Regardless of the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel, the power-assisted rollator 10a keeps turning in the rightward direction in the step S31.

[0215] In the next step S32, the right twin-wheel caster 12a collides with the step 80 at the other end thereof. The determining unit 16a may detect that the right twin-wheel caster 12a has collided with the step based on the values measured by the measuring unit. If such a collision is detected, the control unit 16 determines that the vehicle body has been changing its direction. As a result, the control unit 16 may reduce the difference between the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel. In the step S32, the control unit 16 may not necessarily change the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel. Regardless of the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel, the power-assisted rollator 10a keeps turning in the rightward direction in the step S32.

[0216] In the last step S33, the left twin-wheel caster 12a collides with the step 80 at the other end thereof. The determining unit 16a detects that the right twin-wheel caster 12a has collided with the step based on the values measured by the measuring unit. This means that the front surface of the power-assisted rollator 10a faces the step 80 almost perpendicularly. As a result, the control unit 16 determines that the power-assisted rollator 10a no longer needs to turn in the rightward direction. The control unit 16 controls the driving units such that the driving force d_{pl} of the left rear wheel can be equal to the driving force d_{pr} of the right rear wheel. Here, the driving force d_{pl} of the left rear wheel and the driving force d_{pr} of the right rear wheel may be set at the target value shown in Figs. 18 and 19.

[0217] After the step S33, the power-assisted rollator 10a can overcome the step 80 as being assisted by the driving force d_{pl} applied to the left rear wheel and the driving force d_{pr} applied to the right rear wheel.

[0218] In the example shown in Figs. 22 and 23, the respective twin-wheel casters 12a collide with the step at different times, and each caster 12a collides with the step on more than one occasion. This can cause a plurality of lighter shocks on the power-assisted rollator 10a. Therefore, the acceleration detected by the acceleration sensor 22a may be lower than when the front wheels are single-wheel tires. Similarly, when the speed sensor 22b is used to detect whether the power-assisted rollator collides, the change in speed generated by a single collision may be less than the change in speed generated when the front wheels are single-wheel tires. Accordingly, when the front wheels of the power-assisted rollator (electric vehicle) are twin-wheel casters, a lower threshold value can be used to detect a collision with a step than when the front wheels are single-wheel tires. In this manner, the power-assisted rollator can detect a step.

<Second Embodiment

[0219] Next, a second embodiment of the present disclosure will be described. The second embodiment shown in

Figs. 24 to 30 is different from the first embodiment in terms of the configuration around the rear wheels 13 and the motor 20. Except for these, the second embodiment is the same as the first embodiment. In Figs. 24 to 30, the common elements in the first and second embodiments are assigned with the same reference numbers and not described in detail.

[0220] In the arrangement shown in Figs. 24 to 28, the motors 20 of the power-assisted rollator 10 are coupled to the rear wheels 13 via associated planetary gear mechanisms 50.

[0221] As shown in Figs. 26 to 28, each of the motors 20 includes a housing 61 fixed on the pipe frame 31, an output shaft support 62 housed in the housing 61 and rotatable relative to the housing 61, and an output shaft 63 fixed on the output shaft support 62 and configured to rotate integrally with the output shaft support 62. A flange 64 is fixed on the housing 61, and the output shaft 63 is projected from a middle portion of the housing 61. Between the housing 61 and the output shaft support 62, a bearing 65 is interposed. On the outer periphery of the output shaft support 62, a magnet 66 is provided. Further, a coil 67 is disposed around the magnet 66, and the coil 67 is fixed on the housing 61. The coil 67 is fed with electric power from the battery 21 and causes rotation of the output shaft support 62 having the magnet 66 provided thereon. A cap 68 is provided in the middle portion of the housing 61.

[0222] The rear wheel 13 includes a wheel 71, a tire 72 provided on the outer periphery of the wheel 71, and a wheel retainer 73 connected to the wheel 71. The wheel 71 is fixed on a bearing 75 provided around the flange 64 via a retainer plate 74.

[0223] The planetary gear mechanism 50 includes a sun gear 51, an internal gear 52 disposed around the sun gear 51, three planet gears 53 meshing with the sun gear 51 and the internal gear 52 and configured to rotate and revolve when the output shaft 63 rotates, and a planet carrier 54 that rotatably supports the three planet gears 53 and receives the revolution movement of the planet gears 53.

[0224] The sun gear 51 is connected to the output shaft 63 of the motor 20 and rotatable in accordance with the rotation of the output shaft 63. The internal gear 52 is connected to the wheel 71 of the rear wheel 13. The planet carrier 54 is connected to the flange 64 of the motor 20 and fixed on the pipe frame 31 via the flange 64 and the housing 61.

[0225] The following describes the action of controlling the motors 20 to cause the front wheels 12 to be lifted relative to the rear wheels 13 (the power-assisted rollator 10 is put into wheelie) in the embodiment.

[0226] First, it is supposed that the power-assisted rollator 10 is moving normally with the front wheels 12 not striking a step. In this case, the assist force from the output shaft 63 of the motor 20 is transmitted from the sun gear 51 connected to the output shaft 63 of the motor 20 to the internal gear 52 via the planet gears 53, and then transmitted to the rear wheel 13 connected to the internal gear 52. Thus, the motor 20 assists the movement of the reel wheel 13. Note that the pipe frame 31 connected to the planet carrier 54 does not rotate.

[0227] With the numbers of teeth of the sun gear 51 and the internal gear 52 represented by Za, Zc (Za < Zc), respectively, and the angular speeds of the sun gear 51, the internal tooth tear 52, and the planet carrier 54 represented by Wa, Wc, Wx, respectively, Formula (1) is obtained.

$$Zc(Wc-Wx)=-Za(Wa-Wx) \qquad \text{Formula (1)}$$

[0228] When the power-assisted rollator 10 is moving normally, the planet carrier 54 is fixed, and thus Wx is zero. Therefore, Formula (2) is obtained.

$$Wc=(-Za/Zc)Wa \qquad \text{Formula (2)}$$

[0229] That is, the number of rotations of the output shaft 63 of the motor 20 is reduced to -Za/Zc times of that and transmitted.

[0230] On the other hand, when the front wheels 12 of the power-assisted rollator 10 strike a step, the front wheels 12 are locked and the rear wheels 13 also stop rotating. This also locks the internal gear 52 of the planetary gear mechanism 50 connected to the rear wheel 13. The rotational force from the output shaft 63 of the motor 20 is transmitted to the sun gear 51 connected to the output shaft 63. This rotational force is transmitted from the sun gear 51 to the planet carrier 54 via the planet gears 53 and acts on the pipe frame 31 connected to the planet carrier 54 in the direction of the arrow M (see Fig. 25) (in the direction opposite to the direction in which the power-assisted rollator 10 runs).

[0231] Accordingly, when the front wheels 12 strike a step, the control unit 16 may control the motors 20, so as to rotate the entirety of the power-assisted rollator 10 and lift the front wheels 12 higher than the rear wheels 13. In this case, the control unit 16 may increase the outputs of the motors 20 in accordance with the operation force (the grip force) applied to the handles 14. More specifically, the control unit 16 controls the motors 20 such that, for the same operation force, the outputs of the motors 20 are higher than under normal circumstances (that is, the proportional factor of the motor output for multiplication of the operation force is larger). In this manner, the front wheels 12 can be lifted higher than the rear wheels 13.

[0232] As noted, when the front wheels 12 of the power-assisted rollator 10 strike a step, the internal gear 52 becomes stationary, which means Wc in Formula (1) is zero. Therefore, Formula (3) is obtained.

$$Wx = \{Za/(Zc+Za)\}Wa \qquad \text{Formula (3)}$$

[0233] That is, the number of rotations of the output shaft 63 of the motor 20 is reduced to Za/(Zc+Za) times that, and the entirety of the power-assisted rollator 10 connected to the planet carrier 54 is subject to a rotational force directed oppositely to the direction of the rotational force that causes the power-assisted rollator 10 to move forward (directed to lift the front wheels 12).

[0234] As described above, according to the embodiment, the motors 20 are connected to the rear wheels 13 via the planetary gear mechanisms 50. Thus, when the front wheels 12 of the power-assisted rollator 10 strike a step, the front wheels 12 can be lifted higher than the rear wheels 13 using the planetary gear mechanisms 50. That is, the control unit 16 can put the power-assisted rollator 10 into wheelie by the driving force of the motors 20 and the reaction of the planetary gear mechanisms 50.

[0235] In the embodiment, the planetary gear mechanism 50 includes the sun gear 51 connected to the output shaft 63 of the motor 20, the internal gear 52 disposed around the sun gear 51, the planet gears 53 meshing with the sun gear 51 and the internal gear 52 and configured to rotate and revolve when the output shaft 63 rotates, and the planet carrier 54 that rotatably supports the planet gears 53 and receives the revolution movement of the planet gears 53. The internal gear 52 is connected to the rear wheels 13, and the planet carrier 54 is fixed on the pipe frame 31. Thus, when the front wheels 12 strike a step, the rotational force from the output shaft 63 of the motor 20 can be transmitted from the sun gear 51 to the planet carrier 54 via the planet gears 53 and act on the pipe frame 31 connected to the planet carrier 54. Thus, the entirety of the power-assisted rollator 10 can be rotated, and the front wheels 12 can be lifted relative to the rear wheels 13.

[0236] In the embodiment, the control unit 16 may cause the front wheels 12 to be lifted relative to the rear wheels 13 using the planetary gear mechanisms 50. It may also be possible to replace the planetary gear mechanisms 50 with eccentric reducers or other mechanisms including gears that rotate and revolve.

[0237] Alternatively, the planetary gear mechanism 50 may be replaced with a mechanism including two gears. More specifically, as shown in Figs. 29 and 30, a first gear 57 may be directly connected to the motor 20, a second gear 58 may be directly connected to the rear wheel 13, and the first gear 57 and the second gear 58 may mesh with each other. As shown in Fig. 29, when the power-assisted rollator 10 is running under normal circumstances, the motor 20 assists the rear wheel 13 in moving. On the other hand, as shown in Fig. 30, when the front wheel 12 strikes a step and the front wheel 12 is locked, the rear wheel 13 is also locked. If the motor 20 further rotates with the front and rear wheels 12 and 13 being locked, a force is generated so as to lift the entirety of the power-assisted rollator 10. This creates a rotational force directed oppositely to the direction of the rotational force that causes the power-assisted rollator 10 to move forward. Thus, the front wheels 12 of the power-assisted rollator 10 can readily run over the step.

<Third Embodiment

[0238] Next, a third embodiment of the present disclosure will be described. The third embodiment shown in Figs. 31a, 31b, 32a and 32b is different from the first embodiment in that the driving units for generating a driving force for lifting the front wheels 12 may be separate from the motors 20. In other respects, the third embodiment is configured in the same way as the first embodiment. In Figs. 15 and 16, the common elements in the first and third embodiments are denoted by the same reference numerals and detailed descriptions thereof will be omitted.

[0239] In Figs. 31a and 31b, the driving units for generating a driving force for lifting the front wheels 12 are constituted by additional motors 46 separate from the motors 20. The rotation axis of the additional motors 46 may or may not be aligned with the rotation axis of the rear wheels 13 (the former case is shown in Fig. 31a and the latter case Fig. 31b).

[0240] In Figs. 32a and 32b, the driving units for generating a driving force for lifting the front wheels 12 are constituted by actuators 47 separate from the motors 20. The actuators 47 are connected to the frame 11. The actuator 47 may be either an expanding actuator or a swinging actuator. The expanding actuator is configured to lift the front wheels 12 relative to the rear wheels 13 by expanding and contracting (Fig. 32a), while the swinging actuator is configured to lift the front wheels 12 relative to the rear wheels 13 by swinging (Fig. 32b).

[0241] In Figs. 31a, 31b, 32a, and 32b, the motors 20 may not be necessarily provided.

<Fourth Embodiment

[0242] The following describes a fourth embodiment of the present disclosure with reference to Figs. 33 and 34. In Figs. 33 and 34, the common elements in the first to fourth embodiments are denoted by the same reference numerals, and detailed descriptions thereof will be omitted.

[0243] Fig. 33 is a schematic perspective view showing, as an example, an external appearance of a power-assisted rollator (an electric vehicle) 10 according to the fourth embodiment.

<Configuration of Power-Assisted Rollator>

[0244] As shown in Fig. 33, the power-assisted rollator 10 includes a frame 11, a pair of front wheels 12 and a pair of rear wheels (wheels) 13 provided on the frame 11, and a pair of handles 14 connected to the frame 11.

[0245] The rear wheels 13 each have a motor 20 coupled thereto, and the motor 20 assists movement of the corresponding rear wheel 13. A battery 21 and a control unit 16 are mounted to the frame 11. A control unit 16 has an inclination sensor 23.

[0246] In the present embodiment, the handles 14, which are to be operated by the user, are provided on the upper ends of left and right pipe frames 31. The handles 14 are coupled to each other via a bar handle 17 extending horizontally. The handles 14 and bar handle 17 constitute a substantial U-shape. To the handles 14, an arm support 27 is attached to allow the user to rest his/her arms on it. The arm support 27 has openings into which the handles 27 can be inserted. The handles 14 can be provided in the openings.

[0247] Between the left and right pipe frames 31, a seat 37 is provided to allow the user to be seated on it as necessary.

[0248] The battery 21 supplies power to the elements of the power-assisted rollator 10 such as the motors 20 and the control unit 16. The battery 21 is provided below the seat 37 positioned between the pipe frames 31.

[0249] A speed sensor 22b (mentioned as an example of components of a measuring unit) is provided in each of the rear wheels 13. The speed sensors 22b may not be necessarily embedded in the front and/or rear wheels 12, 13, but can be attached to the frame 11, the handles 14 or any other components. Alternatively, the speed sensors 22 may be disposed adjacently to the control unit 16. In the embodiment, the running speed of the power-assisted rollator 10 may be determined based on the rotational speed of the rear wheels 13, but the present embodiment is not limited to such. The running speed of the power-assisted rollator 10 may be determined based on the rotational speed of the front wheels 12 or both the rotation speeds of the front and rear wheels 12 and 13.

[0250] The measuring unit may include an acceleration sensor 22a. In this case, the rotational acceleration of the rear wheels 13 is not used, and the acceleration sensor 22a directly senses the acceleration of the power-assisted rollator 10 and transmits a signal representing the acceleration to the control unit 16. The control unit 16 calculates the speed by integrating the acceleration.

[0251] The measuring unit may include a global positioning system (GPS) device. In this case, the rotational acceleration of the rear wheels 13 is not used, and the GPS device detects the position of the power-assisted rollator 10. Furthermore, the control unit 16 may differentiate the position information from the GPS device to calculate the speed of the power-assisted rollator 10, and differentiate the position information from the GPS device twice to calculate the acceleration of the rollator.

[0252] The inclination sensor 23 is constituted by an acceleration sensor having two or more axes. The inclination sensor 23 is disposed adjacent to the control unit 16. Alternatively, the inclination sensor 23 may be provided in an upper portion of the power-assisted rollator 10. The inclination sensor 23 may be constituted by a gyrosensor, instead of an acceleration sensor, for estimating an attitude of the power-assisted rollator 10.

[0253] The other features of the power-assisted rollator 10 are the same as the counterparts of the power-assisted rollator 10 of the first embodiment (Figs. 1 and 2).

[0254] In the embodiment, the power-assisted rollator 10 may have no grip sensor, strain sensor, proximity sensor, or pressure sensor that may directly sense whether or not the user grips the pair of handles 14. The present embodiment, however, is not limited to such. The power-assisted rollator 10 relating to the fourth embodiment may also include grip sensors 24 on the handles 14 as in the first embodiment (Figs. 1 and 2).

[0255] The embodiments and modification examples of the present disclosure described above are mere examples and are not intended to limit the scope of the invention. The embodiments and modification examples described above may have various other forms and are susceptible to omission, replacement, and modification of various elements thereof without departing from the spirit of the invention. The embodiments and modification examples described above are included in the scope and the purport of the invention and are also included in the inventions recited in the claims and the equivalents thereof.

LIST OF REFERENCE NUMBERS

[0256]

10, 10a	power-assisted rollator
11	frame

12	front wheel
13	rear wheel
14	handle
15	brake unit
16	control unit
20	motor
21	battery
22a	acceleration sensor
22b	speed sensor
23	inclination sensor
24	grip sensor
25	leg sensor
31	pipe frame

Claims

1. An electric vehicle comprising:

   one or more driving units for driving one or more wheels, the one or more wheels including one or more front wheels provided on a vehicle body, one or more rear wheels provided on the vehicle body, or the front and rear wheels;
   a control unit for performing a step overcoming control on the one or more driving units so that the one or more wheels overcome a step;
   a measuring unit for measuring at least one of speed or acceleration imparted to the vehicle body having the one or more wheels provided thereon; and
   a determining unit for determining, based on a value measured by the measuring unit, whether to cause the control unit to perform the step overcoming control.

2. The electric vehicle of claim 1, wherein the determining unit causes the control unit to perform the step overcoming control if the determining unit determines, based on the value measured by the measuring unit, that the one or more front wheels have touched a step.

3. The electric vehicle of claim 1 or 2, wherein the step overcoming control includes increasing a driving force applied by the one or more driving units to drive the one or more wheels.

4. The electric vehicle of any one of claims 1 to 3, wherein the step overcoming control includes turning the vehicle body.

5. The electric vehicle of any one of claims 1 to 4, wherein the step overcoming control includes increasing a driving force while turning the vehicle body.

6. The electric vehicle of claim 2,

   wherein the one or more front wheels include left and right front wheels spaced away from each other in a width direction of the vehicle body, and
   wherein the determining unit determines, based on the value measured by the measuring unit, which one of the left and right front wheels has touched the step.

7. The electric vehicle of claim 6, wherein the measuring unit at least measures (i) acceleration in the width direction of the vehicle body and (ii) acceleration directed to reduce a speed of the vehicle body or acceleration in a front-rear direction of the vehicle body.

8. The electric vehicle of claim 7,

   wherein the one or more rear wheels include left and right rear wheels spaced away from each other in the width direction of the vehicle body, and
   wherein the measuring unit at least calculates (i) an average value between acceleration of the left rear wheel in a rotational direction and acceleration of the right rear wheel in a rotational direction, or (ii) a difference

between acceleration of the left rear wheel in a rotational direction and acceleration of the right rear wheel in a rotational direction.

9. The electric vehicle of claim 7 or 8, wherein the measuring unit at least calculates (i) an average value between acceleration of the left front wheel in a rotational direction and acceleration of the right front wheel in a rotational direction, or (ii) a difference between acceleration of the left front wheel in a rotational direction and acceleration of the right front wheel in a rotational direction.

10. The electric vehicle of any one of claims 6 to 9,

wherein the measuring unit measures (i) at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and (ii) acceleration in the width direction of the vehicle body, and
wherein the determining unit estimates which one of the left and right front wheels has touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a first threshold value.

11. The electric vehicle of any one of claims 6 to 10,

wherein the measuring unit measures (i) at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and (ii) acceleration in the width direction of the vehicle body, and
wherein the determining unit estimates which one of the left and right front wheels has touched a step when a largest absolute value of the acceleration in the width direction of the vehicle body measured within a predetermined period of time after at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a first threshold value becomes equal to or greater than a second threshold value.

12. The electric vehicle of claim 10 or 11,

wherein the measuring unit measures at least one of acceleration directed to reduce speed of the vehicle body or rearward acceleration of the vehicle body, and
wherein the determining unit estimates that the left and right front wheels have touched a step when at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit becomes equal to or greater than a third threshold value that is less than the first threshold value.

13. The electric vehicle of any one of claims 6 to 12, wherein the control unit controls the one or more driving units such that only a driving unit of a rear wheel located on a same side in the width direction of the vehicle body as one of the front wheels that is estimated to have touched the step generates a driving force.

14. The electric vehicle of any one of claims 6 to 13, wherein the control unit controls the one or more driving units such that only a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step generates a driving force.

15. The electric vehicle of any one of claims 6 to 14, wherein the control unit controls the one or more driving units such that a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step generates a higher driving force than a driving unit of at least one of (i) the front wheel estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

16. The electric vehicle of any one of claims 6 to 15, wherein the control unit controls the one or more driving units such that a driving unit of at least one of (i) one of the front wheels that is estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step generates a higher driving force than a driving unit of at least one of (i) one of the front wheels that is estimated to have touched the step or (ii) a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

17. The electric vehicle of any one of claims 6 to 16, wherein the control unit gradually increases, until a fourth threshold value, (i) a driving force applied by a driving unit of at least one of a front wheel or a rear wheel located on an opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step and (ii) a driving force applied by a driving unit of at least one of the front wheel estimated to have touched the step or a rear wheel located on a same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

18. The electric vehicle of claim 17, wherein (i) the driving force applied by the driving unit of at least one of the front wheel or the rear wheel located on the opposite side in the width direction of the vehicle body to one of the front wheels that is estimated to have touched the step is greater than (ii) the driving force applied by the driving unit of at least one of the front wheel estimated to have touched the step or the rear wheel located on the same side in the width direction of the vehicle body as the front wheel estimated to have touched the step.

19. The electric vehicle of any one of claims 1 to 18, wherein the control unit controls the one or more driving units such that, when the determining unit estimates based on the value measured by the measuring unit that both of the front wheels have touched a step, (i) driving units of the front wheels on respective sides in a width direction of the vehicle body, (ii) driving units of the rear wheels on the respective sides in the width direction of the vehicle body, or (iii) driving units of the front and rear wheels generate equal driving forces.

20. The electric vehicle of any one of claims 1 to 19, wherein, when a largest absolute value of acceleration in a width direction of the vehicle body measured by the measuring unit becomes equal to or greater than a second threshold value, the control unit lowers a fifth threshold value for the acceleration based on which whether or not to perform the step overcoming operation is determined.

21. The electric vehicle of any one of claims 1 to 20, wherein the control unit increases a sixth threshold value for an absolute value of the acceleration based on which whether or not to perform the step overcoming operation is determined, as the speed of the vehicle body measured by the measuring unit increases.

22. The electric vehicle of claim 2,

wherein the measuring unit measures at least one of acceleration directed to reduce the speed of the vehicle body or rearward acceleration of the vehicle body, and
wherein the determining unit estimates that the one or more front wheels have touched a step if at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is greater than a seventh threshold value.

23. The electric vehicle of claim 22, wherein the determining unit does not estimate that the one or more front wheels have touched a step if at least one of the acceleration directed to reduce the speed of the vehicle body or the rearward acceleration of the vehicle body measured by the measuring unit is equal to or less than the seventh threshold value.

24. The electric vehicle of claim 22 or 23, comprising

a memory unit for storing the value measured by the measuring unit,
wherein the determining unit adjusts the seventh threshold value based on the measured value stored on the memory unit.

25. The electric vehicle of claim 24, wherein, after the control unit performs a step overcoming operation for the one or more front wheels, the determining unit lowers the seventh threshold value if acceleration that is lower than the seventh threshold value is detected within a predetermined period of time before the control unit performs the step overcoming control for the one or more front wheels.

26. The electric vehicle of claim 24 or 25, wherein the determining unit increases the seventh threshold value if the acceleration measured by the measuring unit when the control unit performs the step overcoming operation for the one or more front wheels is greater than the seventh threshold value and a difference between the measured acceleration and the seventh threshold value is greater than a predetermined value.

27. The electric vehicle of claim 2,

wherein the measuring unit measures a frequency spectrum of vibration of the vehicle body, and
wherein the determining unit estimates that the one or more front wheels have touched a step if a representative value of values measured by the measuring unit is greater than an eighth threshold value.

28. The electric vehicle of claim 27, wherein the determining unit does not estimate that the one or more front wheels have touched a step if the representative value of the values measured by the measuring unit is equal to or less than the eighth threshold value.

29. The electric vehicle of claim 27 or 28, wherein the vibration of the vehicle body includes vibration of the vehicle body in a front-rear direction.

30. The electric vehicle of any one of claims 1 to 29, comprising
a buffer member covering at least part of a front portion of the vehicle body or respective side surfaces of the vehicle body that face each other in a width direction.

31. The electric vehicle of any one of claims 1 to 30, wherein the one or more front wheels are one or more turnable twin-wheel casters.

32. An electric vehicle comprising:

a driving unit for driving a wheel, the wheel including at least one of a front wheel or a rear wheel;
a control unit for controlling the driving unit to perform a step overcoming control;
a measuring unit for measuring at least one of speed or acceleration imparted to a vehicle body having the wheel provided thereon; and
a determining unit for determining whether to cause the control unit to perform the step overcoming control, based on a value measured by the measuring unit,
wherein the control unit increases a driving force applied by the driving unit to drive the wheel or turns the vehicle body if the determining unit determines, based on the value measured by the measuring unit, that the front wheel has touched a step.

33. A control method of an electric vehicle, the control method comprising steps of:

measuring at least one of speed or acceleration imparted to a vehicle body; and
determining whether to perform a step overcoming control based on at least one of the speed or the acceleration.

34. The control method of claim 33, comprising steps of:

determining whether a front wheel has touched a step based on at least one of the speed or the acceleration; and
performing the step overcoming control when the front wheel is estimated to have touched a step.

35. The control method of claim 33 or 34, wherein the step overcoming control includes at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body.

36. A control program of an electric vehicle, the control program comprising:

measuring at least one of speed or acceleration imparted to a vehicle body;
determining whether to perform a step overcoming control based on at least one of the speed or the acceleration; and
performing the step overcoming control when a front wheel is estimated to have touched a step.

37. The control program of claim 36, wherein the step overcoming control includes at least one of increasing a driving force applied to drive a wheel, turning the vehicle body, or increasing the driving force while turning the vehicle body.

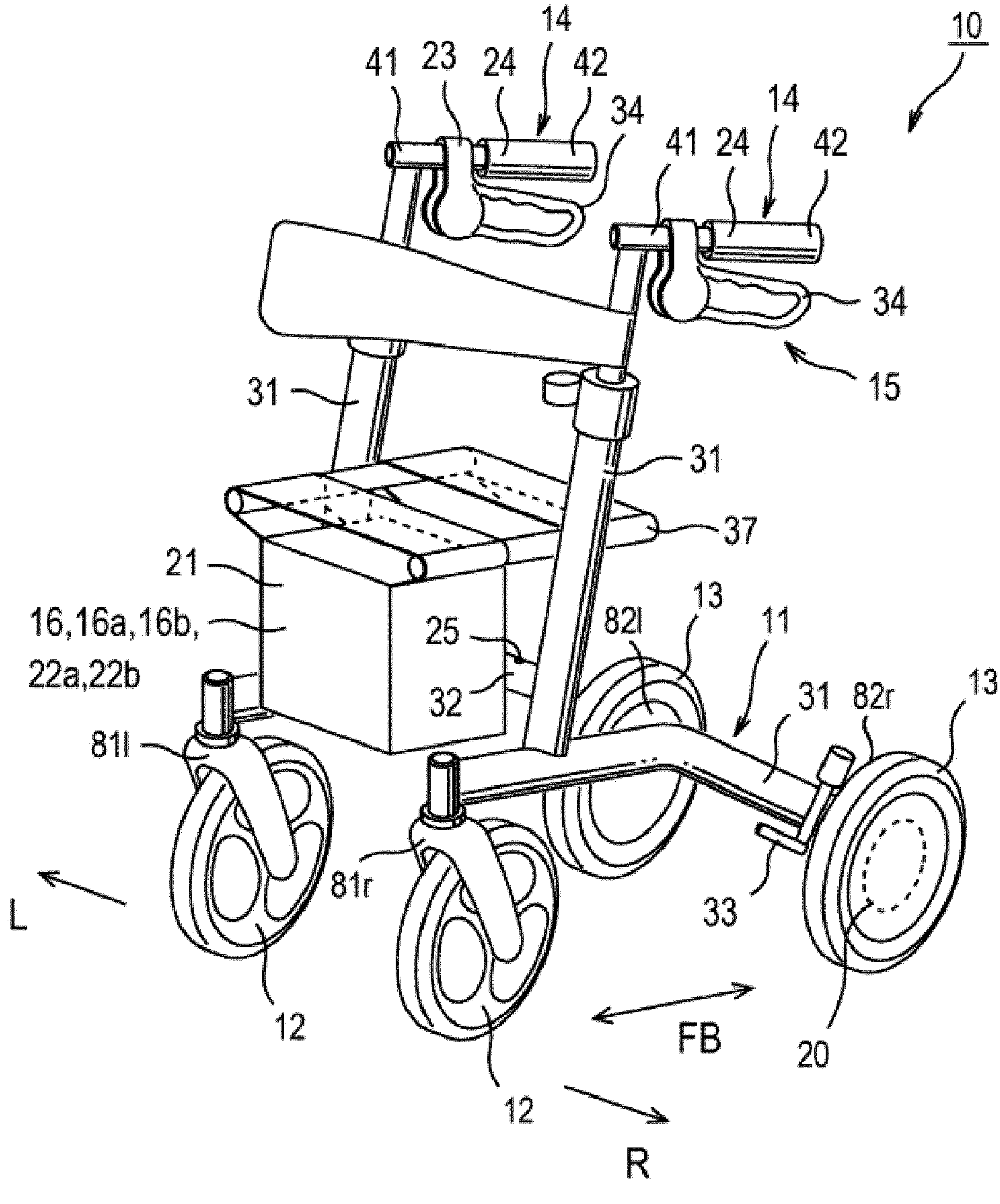
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Fig. 1

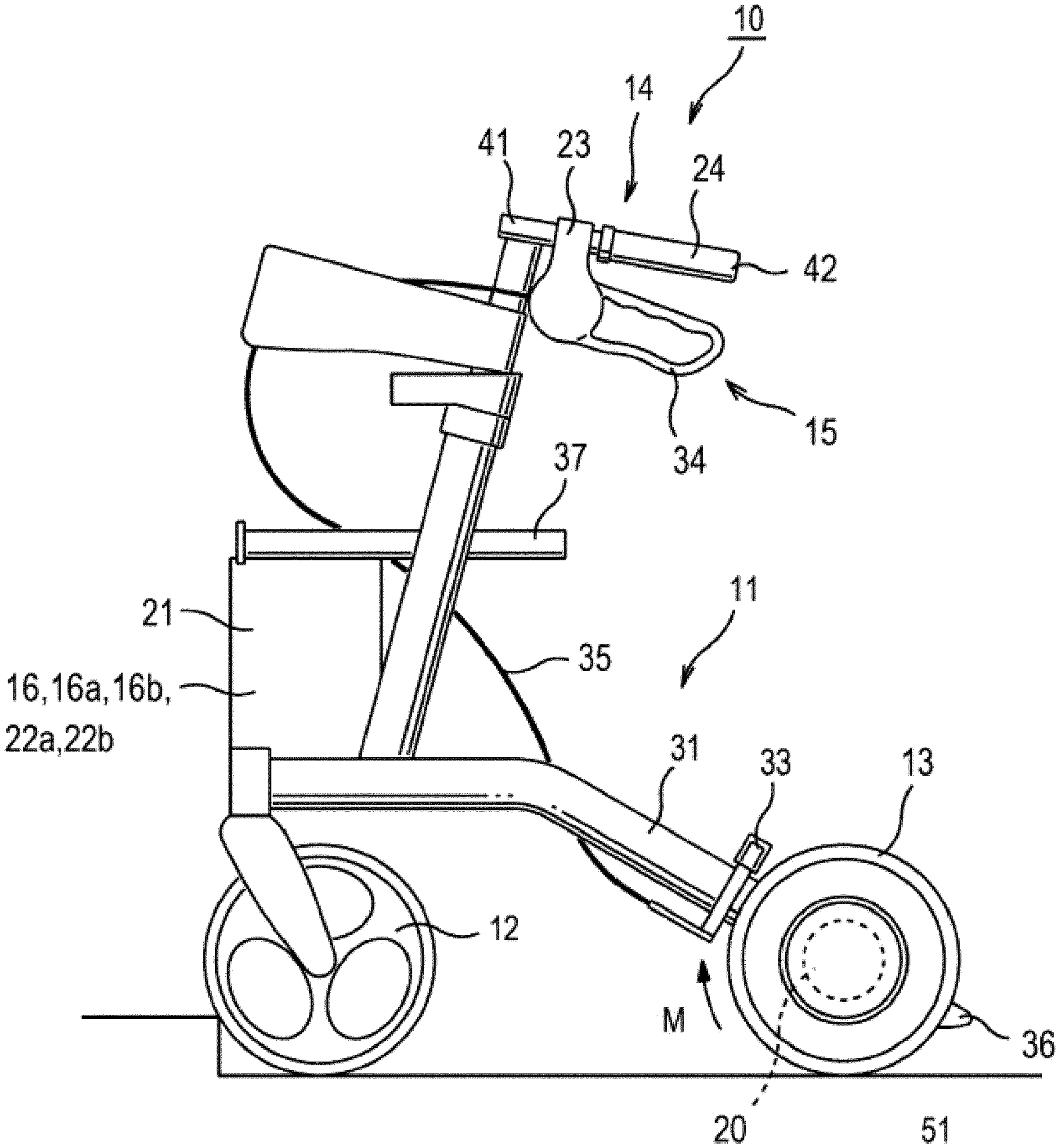
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Fig. 2

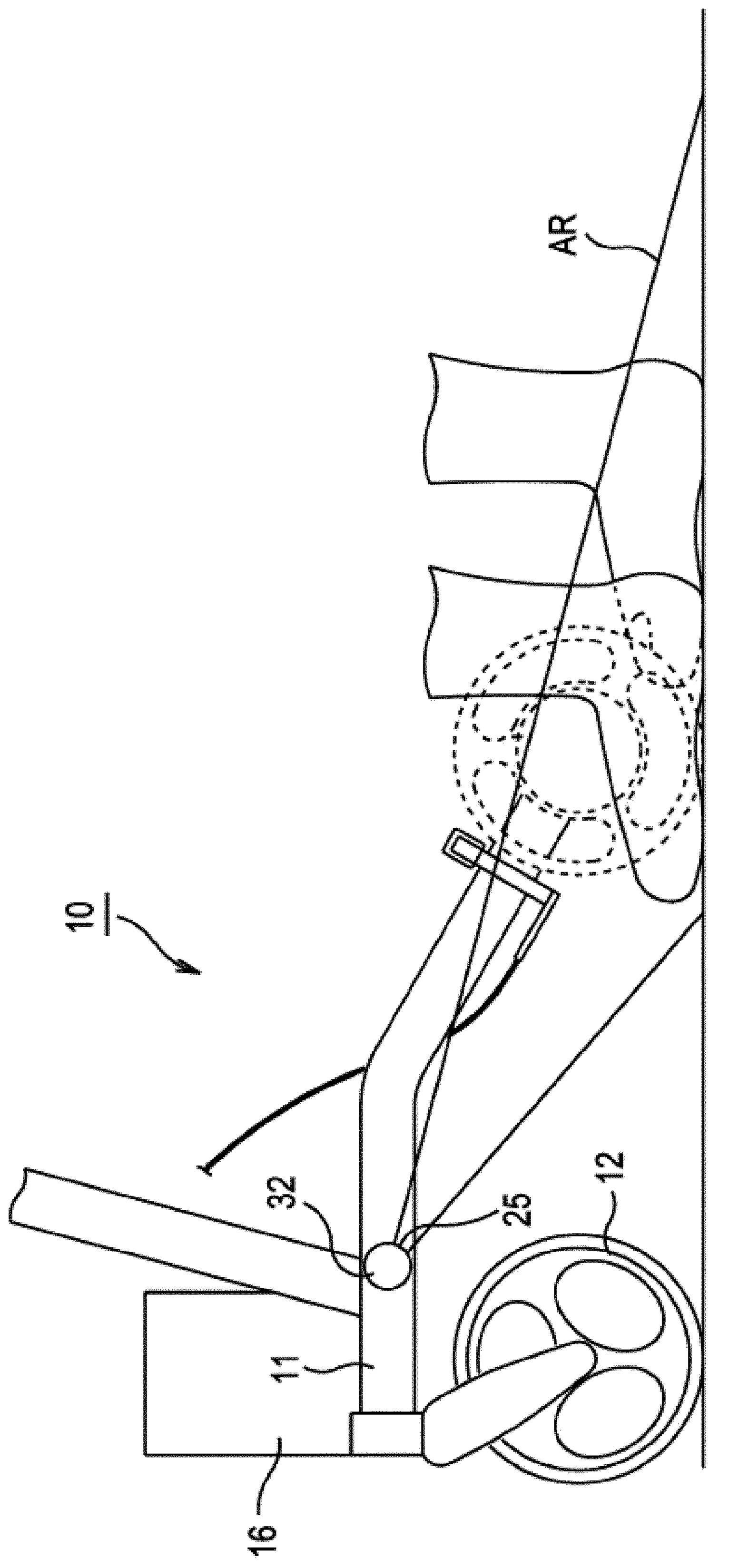


Fig. 3

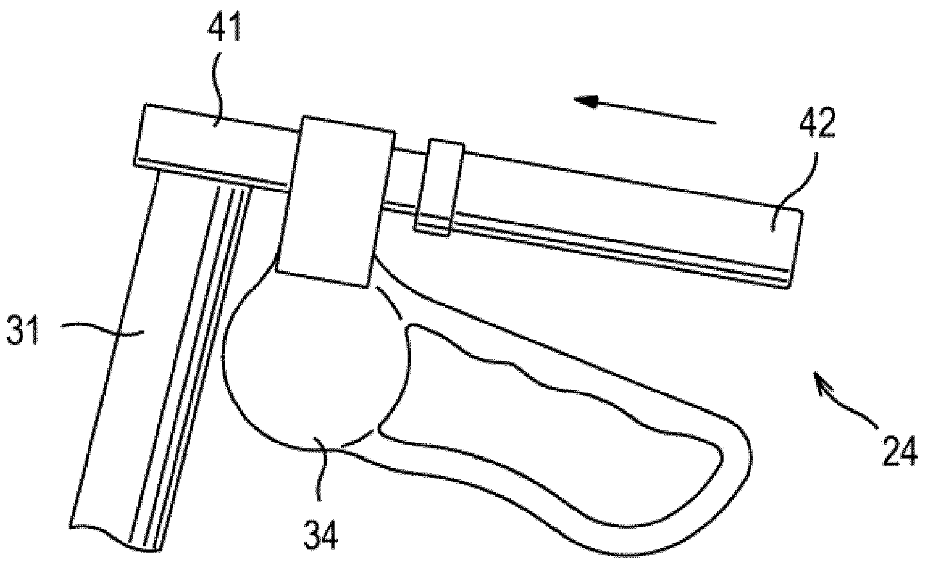


Fig. 4

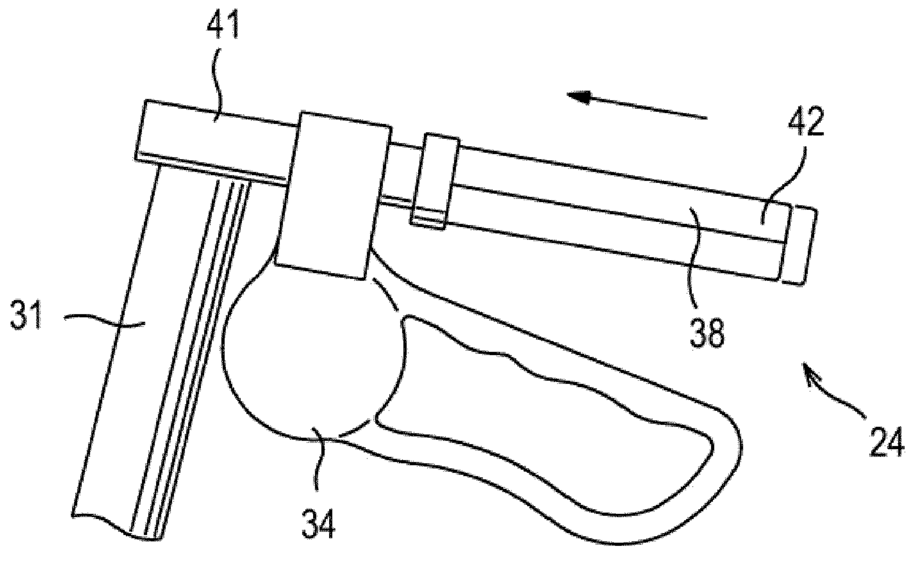


Fig. 5

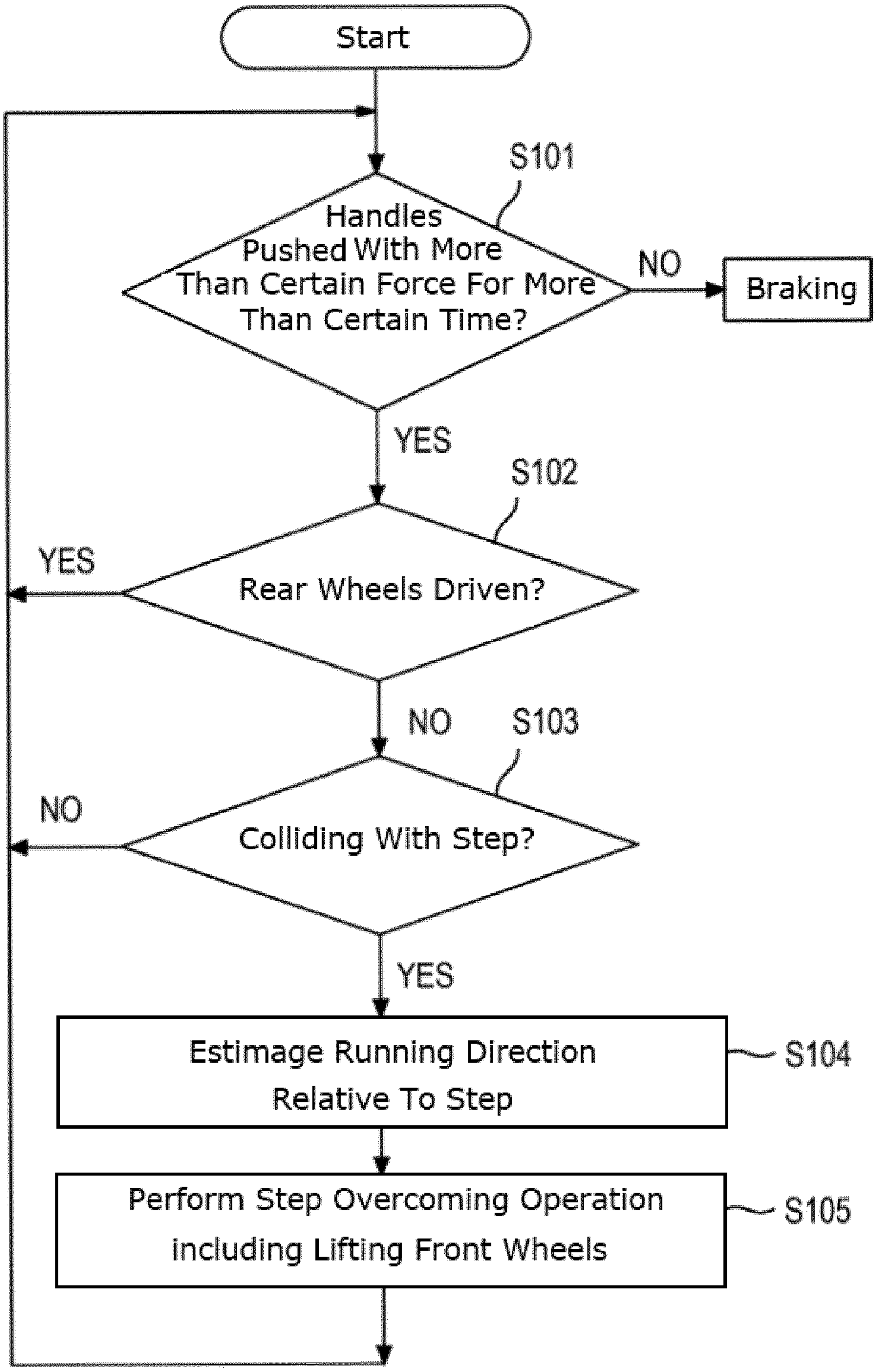

Start
S101
Handles Pushed With More Than Certain Force For More Than Certain Time?
NO
Braking
YES
S102
YES
Rear Wheels Driven?
NO
S103
NO
Colliding With Step?
YES
Estimage Running Direction Relative To Step
S104
Perform Step Overcoming Operation including Lifting Front Wheels
S105

Fig. 6

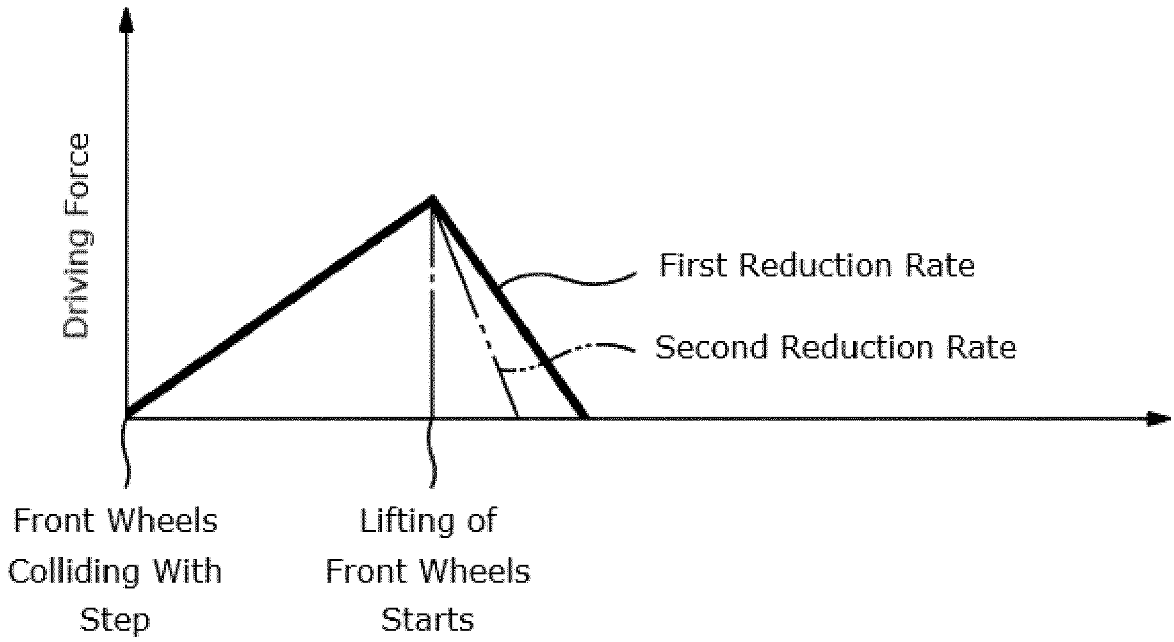
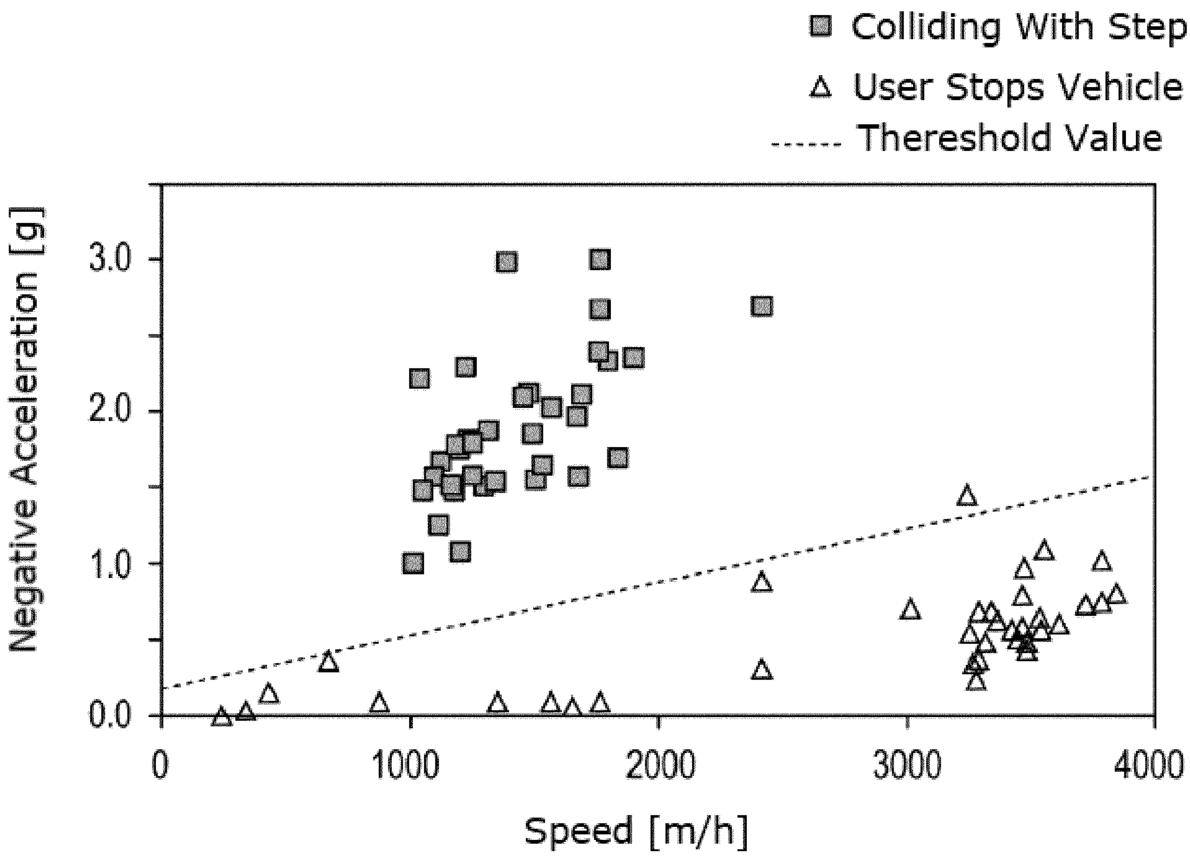
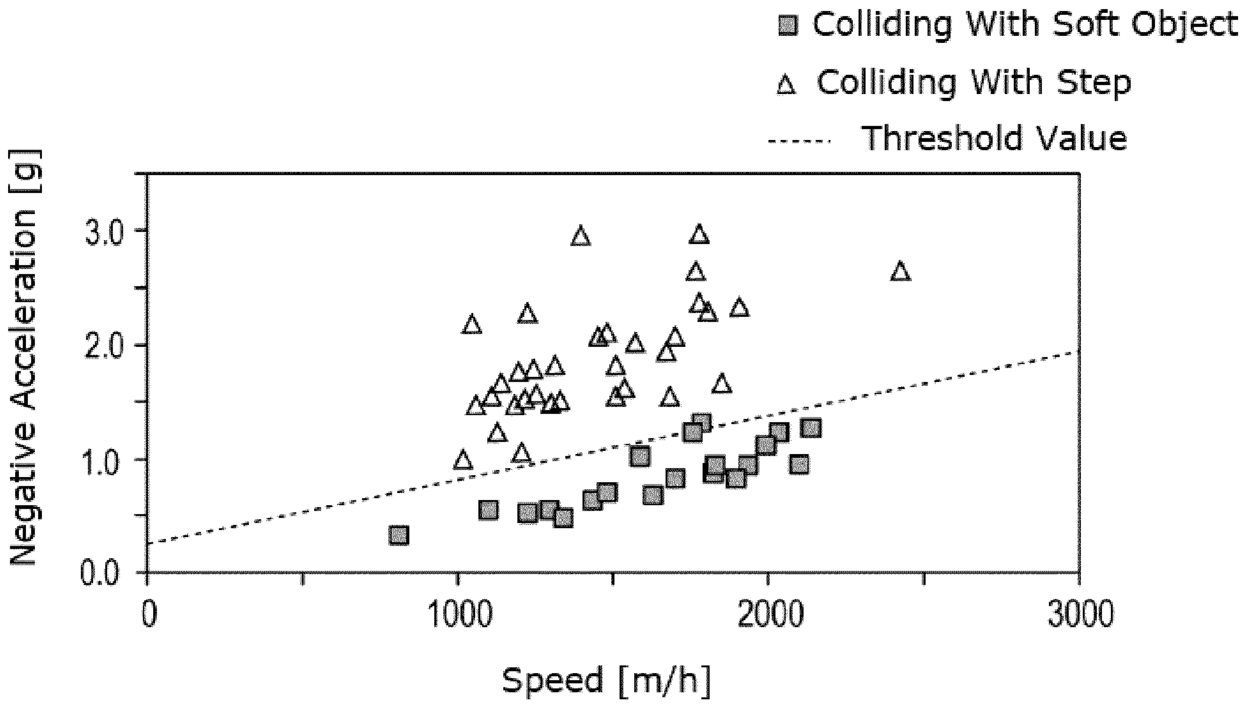

Driving Force
First Reduction Rate
Second Reduction Rate
Front Wheels
Colliding With
Step
Lifting of
Front Wheels
Starts

Fig. 7



Graph Showing Acceleration Detected When Electric Vehicle Collides With Step And When User Stops Electric Vehicle And Threshold Value

Fig. 8



Graph Showing Acceleration Detected When Electric Vehicle Collides With Soft Object And Acceleration Detected When Electric Vehicle Collides With Step

Fig. 9

Schematic View Showing Buffer Member Provided At Front Portion Of Vehicle Body

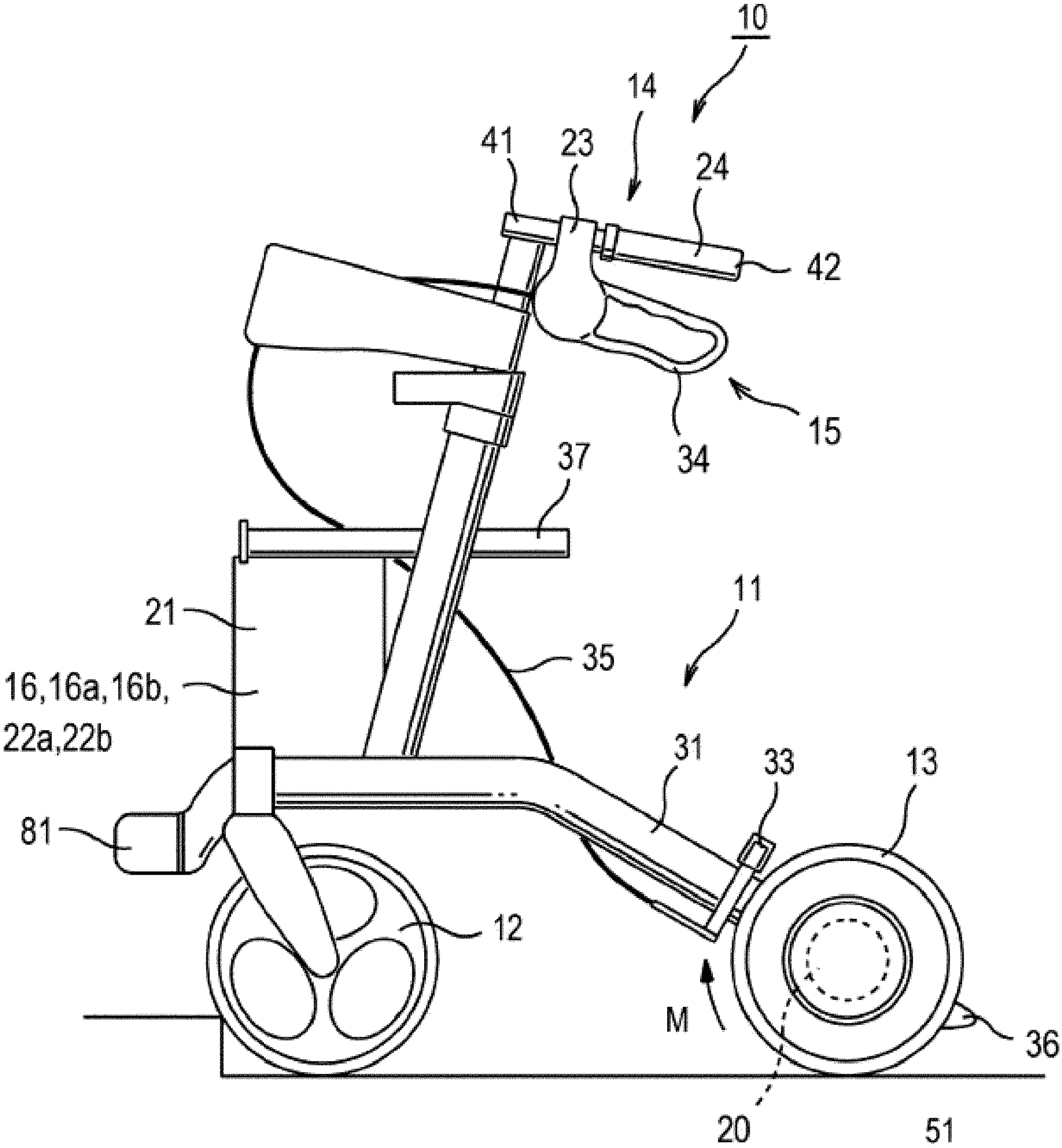


Fig. 10

Example Of Acceleration Applied To Vehicle Body When Electric Vehicle Collides With Step

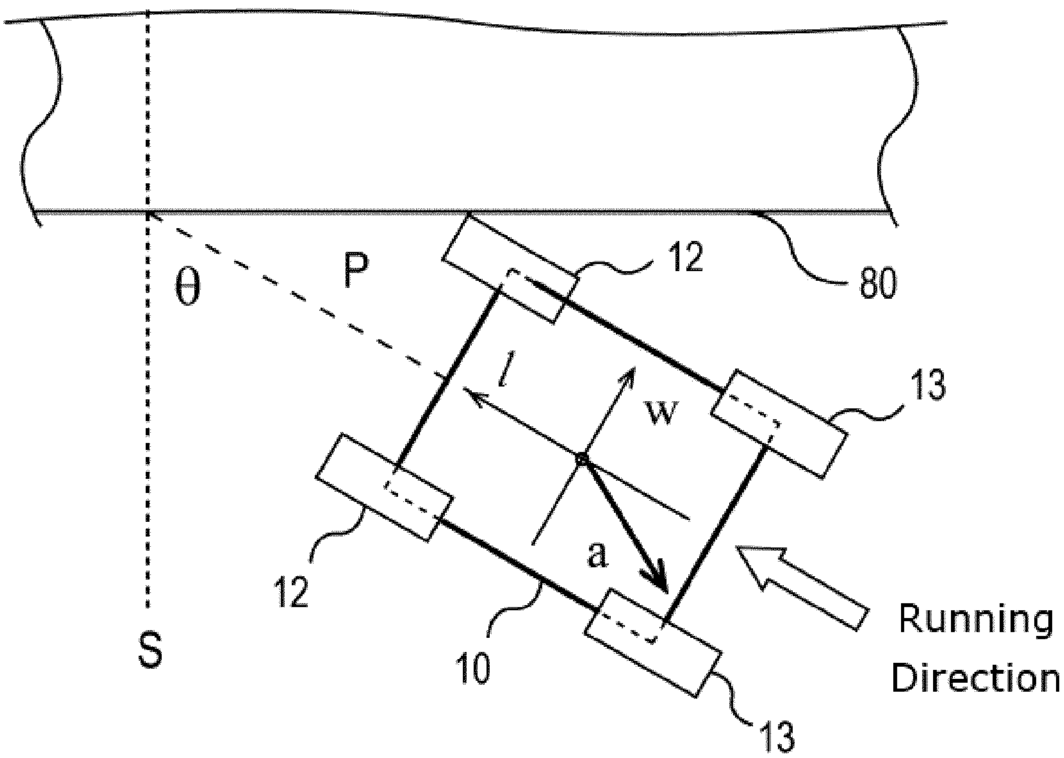
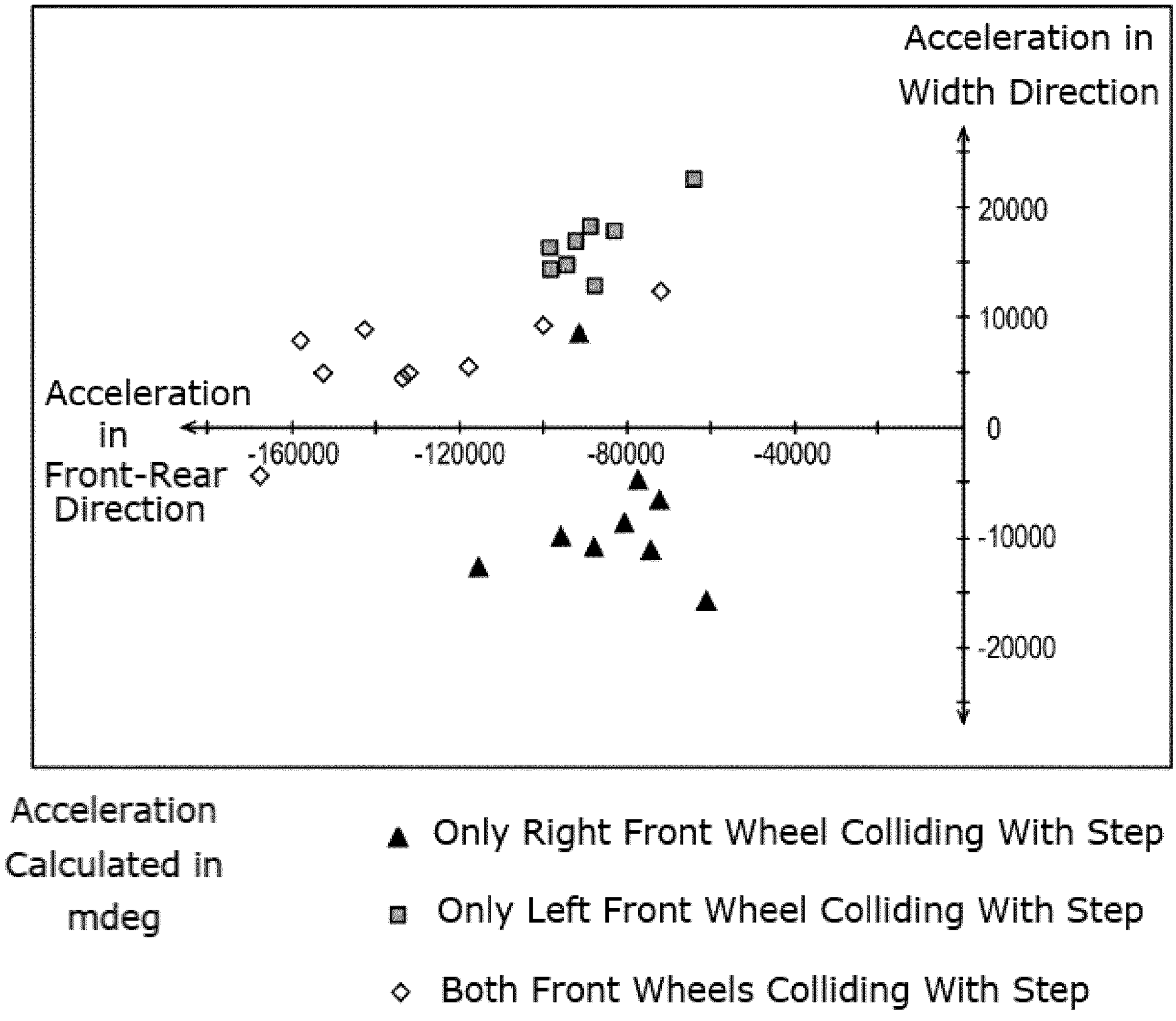
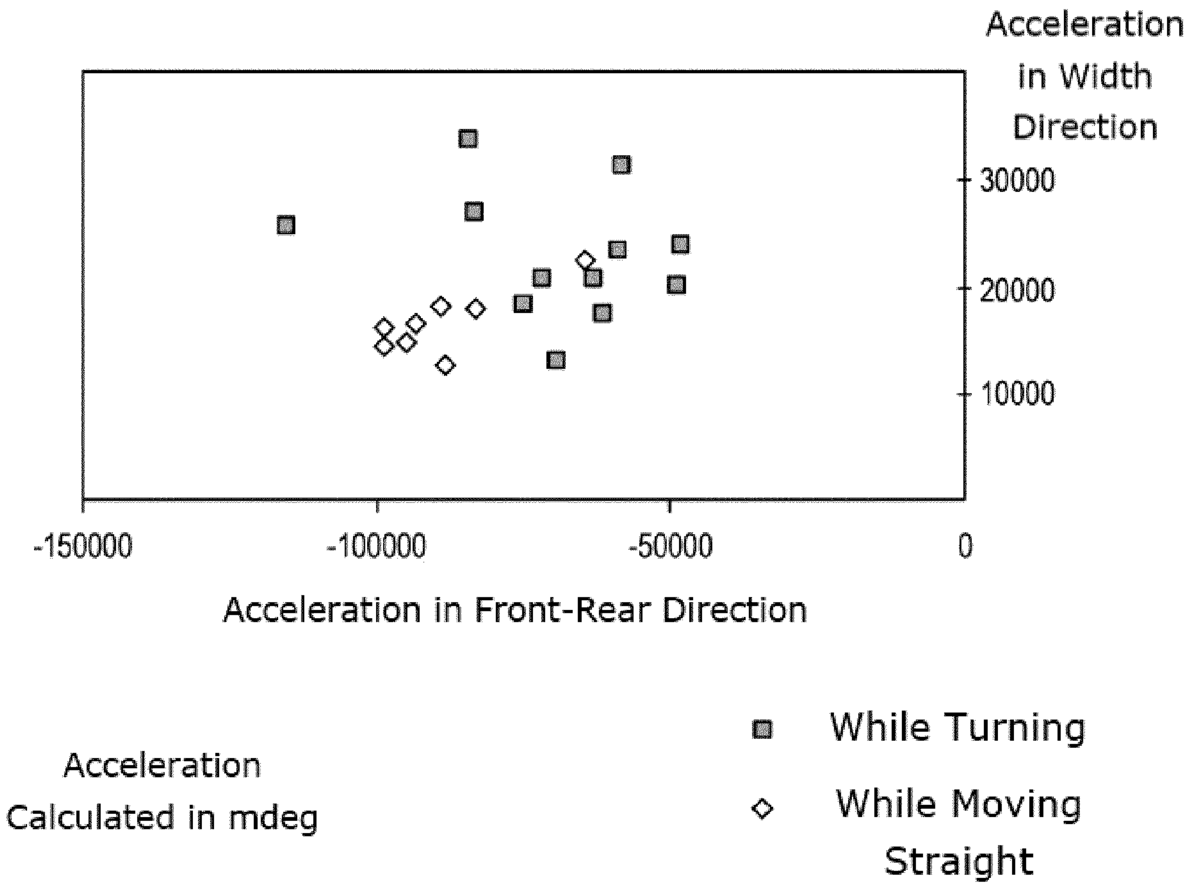


Fig. 11



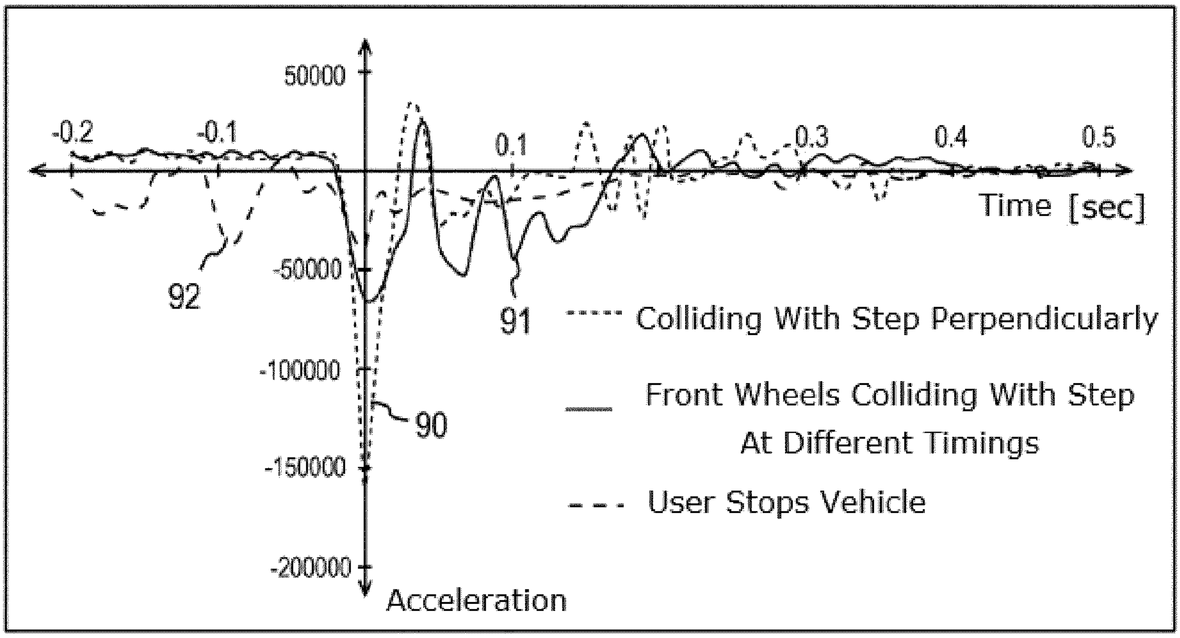
Graph Showing How Detected Values Of Acceleration Differ Depending On Which Front Wheel Collides With Step

Fig. 12



Graph Showing Example Of Acceleration Detected When Electric Vehicle Moves Toward Step While Turning and While Moving Straight

Fig. 13



Acceleration Represented in mdeg

Graph Showing Temporal Waveform Of Acceleration
Measured When Electric Vehicle Collides With Step

Fig. 14

First Example Of How To Turn Electric Vehicle

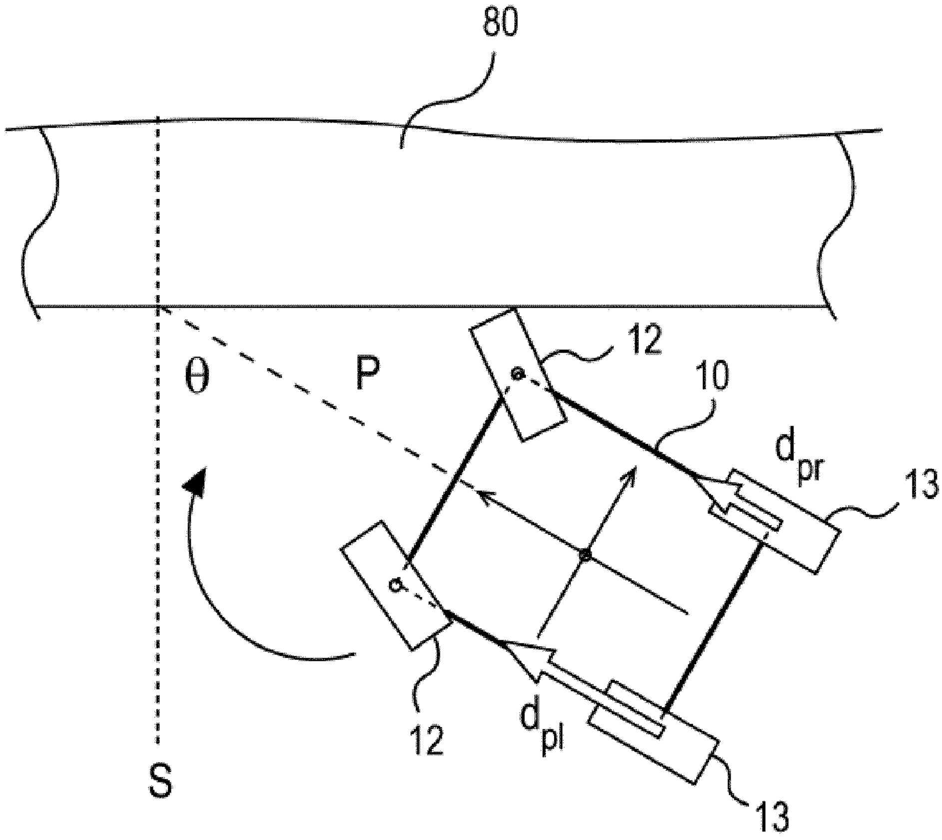


Fig. 15

Second Example of How To Turn Electric Vehicle

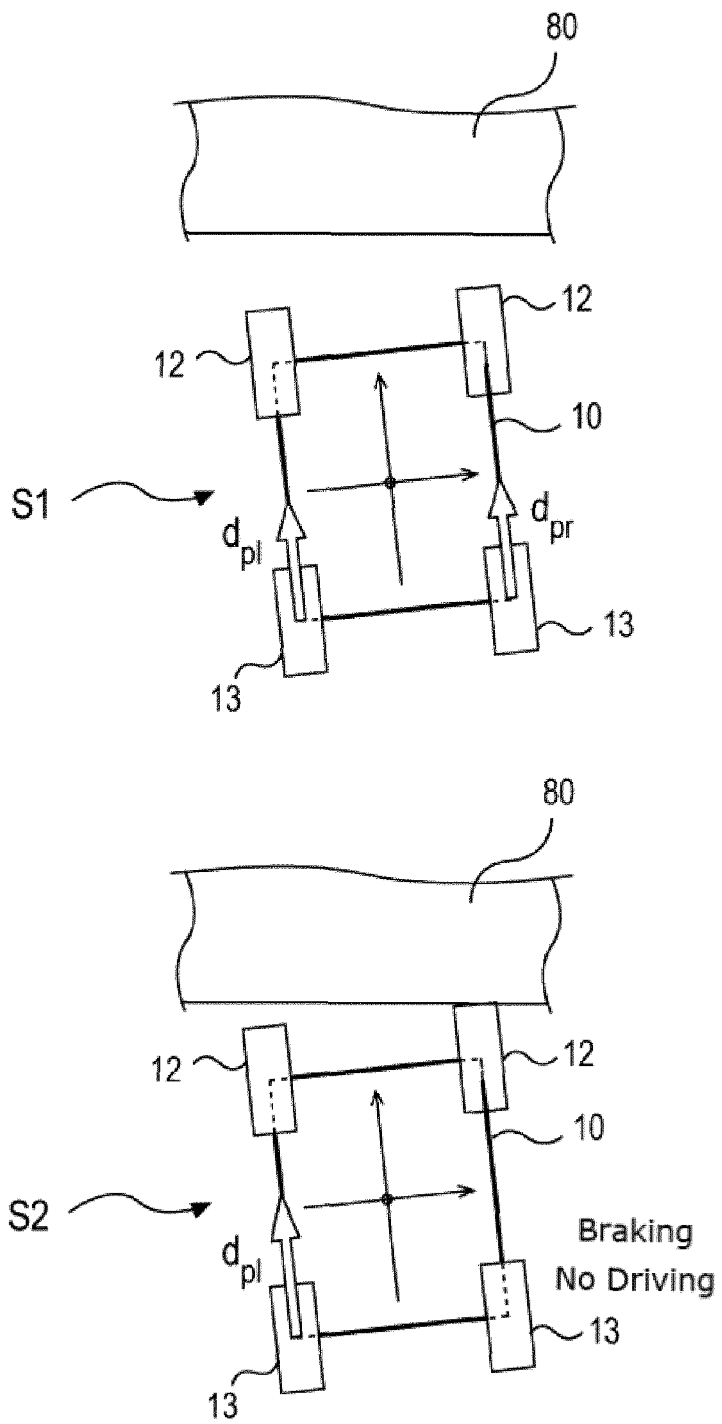


Fig. 16

Second Example Of How To Turn Electric Vehicle

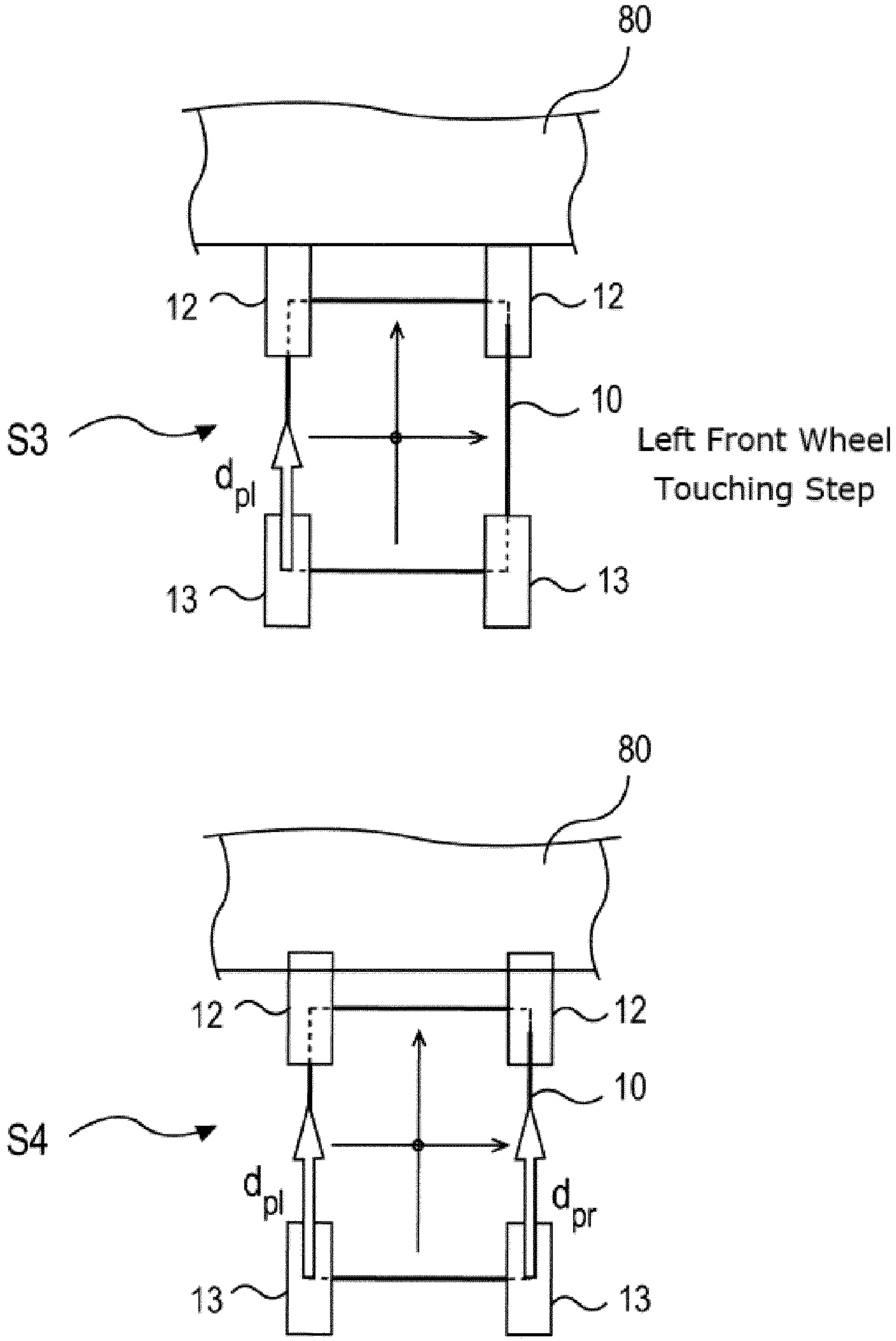


Fig. 17

Graph Showing Example Of How To Control Wheels To Turn Electric Vehicle After Detecting One of Front Wheels Has Touched Step

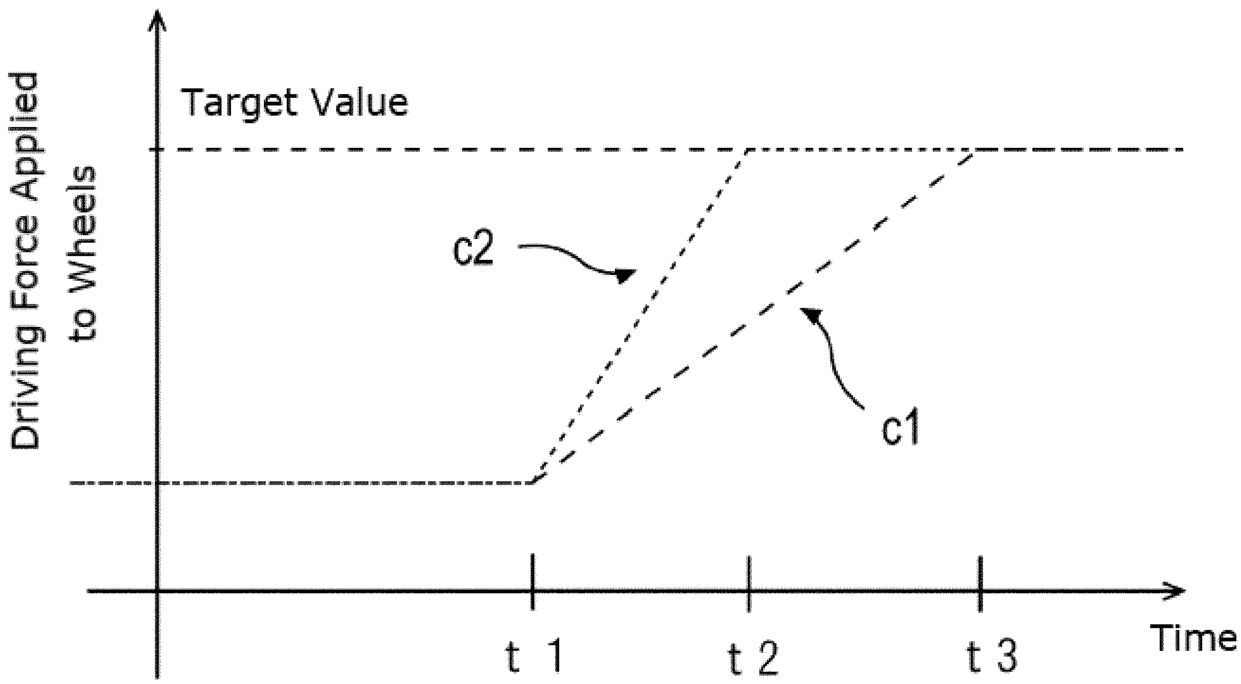


Fig. 18

Graph Showing Example Of How To Control Wheels To Turn Electric Vehicle After Detecting One Of Front Wheels Has Touched Step

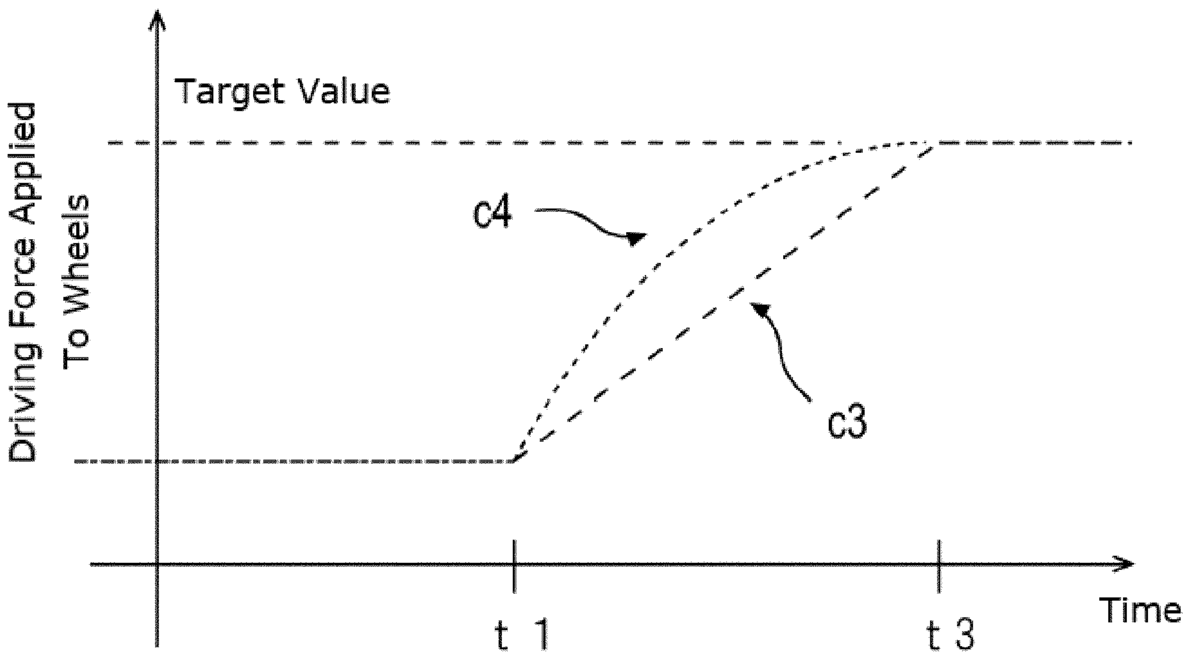


Fig. 19

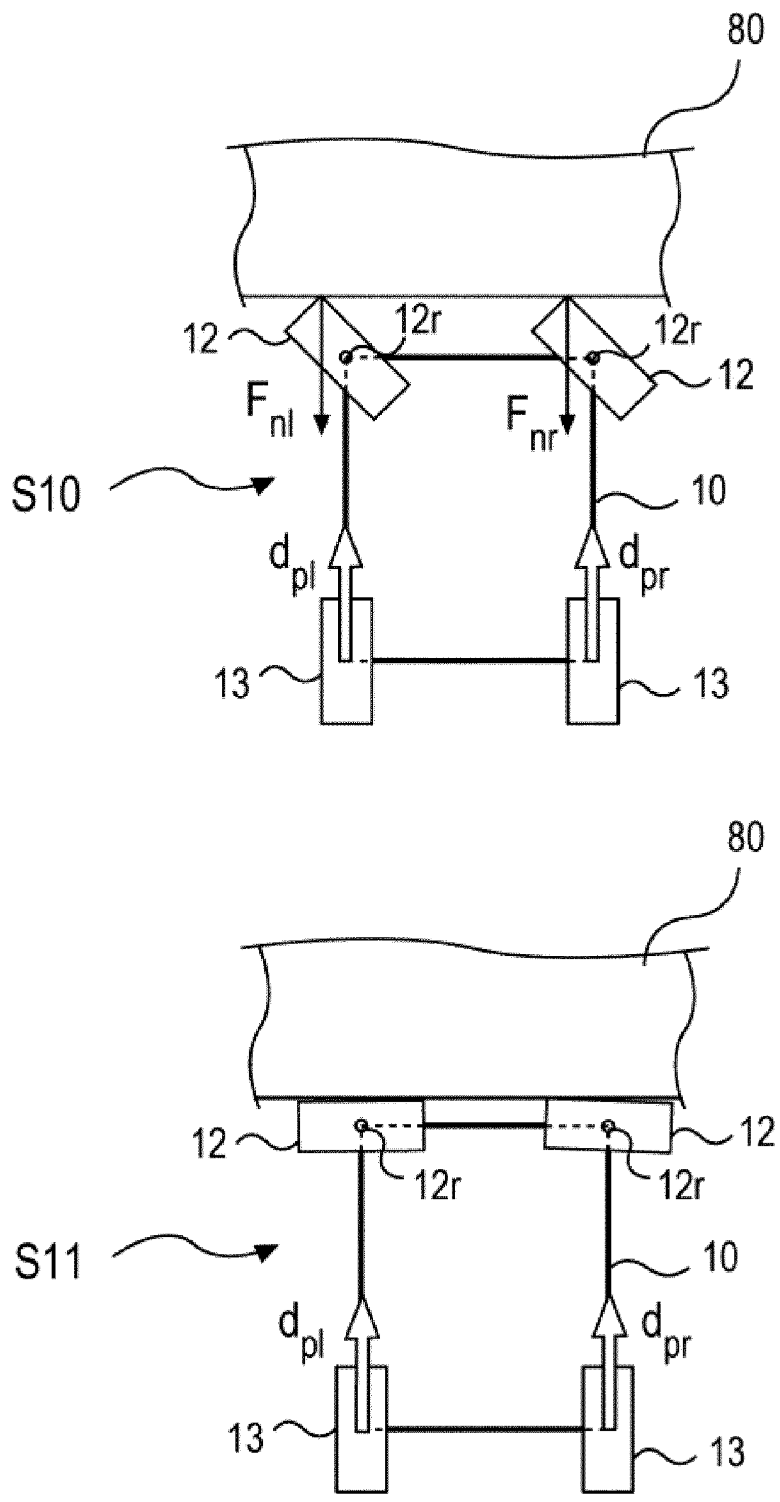

80
12
12r
12r
12
F_{nl}
F_{nr}
S10
10
d_{pl}
d_{pr}
13
13
80
12
12
12r
12r
S11
10
d_{pl}
d_{pr}
13
13

Fig. 20

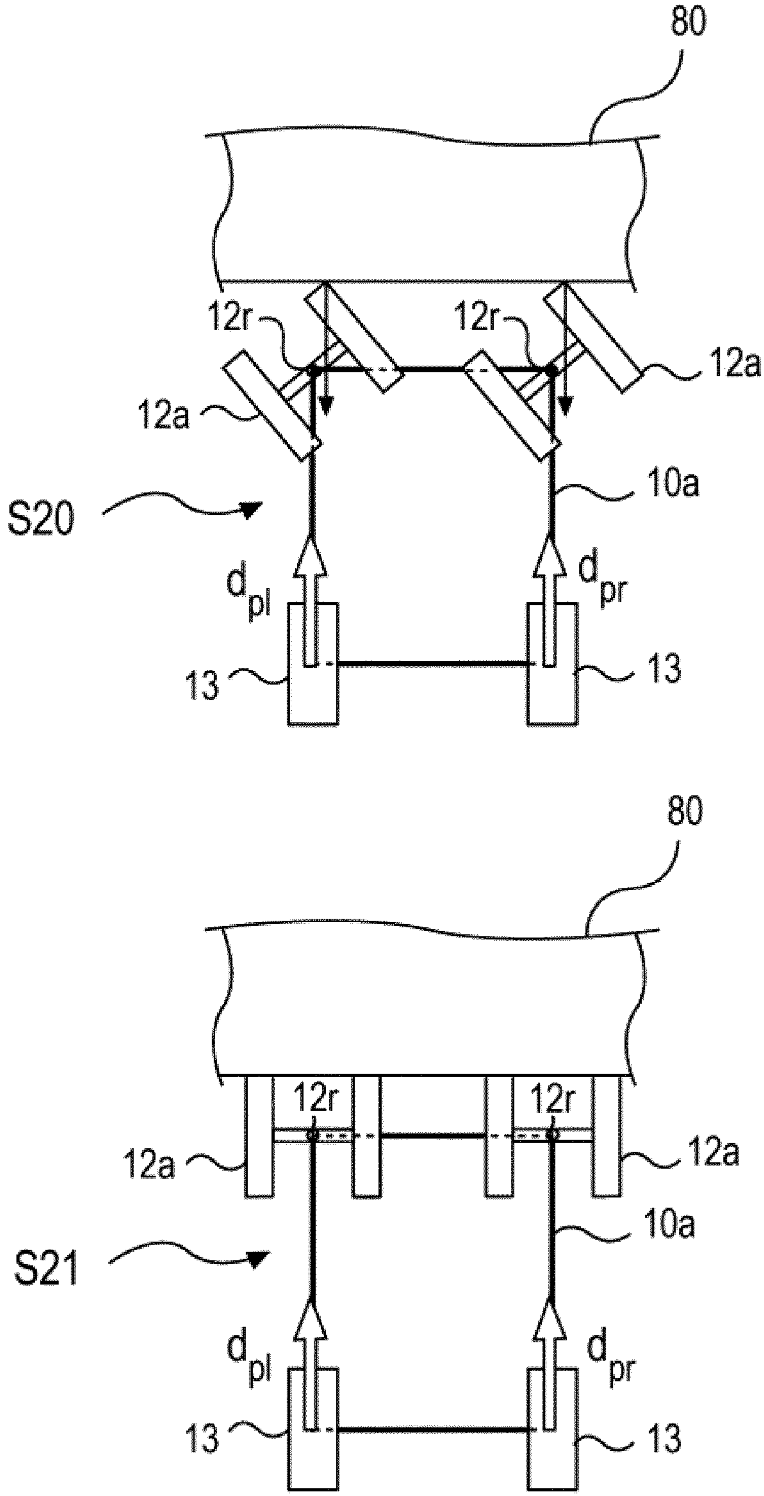

80
12r
12r
12a
12a
10a
S20
d_{pl}
d_{pr}
13
13
80
12r
12r
12a
12a
10a
S21
d_{pl}
d_{pr}
13
13

Fig. 21

Example Case Where Electric Vehicle Collides With Step On Multiple Occasions

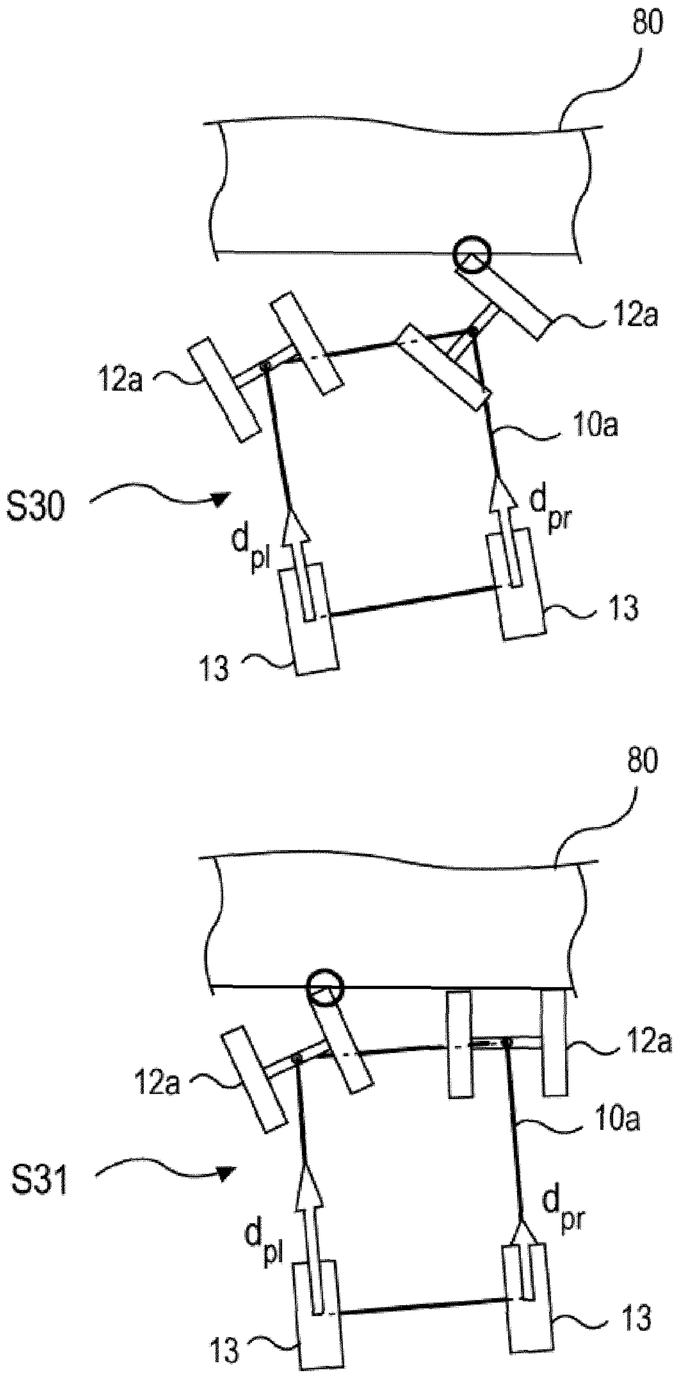


Fig. 22

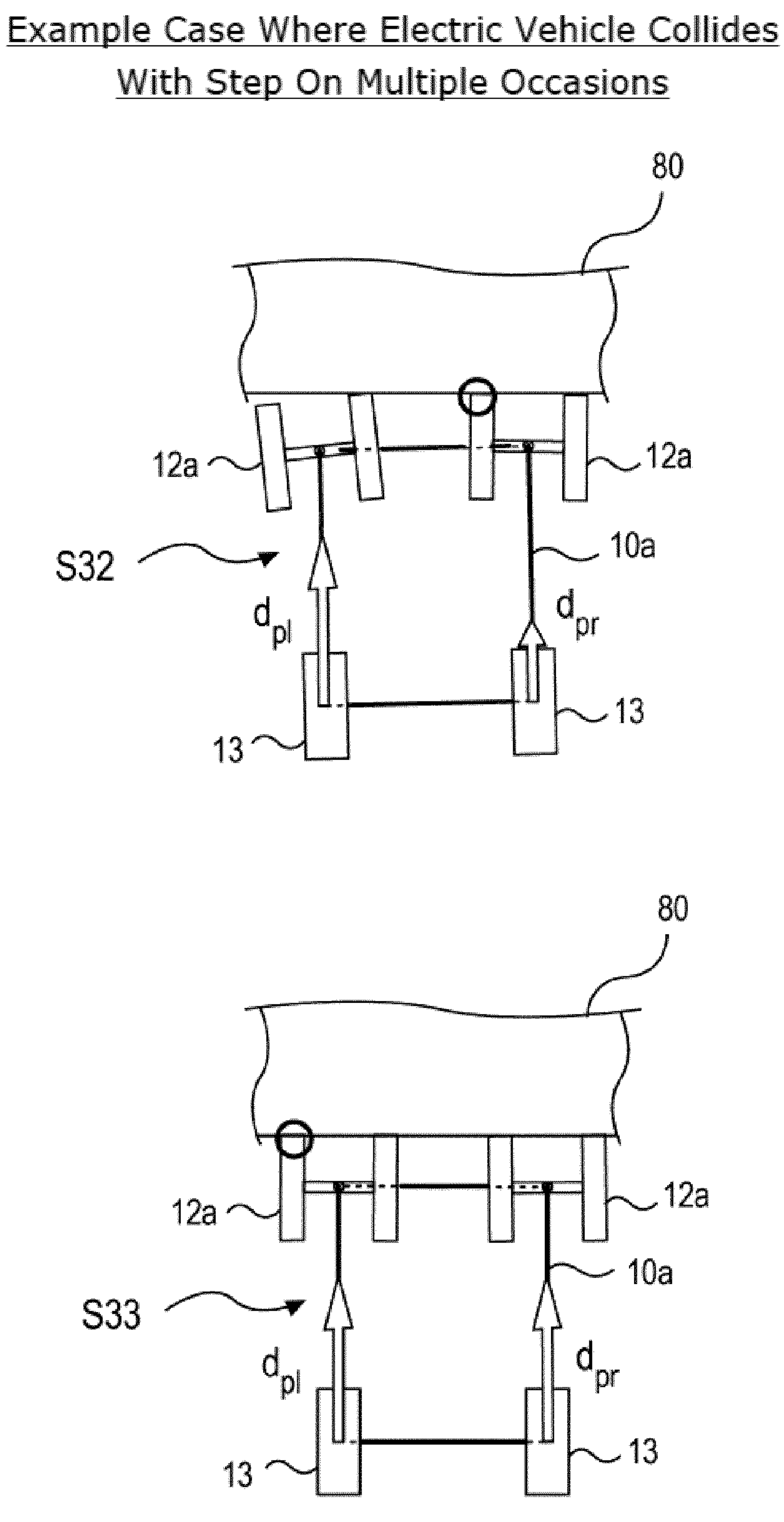

Example Case Where Electric Vehicle Collides
With Step On Multiple Occasions
80
12a
12a
S32
10a
d_{pl}
d_{pr}
13
13
80
12a
12a
10a
S33
d_{pl}
d_{pr}
13
13

Fig. 23

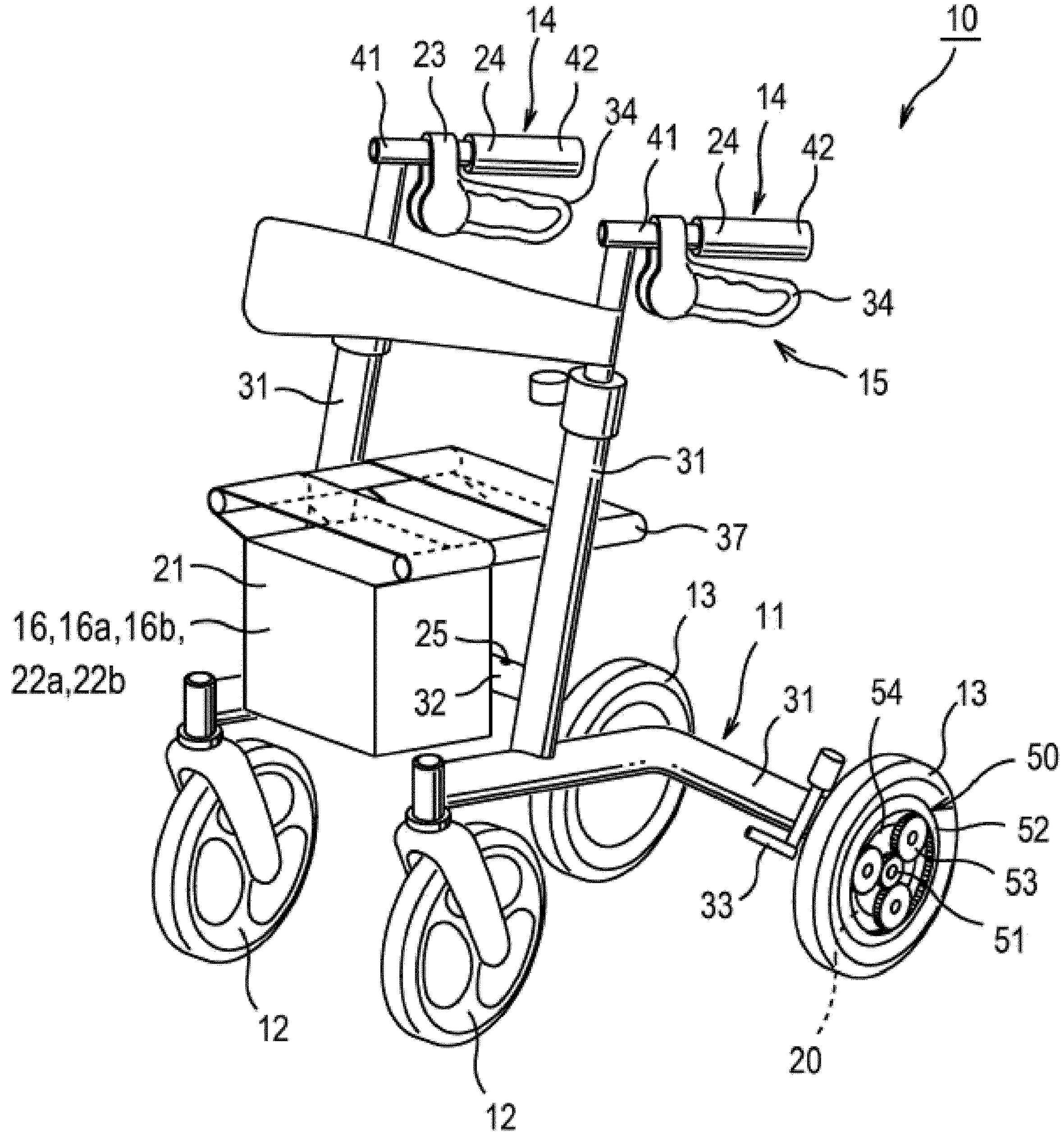

10
14
41
23
24
42
34
14
41
24
42
34
15
31
31
37
21
16,16a,16b,
22a,22b
25
32
13
11
31
54
13
50
52
53
51
33
12
12
20

Fig. 24

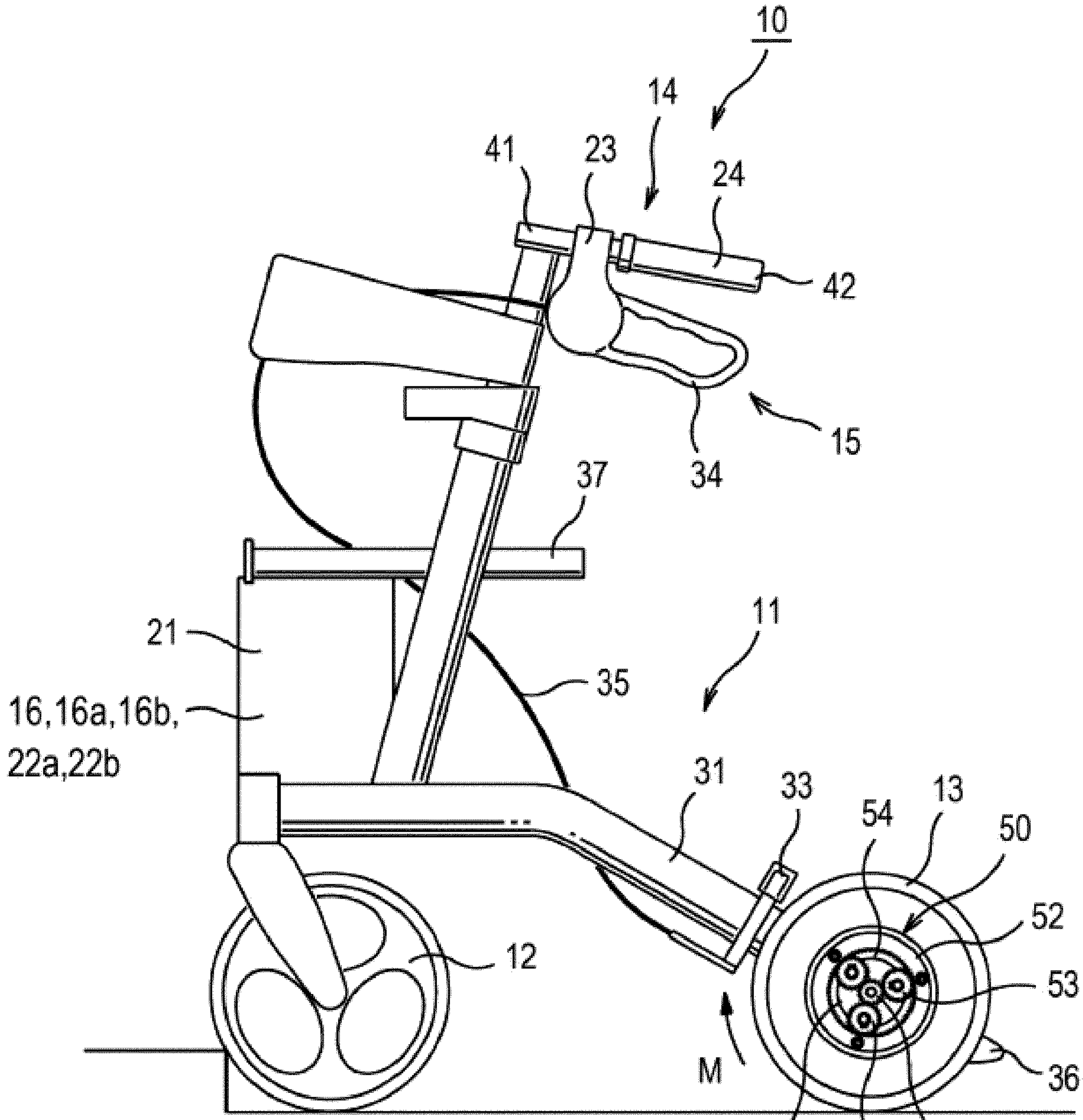

10
14
41
23
24
42
15
34
37
11
21
35
16,16a,16b,
22a,22b
31
33
54
13
50
52
12
53
M
36
20
53
51

Fig. 25

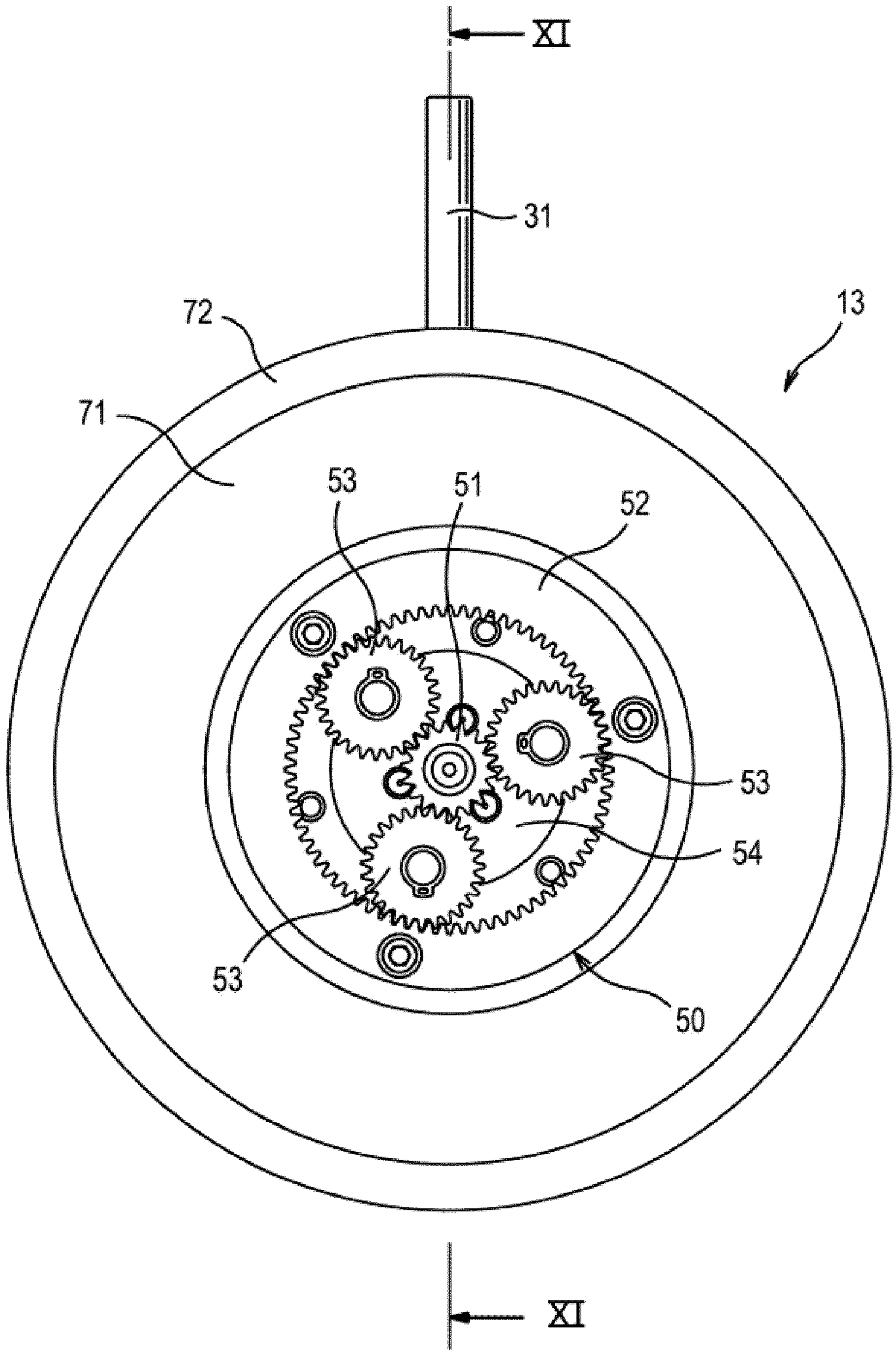


Fig. 26

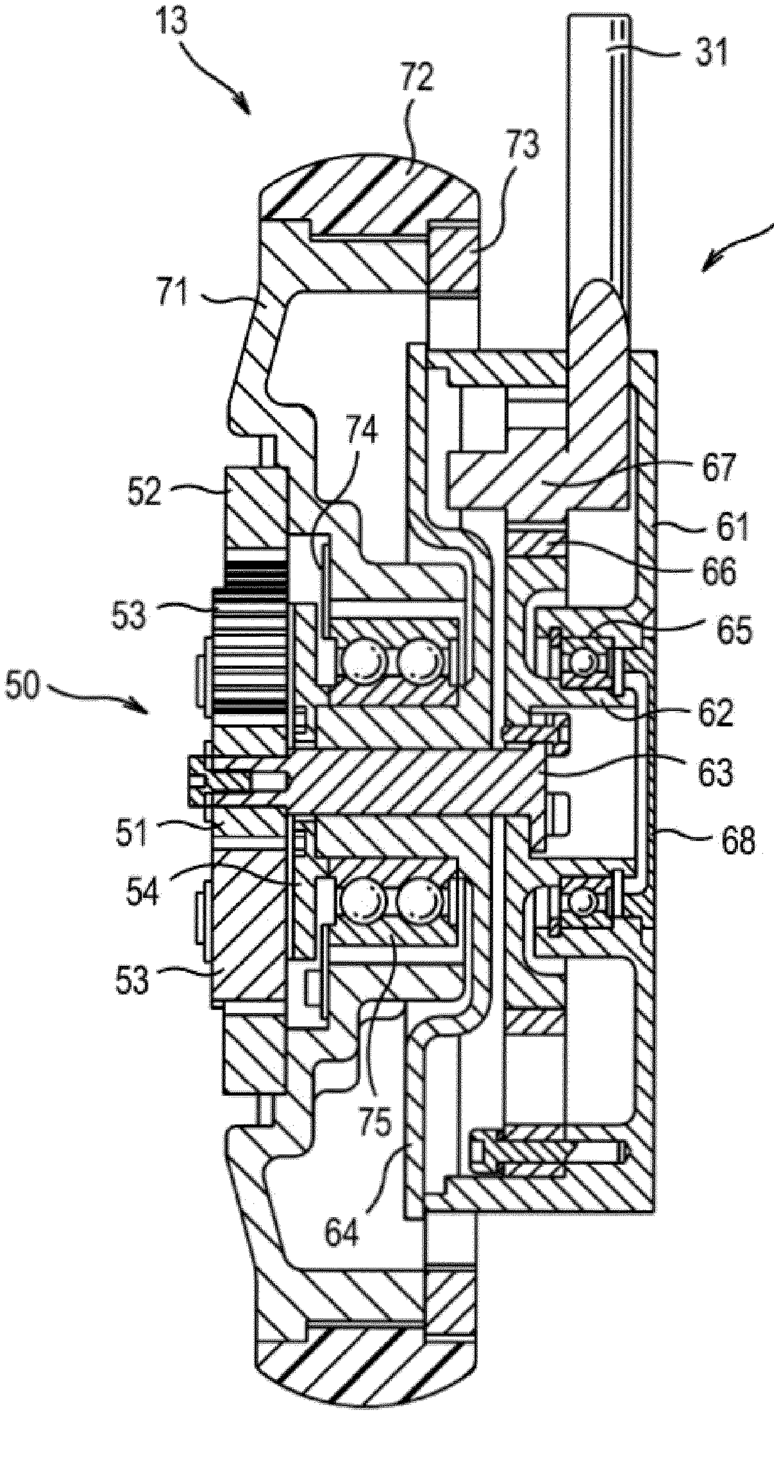


Fig. 27

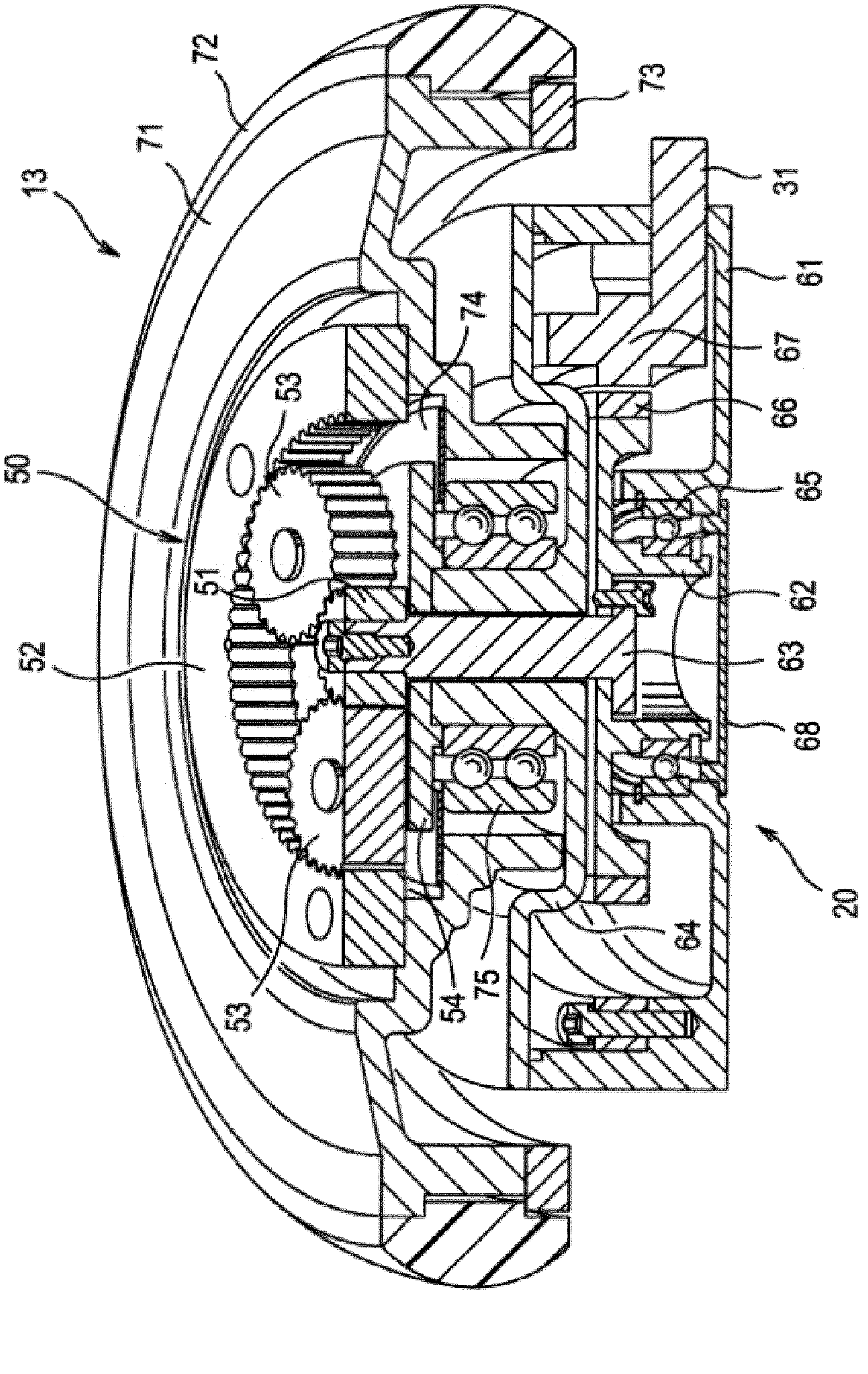


Fig. 28

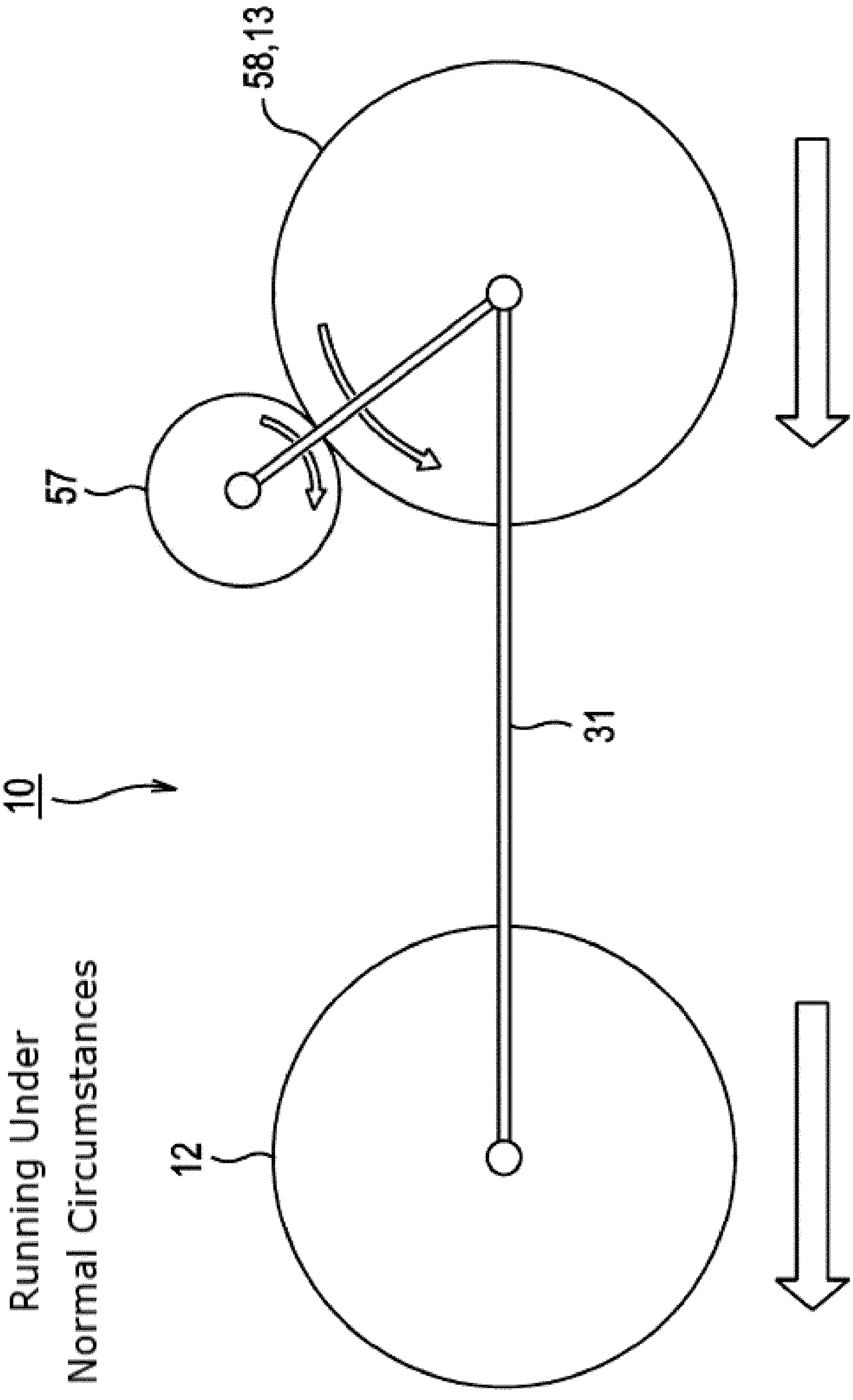


Fig. 29

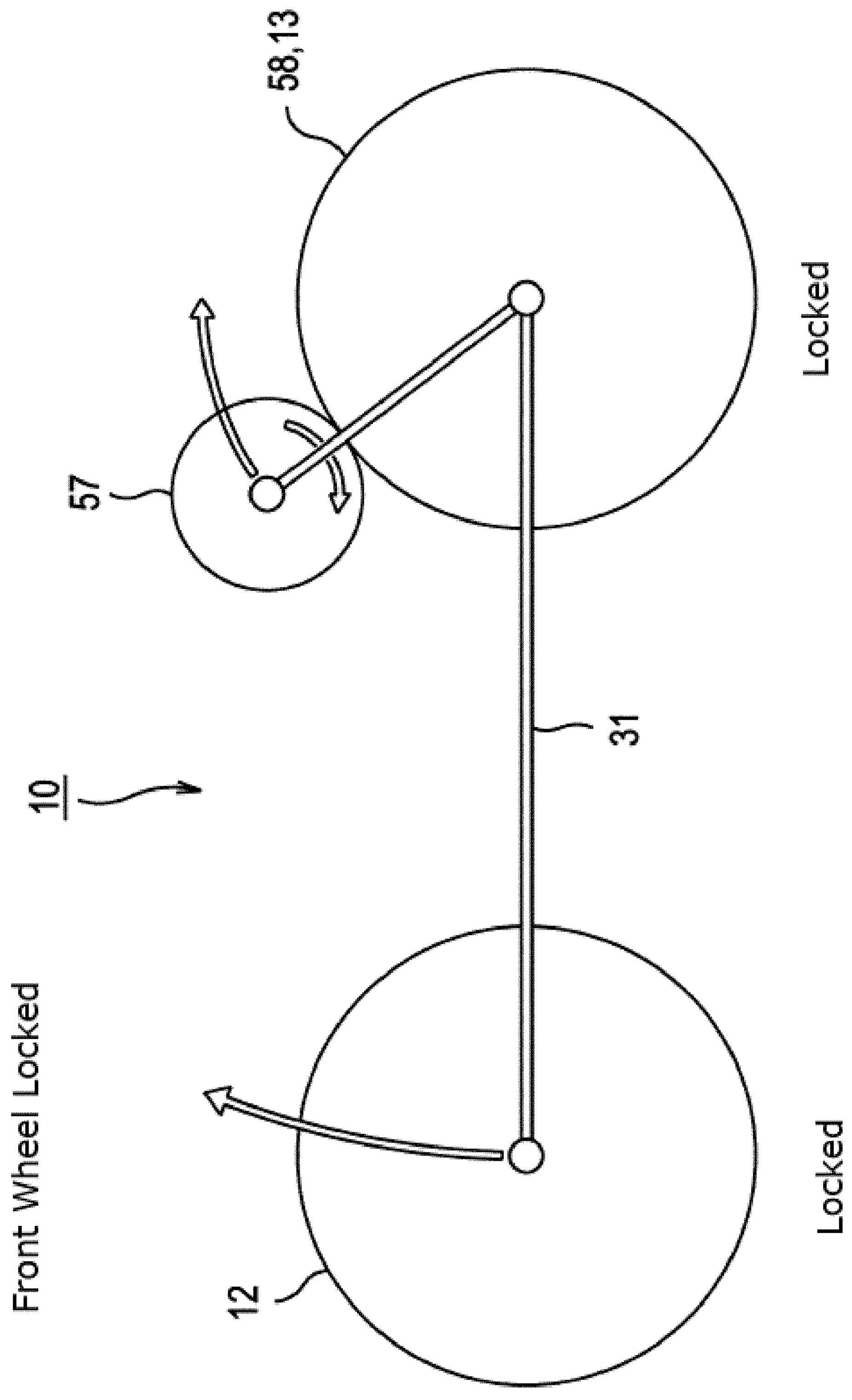


Fig. 30

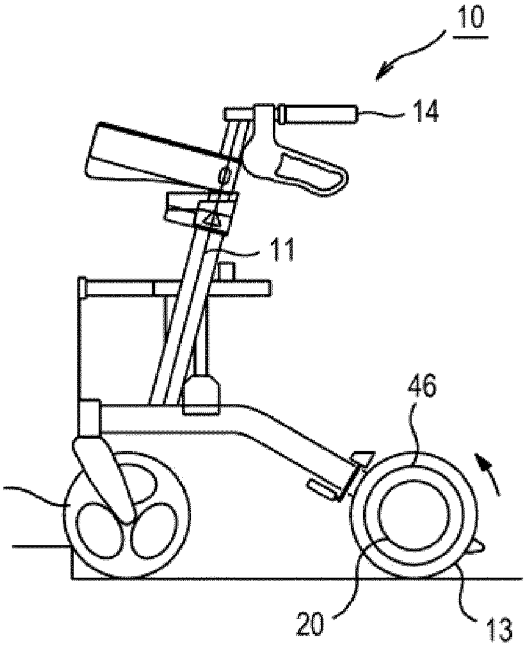


Fig. 31a

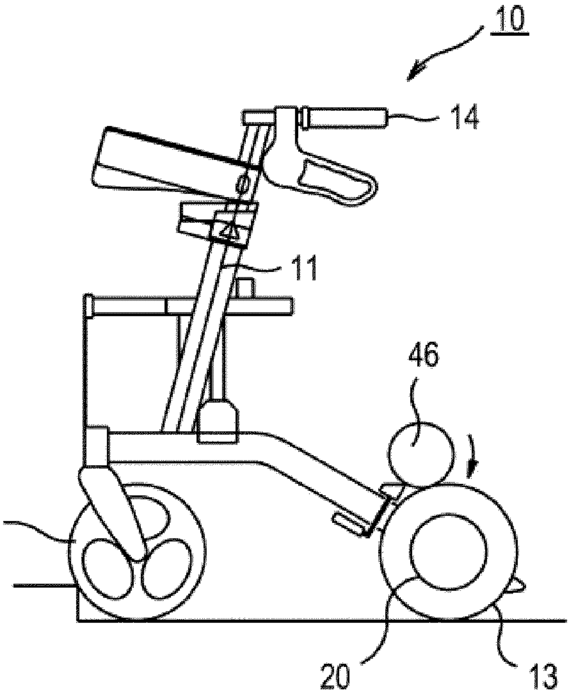


Fig. 31b

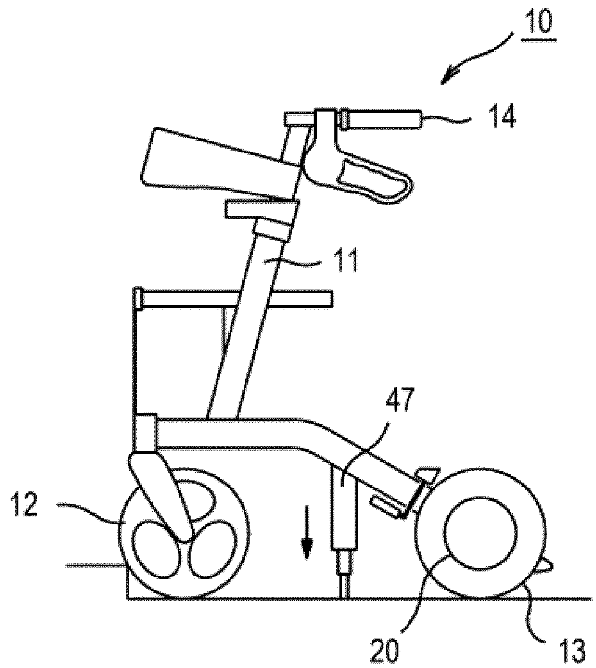


Fig. 32a

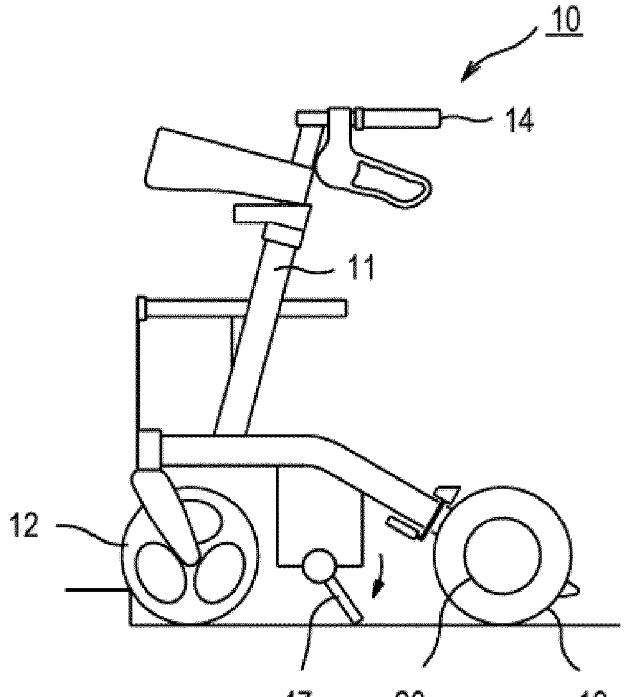


Fig. 32b

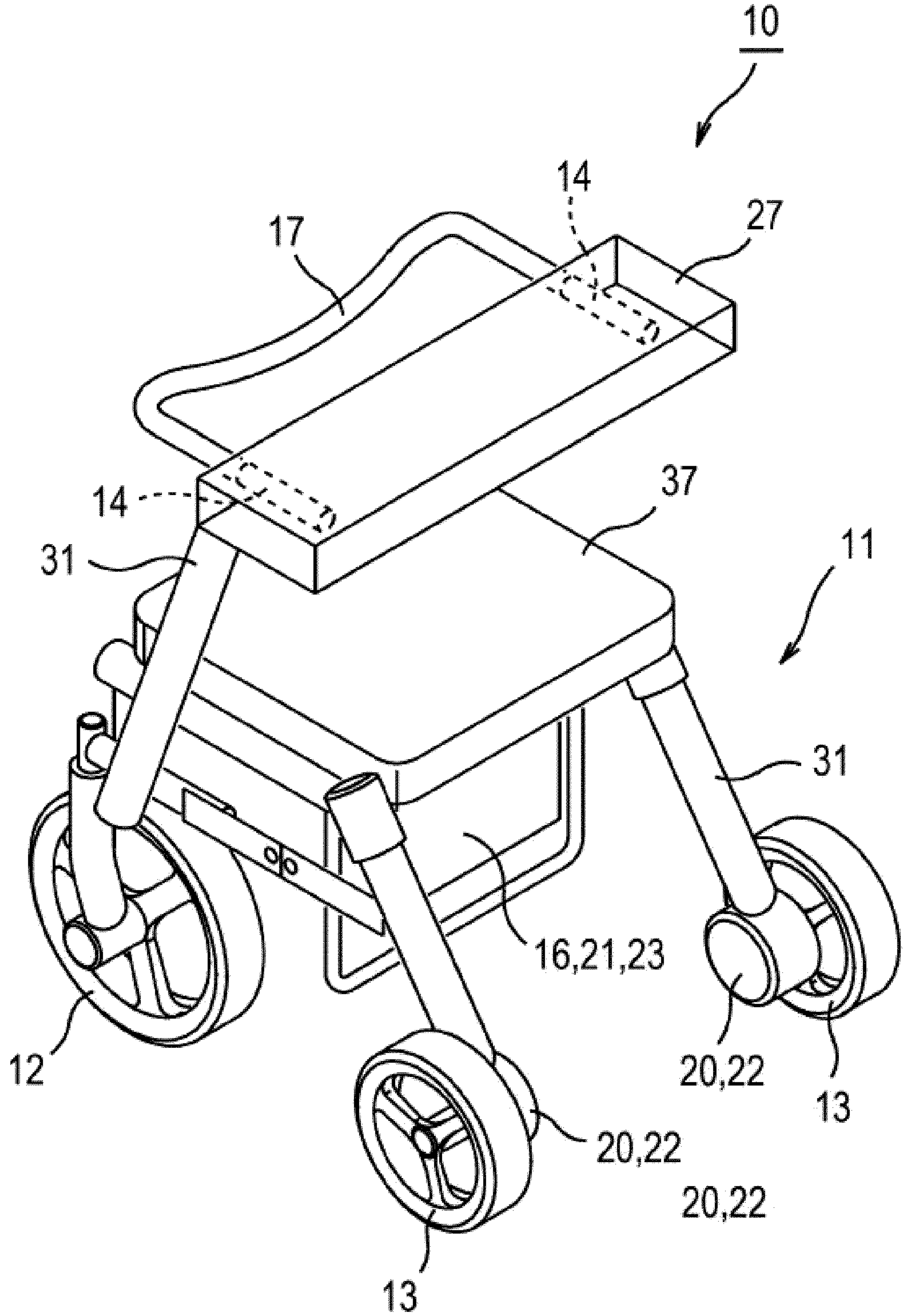


Fig. 33

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/039154

A. CLASSIFICATION OF SUBJECT MATTER
A61H 3/04(2006.01)i
FI: A61H3/04

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)
A61H3/04

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2018-61819 A (NABTESCO CORPORATION) 19 April 2018 (2018-04-19) paragraphs [0049]-[0050], [0083], [0085], fig. 1, 6	1-3,22-26, 30-37 27-31 4-21
Y	JP 2010-95135 A (TOYOTA MOTOR CORP.) 30 April 2010 (2010-04-30) paragraph [0057]	27-31

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 December 2020 (08.12.2020)	22 December 2020 (22.12.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/039154

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2018-61819 A	19 Apr. 2018	EP 3205322 A1 paragraphs [0049]-[0050], [0083], [0085], fig. 1, 6	
JP 2010-9535 A	30 Apr. 2010	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2018061819 A **[0004]**