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(54) **ELECTRIC VEHICLE**

(57) One object is to provide an electric vehicle in which a front wheel can run onto a step without need of an operation causing a large load to users. An electric vehicle includes: 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 at least one front wheel relative to the at least one rear wheel; and a control unit connected to the drive unit and configured to control the drive unit. When the control unit determines that the at least one 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 at least one front wheel relative to the at least one rear wheel.

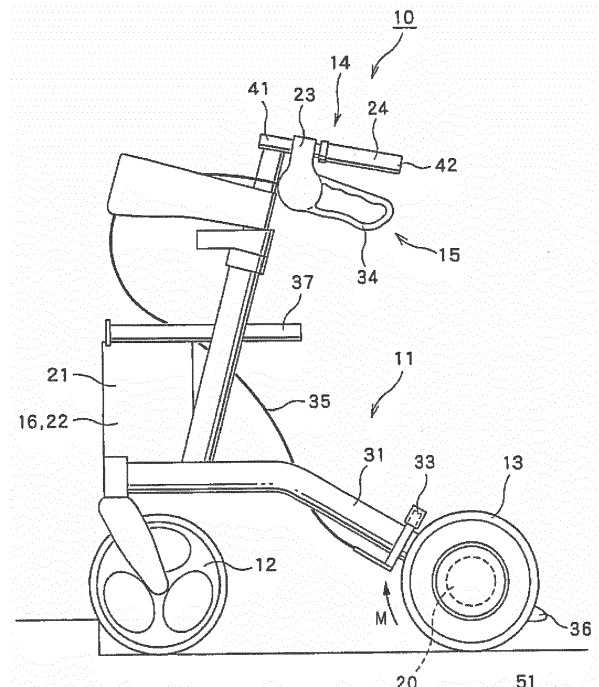


Fig. 2

Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates to an electric vehicle configured to assist elderly people, disabled people, patients and others with a gait impairment in walking.

BACKGROUND

10 **[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 instance, Patent Literature 1 disclosed a walking aid device which can be easily operated by a user to travel straight or turn.

15 **[0003]** The walking aid device (the electric vehicle) disclosed in Patent Literature 1 includes a frame body having a handle portion to be held by a user, more than one wheel provided on the right and left sides of the frame body, more than one driving motor that drives each wheel rotatably, and a controller that detects a counter electromotive force generated at the driving motor and then controls the driving motor based on the detected counter electromotive force.

RELEVANT REFERENCES20 **LIST OF RELEVANT PATENT LITERATURE**

[0004] Patent Literature 1: Japanese Patent Application Publication No. 2009-183407

SUMMARY

25 **[0005]** With such a conventional walking aid device, a front wheel striking a low step can run onto the step with an assist force from the driving motor for normal traveling. However, the front wheel cannot run onto a high step with only the assist force from the driving motor for normal traveling. In this case, for example, a user is required to apply a force downward to the handle of the walking aid device to lift the front wheel relative to the rear wheel such that the front wheel
30 can run onto the step. However, this operation causes a large load to users with a gait impairment.

[0006] One object of the present invention is to provide an electric vehicle in which a front wheel can run onto a step without need of an operation causing a large load to users.

35 **[0007]** An electric vehicle of the present invention comprises: 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 at least one front wheel relative to the at least one rear wheel; and a control unit connected to the drive unit and configured to control the drive unit, wherein when the control unit determines that the at least one 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 at least one front wheel relative to the at least one rear wheel.

40 **[0008]** In the electric vehicle of the invention, when a deceleration of the electric vehicle is equal to or greater than a first threshold value, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0009] In the electric vehicle of the invention, when, after the deceleration has become equal to or greater than the first threshold value, the electric vehicle is not moving backward, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

45 **[0010]** In the electric vehicle of the invention, when, before the deceleration becomes equal to or greater than the first threshold value, the electric vehicle was moving forward, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

50 **[0011]** In the electric vehicle of the invention, when, after the deceleration has become equal to or greater than the first threshold value, a traveling speed of the electric vehicle is equal to or less than a second threshold value, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

55 **[0012]** In the electric vehicle of the invention, the at least one rear wheel comprises left and right rear wheels, and when a deceleration of one of the left and right rear wheels is equal to or greater than a third threshold value, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0013] In the electric vehicle of the invention, when the deceleration of the other of the left and right rear wheels is equal to or greater than a fourth threshold value smaller than the third threshold value, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0014] In the electric vehicle of the invention, when both the decelerations of the left and right rear wheels are equal to or greater than a fifth threshold value between the third and fourth threshold values, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0015] In the electric vehicle of the invention, further comprising an operation unit to be operated by the user, when an operation force applied to the operation unit is equal to or greater than a sixth threshold value, the control unit may determine that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0016] In the electric vehicle of the invention, when the control unit determines that the at least one front wheel has struck a wall surface, the control unit may determine that the at least one front wheel has not struck a step.

[0017] In the electric vehicle of the invention, when the at least one front wheel or the at least one rear wheel is braked, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0018] In the electric vehicle of the invention, when the electric vehicle is on an upslope, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0019] In the electric vehicle of the invention, when the electric vehicle is on a slope inclined left or right with respect to a traveling direction, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0020] In the electric vehicle of the invention, during a predetermined period of time after the electric vehicle has run over a step, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0021] In the electric vehicle of the invention, when the electric vehicle is traveling at a speed equal to or higher than a predetermined speed, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0022] In the electric vehicle of the invention, when the electric vehicle is turning, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0023] In the electric vehicle of the invention, the at least one front wheel comprises left and right front wheels, or the at least one rear wheel comprises left and right rear wheels, and when a difference in traveling speed between the left and right front wheels or between the left and right rear wheels is larger than a predetermined value, the control unit may not determine whether or not the at least one front wheel has struck a step.

[0024] In the electric vehicle of the invention, when the electric vehicle is stopped, a traveling speed of the electric vehicle is equal to or less than a predetermined speed, or a deceleration of the electric vehicle is equal to or greater than a seventh threshold value, the control unit may determine that the at least one front wheel has struck a step.

[0025] In the electric vehicle of the invention, further comprising an operation unit to be operated by the user, the control unit may determine via the operation unit that the user is trying to move the electric vehicle forward.

[0026] In the electric vehicle of the invention, the operation unit includes a handle connected to the frame and configured to be gripped by the user, and when the user pushes the handle forward, the control unit may determine that the user is trying to move the electric vehicle forward.

[0027] In the electric vehicle of the invention, when the user pushes the handle with more than a predetermined amount of force, the control unit may determine that the user is trying to move the electric vehicle forward.

[0028] In the electric vehicle of the invention, when the user pushes the handle with more than a predetermined amount of force for more than a predetermined amount of time, the control unit may determine that the user is trying to move the electric vehicle forward.

[0029] In the electric vehicle of the invention, the drive unit may drive the at least one rear wheel in a forward direction.

[0030] In the electric vehicle of the invention, the drive unit may include a motor configured to drive the at least one rear wheel in a forward direction for traveling.

[0031] In the electric vehicle of the invention, further comprising a handle connected to the frame and configured to be gripped by the user, the control unit may increase or reduce the driving force in accordance with a force of the user to push the handle.

[0032] In the electric vehicle of the invention, the control unit may gradually increase the driving force after determining that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward.

[0033] In the electric vehicle of the invention, further comprising a handle connected to the frame and configured to be gripped by the user, the control unit may increase or reduce the driving force in accordance with an amount of time for which the user pushes the handle.

[0034] In the electric vehicle of the invention, the control unit may cause the at least one front wheel to be lifted relative to the at least one rear wheel, and then control the drive unit to cause the electric vehicle to move forward such that the at least one front wheel contacts with a top portion of the step.

[0035] In the electric vehicle of the invention, when the control unit has determined that the at least one front wheel has struck a step, the control unit may control the drive unit to cause the at least one front wheel to be lifted relative to the at least one rear wheel in accordance with the reduced force of the user to push the handle forward or the force of the user to pull the handle backward.

[0036] In the electric vehicle of the invention further comprising an operation unit to be operated by the user, when the user operates the operation means, the control unit may control the drive unit to cause the at least one front wheel to be lifted relative to the at least one rear wheel.

[0037] In the electric vehicle of the invention, further comprising a handle connected to the frame and configured to be gripped by the user and a brake lever to be operated by the user so as to brake the at least one rear wheel, and when the user pulls the handle backward while operating the brake lever, the control unit may control the drive unit to cause the at least one front wheel to be lifted relative to the at least one rear wheel.

[0038] In the electric vehicle of the invention, the control unit may cause the at least one front wheel to be lifted relative to the at least one rear wheel, and then gradually reduce the driving force of the at least one rear wheel in the forward direction.

[0039] In the electric vehicle of the invention, when the at least one rear wheel rotates, the control unit may gradually reduce the driving force of the at least one rear wheel in the forward direction.

[0040] In the electric vehicle of the invention, when the at least one rear wheel rotates, the control unit may reduce the driving force of the at least one rear wheel in the forward direction at a higher rate in accordance with the rotation speed thereof, or set the driving force of the at least one rear wheel in the forward direction at zero.

[0041] In the electric vehicle of the invention, the control unit may cause the at least one front wheel to be lifted relative to the at least one rear wheel, and then reduce the driving force of the at least one rear wheel in the forward direction at a higher rate in accordance with the inclination angle of the electric vehicle, or set the driving force of the at least one rear wheel in the forward direction at zero.

[0042] In the electric vehicle of the invention, the control unit may have an automatic brake function to automatically brake the at least one rear wheel when the electric vehicle is on a downslope, and the control unit may cancel the automatic brake function when it determines that the at least one front wheel have struck a step while the electric vehicle is on a downslope and the user is trying to move the electric vehicle forward.

[0043] An electric vehicle of the present invention comprises: a frame; at least one front wheel and at least one rear wheel provided on the frame; and a drive unit configured to drive the at least one rear wheel, wherein the drive unit is connected to the at least one rear wheel via a planetary gear mechanism, the planetary gear mechanism includes a sun gear, an internal tooth gear disposed around the sun gear, a plurality of planet gears meshing with the sun gear and the internal tooth gear and configured to rotate and revolve when an output shaft of the drive unit rotates, and a planet carrier that rotatably supports the plurality of planet gears and receives the revolution movement of the plurality of planet gears, the sun gear is connected to the output shaft of the drive unit, the internal tooth gear is connected to the at least one rear wheel, and the planet carrier is fixed on the frame.

[0044] In a method of controlling an electric vehicle of the present invention, the electric vehicle comprises: 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 at least one front wheel relative to the at least one rear wheel; and a control unit connected to the drive unit and configured to control the drive unit, and the method comprises: by means of the control unit, determining that the at least one front wheel has struck a step while the user is trying to move the electric vehicle forward; and by means of the control unit, controlling the drive unit to lift the at least one front wheel relative to the at least one rear wheel.

ADVANTAGES

[0045] According to the present invention, a front wheel can be lifted relative to a rear wheel and run onto a step without need of an operation causing a large load to users.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046]

Fig. 1 is a perspective view of a power-assisted rollator according to a first embodiment of the present invention.

Fig. 2 is a side view of the power-assisted rollator according to the first embodiment of the present invention.

Fig. 3 schematically shows a leg detection sensor.

Fig. 4 schematically shows a grip sensor.

Fig. 5 schematically shows a variation of the grip sensor.

Fig. 6 is a flowchart of one example of the operation of the control unit 16.

Fig. 7 is a graph showing the change in driving force over time after a front wheel strikes a step.

Fig. 8 is a perspective view of a power-assisted rollator according to a second embodiment of the present invention.

Fig. 9 is a side view of the power-assisted rollator according to the second embodiment of the present invention.

Fig. 10 is a side view of a rear wheel of the power-assisted rollator according to the second embodiment of the present invention.

Fig. 11 is a sectional view of a rear wheel of the power-assisted rollator according to the second embodiment of the present invention (a sectional view along the XI-XI line in Fig. 10).

Fig. 12 is a perspective sectional view of a rear wheel of the power-assisted rollator according to the second

embodiment of the present invention.

Fig. 13 schematically shows a variation of the power-assisted rollator (in normal traveling).

Fig. 14 schematically shows a variation of the power-assisted rollator (the front wheels are locked).

Fig. 15a schematically shows a power-assisted rollator according to a third embodiment of the present invention.

Fig. 15b schematically shows the power-assisted rollator according to the third embodiment of the present invention.

Fig. 16a schematically shows the power-assisted rollator according to a variation of the third embodiment of the present invention.

Fig. 16b schematically shows the power-assisted rollator according to the variation of the third embodiment of the present invention.

Fig. 17 is a perspective view of a power-assisted rollator according to a fourth embodiment of the present invention.

Fig. 18 is a flowchart of an example of the operation of the control unit according to the fourth embodiment of the present invention.

DESCRIPTION OF EXAMPLE EMBODIMENTS

First Embodiment

[0047] The first embodiment of the present invention will now be described with reference to Figs. 1 to 7. In the following description, like elements are numbered and labeled similarly. The like elements also have the same names and functions. The descriptions of such elements will appear once.

[0048] 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 view of an example of an external appearance of a power-assisted rollator 10 according to the first embodiment. Fig. 2 is a side view of the power-assisted rollator 10 shown in Fig. 1.

Structure of Power-Assisted Rollator

[0049] Referring to Figs. 1 and 2, the power-assisted rollator 10 may include a frame 11, a pair of front wheels 12 and a pair of rear wheels 13 provided on the frame 11, and a pair of handles (operation units) 14 connected to the frame 11. Each of the handles 14 may be provided with a hand brake 15 for manually stopping the power-assisted rollator 10.

[0050] Each of the pair of rear wheels 13 may be provided with a motor 20 for assisting the movement of the corresponding rear wheel 13. On the frame 11, there may be mounted a battery 21 and a control unit 16. The control unit 16 may have a speed sensor 22. Further, on each of the handles 14, there may be provided an inclination sensor 23 and a grip sensor (an operation force sensor) 24. At a position on the frame 11 and below the pair of handles 14, there may be provided a leg detection sensor 25 for detecting a leg of a user.

[0051] Next, elements of the power-assisted rollator 10 will be described.

[0052] The frame 11 may include a left-right pair of pipe frames 31, and a coupling frame 32 that couples the pair of pipe frames 31 together in a lateral direction.

[0053] On the front ends of the left and right pipe frames 31, there may be provided a pair of front wheels 12. Both of the pair of front wheels 12 may be configured to wheel in a front-rear direction and also rotate about vertical axes.

[0054] On the rear ends of the left and right pipe frames 31, there may be provided a pair of rear wheels 13. The rear wheels 13 may be configured to wheel in the front-rear direction. Accordingly, the power-assisted rollator 10 can be easily moved forward and backward, and moreover, can be easily operated in a left-right direction or easily turned around.

[0055] On the periphery of the rear wheels 13, there may be provided brake shoes 33 capable of mechanical contact. The brake shoes 33 may be coupled to brake levers 34 of the hand brakes 15 with wires. Therefore, when the user manually operates the brake levers 34, the brake shoes 33 may operate to brake the rear wheels 13. The mechanical brakes are not limited to above configuration, but any mechanical brakes can be used.

[0056] A fall prevention member 36 may be 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.

[0057] On the upper ends of the left and right pipe frames 31, there may be provided a pair of handles 14. The pair of handles 14 may be gripped by the hands of the user. Each of the pair of handles 14 may include a pole 41. The poles 41 may each have a grip 42 provided thereon. Also, the poles 41 may each have a brake lever 34 provided thereon. It may also be possible to configure the handles 14 in a different manner. For example, a bar handle may be provided so as to extend horizontally and connect the left and right pipe frames 31, and the bar handle may be provided with grips 42 serving as the left and right handles 14.

[0058] In the embodiment, the motors 20 may be any motors such as servomotors, stepper motors, AC motors, and DC motors. Moreover, a reducer can be integrated with the motors. The motors 20 may assist the rear wheels 13 in operation by driving the rear wheels 13 forward for traveling. In the embodiment, the motors 20 may also serve as drive

units for lifting the front wheels 12 relative to the rear wheels 13. The motors 20 may produce a driving force for applying a moment to the power-assisted rollator 10 in such a direction as to lift the front wheels 12.

[0059] Further, the motors 20 may also function as dynamic brakes. In this case, the motors 20 may further serve as brake units for braking the rear wheels 13. When the motors 20 brake the rear wheels 13, the motors 20 may serve as power generators while braking the rear wheels 13 with resistance forces thereof. When the motors 20 serve as brake units, the motors 20 may be used as reverse brakes in which the motors 20 drive reversely. Alternatively, it may also be possible that the brake units for braking the rear wheels 13 are provided separately from the motors 20. Such brake units may be electromagnetic brakes, mechanical brakes, etc.

[0060] The left and right motors 20 may be controlled as one unit by the control unit 16, or the left and right motors 20 may be controlled independently from each other.

[0061] In the embodiment, the motors 20 may be connected to the rear wheels 13, but it may also be possible that the motors 20 are connected to all of the pair of front wheels 12 and the pair of rear wheels 13.

[0062] The control unit 16 may control the entirety of the power-assisted rollator 10 including the motors 20. The control unit 16 may be provided adjacent to the battery 21. The control by the control unit 16 will be described later.

[0063] The speed sensor 22 may sense the number of rotations or the speed of the rear wheels 13 and send signals representing the number of rotations or the speed to the control unit 16. The speed sensor 22 may be disposed adjacent to the control unit 16. It may also be possible that the speed sensor 22 is installed in the pair of rear wheels 13 of the power-assisted rollator 10. Alternatively, it may also be possible that the speed sensor 22 is provided in only the pair of front wheels 12 or in all of the pair of front wheels 12 and the pair of rear wheels 13.

[0064] If the motors 20 are brushless motors, the speed sensor 22 may calculate the number of rotation or the speed of the wheels or the speed of the power-assisted rollator 10 using a hall element included in the motors 20.

[0065] When the speed can be sensed from a counter electromotive force of the motors 20, the number of rotations or the speed of the wheels or the speed of the power-assisted rollator 10 may be calculated from the counter electromotive force. When angular velocities of the rear wheels 13 or the front wheels 12 can be sensed, the number of rotations or the speed of the wheels or the speed of the power-assisted rollator 10 may be calculated from the angular velocities.

[0066] The speed sensor 22 may be installed in any of the components such as the frame 11 and the pair of handles 14, in addition to the pair of the front wheels 12 and the pair of the rear wheels 13. If the speed sensor includes an acceleration sensor, the speed may be calculated by integrating acceleration components. If the speed sensor includes a global positioning system (GPS), the speed may be calculated by differentiating location information.

[0067] The inclination sensor 23 may sense the inclination of the power-assisted rollator 10, or sense, for example, whether the power-assisted rollator 10 is on a flat surface or on an inclined surface, and may send to the control unit 16 a signal related to the inclination of the power-assisted rollator 10. The inclination sensor 23 may be provided in the upper portion of the power-assisted rollator 10, for example, in the pair of handles 14. Alternatively the inclination sensor 23 may be provided in the lower portion of the power-assisted rollator 10. However, if the inclination sensor 23 is provided in the upper portion, it may be possible to sense the attitude of the power-assisted rollator 10 more accurately as compared to the case where the inclination sensor 23 is provided in the lower portion. The inclination sensor 23 may be a gyro sensor. In addition, the attitude of the power-assisted rollator 10 may be sensed by an acceleration sensor.

[0068] Fig. 3 is a schematic view of an example of the leg detection sensor 25. Referring to Fig. 3, the leg detection sensor 25 may be mounted on the coupling frame 32. The leg detection sensor 25 may be an image sensor, an infrared sensor, or the like. The leg detection sensor 25 can detect behavior of a user's leg by measuring a distance from a foot of the user of the power-assisted rollator 10.

[0069] More specifically, the leg detection sensor 25 shown in Fig. 3 may determine whether the user's leg in the area AR 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.

[0070] Figs. 4 and 5 are schematic views of the grip sensor 24.

[0071] On each of the grips 42 of the pair of handles 14, there may be provided the grip sensor 24 for sensing the operation force (the grip force) of the user to manually push or pull the power-assisted rollator 10. Displacement of the grip sensors 24 in the pushing and/or pulling direction with respect to the poles 41 may be restricted by an elastic member such as a spring (not shown). The grip sensor 24 may further include a potentiometer to detect the displacement.

[0072] As mentioned above, the grips 42 may be movable in the front-rear direction with respect to the poles 41. When the grips are moved in the direction of the arrows in Figs. 4 and 5 (the frontward direction), it may be determined that the power-assisted rollator 10 is pushed by the user. When the grips are moved in the direction opposite to the direction of the arrows in Figs. 4 and 5 (the rearward direction), it may be determined that the power-assisted rollator 10 is pulled by the user. When the grips are not moved, it may be determined that the rollator is neither pushed nor pulled.

[0073] In this manner, it may be 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.

[0074] Each of the left and right handles 14 may have a separate grip sensor 24. The grip sensors 24 may sense an

operation force (a grip force) applied to the handles 14 independently from each other and send a signal of the sensed operation force to the control unit 16. Thus, it can be recognized whether the user grips only one of the pair of handles 14 (the one-hand gripping state), grips none of the pair of handles 14 (the non-hand gripping state), or grips both the pair of the handles 14 (the two-hand gripping state).

[0075] 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 pair of pipe frames 31, and the strain sensors 38 may serve as the grip sensors 24. In this case, the grips 42 may be fixed on the poles 41 so that the structure may be simple. Alternatively, a joy stick, a push button, or a proximity sensor for sensing a hand of the user may be provided on the grips 42 and these may be used as the grip sensors 24. That is, "the determination whether the user is trying to move the electric vehicle forward via the operation unit" may be achieved by sensing the operation force of the user applied to the operation unit when the user pushes or pulls the operation unit by hand or other part of his/her body, or by sensing the intention of the user by means of a switch means such as a joystick or a push button.

Operation in the Embodiment

[0076] Operation in the embodiment configured as above will be hereinafter described. Fig. 6 is a flowchart of one example of the operation of the control unit 16.

[0077] The control unit 16 may determine 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 may determine 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 from the grip sensors 24 provided on both the left and right handles 14 (step S1).

[0078] It may also be possible that the control unit 16 uses 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 more accurately determining 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 user. This may enable further accurate determination.

[0079] When the pair of handles 14 are not pushed with more than a predetermined amount of force ("NO" in step S1), the control unit 16 may determine that the user is not trying to move the power-assisted rollator 10 forward and may not proceed to the following control operation. In this case, the control unit 16 may use the motors 20 as dynamic brakes and thereby brake the rear wheels 13.

[0080] On the other hand, when the pair of handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time ("YES" in step S1), the control unit 16 may determine that the user is trying to move the power-assisted rollator 10 forward. Then, the control unit 16 may determine whether the front wheels 12 have struck a step (step S2).

[0081] More specifically, the speed sensor 22 may sense the number of rotations or the speed of the rear wheels 13 and send signals representing the number of rotations or the speed to the control unit 16. The control unit 16 may calculate the speed of the rear wheels 13 based on the received signals and compare the calculated speed with a predetermined speed V.

[0082] 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 S2), the control unit 16 may determine that the power-assisted rollator 10 is moving in a normal state and continue to assist the movement of the rear wheels 13 by the motors 20.

[0083] On the other hand, when the rear wheels 13 are not driven, that is, the rear wheels are stopped (the power-assisted rollator 10 is stopped) or 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 S2), the control unit 16 may determine that the front wheels 12 have struck a step. In this case, the control unit 16 may control the motor 20 so as to increase or reduce the driving force of the motor 20 gradually in accordance with, e.g., the force 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 in the forward direction of the rear wheels 13 may produce a moment on the power-assisted rollator 10 in the direction to raise the front wheels 12 so as to lift the front wheels 12.

[0084] When it is determined that the user is trying to move the power-assisted rollator 10 forward, the control unit 16 may use the time and force to push the handle 14, as described above, so as to accurately determine that the user is trying to move forward and avoid making a determination inconsistent with the intention of the user. Therefore, the user may feel more safety in using the power-assisted rollator 10. It may also be possible that the above determination is based only on the force to push the handles 14. For example, when the handles 14 are pushed with more than a predetermined amount of force, it may be determined that the user is trying to move the power-assisted rollator 10 forward. In this case, the control unit 16 can determine quickly that the user is trying to move forward, and the user may not need to reduce the walking speed significantly to lift the front wheels 12.

[0085] It may also be possible that 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 enable more accurately determining whether the power-assisted rollator 10 is moving. For example, it may also be possible that, 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 determines that the power-assisted rollator 10 has struck a step, and in other cases, the control unit 16 determines that the power-assisted rollator 10 has not struck a step.

[0086] Further, it may also be possible that, 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 (the seventh threshold value), the control unit 16 determines that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward. That is, 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 are stopped 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. Therefore, the grip sensors 24 may not necessarily be provided. It should be noted that, as described above, a deceleration is a negative acceleration that 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.

[0087] Further, it may also be possible that, when the pair of 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 determines that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward. This may enable accurately determining whether the power-assisted rollator 10 is moving. As described above, it can be determined based on the signals from the grip sensors 24 whether the pair of handles 14 are pushed with more than a predetermined amount of force for more than a predetermined amount of time.

[0088] When the step is relatively low, the driving force of the rear wheels 13 described above may cause the front wheels 12 to be lifted and run onto the step. When the front wheels 12 are not lifted, the user may then reduce the force to push the handles 14. At this time, the moment applied to the power-assisted rollator 10 in the direction to press down the front wheels 12 (the moment opposed to lifting of the front wheels 12) may be reduced. The control unit 16 may maintain the driving force of the rear wheels 13 in the forward direction for a period of time to drive the rear wheels 13 forward (see Fig. 7). Consequently, the moment in the direction to raise the front wheels 12 may be increased and act to lift the front wheels 12.

[0089] If the front wheels 12 are still not lifted, the user may then pull the handles 14 backward. At this time, the force to pull the handles 14 backward may produce a moment in the direction to raise the front wheels 12, and the produced moment may act to lift the front wheels 12 in cooperation with the driving force of the rear wheels 13. Thus, in addition to the driving force from the motors 20, the operation of the handles 14 by the user may produce a moment on the power-assisted rollator 10 in the direction to raise the front wheels 12 (see the arrow M in Fig. 2), thereby ensuring that the front wheels 12 are lifted (the power-assisted rollator 10 is put into wheelle). It may also be possible that the user treads a pedal (not shown) fixed behind the rotation axis of the rear wheels 13, instead of pulling the handles 14 backward, so as to raise the front wheels 12.

[0090] In this case, when the front wheels 12 are lifted relative to the rear wheels 13, a gap may be 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 may move forward to narrow the gap until the front wheels 12 contact with the top portion of the step. Thus, the front wheels 12 can run onto the step smoothly.

[0091] After lifting the front wheels 12, the control unit 16 may gradually reduce the driving force of the rear wheels 13 in the forward direction at a first reduction rate. Thus, the rear wheels 13 are not accelerated too much after the front wheels 12 move beyond the step, and therefore, the front wheels 12 can run over the step smoothly. The reduction of the driving force may be started at the timing when the conditions for the control unit 16 to control the drive units to lift the front wheels 12 (the conditions to determine that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward) become unsatisfied. For example, the reduction of the driving force may

be started at the timing 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 rotates forward at a speed higher than the predetermined speed.

[0092] The user may then push the pair of handles 14 while the front wheels 12 are lifted 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.

[0093] Thus, when the user pulls the handles 14 backward, a moment around the rear wheels 13 can be produced. This moment may cooperate with the driving force from the motors 20, such that the front wheels 12 can be readily lifted. 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, it may be possible that, when the step is low, the user is not necessarily required to pull the handles 14 backward, and the front wheels 12 are lifted only by increasing the driving force from the motors 20.

[0094] By the way, as described above, when 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. Therefore, 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 the power-assisted rollator 10 from being accelerated further. In this case, the control unit 16 may control the motors 20 such that the driving force of the rear wheels 13 by the motors 20 is reduced at a higher rate. More specifically, the reduction rate of the driving force of the rear wheels 13 in the forward direction may be set at a second reduction rate that may be higher than the first reduction rate described above (see the two-dot chain line in Fig. 7). It may also be possible that the control unit 16 may set the driving force of the rear wheels 13 in the forward direction at zero.

(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).

(2) The rotation speed of the rear wheels 13 sensed by the speed sensor 22 satisfies a predetermined condition. For example, the rotation speed of the rear wheels 13 is equal to or greater than a predetermined value. (At the moment the front wheels 12 run over the step, the speed of the rear wheels 13 may increase; and when the rear wheels 13 rotate idly, the rotation speed of the rear wheels 13 may increase.)

(3) The distance between the user and the power-assisted rollator 10 sensed by the leg detection sensor 25 is equal to or greater than a predetermined value. (At the moment the front wheels 12 run over the step, the speed of the rear wheels 13 may increase, and the power-assisted rollator 10 may move away from the user.)

[0095] The condition to determine that the user is trying to move the electric vehicle forward may not be limited to the above but may include one or more elements selected from, e.g., (i) the amount of rotation of the front wheels 12 or the rear wheels 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 wheels 12 or the rear wheels 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 handle 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.

[0096] In the embodiment as described above, when it is determined that the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward, the control unit 16 may control the motors 20 such that the front wheels 12 are lifted relative to the rear wheels 13. Thus, the front wheels 12 can readily run over the step without need of an operation causing a large load to users.

[0097] In the embodiment, when the rear wheels 13 are stopped or the speed of the rear wheels 13 is equal to or less than a predetermined value V, the control unit 16 may determine that the front wheels 12 have struck the step. Thus, the control unit 16 can properly determine that the front wheels 12 have struck the step. The existing speed sensor 22 can be used to sense that the front wheels 12 have struck the step.

[0098] In the embodiment, the control unit 16 may determine via the handles 14 (the operation units) that the user is trying to move the power-assisted rollator 10 forward. Thus, when the user ordinarily operates the handles 14 as usual, the control unit 16 can properly determine that the user is trying to move the power-assisted rollator 10 forward.

[0099] In the embodiment, when the user pushes the handles 14 forward, the control unit 16 may determine that the user is trying to move the power-assisted rollator 10 forward. Thus, when the user simply performs an ordinary operation of pushing the handles 14 forward as usual, the control unit 16 can properly determine that the user is trying to move the power-assisted rollator 10 forward.

[0100] In the embodiment, when the user pushes the handles 14 with more than a predetermined amount of force, the control unit 16 may determine that the user is trying to move the power-assisted rollator 10 forward. Thus, the control unit 16 can quickly determine that the user is trying to move the power-assisted rollator forward, and the user may not need to reduce the walking speed significantly to lift the front wheels 12. The existing grip sensors 24 can be used to sense that the user is trying to move the power-assisted rollator 10 forward.

[0101] In the embodiment, when the user pushes the handles 14 with more than a predetermined amount of force for more than a predetermined amount of time, the control unit 16 may determine that the user is trying to move the power-assisted rollator 10 forward. Thus, the control unit 16 can accurately determine that the user is trying to move the power-assisted rollator 10 forward and avoid making a determination inconsistent with the intention of the user.

[0102] In the embodiment, the motors 20 may drive the rear wheels 13 in the forward direction to lift the front wheels 12 relative to the rear wheels 13, and therefore, the front wheels 12 can be smoothly raised using the rear wheels 13 without need of using another raising means or the like.

[0103] In the embodiment, the motors 20 may drive the rear wheels 13 in the forward direction for traveling to lift the front wheels 12 relative to the rear wheels 13, and therefore, the front wheels 12 can be smoothly raised using the motors 20 for traveling of the rear wheels 13.

[0104] In the embodiment, the control unit 16 may increase or reduce the driving force in accordance with the force of the user to push the handles 14, and therefore, the driving force can be obtained properly from the motors 20 in accordance with the operation force applied to the handles 14 and thus in accordance with the intention of the user.

[0105] In the embodiment, the control unit 16 may increase or reduce the driving force in accordance with the amount of time for which the user pushes the handles 14, and thus the driving force from the motors 20 may be increased or reduced gradually while the user pushes the handles 14. Therefore, the driving force can be obtained properly in accordance with the height of the step (a small driving force may be produced for a low step, and a large driving force for a high step).

[0106] In the embodiment, the control unit 16 may cause the front wheels 12 to be lifted relative to the rear wheels 13, and then control the motors 20 to cause the power-assisted rollator 10 to move forward such that the front wheels 12 contact with the top portion of the step. Therefore, the front wheels 12 can smoothly run onto the step.

[0107] In the embodiment, when it is determined that the front wheels 12 have struck a step, the control unit 16 may control the motors 20 to cause the front wheels 12 to be lifted relative to the rear wheels 13 in accordance with the reduced force of the user to push the handles 14 forward or the force of the user to pull the handles 14 backward. Therefore, it can be ensured using the operation force on the handles and the driving force from the motors 20 that the front wheels 12 are lifted.

[0108] In the embodiment, the control unit 16 may cause the front wheels 12 to be lifted relative to the rear wheels 13, and then gradually reduce the driving force of the rear wheels 13 in the forward direction. Thus, it is possible to prevent sudden acceleration immediately after the raised front wheels 12 contacts with the ground again.

[0109] In the embodiment, when the rear wheels 13 rotate, the control unit 16 may gradually reduce the driving force of the rear wheels 13 in the forward direction. Thus, when the rear wheels 13 starts to rotate, the control unit 16 can determine that the front wheels 12 have been raised.

[0110] In the embodiment, when the rear wheels 13 rotate, the control unit 16 may reduce the driving force of the rear wheels 13 in the forward direction at a higher rate in accordance with the rotation speed thereof, or set the driving force of the rear wheels 13 in the forward direction at zero. Thus, when the rotation speed of the rear wheels 13 is suddenly increased, the control unit 16 may reduce the driving force of the rear wheels 13 significantly so as to prevent sudden acceleration of the power-assisted rollator 10 or idling of the rear wheels 13.

[0111] In the embodiment, the control unit 16 may cause the front wheels 12 to be lifted relative to the rear wheels 13, and then reduce the driving force of the rear wheels 13 in the forward direction at a higher rate in accordance with the inclination angle of the power-assisted rollator 10, or set the driving force of the rear wheels 13 in the forward direction at zero. Thus, it is possible to prevent the power-assisted rollator 10 from failing backward when it is inclined at an angle larger than an allowable angle. In addition, it is possible to prevent the control unit 16 from driving the motors 20 independently of the intention of the user when the power-assisted rollator 10 is inclined backward and thus the hands of the user gripping the handles 14 pushes the handles 14 forward.

Variations of Method of Lifting Front Wheels

[0112] The following are the variations of the methods for the control unit 16 to control the motors 20 to cause the front wheels 12 to be lifted relative to the rear wheels 13.

Variation 1

[0113] In the embodiment described above, the control unit 16 may automatically determine that the front wheels 12 have struck a step. Alternatively, it may also be possible that the control unit 16 causes the front wheels 12 to be lifted relative to the rear wheels 13 in accordance with a predetermined operation by the user, irrespective of whether the front wheels have struck the step.

[0114] In this case, the user may first operate the brake levers 34 manually and pull the handles 14 backward. At this time, the control unit 16 may recognize by a sensor (not shown) that the brake levers 34 are operated and recognize

that the handles 14 are pulled backward, based on the signals from the grip sensors 24.

[0115] As in the embodiment described above, the control unit 16 may then increase the output of 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). The user may then push the pair of handles 14 while the front wheels 12 are lifted 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. During this operation, the user continues to operate the brake levers 34 manually. After the front wheels 12 have run over the step, the user may take his/her hands away from the brake levers 34. Through such operation, the control unit 16 can accurately recognize whether the user is trying to cause the power-assisted rollator 10 to run over a step or trying to pull the power-assisted rollator 10 backward.

[0116] The method for the control unit 16 to recognize whether the user is trying to cause the front wheels 12 to be lifted may not be limited to use of the brake levers 34 by the user and may employ other approaches. For example, it may also be possible that when the user operates an operation means such as a press button switch (not shown) provided on the handles 14, the control unit 16 may control the motors 20 to cause the front wheels 12 to be lifted relative to the rear wheels 13.

[0117] According to this variation, when the user pulls the handles 14 backward, a moment around the rear wheels 13 can be produced. This moment may cooperate with the driving force from the motors 20, such that the front wheels 12 can be readily lifted. 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. According to this variation, the front wheels 12 can be lifted relative to the rear wheels 13 as necessary, even when the front wheels 12 have not struck the step. In particular, in the case where the front wheels 12 can be lifted by the operation of the brake levers 34, there is no need of additionally providing a dedicated operation means, and the front wheels 12 can be raised smoothly by using the brake levers 34.

Variation 2

[0118] The power-assisted rollator 10 in this variation may be provided with a function to automatically brake the rear wheels 13 such that the power-assisted rollator 10 is not accelerated too much on a downslope (an automatic brake function). In addition, the front wheels 12 may strike a step while the power-assisted rollator 10 is traveling on a downslope.

[0119] In this variation, the control unit 16 may cancel the automatic brake function when it determines that the front wheels 12 have struck a step while the power-assisted rollator 10 is on a downslope and the user is trying to move the power-assisted rollator 10 forward. As in the embodiment described above, the control unit 16 may then increase the output of the motors 20 thereby to increase the driving force of the rear wheels 13 in the forward direction. The control unit 16 may determine whether the power-assisted rollator 10 is on a downslope based on the signals from the inclination sensor 23.

[0120] In this variation, it is possible to prevent the automatic brake function from making it difficult for the front wheels 12 to run over the step.

Second Embodiment

[0121] Next, the second embodiment of the invention will be described. The second embodiment shown in Figs. 8 to 14 may have different features related to the rear wheels 13 and the motors 20. In other respects, this embodiment may be configured in substantially the same way as the first embodiment. In Figs. 8 to 14, the same elements as in the first embodiment are denoted by the same reference numerals and detailed descriptions thereof will be omitted.

[0122] In the arrangement shown in Figs. 8 to 12, the motors 20 of the power-assisted rollator 10 may be connected to the rear wheels 13 via associated planetary gear mechanisms 50.

[0123] As shown in Figs. 10 to 12, each of the motors 20 may include a housing 61 fixed on the pipe frame 31, an output shaft support 62 housed in the housing 61 and rotatable on 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 may be fixed on the housing 61, and the output shaft 63 may be projected from a middle portion of the housing 61. Between the housing 61 and the output shaft support 62, there may be interposed a bearing 65. On the outer periphery of the output shaft support 62, there may be provided a magnet 66. Further, a coil 67 may be disposed around the magnet 66, and the coil 67 may be fixed on the housing 61. The coil 67 may be fed with electric power from the battery 21 and may cause rotation of the output shaft support 62 having the magnet 66 provided thereon. A cap 68 may be provided in the middle portion of the housing 61.

[0124] A rear wheel 13 may include 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 may be fixed on a bearing 75 provided around the flange 64 via a retainer plate 74.

[0125] The planetary gear mechanism 50 may include a sun gear 51, an internal tooth gear 52 disposed around the sun gear 51, three planet gears 53 meshing with the sun gear 51 and the internal tooth 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.

[0126] The sun gear 51 may be connected to the output shaft 63 of the motor 20 and may be rotatable in accordance with the rotation of the output shaft 63. The internal tooth gear 52 may be connected to the wheel 71 of the rear wheel 13. The planet carrier 54 may be connected to the flange 64 of the motor 20 and may be fixed on the pipe frame 31 via the flange 64 and the housing 61.

[0127] The following is 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.

[0128] First, it is supposed that the power-assisted rollator 10 is moving normally with the front wheels 12 thereof not striking a step. In this case, the assist force from the output shaft 63 of the motor 20 may be transmitted from the sun gear 51 connected to the output shaft 63 of the motor 20 to the internal tooth gear 52 via the planet gears 53, and then transmitted to the rear wheel 13 connected to the internal tooth gear 52. Thus, the motor 20 may assist the movement of the rear wheel 13. At this time, the pipe frame 31 connected to the planet carrier 54 may not rotate.

[0129] With the numbers of teeth of the sun gear 51 and the internal tooth gear 52 represented by Z_a , Z_c ($Z_a < Z_c$), respectively, and the angular speeds of the sun gear 51, the internal tooth gear 52, and the planet carrier 54 represented by W_a , W_c , W_x , respectively, Formula (1) is obtained.

$$Z_c(W_c - W_x) = -Z_a(W_a - W_x) \quad \text{Formula (1)}$$

[0130] When the power-assisted rollator 10 is moving normally, the planet carrier 54 may be fixed, and thus W_x is zero. Therefore, Formula (2) is obtained.

$$W_c = (-Z_a/Z_c)W_a \quad \text{Formula (2)}$$

That is, the number of rotations of the output shaft 63 of the motor 20 may be reduced to $-Z_a/Z_c$ times that and transmitted.

[0131] On the other hand, when the front wheels 12 of the power-assisted rollator 10 strike a step, the front wheels 12 may be locked and the rear wheels 13 may also stop rotating. At this time, the internal tooth gear 52 of the planetary gear mechanism 50 connected to the rear wheel 13 may also be locked. The rotational force from the output shaft 63 of the motor 20 may be transmitted to the sun gear 51 connected to the output shaft 63. This rotational force may be transmitted from the sun gear 51 to the planet carrier 54 via the planet gears 53 and may act on the pipe frame 31 connected to the planet carrier 54 in the direction of the arrow M (see Fig. 9) (in the direction opposite to the traveling direction of the power-assisted rollator 10).

[0132] 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 relative to the rear wheels 13. In this case, the control unit 16 may increase the output of the motor 20 in accordance with the operation force (the grip force) applied to the handles 14. More specifically, when the motors 20 are controlled such that the output of the motor 20 is larger for the same operation force than in the normal state (that is, the proportional factor of the motor output for multiplication of the operation force is larger), the front wheels 12 can be lifted relative to the rear wheels 13.

[0133] Thus, when the front wheels 12 of the power-assisted rollator 10 strikes a step, the internal tooth gear 52 may be fixed, and therefore, W_c in Formula (1) is zero. Therefore, Formula (3) is obtained.

$$W_x = \{Z_a/(Z_c + Z_a)\}W_a \quad \text{Formula (3)}$$

That is, the number of rotations of the output shaft 63 of the motor 20 may be reduced to $Z_a/(Z_c + Z_a)$ times that, and the entirety of the power-assisted rollator 10 connected to the planet carrier 54 may receive a rotational force in the direction opposite to the traveling direction (in the direction for lifting the front wheels 12).

[0134] As described above, according to the embodiment the motors 20 may be 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 relative to the rear wheels 13 using the planetary gear mechanisms 50. That is, the control unit 16 can cause the front wheels 12 to be lifted relative to the rear wheels 13 (the power-assisted rollator 10 is put into wheelie) by the driving force of the motors 20 and the reaction of the planetary gear mechanisms 50.

[0135] In the embodiment, the planetary gear mechanism 50 may include a sun gear 51 connected to the output shaft

of the motor 20, an internal tooth gear 52 disposed around the sun gear 51, planet gears 53 meshing with the sun gear 51 and the internal tooth gear 52 and configured to rotate and revolve when the output shaft 63 rotates, and a planet carrier 54 that rotatably supports the planet gears 53 and receives the revolution movement of the planet gears 53. The internal tooth gear 52 may be connected to the rear wheels 13, and the planet carrier 54 may be fixed on the pipe frame 31. Thus, when the front wheel 12 strike a step, the rotational force from the output shaft 63 of the motor 20 may be transmitted from the sun gear 51 to the planet carrier 54 via the planet gears 53 and may 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.

[0136] 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.

[0137] Alternatively, the planetary gear mechanism 50 may be replaced with a mechanism including two gears. More specifically, as shown in Figs. 13 and 14, 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. 13, in normal traveling, the power-assisted rollator 10 may travel with the motor 20 assisting the rear wheel 13 in moving. On the other hand, as shown in Fig. 14, when the front wheel 12 strikes a step and the front wheel 12 is locked, the rear wheel 13 may be also locked. When the motor 20 further rotates, a force may be generated so as to lift the entirety of the power-assisted rollator 10. At this time, a force may act to rotate in the direction opposite to traveling of the power-assisted rollator 10. Thus, the front wheels 12 of the power-assisted rollator 10 can readily run over the step.

Third Embodiment

[0138] Next, the third embodiment of the invention will be described. The third embodiment shown in Figs. 15a, 15b, 16a, and 16b may be different from the first embodiment in that the drive units for generating a driving force for lifting the front wheels 12 may be separate from the motors 20. In other respects, this embodiment may be configured in substantially the same way as the first embodiment. In Figs. 15a, 15b, 16a, and 16b, the same elements as in the first embodiment are denoted by the same reference numerals and detailed descriptions thereof will be omitted.

[0139] In Figs. 15a and 15b, the drive units for generating a driving force for lifting the front wheels 12 may be constituted by additional motors 46 separate from the motors 20. The rotation axis of the additional motors 46 may be either the same as the rotation axis of the rear wheels 13 (Fig. 15a) or different from the rotation axis of the rear wheels 13 (Fig. 15b).

[0140] In Figs. 16a and 16b, the drive units for generating a driving force for lifting the front wheels 12 may be constituted by actuators 47 separate from the motors 20. The actuators 47 may be connected to the frame 11. In this arrangement, the actuator 47 may be either an expanding actuator or a rocking actuator. An expanding actuator may expand and contract to lift the front wheels 12 relative to the rear wheels 13 (Fig. 16a), while the rocking actuator may rock to lift the front wheels 12 relative to the rear wheels 13 (Fig. 16b).

[0141] In Figs. 15a, 15b, 16a, and 16b, the motors 20 may not be necessarily provided.

Fourth Embodiment

[0142] Following is description of the fourth embodiment with reference to Figs. 17 and 18. In Figs. 17 and 18, the same elements as in the first to third embodiments are denoted by the same reference numerals and detailed descriptions thereof will be omitted.

[0143] Fig. 17 is a schematic perspective view of an example of an external appearance of a power-assisted rollator (an electric vehicle) 10 according to the embodiment.

Structure of Power-Assisted Rollator

[0144] Referring to Fig. 17, the power-assisted rollator 10 may include a frame 11, a pair of front wheels 12 and a pair of rear wheels 13 provided on the frame 11, and a pair of handles 14 connected to the frame 11.

[0145] Each of the pair of rear wheels 13 may be provided with a motor 20 for assisting the movement of the rear wheel 13. On the frame 11, there may be mounted a battery 21 and a control unit 16. The control unit 16 may have an inclination sensor 23.

[0146] In the embodiment, on the upper ends of the left and right pipe frames 31, there may be provided a pair of handles 14 to be operated by a user. The pair of handles 14 may be connected to each other via a bar handle 17 extending horizontally. The pair of handles 14 and the bar handle 17 may constitute a substantial U-shape. The pair of handles 14 may further be provided with an arm support 27 that supports elbows of the user. The arm support 27 may have openings in which the pair of handles 27 are inserted respectively for mounting.

[0147] Between the left and right pipe frames 31, there may be provided a seat 37 on which the user can sit as necessary.

[0148] The battery 21 may supply power to elements of the power-assisted rollator 10 such as the motors 20 and the control unit 16. The battery 21 may be provided below the seat 37 positioned between the pair of pipe frames 31.

[0149] Each of the pair of rear wheels 13 may be provided with a speed sensor (sensing unit) 22. The speed sensor 22 may also be installed in any of the components such as the frame 11 and the pair of handles 14, instead of the pair of front wheels 12 and/or the pair of rear wheels 13. Alternatively, it may be possible that the speed sensor 22 is disposed adjacent to the control unit 16. In the embodiment, the traveling speed of the power-assisted rollator 10 may be determined based on the rotation speed of the rear wheels 13, but this is not limitative. It may also be possible to determine the traveling speed based on the rotation speed of the front wheels 12 or both the rotation speeds of the front wheels 12 and the rear wheels 13.

[0150] Alternatively, it may be possible that the sensing unit is constituted by an acceleration sensor. The acceleration sensor may directly sense the acceleration of the power-assisted rollator 10 and send the signals of the acceleration to the control unit 16, instead of using the rotational acceleration of the rear wheels 13. The control unit 16 may be configured to calculate the speed by integrating the acceleration.

[0151] It may also be possible that the sensing unit is constituted by a global positioning system (GPS) device. The GPS device may detect the position of the power-assisted rollator 10, instead of using the rotational acceleration of the rear wheels 13. The control unit 16 may be configured to differentiate the positional information from the GPS device to calculate the speed of the power-assisted rollator 10, and differentiate the positional information from the GPS device twice to calculate the acceleration.

[0152] The inclination sensor 23 may be constituted by an acceleration sensor having two or more axes. The inclination sensor 23 may be disposed adjacent to the control unit 16. Alternatively, it may be possible that the inclination sensor 23 is provided in the upper portion of the power-assisted rollator 10. In addition, it may also be possible that the inclination sensor 23 is constituted by a gyro sensor, instead of the acceleration sensor, for sensing the attitude of the power-assisted rollator 10.

[0153] Other features of the power-assisted rollator 10 are substantially the same as those of the power-assisted rollator 10 of the first embodiment (Figs. 1 and 2).

[0154] 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. However, this is not limitative. In the embodiment, it may be possible that the power-assisted rollator 10 includes grip sensors 24 on the handles as in the first embodiment (Figs. 1 and 2).

Operation in The Embodiment

[0155] Operation in the embodiment configured as above will be hereinafter described. Fig. 18 is a flowchart of one example of the operation of the control unit 16.

Determination of Whether to Enter the Step Mode

[0156] First, the control unit 16 may determine whether the control on the power-assisted rollator 10 enters a step mode (step S11 in Fig. 18). As will be described later, a step mode may constitute a basis for the control unit 16 to determine whether or not the front wheels 12 have struck a step. In other words, when the control unit 16 is not in the step mode, the control unit 16 may not determine whether or not the front wheels 12 have struck a step, in order to increase the safety and prevent erroneous determination. Therefore, in any modes other than the step mode, the control unit 1 may not cause the front wheels 12 to be lifted relative to the rear wheels 13.

[0157] The control unit 16 may determine whether to enter the step mode in consideration of the conditions (A-1) to (A-7) below. When any one of the conditions (A-1) to (A-7) below is satisfied, the control unit 16 may not enter the step mode. Alternatively, it may be possible that when two or more of the conditions (A-1) to (A-7) below are satisfied, the control unit 16 does not enter the step mode.

- Condition (A-1)

[0158] When the front wheels 12 or the rear wheels 13 are braked, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step).

[0159] For example, when the fall prevention brake is applied and the power-assisted rollator 10 is suddenly stopped as in the case where the motors 20 are used as reverse brakes, the control unit 16 may erroneously determine that the front wheels 12 have struck a step. Therefore, when the fall prevention brake is applied, the control unit 16 may preferably not enter the step mode.

[0160] For another example, when the user pushes the power-assisted rollator 10 with his/her hands only placed

lightly on the grips 42 (see Figs. 1 and 2), the control unit 16 may erroneously determine that the user has taken away his/her hands from the handles 14 and control the motors 20 to suddenly stop the power-assisted rollator 10. In such a case, the control unit 16 may preferably not enter the step mode, so as to avoid erroneously determining that the front wheels 12 have struck a step.

[0161] For still another example, when the user operates the brake levers 34 (see Figs. 1 and 2), the rear wheels 13 may stop suddenly and the handles 14 may be pushed. In such a case, the control unit 16 may preferably not enter the step mode, so as to avoid erroneously determining that the front wheels 12 have struck a step.

[0162] Thus, when the front wheels 12 or the rear wheels 13 are braked, the control unit 16 may not enter the step mode, so as to avoid erroneously determining that the front wheels 12 have struck a step.

- Condition (A-2)

[0163] When the power-assisted rollator 10 is on an upslope, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step). The control unit 16 may determine whether the power-assisted rollator 10 is on an upslope based on the signals from the inclination sensor 23.

[0164] For example, when the front wheels 12 run over a step and then the rear wheels strike the step, the step is positioned near the feet of the user. Therefore, it may be dangerous that the power-assisted rollator 10 enters the step mode and accelerates. The motors 20 may preferably not increase its output for assistance. Further, it may be preferable in terms of safety that the power-assisted rollator 10 is not capable of moving upstairs. To prevent the control unit 16 from entering the step mode in such circumstances, the control unit 16 may preferably not enter the step mode when the sensed inclination reaches or exceeds such a level that the front wheels 12 are presumed to have run onto the step.

[0165] Thus, when the power-assisted rollator 10 is on an upslope, the control unit 16 may not enter the step mode, so as to increase the safety.

- Condition (A-3)

[0166] When the power-assisted rollator 10 is on a slope inclined left or right with respect to the traveling direction, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step).

[0167] For example, when the power-assisted rollator 10 is on a stepped slope and it accidentally run over a side edge of the stepped slope, the power-assisted rollator 10 may fall down. Therefore, when the power-assisted rollator 10 is on a slope inclined left or right with respect to the traveling direction, the control unit 16 may preferably not enter the step mode.

[0168] Thus, when the power-assisted rollator 10 is on a slope inclined left or right with respect to the traveling direction, the control unit 16 may not enter the step mode, so as to increase the safety.

- Condition (A-4)

[0169] The control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step) during a predetermined period of time after the power-assisted rollator 10 has run over a step.

[0170] As described above for Condition (A-2), the control unit 16 may not enter the step mode when the rear wheels 13 run over a step or the front wheels 12 have struck a stair. Therefore, the power-assisted rollator 10 may not run over two or more steps successively. In addition, it may be dangerous that when the power-assisted rollator 10 fails to run over a step, an impact occurs and causes the power-assisted rollator 10 to enter the step mode again and make oscillation. Therefore, after the power-assisted rollator 10 runs over a step, it may preferably not enter the step mode again during a predetermined period of time.

[0171] Thus, the control unit 16 may not enter the step mode during a predetermined period of time after the power-assisted rollator 10 have run over a step, so as to increase the safety.

- Condition (A-5)

[0172] When the power-assisted rollator 10 is traveling at a speed equal to or higher than a predetermined speed, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step).

[0173] When the front wheels 12 of the power-assisted rollator 10 strike a step at a high speed, the rear wheels 13 may tend to be lifted. In the case where the front wheels 12 run over the step, the user may stumble. When the power-assisted rollator 10 is traveling at a speed equal to or higher than a predetermined speed and the front wheels 12 strike a step, the control unit 16 may preferably not enter the step mode.

[0174] Thus, when the power-assisted rollator 10 is traveling at a speed equal to or higher than a predetermined speed, the control unit 16 may not enter the step mode, so as to increase the safety.

- Condition (A-6)

[0175] When the power-assisted rollator 10 is turning, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step).

[0176] As will be described above (see Condition B-5 below), even when only one of the pair of front wheels 12 strikes a step, the front wheel 12 may preferably run over the step. However, when the power-assisted rollator 10 is turning, there may be possibility that it is erroneously determined that the front wheel 12 has struck a step in the case, e.g., a caster of the front wheel 12 sticks. Therefore, it may be preferable that when the difference in traveling speed between the left and right front wheels 12 or between the left and right rear wheels 13 is larger than a predetermined value, the control unit 16 determines that the power-assisted rollator 10 is turning and does not enter the step mode.

[0177] Thus, when the power-assisted rollator is turning, the control unit 16 may not enter the step mode, so as to avoid erroneously determining that the front wheel 12 has struck a step.

- Condition (A-7)

[0178] When the difference in traveling speed between the left and right front wheels 12 or between the left and right rear wheels 13 is larger than a predetermined value, the control unit 16 may not enter the step mode (may not determine whether or not the front wheels 12 have struck a step).

[0179] For example, in the power-assisted rollator 10 having grip sensors 24 (see Figs. 1 and 2), the motor may be in an assistance state when the handles 14 are pushed. If one of the rear wheels 13 is lifted and rotated idly, a difference in traveling speed may be produced between the left and right front wheels 12 or between the left and right rear wheels 13. Therefore, it may be preferable that when the difference in traveling speed between the left and right front wheels 12 or between the left and right rear wheels 13 is larger than a predetermined value, the control unit 16 determines that one of the front wheels 12 or the rear wheels 13 is rotated idly and does not enter the step mode.

[0180] Thus, when the difference in traveling speed between the left and right front wheels 12 or between the left and right rear wheels 13 is larger than a predetermined value, the control unit 16 may not enter the step mode, so as to avoid erroneously determining that the front wheels 12 have struck a step when one of the front wheels 12 or the rear wheels 13 is rotated idly.

Determination of Whether the Front Wheels Have Struck a Step

[0181] The control unit 16 may enter the step mode when none of the Conditions (A-1) to (A-7) described above is satisfied. Next, the control unit 16 may determine whether the front wheels 12 have struck a step while the user is trying to move the power-assisted rollator 10 forward (step S12 in Fig. 18).

[0182] The control unit 16 may consider Conditions (B-1) to (B-9) below. For example, when all of the Conditions (B-1) to (B-9) below are satisfied, 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. Alternatively, it may also be possible that when at least one (a part) of Conditions (B-1) to (B-9) below is satisfied, the control unit 16 may determine that the front wheels 12 have struck a step.

- Condition (B-1)

[0183] When the deceleration of the rear wheels 13 is equal to or greater than a threshold value (a first 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.

[0184] That is, when the front wheels 12 strike a step, the power-assisted rollator 10 may be stopped suddenly, and a deceleration (a negative acceleration) may occur to the rear wheels 13. Sensing the deceleration of the rear wheels 13 may make it possible to determine that the front wheels 12 have struck the step. The threshold value (the first threshold value) of the deceleration of the rear wheels 13 may preferably be set at such a value that the control unit 16 does not erroneously determine that the front wheels 12 have struck a step when the power-assisted rollator 10 is stopped suddenly by the user's force. The deceleration of the rear wheels 13 may be either determined based on the number of rotations of the rear wheels 13 or determined using the acceleration sensors attached to the left and right rear wheels 13.

[0185] Thus, when the deceleration of the rear wheels 13 is equal to or greater than the threshold value (the first 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. In this manner, the control unit 16 can simply determine that the front wheels have struck a step without use of grip sensors 24, for example.

- Condition (B-2)

[0186] When Condition (B-1) is satisfied, and after the deceleration of the rear wheels 13 has become equal to or greater than the threshold value (the first threshold value) (the deceleration has occurred), the rotation speed of the rear wheels 13 is equal to or greater than a negative threshold value (the power-assisted rollator 10 is not moving backward), 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.

[0187] In Condition (B-1), the control unit 16 may determine whether the front wheels 12 have struck a step based only on the deceleration of the rear wheels 13. Therefore, there may be possibility that the control unit 16 erroneously determines that the front wheels 12 have struck a step when the user pulls the handles 14 backward. The control unit 16 may additionally examine the condition that after the deceleration of the rear wheels 13 has become equal to or greater than the threshold value (the first threshold value), the rotation speed of the rear wheels 13 is equal to or greater than the negative threshold value, so as to avoid erroneously determining that the front wheels 12 have struck a step when the user pulls the handles 14 backward. The negative threshold value may preferably be approximately zero.

[0188] Thus, when, after the deceleration of the rear wheels 13 has become equal to or greater than the threshold value (the first threshold value), the rotation speed of the rear wheels 13 is equal to or greater than the negative threshold value (the power-assisted rollator 10 is not moving backward), 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. Thus, the control unit 16 can more accurately determine that the front wheels 12 have struck the step.

- Condition (B-3)

[0189] When Condition (B-2) is satisfied, and before the deceleration of the rear wheels 13 becomes equal to or greater than the threshold value (the first threshold value) (the deceleration occurs), the rotation speed of the rear wheels 13 was positive (the power-assisted rollator 10 was moving forward), 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.

[0190] Particularly when the power-assisted rollator 10 is not provided with the grip sensors 24, it may be difficult to determine whether or not the user is trying to move the power-assisted rollator 10 forward. Therefore, when the power-assisted rollator 10 was moving forward (the rotation speed of the rear wheels 13 was positive) before the deceleration occurs, the control unit 16 may determine that the user is trying to move the power-assisted rollator 10 forward.

[0191] Thus, when, before the deceleration of the rear wheels 13 becomes equal to or greater than the threshold value (the first threshold value) (the deceleration occurs), the rotation speed of the rear wheels 13 was positive (the power-assisted rollator 10 was moving forward), 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. Thus, the control unit 16 can more accurately determine that the user was trying to move the power-assisted rollator forward when the front wheels 12 struck the step.

- Condition (B-4)

[0192] When, after the deceleration of the rear wheels 13 has become equal to or greater than the threshold value (the first threshold value), the rotation speed of the rear wheels 13 (the traveling speed of the power-assisted rollator 10) is equal to or less than a positive threshold value (a second 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.

[0193] When the front wheels 12 strike a step, the speed of the rear wheels 13 may become approximately zero. However, in the case where for example the speed of the rear wheels 13 is calculated with pulses from a hall element, the speed calculated with the hall element may not immediately become zero when the actual speed of the rear wheels 13 is zero. Therefore, when the rotation speed of the rear wheels 13 is equal to or less than the positive threshold value (the second threshold value), the control unit 16 may determine that the front wheels 12 have struck a step, thereby to increase the accuracy in determining that the front wheels 12 have struck a step.

[0194] Thus, when, after the deceleration of the rear wheels 13 has become equal to or greater than the threshold value (the first threshold value), the rotation speed of the rear wheels 13 (the traveling speed of the power-assisted rollator 10) is equal to or less than the positive threshold value (the second 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. Thus, the control unit 16 can more accurately determine that the front wheels 12 have struck the step.

- Condition (B-5)

[0195] When the deceleration of one of the left and right rear wheels 13 is equal to or greater than a threshold value (a third 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.

[0196] When both left and right front wheels 12 strike a step, a large deceleration may occur to both the left and right rear wheels 13. However, when the power-assisted rollator 10 approaches a step in a slightly slanted position in a plan view, there may be possibility that only one of the front wheels 12 strikes the step. In such a case, a large deceleration may occur to the rear wheel 13 on the same side as the front wheel 12 striking the step, whereas the front wheel 12 that did not strike the step can move further, and therefore, a smaller deceleration may tend to occur to the rear wheel 13 on the same side as the front wheel 12 that did not strike the step. To accurately determine that one of the front wheels 12 has struck a step, it may be preferable that when the deceleration occurring to one of the rear wheels 13 becomes equal to or greater than the threshold value (the third threshold value), the control unit 16 may determine that the front wheel has struck the step. The deceleration of the rear wheels 13 may be calculated with a component in the front-rear direction sensed by the acceleration sensors mounted on the left and right rear wheels 13, instead of the number of rotations of the rear wheels 13.

[0197] Thus, when the deceleration of one of the left and right rear wheels 13 is equal to or greater than the threshold value (the third 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. Thus, even when the power-assisted rollator 10 approaches a step in a slanted position in a plan view, the control unit 16 can accurately determine that the front wheels 12 have struck the step.

- Condition (B-6)

[0198] When Condition (B-5) is satisfied, and the deceleration of the other of the left and right rear wheels 13 is equal to or greater than a threshold value (a fourth threshold value) smaller than the third 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.

[0199] When one of the left and right front wheels 12 strikes a step, the rear wheel 13 on the other side may be decelerated to a certain degree. Therefore, the control unit 16 may examine the condition that the deceleration of the rear wheel 13 on the other side is equal to or greater than the threshold value (the fourth threshold value), so as to avoid erroneously determining that one of the front wheel 12 has struck a step when the power-assisted rollator 10 turns lightly. It may also be possible that the deceleration of the rear wheels 13 may be calculated with a component in the front-rear direction sensed by the acceleration sensors mounted on the left and right rear wheels 13, instead of the number of rotations of the rear wheels 13.

[0200] Thus, when the deceleration of the other of the left and right rear wheels 13 is equal to or greater than the threshold value (the fourth threshold value) smaller than the third 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. Thus, the control unit 16 may avoid erroneously determining that one of the front wheel 12 has struck a step when the power-assisted rollator 10 turns lightly.

- Condition (B-7)

[0201] When both the decelerations of the left and right rear wheels 13 are equal to or greater than a threshold value (a fifth threshold value) between the third and fourth threshold values, 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.

[0202] That is, the control unit 16 may examine the condition that both the decelerations of the left and right rear wheels 13 have exceeded the moderate threshold value (the fifth threshold value).

[0203] Thus, when both the decelerations of the left and right rear wheels 13 are equal to or greater than the threshold value (the fifth threshold value) between the third and fourth threshold values, 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. Thus, the control unit 16 can determine accurately when the left and right rear wheels 12 strike a step almost at the same time,

[0204] It may also be possible to determine that the front wheels 12 strike a step when the sum of the decelerations of the left and right rear wheels 13 is equal to or greater than a predetermined threshold value.

- Condition (B-8)

[0205] When the operation force applied to the handles 14 is equal to or greater than a threshold value (a sixth 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.

[0206] In the case where the power-assisted rollator 10 is provided with the grip sensors 24 (Figs. 1 and 2), when one of the front wheels 12 strikes a step, at least the grip 42 on the same side as the front wheel 12 striking the step may

be pressed by the reaction force. Therefore, the control unit 16 may examine the condition that the grip force applied to the same side as a larger deceleration is sensed is equal to or greater than the threshold value, so as to determine that one of the front wheel 12 has struck the step. Because of this condition, for example, when the power-assisted rollator 10 strikes an object while the user takes his/her hands away from the handles 14, or when the power-assisted rollator 10 moves forward on a slope or due to inertia and strikes a step, the control unit 16 can refrain from causing the front wheels 12 to be lifted relative to the rear wheels 13.

[0207] Thus, when the operation force applied to the handles 14 is equal to or greater than the threshold value (the sixth 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. Thus, when there is no need to lift the front wheels 12, the control unit 16 can refrain from causing the front wheels 12 to be lifted relative to the rear wheels 13.

- Condition (B-9)

[0208] When the control unit 16 determines that the front wheels 12 have struck a wall surface, it may determine that the front wheels 12 have not struck a step.

[0209] When the front wheels 12 strike a step, the power-assisted rollator 10 may tend to bound due to the reaction force from the step or the rotational inertia of the front wheels 12. When the front wheels 12 strike an ordinary step, the downward acceleration applied to the power-assisted rollator 10 may not exceed the gravitational acceleration. By contrast, when the front wheels 12 strike a wall surface, the power-assisted rollator 10 may be subjected to a large downward acceleration due to the friction between the front wheels 12 and the wall surface. Therefore, when the vertical acceleration applied to the power-assisted rollator 10 is equal to or greater than a threshold value, the control unit 16 may recognize that the front wheels 12 have struck the wall surface and may not cause the front wheels 12 to be lifted relative to the rear wheels 13. Alternatively, it may also be possible that a switch or a range sensor is provided to sense a step positioned in front of the front wheels 12 and having a predetermined height or more, and the control unit 16 may determine that the front wheels 12 have struck the wall surface based on the signals from the switch or the range sensor.

[0210] Thus, when the control unit 16 determines that the front wheels 12 have struck a wall surface, it may determine that the front wheels 12 have not struck a step. Thus, when the front wheels 12 have struck a step, the control unit 16 can refrain from causing the front wheels 12 to be lifted relative to the rear wheels 13.

[0211] As described above, when any of the above conditions (B-1) to (B-9) is not satisfied ("NO" at step S12 in Fig. 18), the control unit 16 may not cause the front wheels 12 to be lifted relative to the rear wheels 13.

[0212] On the other hand, when all of the Conditions (B-1) to (B-9) described above are satisfied ("YES" at step S12 in Fig. 18), 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 control unit 16 may then control the motors 20 to cause the front wheels 12 to be lifted relative to the rear wheels 13.

[0213] A predetermined amount of waiting time may be provided to accurately determine that the front wheels 12 have struck a step. When it is determined during the waiting time that all of the conditions (B-1) to (B-9) are satisfied, the control unit 16 may gradually increase the driving force of the rear wheels 13 delivered from the motor 20. When the assist force of the rear wheels 13 reaches its maximum value, this state may be kept for a period of time. Then, the control unit 16 may terminate the step mode irrespective of whether the front wheels 12 have run over the step.

[0214] The operation performed after the control unit determines that the front wheels 12 have struck the step may be substantially the same as for the first embodiment and therefore will not be described again.

[0215] The embodiments and the variations of the present invention described above are mere examples and are not intended to limit the scope of the invention. The embodiments and the variations described above may have various other forms and are susceptible to omission, replacement, and modification of various elements thereof within the scope of the invention. The embodiments and the variations 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

[0216]

- 10 power-assisted rollator
- 11 frame
- 12 front wheels
- 13 rear wheels
- 14 handles
- 15 hand brakes
- 16 control unit

20 motors
 21 battery
 22 speed sensors
 23 inclination sensors
 5 24 grip sensors
 25 leg detection sensor
 31 pipe frame

10 Claims

1. An electric vehicle (10) comprising:

a frame (11);

15 at least one front wheel (12) and at least one rear wheel (13) provided on the frame (11);

a drive unit (20) configured to produce a driving force to lift the at least one front wheel (12) relative to the at least one rear wheel (13); and

a control unit (16) connected to the drive unit (20) and configured to control the drive unit (20),

20 wherein when the control unit (16) determines that the at least one front wheel (12) has struck a step while a user is trying to move the electric vehicle (10) forward, the control unit (16) controls the drive unit (20) to lift the at least one front wheel (12) relative to the at least one rear wheel (13).

2. The electric vehicle (10) of claim 1, wherein when a deceleration of the electric vehicle (10) is equal to or greater than a first threshold value, the control unit (16) determines that the at least one front wheel (12) has struck a step while the user is trying to move the electric vehicle (10) forward.

3. The electric vehicle (10) of claim 1 or 2, wherein the at least one rear wheel (13) comprises left and right rear wheels (13), and when a deceleration of one of the left and right rear wheels (13) is equal to or greater than a third threshold value, the control unit (16) determines that the at least one front wheel (12) has struck a step while the user is trying to move the electric vehicle (10) forward.

4. The electric vehicle (10) of any one of claims 1 to 3 wherein when the at least one front wheel (12) or the at least one rear wheel (13) is braked, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

5. The electric vehicle (10) of any one of claims 1 to 4 wherein when the electric vehicle (10) is on an upslope, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

6. The electric vehicle (10) of any one of claims 1 to 5 wherein when the electric vehicle (10) is on a slope inclined left or right with respect to a traveling direction, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

7. The electric vehicle (10) of any one of claims 1 to 6 wherein when the electric vehicle (10) is traveling at a speed equal to or higher than a predetermined speed, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

8. The electric vehicle (10) of any one of claims 1 to 7 wherein when the electric vehicle (10) is turning, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

9. The electric vehicle (10) of any one of claims 1 to 8 wherein the at least one front wheel (12) comprises left and right front wheels (12), or the at least one rear wheel (13) comprises left and right rear wheels (13), and wherein when a difference in traveling speed between the left and right front wheels (12) or between the left and right rear wheels (13) is larger than a predetermined value, the control unit (16) does not determine whether or not the at least one front wheel (12) has struck a step.

10. The electric vehicle (10) of any one of claims 1 to 9 wherein when the electric vehicle (10) is stopped, a traveling speed of the electric vehicle (10) is equal to or less than a predetermined speed, or a deceleration of the electric vehicle (10) is equal to or greater than a seventh threshold value, the control unit (16) determines that the at least

one front wheel (12) has struck a step.

11. The electric vehicle (10) of any one of claims 1 to 10 further comprising an operation unit (14) to be operated by the user,
 wherein the control unit (16) determines via the operation unit (14) that the user is trying to move the electric vehicle (10) forward.

12. The electric vehicle (10) of claim 11 wherein
 the operation unit (14) includes a handle (14) connected to the frame (11) and configured to be gripped by the user, and
 when the user pushes the handle (14) forward, the control unit (16) determines that the user is trying to move the electric vehicle (10) forward.

13. The electric vehicle (10) of any one of claims 1 to 12, wherein the drive unit (20) drives the at least one rear wheel (13) in a forward direction.

14. The electric vehicle (10) of claim 1 further comprising an operation means to be operated by the user,
 wherein when the user operates the operation means, the control unit (16) controls the drive unit (20) to lift the at least one front wheel (12) relative to the at least one rear wheel (13).

15. A method of controlling an electric vehicle (10),
 the electric vehicle comprising:

a frame (11);

at least one front wheel (12) and at least one rear wheel (13) provided on the frame (11);

a drive unit (20) configured to produce a driving force to lift the at least one front wheel (12) relative to the at least one rear wheel (13); and

a control unit (16) connected to the drive unit (20) and configured to control the drive unit (20),

the method comprising:

by means of the control unit (16), determining that the at least one front wheel (12) has struck a step while the user is trying to move the electric vehicle (10) forward; and

by means of the control unit (16), controlling the drive unit (20) to lift the at least one front wheel (12) relative to the at least one rear wheel (13).

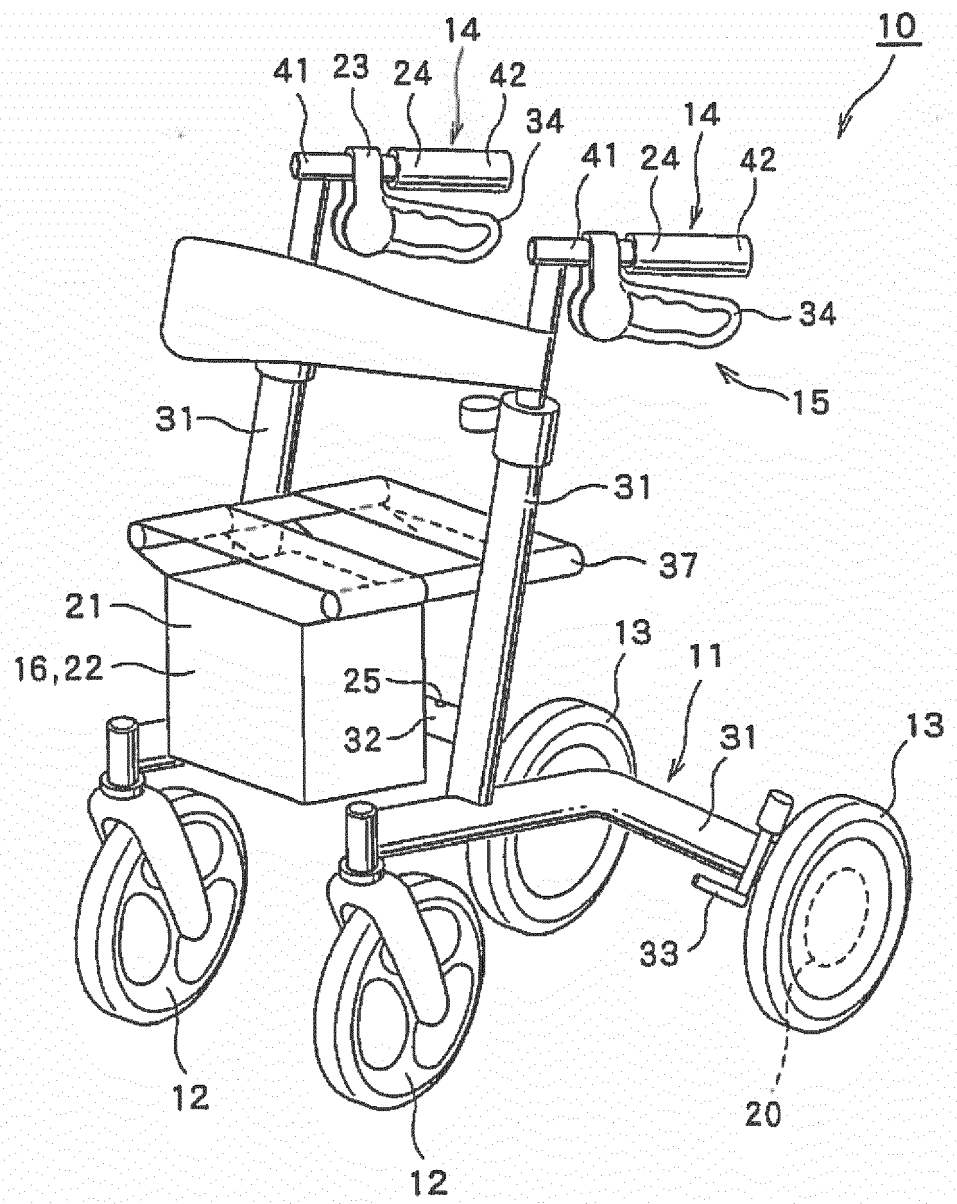


Fig. 1

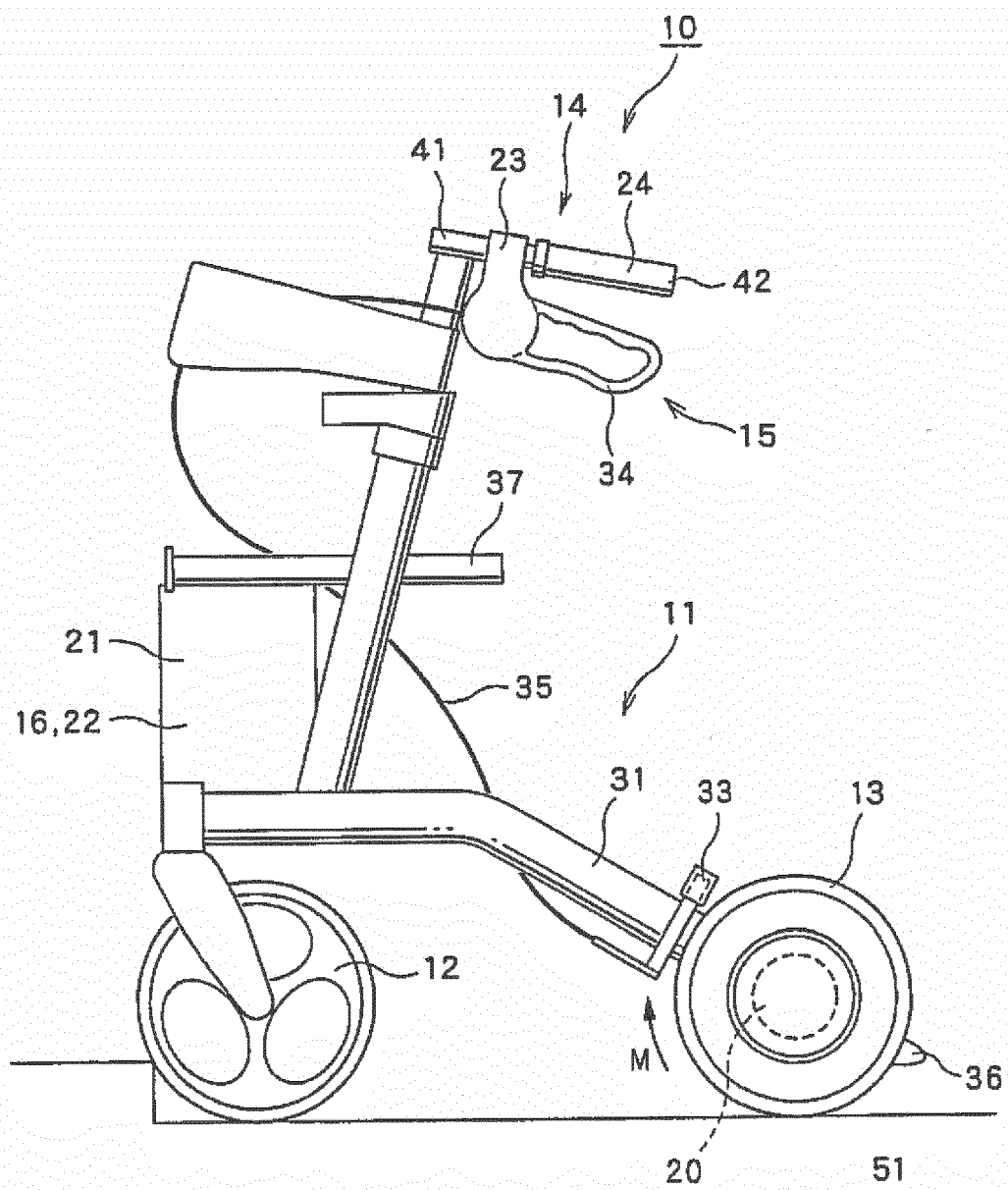


Fig. 2

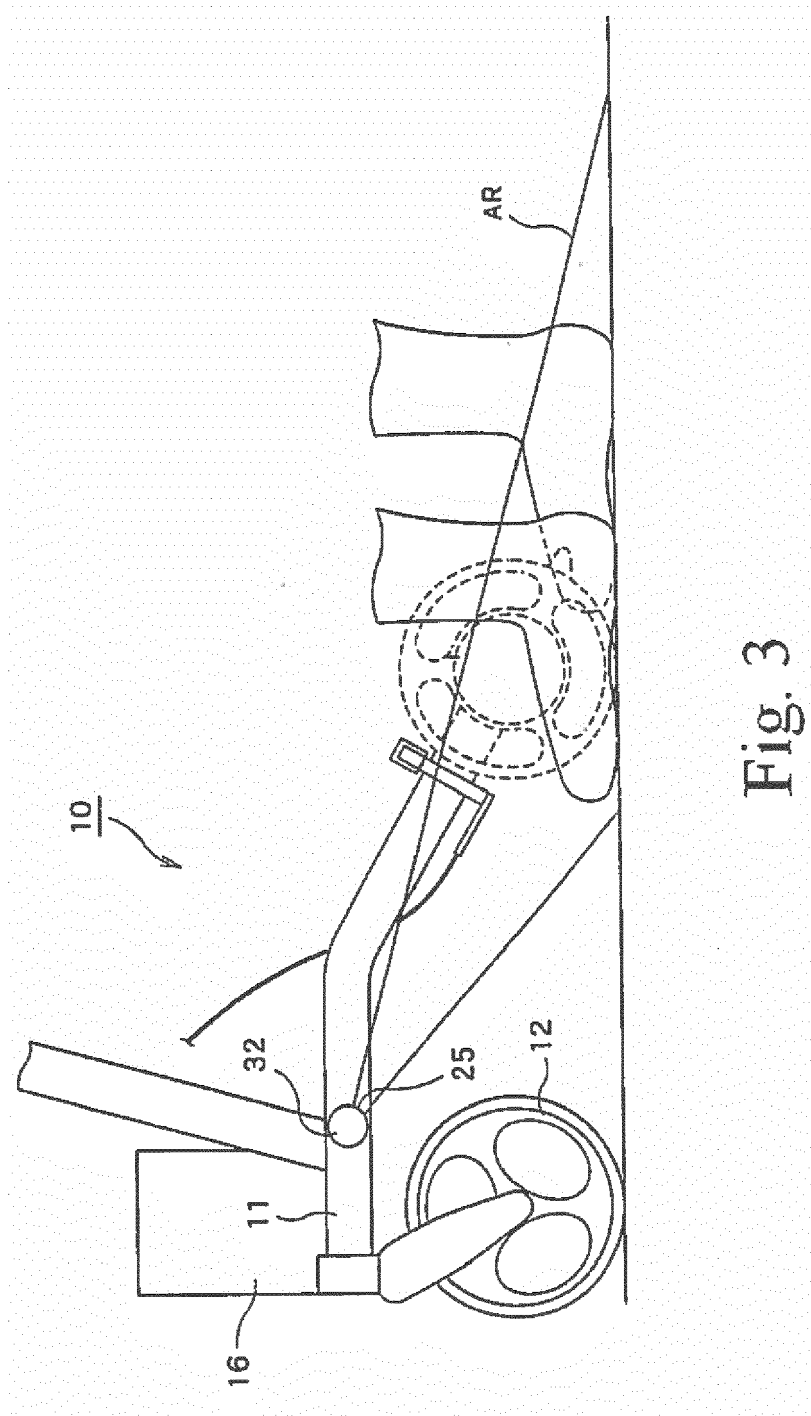


Fig. 3

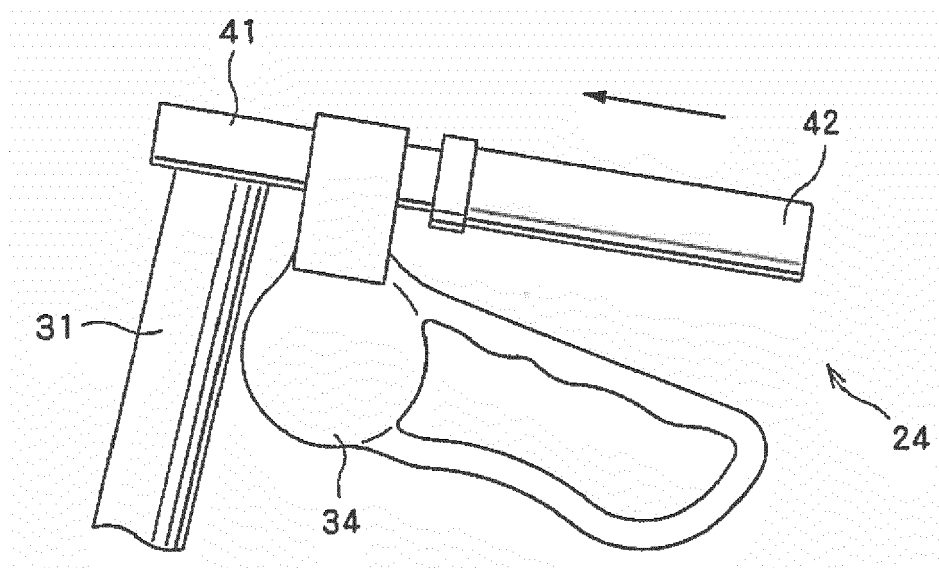


Fig. 4

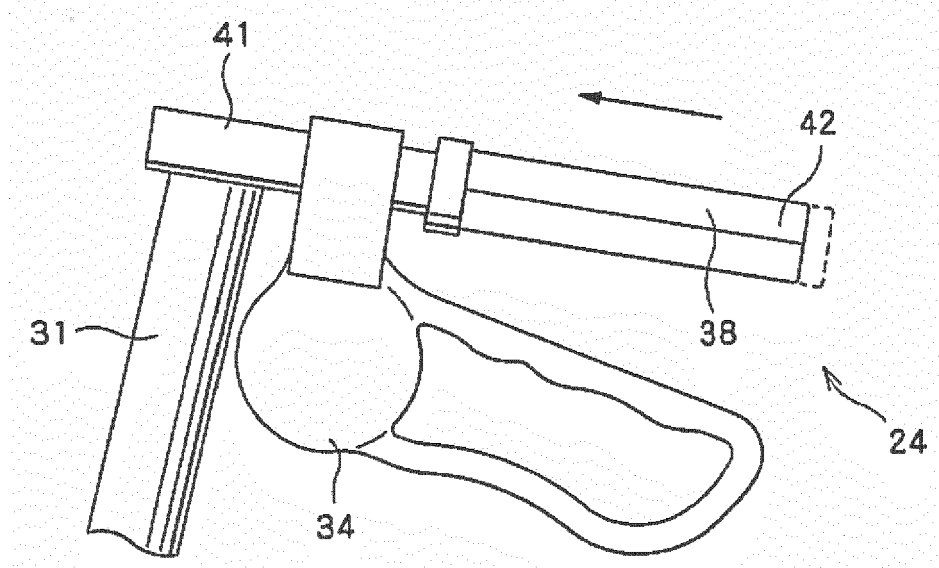


Fig. 5

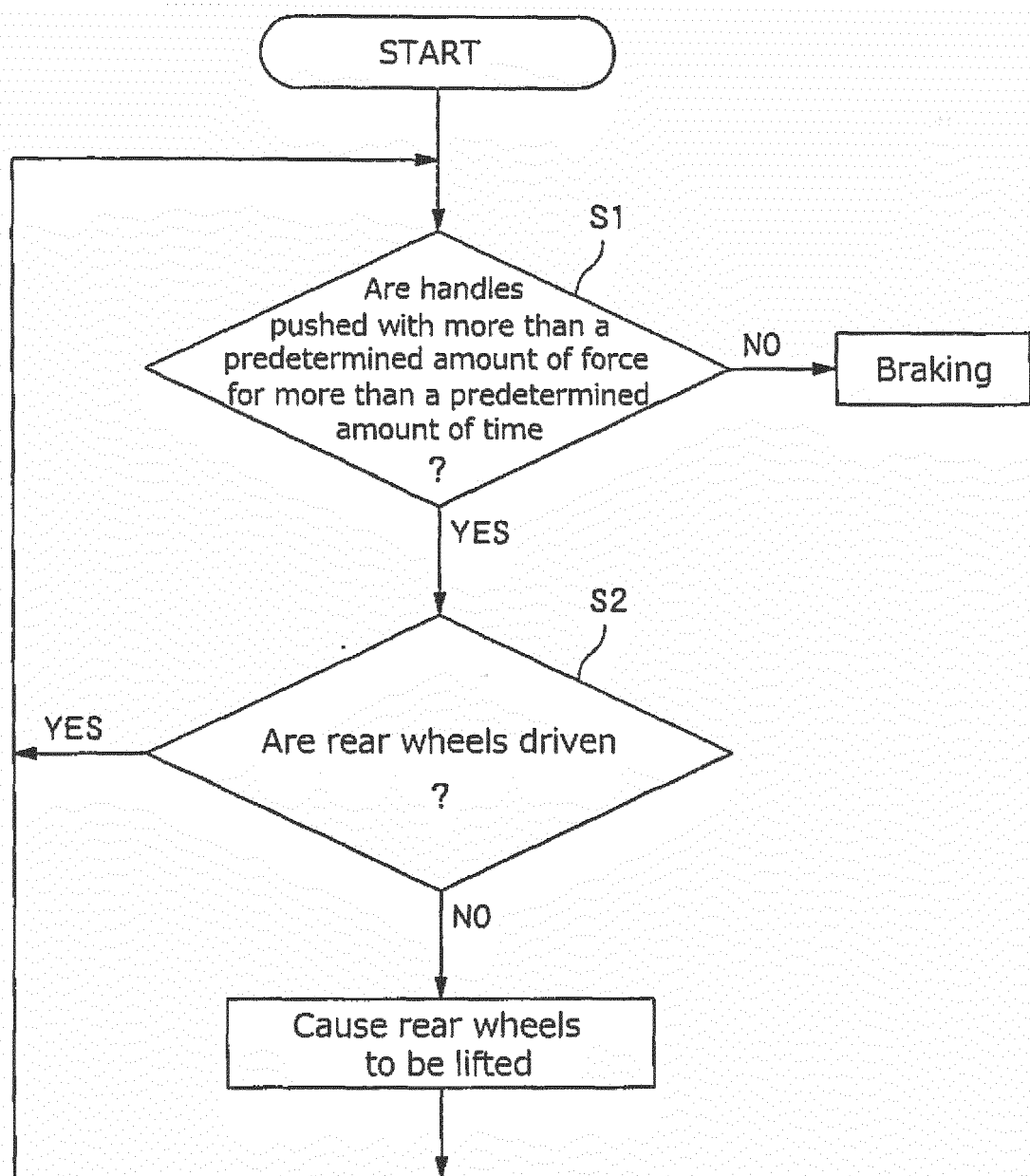
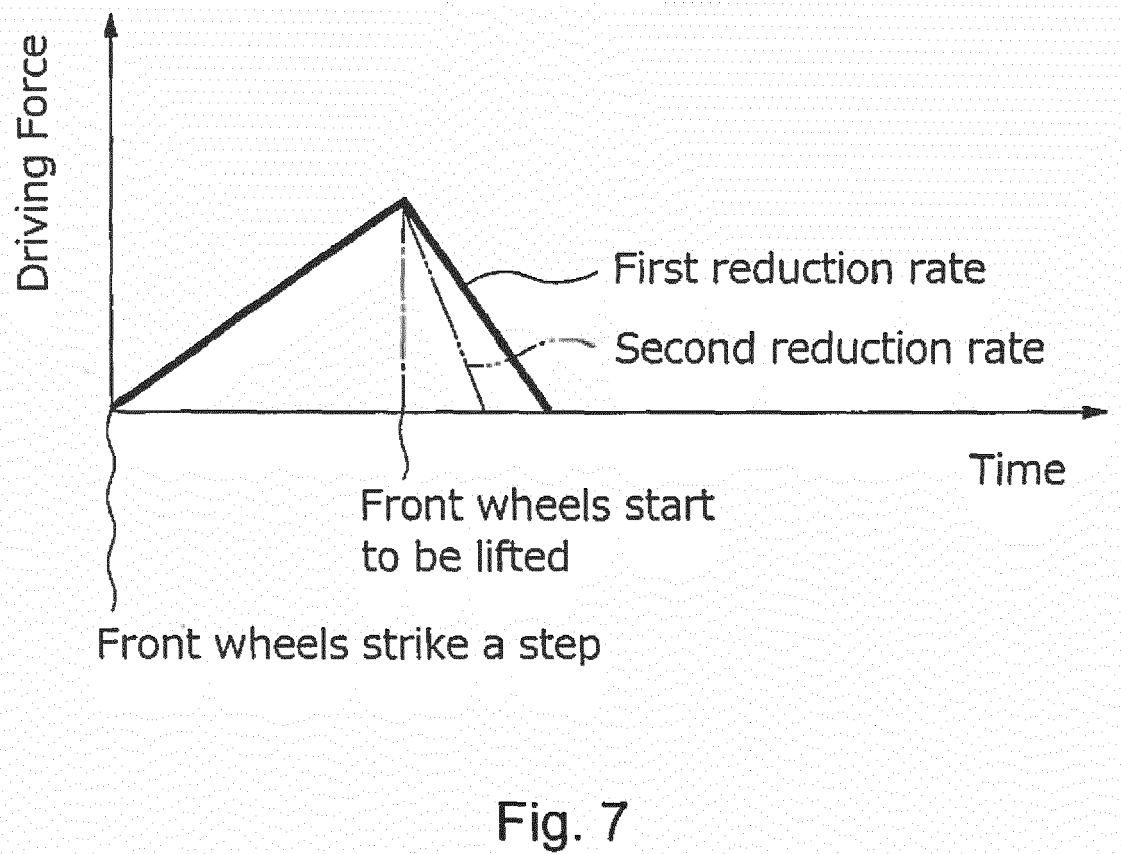


Fig. 6



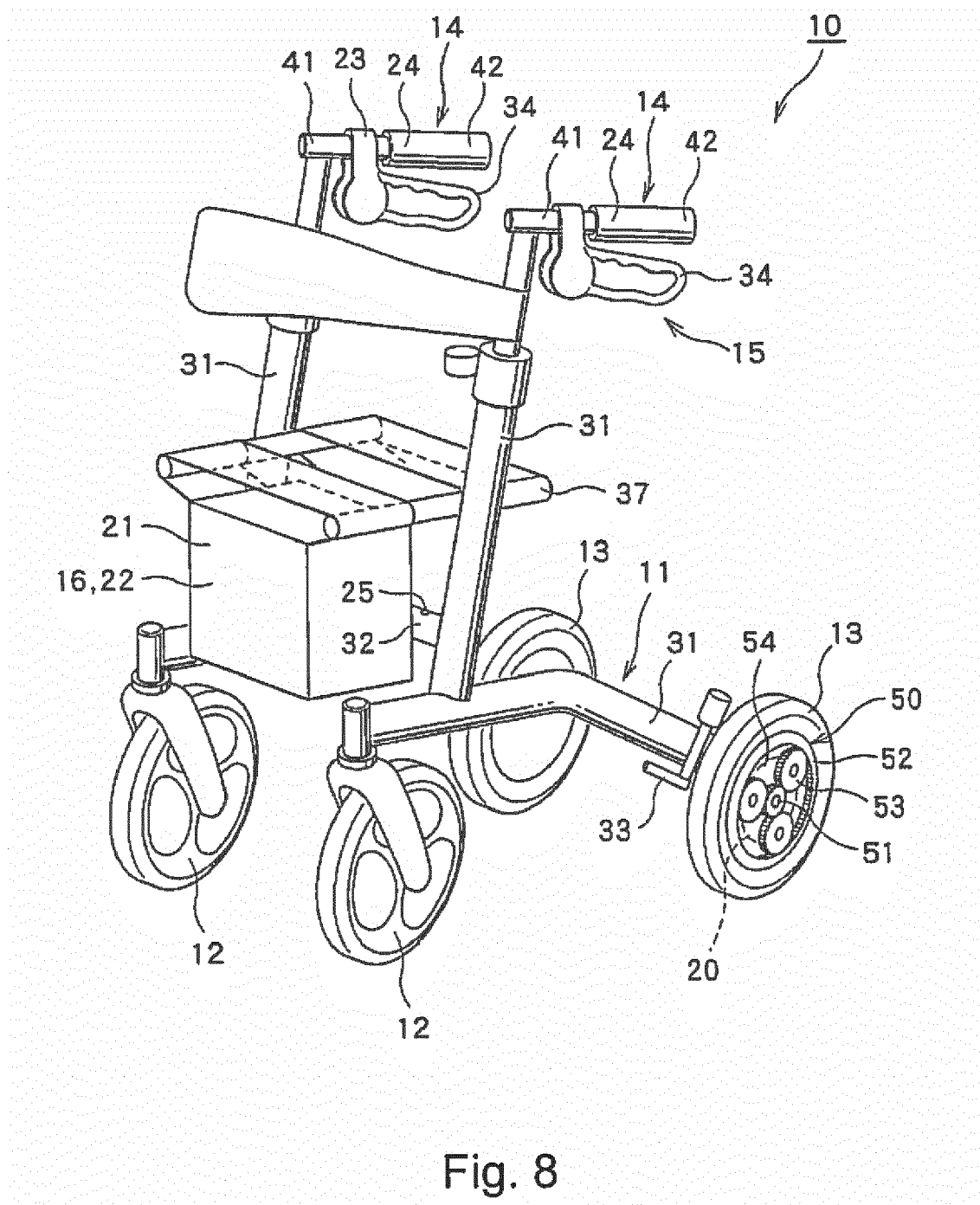
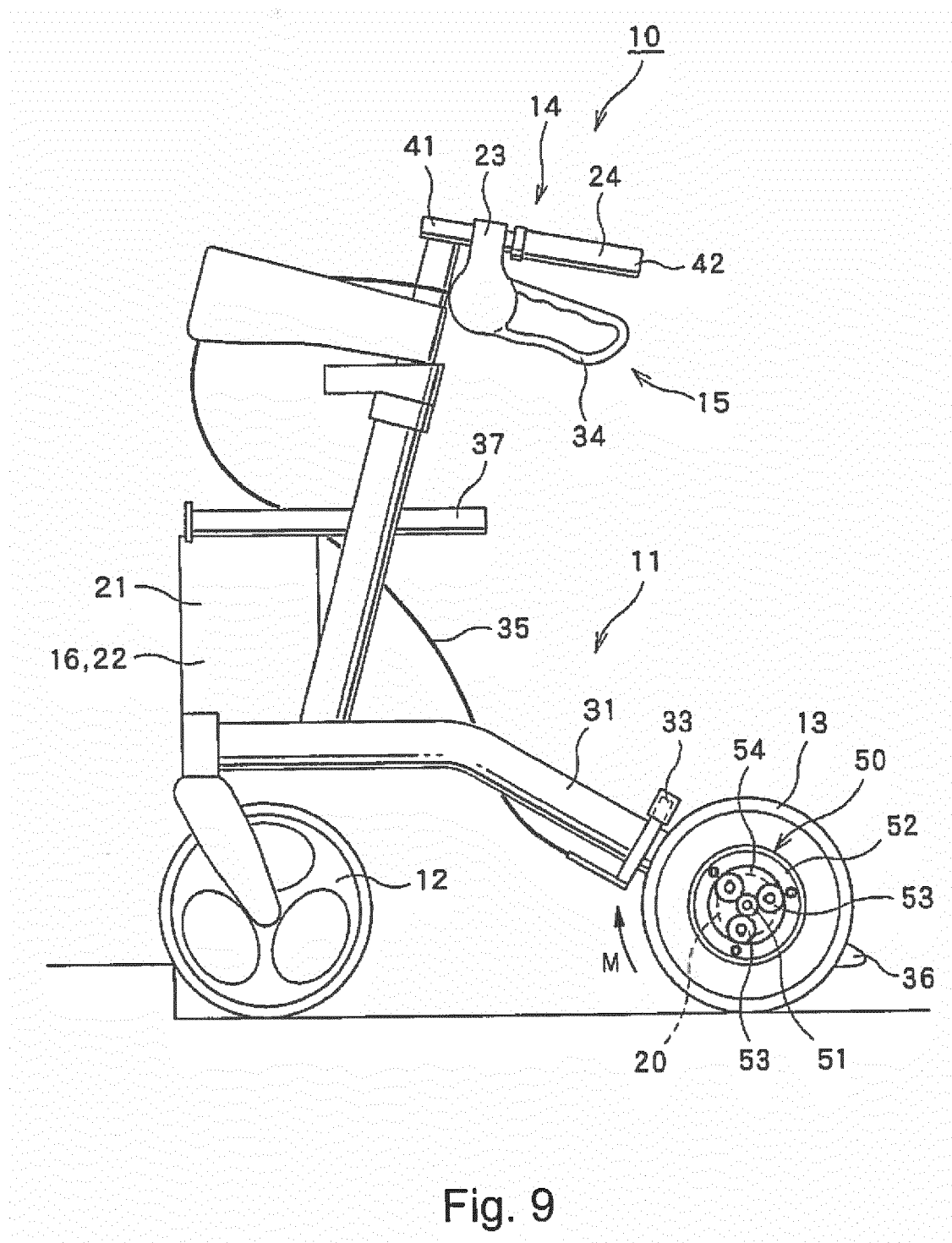


Fig. 8



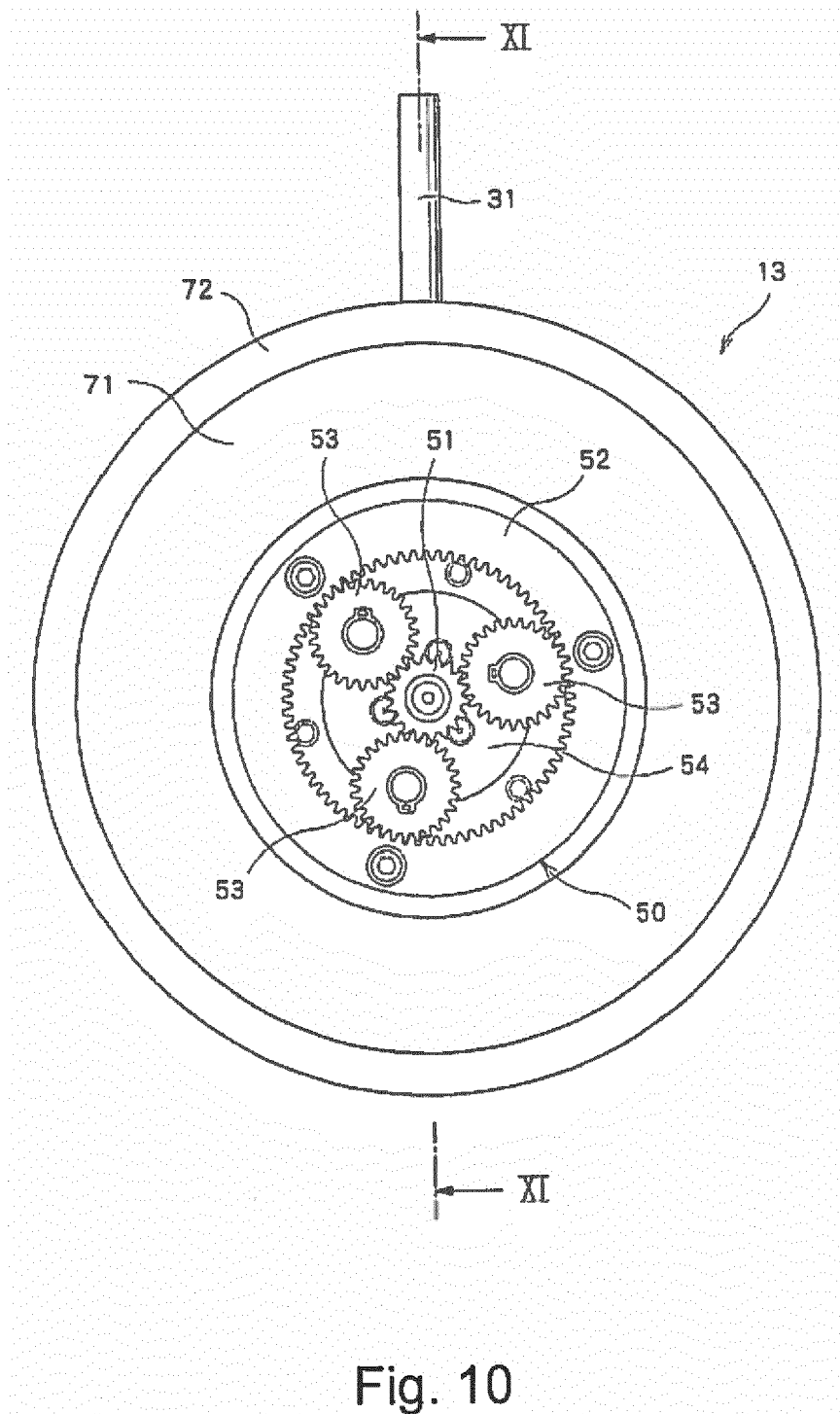


Fig. 10

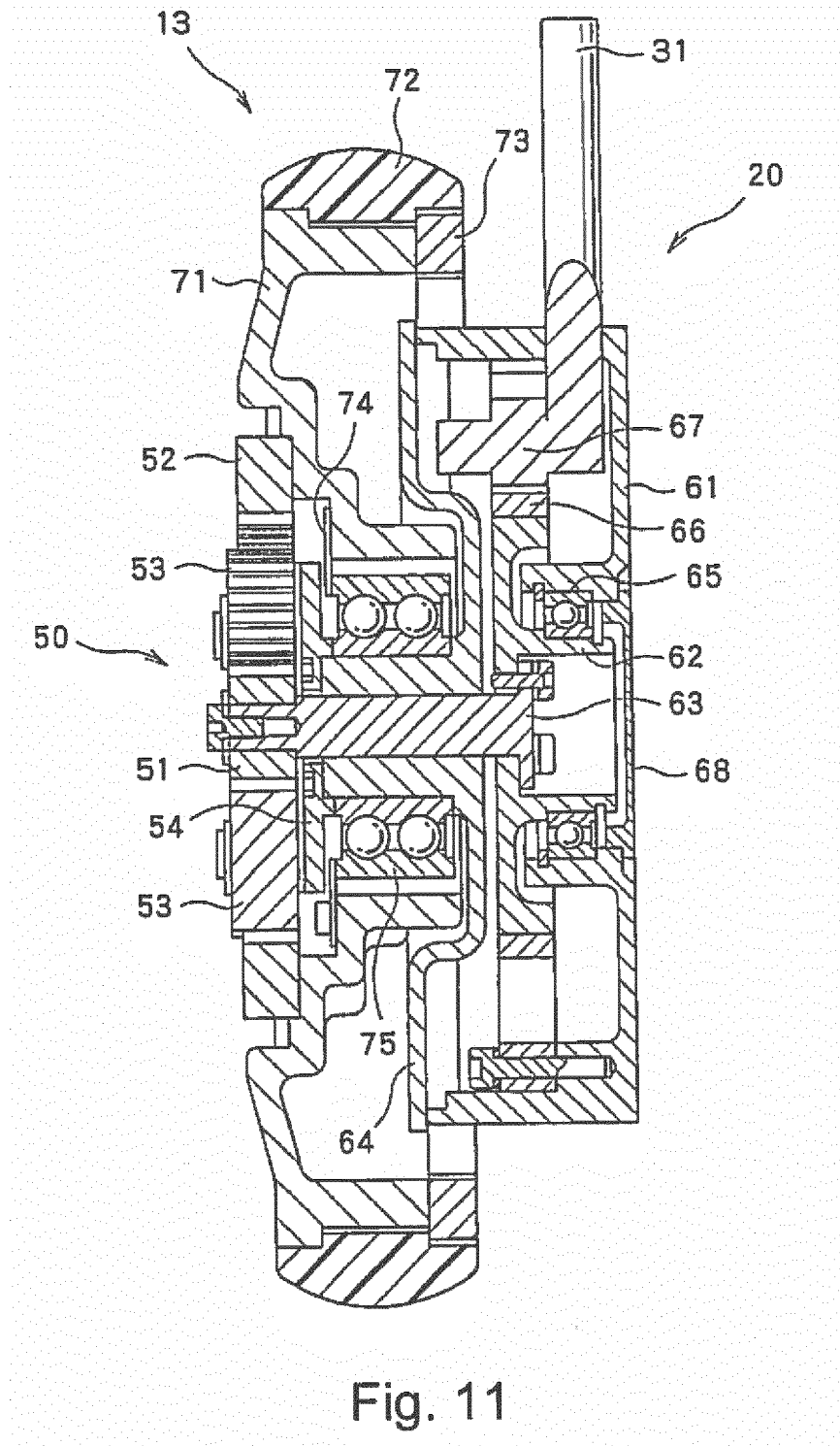
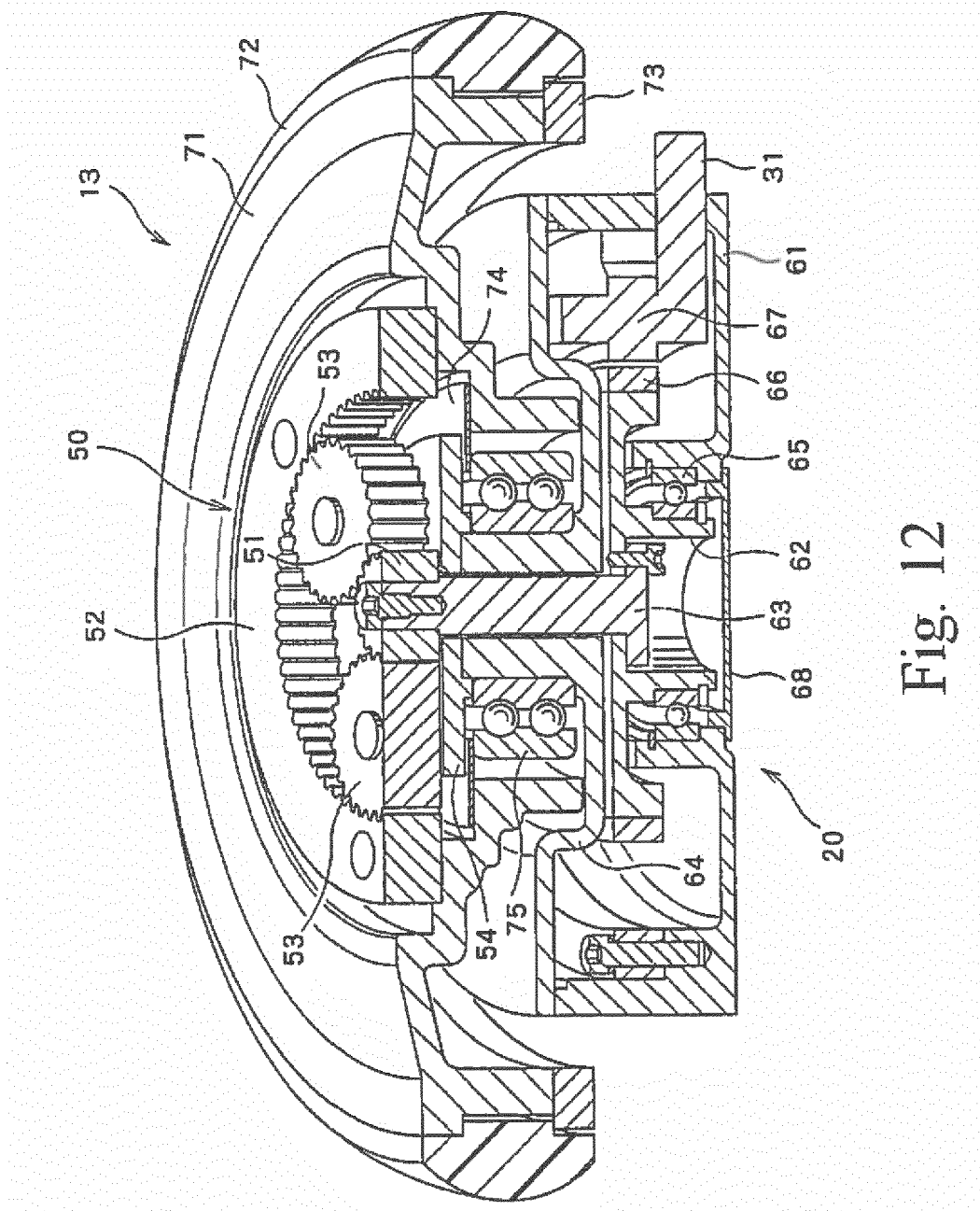
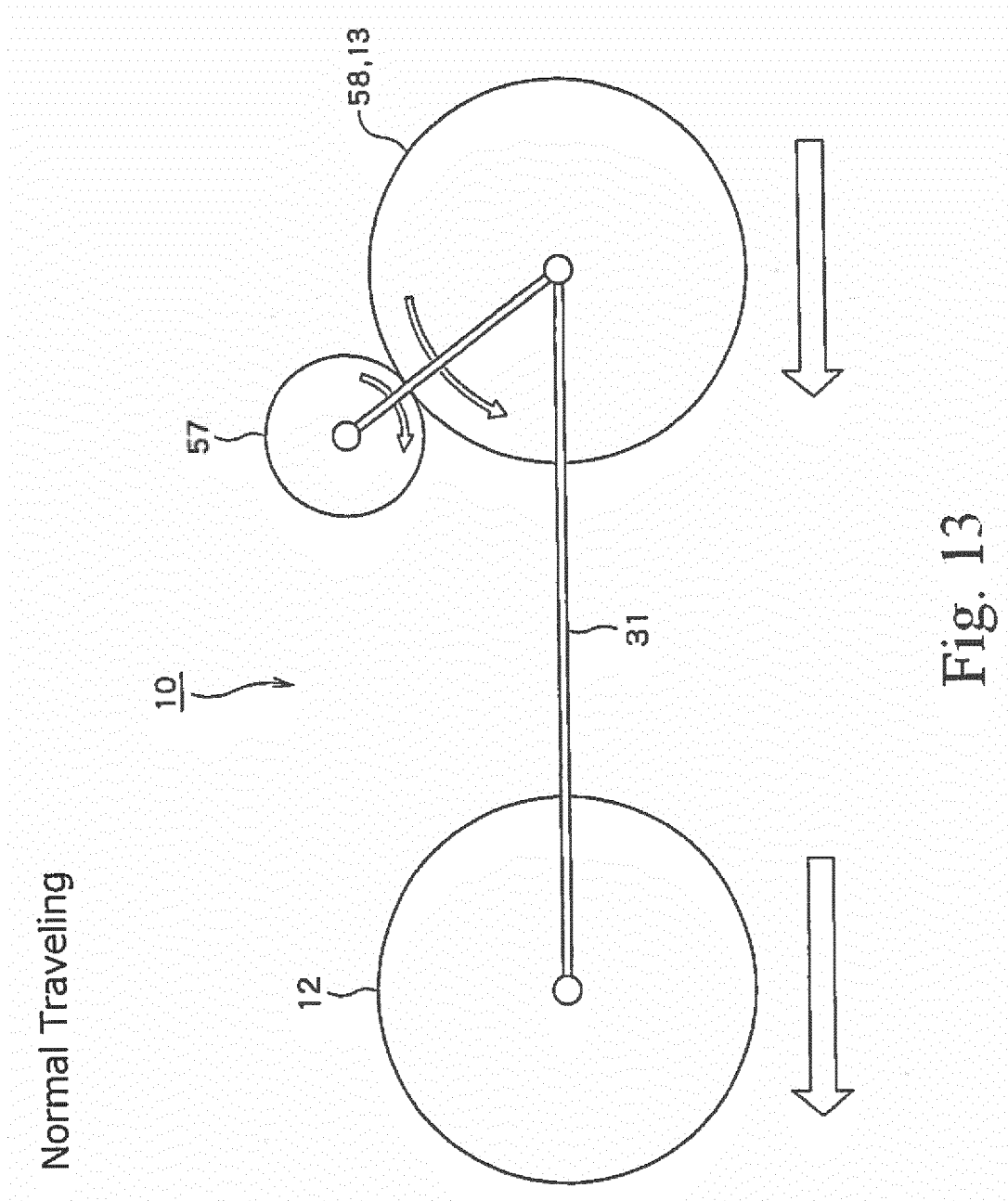
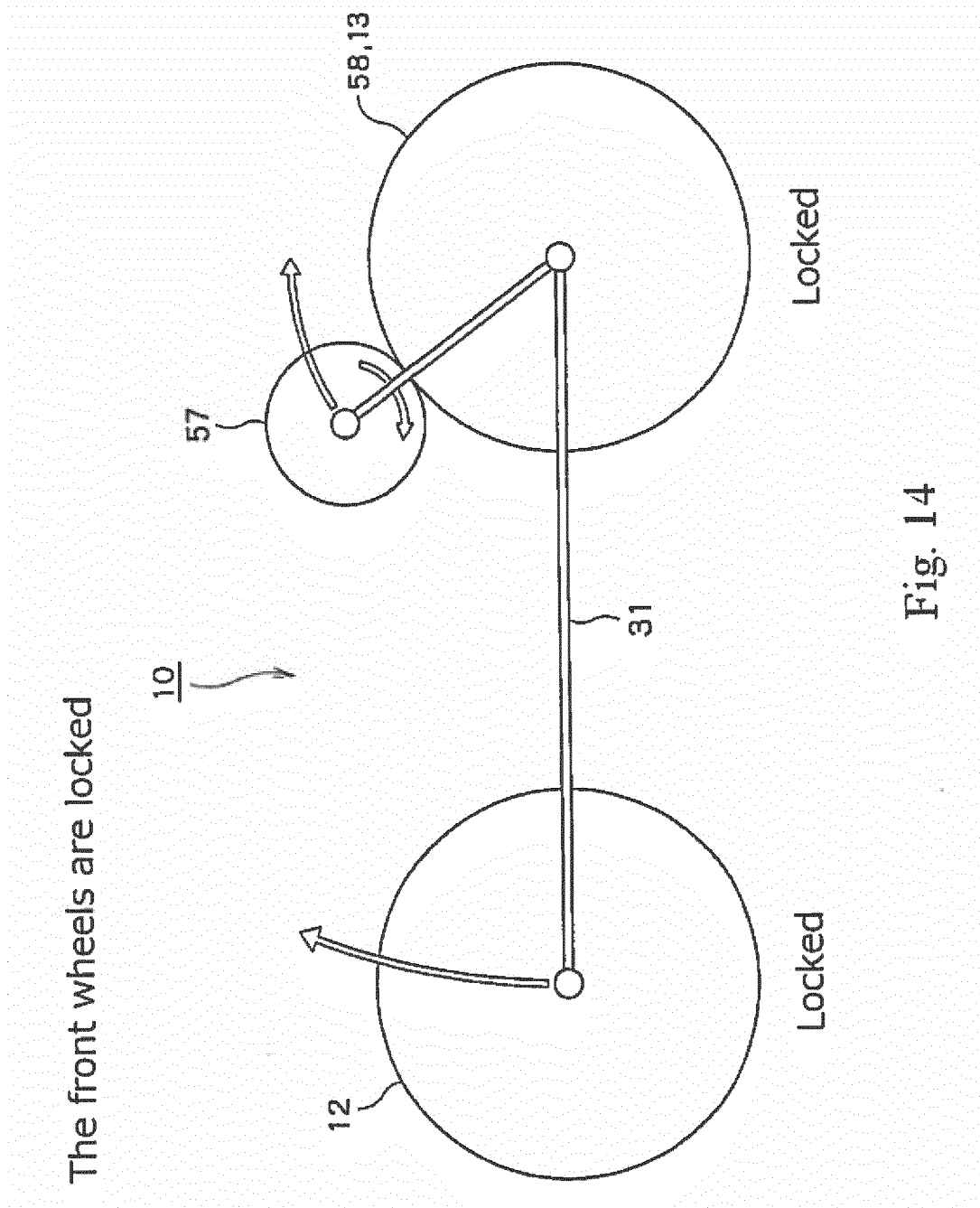
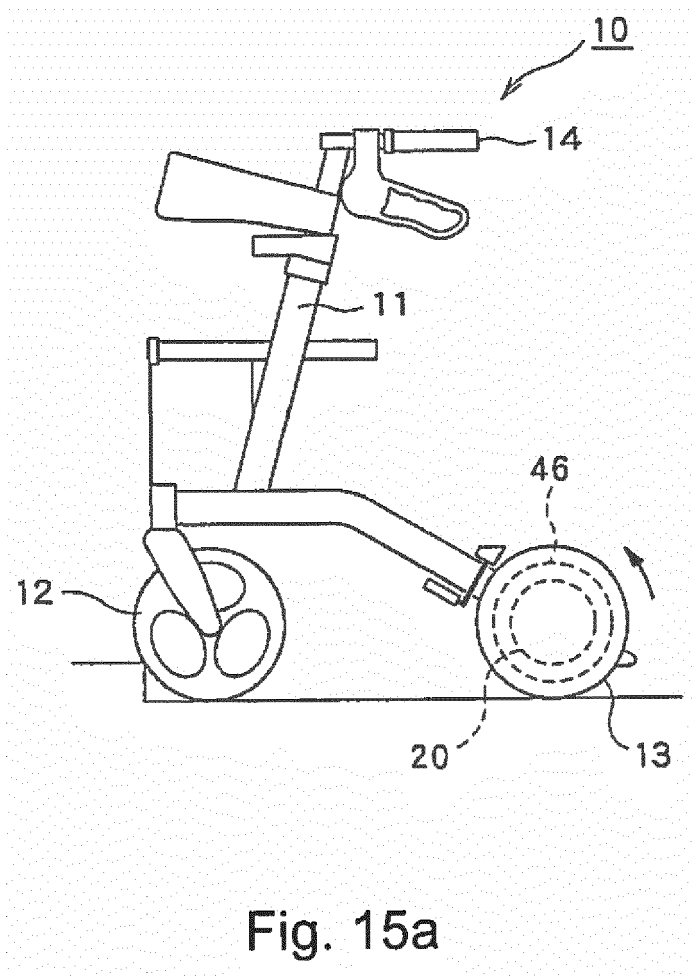


Fig. 11









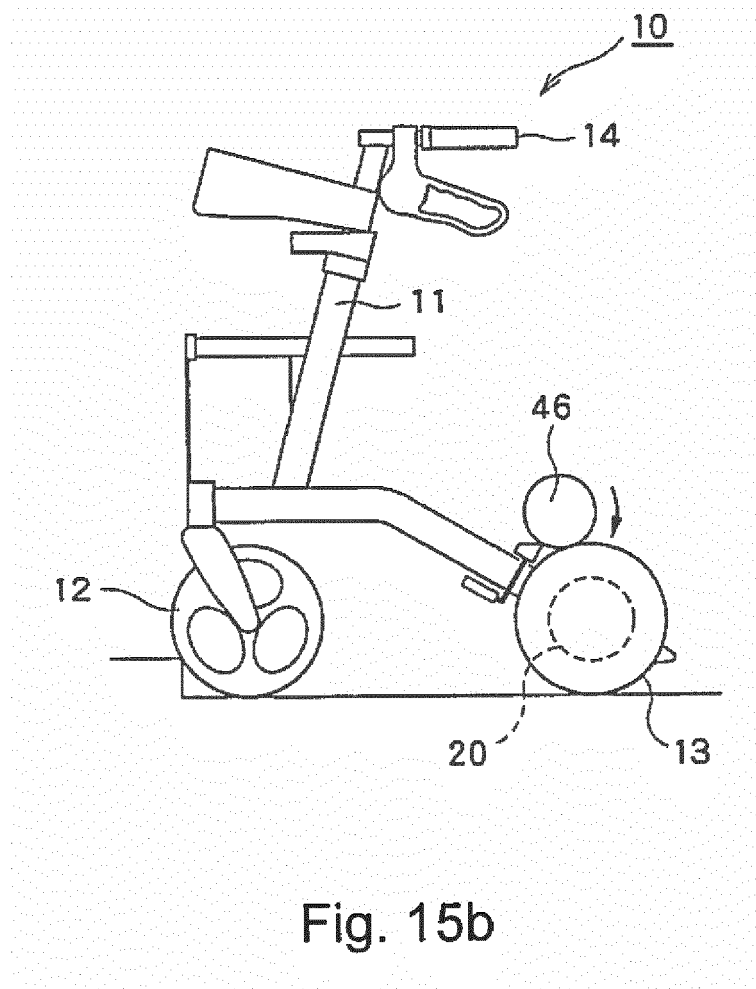


Fig. 15b

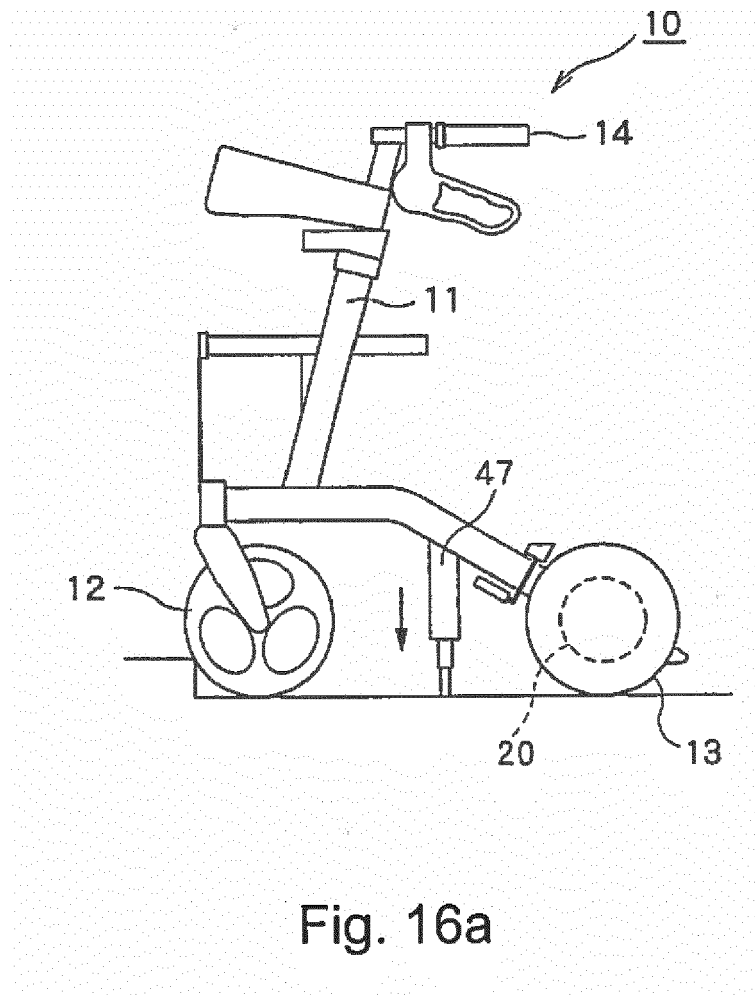
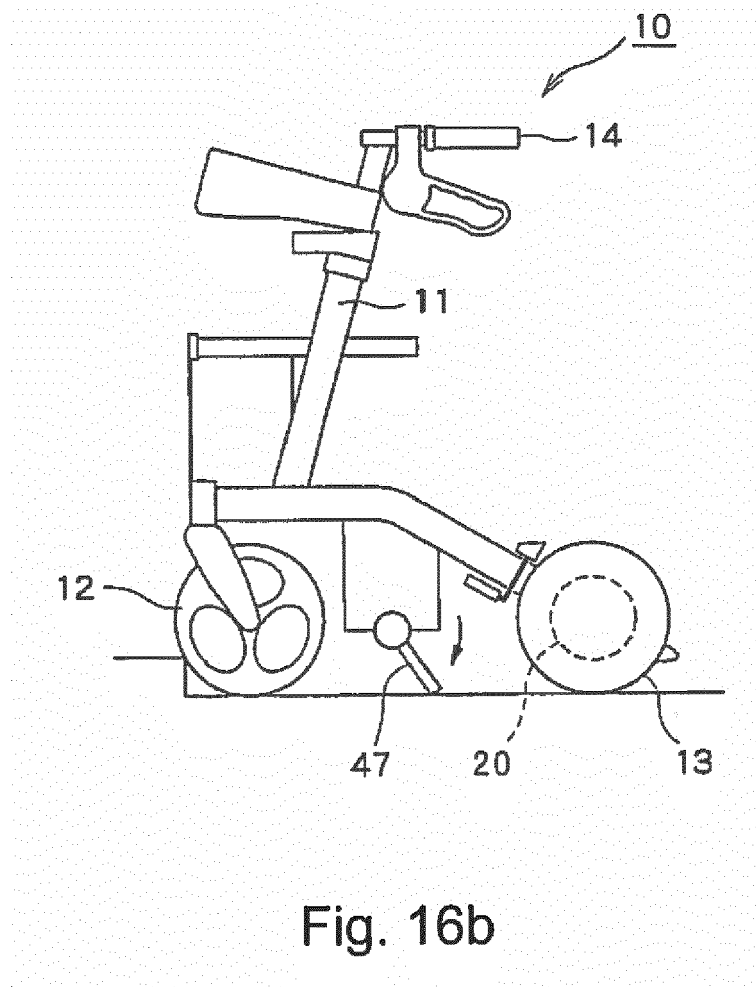


Fig. 16a



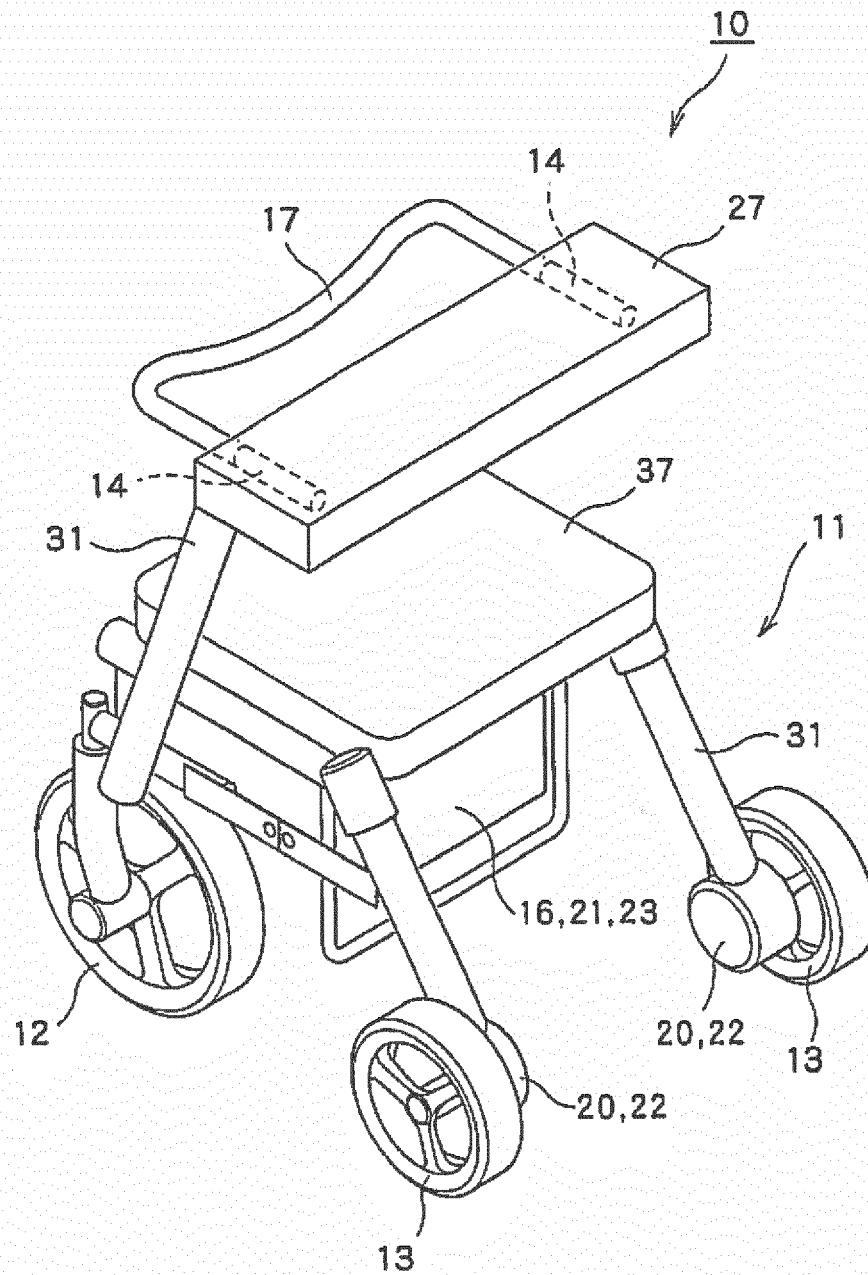


Fig. 17

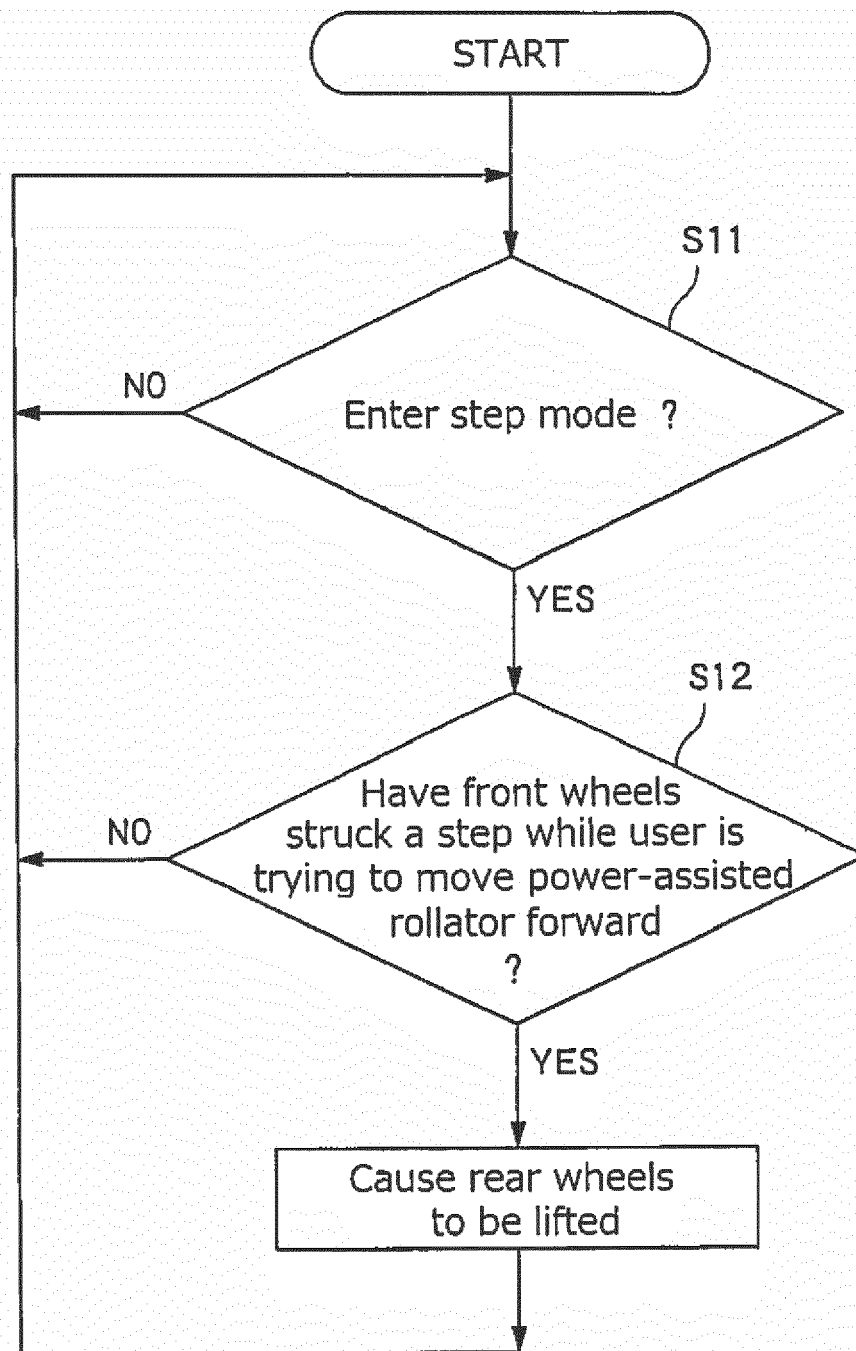


Fig. 18



EUROPEAN SEARCH REPORT

Application Number
EP 17 15 6208

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			A61H A61G
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 22 June 2017	Examiner Turmo, Robert
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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