

[DESCRIPTION]

[Title of Invention]

POWER-ASSISTED CART AND METHOD FOR CONTROLLING
POWER-ASSISTED CART

5 [Technical Field]

[0001]

The present invention relates to a power-assisted cart which controls a motor based on a force applied to a handlebar, and moves using power provided from the motor.

10 [Background Art]

[0002]

Barrows and carts are used as transportation carts for transporting heavy loads. In order to manually move a transportation cart, exhausting labor is required of its user. Hence, to overcome the problem, power-assisted carts have been suggested. A power-assisted cart is a transportation cart having a motor, and moves using power provided from the motor based on a force applied by a user to the handlebar of the cart.

[0003]

20 When the user pushes the handlebar of the power-assisted cart to walk, the motor generates assisting power for assisting a propelling force applied to the power-assisted cart by the user through the handlebar. Taking advantage of the assistance by the assisting power for the moving, the user can move the power-assisted cart with a little force.

[0004]

FIG. 8 shows a side view of a conventional power-assisted cart 1. The power-assisted cart 1 includes a cart main body 2, a handlebar 3, a motor 4a, a control unit 4b for controlling the motor 4a, and a wheel 5 driven by the motor 4a. Moreover, an operation input sensor 6, which is a part of the handlebar 3, includes: a sliding input unit 7 which is slidable back and forth with respect to its original position; and a spring 8 which urges the sliding input unit 7 into the original position. Since urged into the original position by

the spring 8, the sliding input unit 7 always returns to the original position.

[0005]

When the user walks, pushing the operation input sensor 6, the operation input sensor 6 detects, as an operating amount, a sliding amount of the sliding input unit 7 that is pushed and slides from the original position. The control unit 4b controls the state of an output from the motor 4a in proportion to the magnitude of the operating amount.

10 [0006]

Here, the control unit 4b calculates an input data value based on the operating amount detected by the operation input sensor 6. Next, the control unit 4b multiplies the input data value by a proportionality constant to obtain an output data value. Then, based on the output data value, the control unit 4b controls the speed of the motor 4a.

[0007]

It is noted that in the case where the sliding input unit 7 slides forward of the original position (on the left in FIG. 8), the operation input sensor 6 detects the input data value as a positive value. When the operation input sensor 6 detects the input data value as the positive value, the motor 4a generates assisting power for moving the power-assisted cart 1 forward. It is noted that in the case where the sliding input unit 7 slides backward of the original position, the operation input sensor 6 detects the input data value as a negative value. When the operation input sensor 6 detects the input data value as the negative value, the motor 4a generates assisting power for moving the power-assisted cart 1 backward (See Patent Literature 1, for example).

30 [0008]

Hence, the power-assisted cart 1 reduces the labor of the user moving the cart.

[Citation List]

[Patent Literature]

[0009]

[PTL 1]

Japanese Unexamined Patent Application Publication No.
2005-75043

5 [Summary of Invention]

[Technical Problem]

[0010]

When the user uses the power-assisted cart 1 just like a
manual transportation cart, the user pushes the handlebar 3 forward.

10 The conventional power-assisted cart 1, however, controls the state
of an output from the motor 4a in proportion to the operating amount
detected by the operation input sensor 6. Hence, when the
handlebar 3 of the power-assisted cart 1 is pushed forward and then
suddenly pulled backward, the motor 4a is controlled to reverse.

15 The reverse control inevitably causes the motor 4a to generate
assisting power in the opposite direction of the moving direction of
the power-assisted cart 1. When the assisting power is suddenly
generated in the opposite direction of the moving direction of the
power-assisted cart 1, the power-assisted cart 1 loses its stability.

20 When the power-assisted cart 1 loses its stability, the user might fall
down.

[0011]

In other words, the conventional power-assisted cart 1 has a
problem of losing its stability when the user moves the handlebar 3 in
25 the opposite direction of the motion of the cart, as if he or she were
moving a manual transportation cart.

[0012]

The present invention is conceived in view of the above
problems and aims to provide a power-assisted cart which a user can
30 operate just like a manual transportation cart.

[Solution to Problem]

[0013]

In order to achieve the above aims, a power-assisted cart of
the present invention includes: a cart main body; a handlebar which

is provided to the cart main body; a speed sensor which detects a moving speed and a moving direction of the cart main body; a force detecting unit configured to detect a magnitude and a direction of an operating force which is applied to the handlebar with respect to the moving direction of the cart main body; a driving source which moves the cart main body; a target speed generating unit configured to generate a target speed based on the magnitude of the operating force and the moving speed; and a control unit configured to control the driving source based on the target speed, wherein the target speed generating unit is configured to generate the target speed to be (i) faster than the moving speed in the case where the moving direction and the direction of the operating force are same, and (ii) slower than the moving speed in the case where the moving direction and the direction of the operating force are opposite.

[0014]

Moreover, in order to achieve the above aims, a method for controlling a power-assisted cart including a cart main body, a handlebar which is provided to the cart main body, a speed sensor which detects a moving speed and a moving direction of the cart main body, and a force detecting unit configured to detect a magnitude and a direction of an operating force which is applied to the handlebar with respect to the moving direction of the cart main body. The method includes: generating the target speed to be (i) faster than the moving speed in the case where the moving direction and the direction of the operating force are same, and (ii) slower than the moving speed in the case where the moving direction and the direction of the operating force are opposite, and moving the cart main body based on the target speed.

[Advantageous Effects of Invention]

[0015]

The present invention can provide a power-assisted cart which allows a user to operate just like a manual transportation cart, and a method for controlling the power-assisted cart.

[Brief Description of Drawings]

[0016]

[Fig. 1A]

FIG. 1A shows a perspective view of a power-assisted cart according to Embodiment 1 of the present invention.

5 [Fig. 1B]

FIG. 1B shows a block diagram of the power-assisted cart according to Embodiment 1 of the present invention.

[Fig. 2]

FIG. 2 shows a perspective view of the power-assisted cart
10 coupled with a trailer according to Embodiment 1.

[Fig. 3]

FIG. 3 depicts a flowchart showing how to generate a target speed in Embodiment 1.

[Fig. 4]

15 FIG. 4 shows a block diagram of a power-assisted cart according to Embodiment 2 of the present invention.

[Fig. 5]

FIG. 5 depicts a first flowchart showing how to generate a target speed in Embodiment 2.

20 [Fig. 6]

FIG. 6 depicts a second flowchart showing how to generate the target speed in Embodiment 2.

[Fig. 7]

FIG. 7 shows a block diagram of a power-assisted cart
25 according to Embodiment 3 of the present invention.

[Fig. 8]

FIG. 8 is a side view of a conventional power-assisted cart.

[Description of Embodiments]

30 [0017]

Hereinafter, embodiments of the present invention shall be described with reference to the drawings. It is noted that identical constitutional elements share the same reference sign, and the details of such elements may be omitted. For the sake of

convenience, a drawing schematically and mainly shows each of the constitutional elements. Moreover, each of the embodiments described below is a specific example of the present invention. The constitutional elements, arrangement positions of the constitutional elements, steps, and an order of the steps all described in the

[0018]

[Embodiment 1]

FIG. 1A shows a perspective view of a power-assisted cart 10 according to Embodiment 1 of the present invention. FIG. 1B shows a block diagram of the power-assisted cart 10 according to Embodiment 1 of the present invention. In FIG. 1A, arrows A and B respectively show the forward and backward directions of the power-assisted cart 10.

[0019]

The power-assisted cart 10 includes a cart main body 12, a wheel 18, a sub wheel 19, a handlebar 11, an operating force detecting unit 13, a motor 14, a speed sensor 15, and a control unit 41. The control unit 41 includes a target speed generating unit 16 and a motor control unit 17. The wheel 18 supports the cart main body 12 from under the cart main body 12. The wheel 18 is driven by the motor 14 to move the cart main body 12, using a friction force acting on the ground. The handlebar 11 is provided to the cart main body 12 and receives an operation from the user. The operating force detecting unit 13 detects, as an operating force $S(t)$, the magnitude of an operating force applied to the handlebar 11. The motor 14 is a driving source to drive the wheel 18. The speed sensor 15 detects the moving speed $K(t)$ of the power-assisted cart 10. The target speed generating unit 16 generates a target speed $M(t)$ based on the operation of the user, and transmits the target speed $M(t)$. The motor control unit 17 controls the motor 14 based on the target speed $M(t)$ transmitted from the target speed generating unit 16. Here, the "target speed $M(t)$ " is the speed of the power-assisted cart 10 that the user desires to achieve when the user is applying the

operating force $S(t)$ to the handlebar 11.

[0020]

The handlebar 11 has a spring (not shown) provided to its base. When the user does not apply the operating force $S(t)$ to the handlebar 11, the spring provided to the base of the handlebar 11 allows the handlebar 11 to be positioned at the neutral position shown in FIG. 1A.

[0021]

Through a magnetostrictive sensor attached to the handlebar 11, the operating force detecting unit 13 detects, as the operating force $S(t)$, an operating force applied by the user to the handlebar 11. The speed sensor 15 detects the rotation speed of a rotating shaft of the motor 14, using an encoder attached to the rotating shaft. Based on the rotation speed of the rotating shaft, the speed sensor 15 calculates the moving speed $K(t)$ of the power-assisted cart 10.

[0022]

It is noted that when the user in front of the power-assisted cart 10 moves the handlebar 11 forward (pulls the handlebar 11 in the direction of the arrow A from the neutral position), the operating force detecting unit 13 detects the operating force $S(t)$ as a positive value. When the user moves the handlebar 11 backward (pushes the handlebar 11 in the direction of the arrow B from the neutral position), the operating force detecting unit 13 detects the operating force $S(t)$ as a negative value. In other words, the operating force detecting unit 13 detects the direction of the operating force applied to the handlebar 11 as a positive operating force $S(t)$ or a negative operating force $S(t)$, as well as detects the magnitude of an operating force applied to the handlebar 11 as the absolute value of the operating force $S(t)$.

[0023]

When the power-assisted cart 10 is moving forward, the speed sensor 15 detects the moving speed $K(t)$ as a positive value. When the power-assisted cart 10 is moving backward, the speed sensor 15 detects the moving speed $K(t)$ as a negative value. In other words,

the speed sensor 15 detects a direction in which the power-assisted cart 10 (the cart main body 12) is moving, as well as detects the absolute value of the moving speed $K(t)$.

[0024]

5 The moving speed $K(t)$ of the power-assisted cart 10 can be calculated based on the rotation speed of the rotating shaft of the motor 14. This is because the motor 14 and the wheel 18 rotate together via a reducer, so that the moving speed and the rotation speed are proportional to each other.

10 [0025]

 Then, based on the operating force $S(t)$ detected by the operating force detecting unit 13, the target speed generating unit 16 generates the target speed $M(t)$. Here, the current speed of the power-assisted cart 10 affects the calculation by the target speed
15 generating unit 16 of the target speed $M(t)$. Hence, the target speed $M(t)$ is calculated based on the moving speed $K(t)$ detected by the speed sensor 15 and the operating force $S(t)$.

[0026]

 Suppose the power-assisted cart 10 is moving forward
20 (moving in the direction of the arrow A). When the power-assisted cart 10 is moving forward and the operating force detecting unit 13 detects the positive operating force $S(t)$, the target speed generating unit 16 generates a target speed $M(t)$ which is faster than the moving speed $K(t)$ detected by the speed sensor 15. When the
25 power-assisted cart 10 is moving forward and the operating force detecting unit 13 detects the negative operating force $S(t)$, the target speed generating unit 16 generates a target speed $M(t)$ which is slower than the moving speed $K(t)$ detected by the speed sensor 15. The target speed $M(t)$ is calculated based on the following
30 Expressions 1 and 2:

[0027]

$$I(t) = S(t) \times A \quad (\text{Expression 1})$$

$$M(t) = K(t) + I(t) \quad (\text{Expression 2})$$

[0028]

Here, $I(t)$ is a power-assisted speed and A is a power-assist coefficient.

[0029]

It is noted that the power-assisted speed $I(t)$ is the speed of the power-assisted cart 10 moved by the assisting power. Here, the assisting power is provided to the power-assisted cart 10 when the motor 14 rotates. Moreover, the power-assist coefficient A is a predetermined coefficient to be used for converting the operating force $S(t)$ to the power-assisted speed $I(t)$. The power-assisted speed $I(t)$ is a variable number, and the power-assist coefficient A is a constant number.

[0030]

The control unit 41 of the power-assisted cart 10 in FIG. 1B compares the moving speed $K(t)$ detected by the speed sensor 15 with the target speed $M(t)$ calculated by the target speed generating unit 16. Along with the comparison, the control unit 41 causes the motor control unit 17 to control the rotation of the motor 14 so that a prospective moving speed $K(t + 1)$ approaches the target speed $M(t)$. As a result of the control, the moving speed $K(t)$ of the power-assisted cart 10 gradually approaches the target speed $M(t)$.

[0031]

Suppose the case where the user stands in front of the power-assisted cart 10 and walks, pulling the handlebar 11 in the direction of the arrow A. Here, the target speed $M(t)$ of the power-assisted cart 10 is set faster than the moving speed $K(t)$ of the power-assisted cart 10. The motor 14 is controlled to gradually increase the moving speed $K(t)$ so that the moving speed $K(t)$ approaches the target speed $M(t)$.

[0032]

In contrast, suppose the case where the user in front of the power-assisted cart 10 is walking forward and pushing the handlebar 11 in the direction of the arrow B. Here, the target speed $M(t)$ of the power-assisted cart 10 is set slower than the moving speed $K(t)$ of the power-assisted cart 10. The motor 14 is controlled to gradually

decrease the moving speed $K(t)$ so that the moving speed $K(t)$ approaches the target speed $M(t)$.

[0033]

Hence, in Embodiment 1, even though the handlebar 11 is
5 moved in the opposite direction of the moving direction of the
power-assisted cart 10, the assisting power is not suddenly provided
in the opposite direction of the moving direction. Instead, the
assisting power provided in the moving direction gradually decreases.
Hence, the user can use the power-assisted cart 10 according to
10 Embodiment 1 just like a manual transportation cart especially when
he or she desires to suddenly reverse the moving direction of the
power-assisted cart 10.

[0034]

Here, the power-assisted cart 10 according to Embodiment 1
15 decelerates based on the moving speed $K(t)$ when the user, pulling
the handlebar 11 in the direction of the arrow A, suddenly pushes the
handlebar 11 in the direction of the arrow B. Hence, even though
the user suddenly pushes back the handlebar 11 while pulling the
handlebar 11, the motor 14 will not reverse. Thus, even though the
20 user suddenly pushes back the handlebar 11 while pulling the
handlebar 11, the power-assisted cart 10 will not lose its stability.

[0035]

Next, suppose the case where the power-assisted cart 10 is
moving backward (the case where the power-assisted cart 10 is
25 moving in the direction of the arrow B). When the operating force
detecting unit 13 detects a positive operating force $S(t)$ while the
power-assisted cart 10 is moving backward, the target speed
generating unit 16 generates a target speed $M(t)$ which is slower
than the moving speed $K(t)$ detected by the speed sensor 15. When
30 the operating force detecting unit 13 detects a negative operating
force $S(t)$ while the power-assisted cart 10 is moving backward, the
target speed generating unit 16 generates a target speed $M(t)$ which
is faster than the moving speed $K(t)$ detected by the speed sensor 15.
It is noted that the operating force $S(t)$ is a positive value when the

handlebar 11 is moved forward from the neutral position (in the direction of the arrow A). The operating force $S(t)$ is a negative value when the handlebar 11 is moved backward from the neutral position (in the direction of the arrow B).

5 [0036]

Hence, when moving backward, the power-assisted cart 10 according to Embodiment 1 can change the moving speed $K(t)$ just like a manual transportation cart. Consequently, the user can operate the power-assisted cart 10 as if he or she were using a manual transportation cart.

10 [0037]

It is noted that the power-assisted cart 10 according to Embodiment 1 is supported by the wheel 18 and the sub wheel 19. Hence, the power-assisted cart 10 can be moved alone without coupling with a trailer.

15 [0038]

FIG. 2 shows a perspective view of the power-assisted cart 10 coupled with a trailer 21. A trailer wheel 21a is attached to the lower side of the trailer 21. The trailer 21 does not include any driving units to rotate the trailer wheel 21a. In order to move the trailer 21, the user couples the trailer 21 to the power-assisted cart 10, and moves the trailer 21 by the power of the power-assisted cart 10. Just like a manual transportation cart, the user pulls and pushes the handlebar 11 of the power-assisted cart 10 according to Embodiment 1 to use the assisting power of the power-assisted cart 10.

20 [0039]

Described next is how to generate the target speed $M(t)$ with reference to a flowchart. FIG. 3 depicts a flowchart showing how to generate the target speed $M(t)$ of the target speed generating unit 16.

30 [0040]

First, the target speed generating unit 16 obtains the moving speed $K(t)$ of the power-assisted cart 10 through the speed sensor 15

(Step S01). Then, the target speed generating unit 16 obtains the operating force $S(t)$ applied to the handlebar 11 and detected by the operating force detecting unit 13 (Step S02). In Step S02, the operating force $S(t)$ is (i) a positive value (in other words, $S(t) > 0$) when the handlebar 11 moves forward (the handlebar 11 is pulled),
5 (ii) 0 (in other words, $S(t) = 0$) when the handlebar 11 is at the neutral position (the handlebar 11 does not move), and (iii) a negative value (in other words, $S(t) < 0$) when the handlebar 11 moves backward (the handlebar 11 is pushed).

10 [0041]

Then, using the above Expression 1, the target speed generating unit 16 multiplies the operating force $S(t)$ by the power-assist coefficient A , and obtains the power-assisted speed $I(t)$ for increasing and decreasing the moving speed $K(t)$ of the
15 power-assisted cart 10 (Step S03). In Step S03, the power-assisted speed $I(t)$ is (i) a positive value (in other words, $I(t) > 0$) when the handlebar 11 moves forward, (ii) 0 (in other words, $I(t) = 0$) when the handlebar 11 is at the neutral position, and (iii) a negative value (in other words, $I(t) < 0$) when the handlebar 11 moves backward.

20 [0042]

Then, using the above Expression 2, the target speed generating unit 16 adds the power-assisted speed $I(t)$ to the moving speed $K(t)$ to obtain the target speed $M(t)$ (Step S04). In Step S04, the target speed $M(t)$ is faster than the moving speed $K(t)$ (in other
25 words, the power-assisted cart 10 accelerates) when the handlebar 11 moves forward and the power-assisted speed $I(t)$ is a positive value. The target speed $M(t)$ is equal to the moving speed $K(t)$, when the handlebar 11 is at the neutral position and the power-assisted speed $I(t)$ is 0. The target speed $M(t)$ is slower than
30 the moving speed $K(t)$ (in other words, the power-assisted cart 10 decelerates), when the handlebar 11 moves backwards and the power-assisted speed $I(t)$ is a negative value.

[0043]

Hence, in calculating the target speed $M(t)$, acceleration or

deceleration is made as much as the power-assisted speed $I(t)$ with respect to the moving speed $K(t)$. It is noted that the calculation of the target speed $M(t)$ also includes the case of maintaining the moving speed $K(t)$. Thus, even though the user suddenly reverses the direction in which he or she moves the handlebar 11, the rotation direction of the motor 14 does not reverse. Consequently, the power-assisted cart 10 does not lose its stability. It is noted that in the case where the moving speed $K(t)$ is close to 0, the rotation direction of the motor 14 can reverse. In such a case, however, the power-assisted cart 10 almost stops. Hence, even though the rotation direction of the motor 14 reverses, the power-assisted cart 10 does not lose its stability.

[0044]

Then, the target speed generating unit 16 sends the generated target speed $M(t)$ to the motor control unit 17 (Step S05).

[0045]

Hence, the target speed generating unit 16 repeats Step S01 through Step S05 to generate the target speed $M(t)$ based on the operating force $S(t)$ applied to the handlebar 11 and the moving speed $K(t)$. Then, the target speed generating unit 16 transmits the generated target speed $M(t)$.

[0046]

Next, the motor control unit 17 receives the target speed $M(t)$ transmitted from the target speed generating unit 16. Then, the motor control unit 17 controls the motor 14 so that the moving speed $K(t)$ of the power-assisted cart 10 approaches the target speed $M(t)$.

[0047]

In the case where the user moves the handlebar 11 forward (in the direction of the arrow A) when the power-assisted cart 10 is moving forward (in the direction of the arrow A), the target speed $M(t)$ is generated to be faster than the moving speed $K(t)$. Since the motor 14 is controlled to generate the target speed $M(t)$ to be faster than the moving speed $K(t)$, the power-assisted cart 10 gradually accelerates. In the case where the user moves the handlebar 11

backward (in the direction of the arrow B) when the power-assisted cart 10 is moving forward, the target speed $M(t)$ is generated to be slower than the moving speed $K(t)$. Since the motor 14 is controlled to generate the target speed $M(t)$ to be slower than the moving speed
5 $K(t)$, the power-assisted cart 10 gradually decelerates.

[0048]

In addition, in the case where the user moves the handlebar 11 forward (in the direction of the arrow A) when the power-assisted cart 10 is moving backward (in the direction of the arrow B), the
10 target speed $M(t)$ is generated to be slower than the moving speed $K(t)$. Since the motor 14 is controlled to generate the target speed $M(t)$ to be slower than the moving speed $K(t)$, the power-assisted cart 10 gradually decelerates. In the case where the user moves the handlebar 11 backward (in the direction of the arrow B) when the
15 power-assisted cart 10 is moving backward, the target speed $M(t)$ is generated to be faster than the moving speed $K(t)$. Since the motor 14 is controlled to generate the target speed $M(t)$ to be faster than the moving speed $K(t)$, the power-assisted cart 10 gradually accelerates.

20 [0049]

It is noted that when the handlebar 11 is at the neutral position and the operating force is 0 ($S(t) = 0$), the target speed $M(t)$ is equal to the moving speed $K(t)$. In other words, the motor 14 is controlled not to decelerate by itself and to maintain the moving
25 speed $K(t)$.

[0050]

Hence, in Embodiment 1, the power-assisted cart 10 can increase or decrease its moving speed $K(t)$ based on the operating force $S(t)$ applied to the handlebar 11. Thus, the user can operate
30 the power-assisted cart 10 as if he or she were using a manual transportation cart. Moreover, the power-assisted cart 10 according to Embodiment 1 is free from the loss of its stability caused by the reverse of the motor 14, even though the user suddenly moves the handlebar 11 in the opposite direction.

[0051]

In the above description, the following cases are subject to the same condition: the case where the moving direction of the power-assisted cart 10 and the direction of the operating force applied to the handlebar 11 are the same; and the case where the moving direction of the power-assisted cart 10 and the direction of the operating force applied to the handlebar 11 are opposite. In the case where the moving direction is opposite the direction of the operating force, however, the user is likely to feel uncomfortable with the case. Hence, in the power-assisted cart 10 according to Embodiment 1, a power-assist coefficient, that is used when the moving direction and the direction of the operating force are opposite, may preferably be set larger than a power-assist coefficient used when the moving direction and the direction of the operating force are the same. Hence, when the moving direction and the direction of the operating force are opposite, the power-assisted cart 10 may improve its reactivity by setting the power-assist coefficient, that is used when the moving direction and the direction of the operating force are opposite, larger than the power-assist coefficient that is used when the moving direction and the direction of the operating force are the same.

[0052]

Embodiment 2

FIG. 4 shows a block diagram of a power-assisted cart 20 according to Embodiment 2 of the present invention. The power-assisted cart 20 according to Embodiment 2 differs from the power-assisted cart 10 according to Embodiment 1 in that the power-assisted cart 20 has a control unit 42 instead of the control unit 41. The control unit 42 includes a target speed generating unit 26 and the motor control unit 17. The target speed generating unit 26 according to Embodiment 2 includes a power-assist reducing unit 27, an insensible region generating unit 28, and an acceleration and deceleration limiting unit 29. The power-assist reducing unit 27 reduces the moving speed $K(t)$ of the power-assisted cart 20 slower

than or equal to the walking speed of the user moving the power-assisted cart 20. Here, the "walking speed of the user moving the power assisted cart 20" is a walking speed to be set for each power-assisted cart 20, as well as an appropriate walking speed for the user to move the power-assisted cart 20. The insensible region generating unit 28 sets a play (allowance between parts) for the handlebar 11. The acceleration and deceleration limiting unit 29 prevents a target speed $M(t)$ from changing suddenly in the case where there is a temporal and sudden increase or decrease in moving speed due to an external factor. The acceleration and deceleration limiting unit 29 is used for generating the target speed $M(t)$ so that the power-assisted cart 20 can safely move.

[0053]

Suppose the case where the moving speed $K(t)$ of the power-assisted cart 20 reaches the fastest walking speed of the user. It is noted that the "fastest walking speed" is the maximum value of the walking speed of the user moving the power assisted cart 20. Hence, the fastest walking speed can be faster than the current walking speed of the user moving the power assisted cart 20. Here, even though the user relaxes a force applied to the handlebar 11, already-working assisting power has provided acceleration to the power-assisted cart 20. Thus, the moving speed $K(t)$ of the power-assisted cart 20 can be significantly faster than the walking speed of the user moving the power assisted cart 20. Consequently, the user could be pulled or pushed by the power-assisted cart 20.

[0054]

First, the target speed generating unit 26 according to Embodiment 2 obtains the target speed $M(t)$ by adding the power-assisted speed $I(t)$ to the moving speed $K(t)$. It is noted that the power-assisted speed $I(t)$ is obtained by multiplying an operating force $S(t)$ detected by the operating force detecting unit 13 by a power-assist coefficient A . The moving speed $K(t)$ is detected by the speed sensor 15. Here, in the case where the moving speed $K(t)$ is faster than a power-assist deceleration constant GS (speed

reference value), the target speed generating unit 26 multiplies the power-assisted speed $I(t)$ by a power-assist reduction rate $G(t)$ to obtain the target speed $M(t)$.

[0055]

5 It is noted that the power-assist deceleration constant GS is used to select, based on an operating force applied to the handlebar 11, an expression for calculating a power-assisted speed, so that generation of excessive assisting power is prevented when the power-assisted cart 20 started to move fast. The power-assist
10 deceleration constant GS is a threshold value to determine whether the power-assisted cart 20 is moving fast or slow. The power-assist deceleration constant GS is set for each power-assisted cart 20.

[0056]

 Thanks to the power-assist reducing unit 27 in the target
15 speed generating unit 26, the power-assisted cart 20 according to Embodiment 2 can reduce an increase in the moving speed $K(t)$ of the power-assisted cart 20, using the after-described power-assist reduction rate $G(t)$. The power-assist deceleration constant GS is set slightly slower than the walking speed of the user moving the
20 power assisted cart 20, so that, when the moving speed $K(t)$ of the power-assisted cart 20 approaches the walking speed of the user moving the power assisted cart 20, the moving speed $K(t)$ is controlled to gradually increase even though the operating force $S(t)$ is large.

25 [0057]

 Furthermore, the user usually holds the handlebar 11 when he or she is moving the power-assisted cart 20. Hence, in order to prevent excessively sensitive detection of a force applied to the handlebar 11, the handlebar 11 has to have a play (allowance
30 between parts). Here, the play for the handlebar 11 is a space to provide an allowance of an operating area in which a slight move of the handlebar 11 does not cause any reactions. Instead of providing a play to the handlebar 11, the power-assisted cart 20 according to Embodiment 2 has an insensible region threshold value F generated

by the insensible region generating unit 28. Here, in the case where the absolute value of the operating force $S(t)$ is smaller than the insensible region threshold value F , the target speed generating unit 26 generates a target speed, determining that the operating force $S(t)$ is 0. In other words, the target speed generating unit 26 generates the current moving speed as the target speed even though the magnitude of the operating force $S(t)$ changes within the range of the insensible region threshold value F . It is noted that the insensible region threshold value F is a slight force when the operating force $S(t)$ is 0 or close to 0. In Embodiment 2, the insensible region generating unit 28 generates an insensitive region whose threshold value is the insensible region threshold value F . Such an insensitive region acts as a play (allowance between parts) for the handlebar 11. This feature prevents the power-assisted cart 20 from malfunctioning due to an excessively sensitive reaction.

[0058]

Moreover, the target speed generating unit 26 causes the acceleration and deceleration limiting unit 29 to limit the target speed $M(t)$ calculated based on the operating force $S(t)$ and the moving speed $K(t)$. Specifically, in the case where the target speed $M(t)$ suddenly becomes faster than a previous target speed $M(t - 1)$ which was previously calculated by an acceleration and deceleration limitation speed KG or faster, the acceleration and deceleration limiting unit 29 sets the sum of the previous target speed $M(t - 1)$ and the acceleration and deceleration limitation speed KG for the target speed $M(t)$ to be sent to the motor control unit 17. In the case where the target speed $M(t)$ suddenly becomes slower than the previous target speed $M(t - 1)$ by the acceleration and deceleration limitation speed KG or slower, the acceleration and deceleration limiting unit 29 sets a value, obtained by subtracting the acceleration and deceleration limitation speed KG from the target speed $M(t)$, for the target speed $M(t)$ to be sent to the motor control unit 17. It is noted that the acceleration and deceleration limitation speed KG is a predetermined one.

[0059]

In the case where the moving speed of the power-assisted cart 20 temporarily and suddenly increases or decreases due to, for example, an external factor such as going over a bump, the above feature can prevent a sudden increase or decrease in the target speed of the power-assisted cart 20, so that the power-assisted cart 20 can maintain a steady moving speed. It is noted that the acceleration and deceleration limitation speed K_G is a value to determine whether there is a sudden and temporal increase or decrease in moving speed due to an external factor.

[0060]

Described next is how the target speed generating unit 26, including the power-assist reducing unit 27, the insensible region generating unit 28, and the acceleration and deceleration limiting unit 29, generates the target speed $M(t)$.

[0061]

FIGS. 5 and 6 depict flowcharts showing how to generate the target speed $M(t)$. FIGS. 5 and 6 show how the target speed $M(t)$ is generated when power-assisted cart 20 is moving forward.

20 [0062]

First, the target speed generating unit 26 obtains a moving speed $K(t)$ through the speed sensor 15 (Step S21).

[0063]

Next, the target speed generating unit 26 obtains through the operating force detecting unit 13 an operating force $S(t)$ to which the user has applied to the handlebar 11 (Step S22).

[0064]

Then, the operating force detecting unit 13 determines whether or not the absolute value of the operating force $S(t)$ is greater than or equal to the insensible region threshold value F , so that the operating force detecting unit 13 avoids detecting a slight force applied to the handlebar 11 and thereby causing excessive reaction of the power-assisted cart 20 (Step S23). In the case where the absolute value is greater than or equal to the insensible

region threshold value F (Step S23: Yes), the target speed generating unit 26 obtains the power-assisted speed $I(t)$ ($= S(t) \times A$ (power-assist coefficient) + power-assist offset value) (Step S24). It is noted that the power-assist offset value, which is a
5 predetermined value, is a constant for assisting the start-up of the assisting power. Hence, thanks to the power-assist offset value, the user can easily sense that the assisting power has been generated when the assisting power is generated for the power-assisted cart 20. It is noted that the power-assist offset value is not always necessary.

10 [0065]

Then, when the moving speed $K(t)$ reaches the walking speed of the user moving the power assisted cart 20, the target speed generating unit 26 determines whether or not both the following
15 conditions are met to prevent the user from being pushed by the power-assisted cart 20: The operating force $S(t)$ is a positive value and the moving speed $K(t)$ is greater than or equal to the power-assist deceleration constant GS (Step S25).

[0066]

In the case where the operating force $S(t)$ is a positive value
20 and the moving speed $K(t)$ is greater than or equal to the power-assist deceleration constant GS (Step S25: Yes), the target speed generating unit 26 obtains a power-assist reduction rate $G(t)$ ($= 1 - (K(t) - GS) \times$ power-assist reduction coefficient) to be used for reducing a power-assisted speed $I(t)$ (Step S26). It is noted that
25 the power-assist reduction rate $G(t)$ is calculated to be 0 in Step S26 when $G(t)$ is smaller than or equal to 0.

[0067]

In the case where the operating force $S(t)$ is a negative value or the moving speed $K(t)$ is smaller than or equal to the power-assist
30 deceleration constant GS in Step S25 (Step S25: No), the target speed generating unit 26 determines that the power-assist reduction rate $G(t)$ is 1 (Step S27).

[0068]

After obtaining the power-assist reduction rate $G(t)$ in Step

S26 or Step S27, the target speed generating unit 26 obtains the target speed $M(t)$ ($= K(t) + I(t) \times G(t)$) (Step S28). It is noted that when power-assist reduction rate $G(t)$ is 1 in Step S27, this means that the power-assist reduction rate $G(t)$ is not multiplied in Step

[0069]

In the case where the operating force $S(t)$ is a positive value and the moving speed $K(t)$ is greater than or equal to the power-assist deceleration constant GS (Step S25: Yes), the moving speed $K(t)$ of the power-assisted cart 20 is close to the walking speed of the user moving the power assisted cart 20. In Embodiment 2, the target speed generating unit 26 limits the acceleration of the power-assisted cart 20 when the user pulls the handlebar 11, so that the target speed generating unit 26 avoids an excessive increase in the moving speed $K(t)$. Specifically, when the moving speed $K(t)$ is greater than or equal to the power-assist deceleration constant GS , the target speed generating unit 26 sets the power-assist reduction rate $G(t)$ for smaller than 1 to limit the acceleration of the power-assisted cart 20. Hence, the target speed generating unit 26 avoids an excessive increase in the moving speed $K(t)$.

[0070]

Then, as shown in FIG. 6, the acceleration and deceleration limiting unit 29 determines whether or not the difference between the target speed $M(t)$ that is calculated in Step S28 and the previous target speed $M(t - 1)$ that was previously calculated is greater than or equal to the acceleration and deceleration limitation speed KG (Step S29).

[0071]

In the case where the difference between the target speed $M(t)$ and the previous target speed $M(t - 1)$ that was previously calculated is greater than or equal to the acceleration and deceleration limitation speed KG (Step S29: Yes), the acceleration and deceleration limiting unit 29 determines that the moving speed $K(t)$ has temporarily and suddenly increased or decreased due to, for

example, an external factor such as going over a bump.

[0072]

Then, in order to determine whether the moving speed $K(t)$ suddenly increased or decreased, the acceleration and deceleration limiting unit 29 compares the magnitude of the target speed $M(t)$ with that of the previous target speed $M(t - 1)$ to determine whether or not the difference between the target speed $M(t)$ and the previous target speed $M(t - 1)$ is greater than or equal to the acceleration and deceleration limitation speed KG (Step S30).

10 [0073]

In the case where the target speed $M(t)$ is faster than the previous target speed $M(t - 1)$ (Step S30: Yes), the target speed generating unit 26 resets for the target speed $M(t)$ the sum of the previous target speed $M(t - 1)$ and the acceleration and deceleration limitation speed KG (Step S31).

15 [0074]

In the case where the target speed $M(t)$ is slower than or equal to the previous target speed $M(t - 1)$ (Step S30: No), the target speed generating unit 26 resets for target speed $M(t)$ the difference obtained by subtracting the acceleration and deceleration limitation speed KG from the previous target speed $M(t - 1)$ (Step S32).

20 [0075]

Then, the target speed generating unit 26 sends to the motor control unit 17 the target speed $M(t)$ that has been reset in Step S31 or Step S32 (Step S33).

25 [0076]

In Step S29, in the case where the difference between the target speed $M(t)$ and the previous target speed $M(t - 1)$ that was previously obtained is within the acceleration and deceleration limitation speed KG (Step S29: No), the target speed generating unit 26 sends to the motor control unit 17 the target speed $M(t)$ obtained in Step S28. The motor control unit 17 controls the motor 14 to make the moving speed $K(t)$ as fast as the target speed $M(t)$.

30 [0077]

[0077]

It is noted that in the case where the absolute value of the operating force $S(t)$ is smaller than the insensible region threshold value F in Step S23 shown in FIG. 5 (Step S23: No), the flow proceeds to Step S34 in FIG. 6. In Step S34, the target speed generating unit 26 sets for the target speed $M(t)$ the difference obtained by subtracting an insensible region deceleration constant from the previous target speed $M(t - 1)$ (Step S34). Hence, when the absolute value of the operating force $S(t)$ is found in a range smaller than the insensible region threshold value F , the target speed generating unit 26 generates the same target speed $M(t)$ regardless of the operating force $S(t)$. Thus, within the operation range of the handlebar 11 in which the operating force $S(t)$ is within the smaller range, the target speed generating unit 26 maintains the current moving speed $K(t)$ without acceleration or deceleration. Such a feature acts as a play (allowance between parts) for the handlebar 11.

[0078]

Moreover, thanks to the calculation of the target speed $M(t)$, the power-assisted cart 20 is controlled, as a manual transportation cart is so, to gradually decelerate when no operating force $S(t)$ is applied thereto. It is noted that in the case where the difference that is obtained by subtracting the insensible region deceleration constant from the previous target speed $M(t - 1)$ is negative, the target speed $M(t)$ is set for 0. Such a feature prevents the power-assisted cart 20 from moving backward when the power-assisted cart 20 stops.

[0079]

Then, the target speed generating unit 26 sends the target speed $M(t)$ obtained in Step S34 to the motor control unit 17 in Step S33. After sending the target speed $M(t)$ to the motor control unit 17 in Step S33, the target speed generating unit 26 calculates again another target speed $M(t)$ in Step S21.

[0080]

As described above, the target speed generating unit 26

repeats Steps S21 through S34 for every 0.01 seconds ($t = 1, 2, 3, \dots$), and generates a target speed $M(t)$ based on an operating force $S(t)$ applied to the handlebar 11 and a moving speed $K(t)$. Furthermore, the target speed generating unit 26 includes the power-assist reducing unit 27, the insensible region generating unit 28, and the acceleration and deceleration limiting unit 29, so that the target speed generating unit 26 can generate the target speed $M(t)$ for safer moving of the power-assisted cart 20.

[0081]

It is noted that the power-assisted cart 20 has the power-assist reducing unit 27 included in the target speed generating unit 26. Thus, when the moving speed $K(t)$ of the power-assisted cart 20 becomes faster than a power-assist deceleration constant GS and approaches the walking speed of the user moving the power assisted cart 20, the power-assist reducing unit 27 reduces the acceleration of the moving speed $K(t)$. Instead of the power-assist reducing unit 27, the target speed generating unit 26 may include a power-assist coefficient changing unit. The power-assist coefficient changing unit increases a power-assist coefficient A when the difference between a moving speed $K(t)$ and a target speed $M(t)$ is great, and decreases the power-assist coefficient A when the difference between the moving speed $K(t)$ and the target speed $M(t)$ is small. When the moving speed $K(t)$ of the power-assisted cart 20 approaches the walking speed of the user moving the power assisted cart 20, the power-assist coefficient changing unit can reduce the difference between the moving speed $K(t)$ and the target speed $M(t)$ without setting, for each operator, a walking speed of the user moving the power assisted cart 20. Hence, instead of the power-assist reducing unit 27, the power-assist coefficient changing unit can also reduce the acceleration of the power-assisted cart 20.

[0082]

Embodiment 3

FIG. 7 shows a block diagram of a power-assisted cart 30

according to Embodiment 3 of the present invention.

[0083]

A comparison between the power-assisted cart 30 according to Embodiment 3 and the power-assisted cart 10 according to Embodiment 1 shows that the power-assisted cart 30 includes a control unit 43 instead of the control unit 41. A receiving unit 34 included in the control unit 43 receives information of weight detected by a weight sensor 32 of a loading platform 31 coupled to the cart main body 12. The control unit 43 further includes the motor control unit 17 and a target speed generating unit 33. The target speed generating unit 33 includes the power-assist reducing unit 27. Then, depending on a load detected by the weight sensor 32, the target speed generating unit 33 changes a power-assist coefficient A and a power-assist deceleration constant GS.

[0084]

For example, when a load placed on the loading platform 31 is heavy, the target speed generating unit 33 increases the power-assist coefficient A so that the power-assisted cart 30 can get quick acceleration. However, as much as the load placed on the loading platform 31 is heavier, the inertia of the loading platform 31 increases when the power-assisted cart 30 is accelerated. This inertia can make the moving speed $K(t)$ of the power-assisted cart 30 faster than the walking speed of the user moving the power assisted cart 30. In order to slow down the moving speed $K(t)$, the target speed generating unit 33 sets the power-assist coefficient A higher when a load placed on the loading platform 31 is heavy, and sets the power-assist deceleration constant GS for a slower speed. Moreover, the target speed generating unit 33 sets the power-assist coefficient A lower when the load on the loading platform 31 is light, and sets the power-assist deceleration constant GS for a faster speed.

[0085]

The above settings allow the power-assisted cart 30 to start moving smoothly, and to reduce the chance of sudden acceleration of the power-assisted cart 30. In other words, the target speed

generating unit 33 controls the target speed $M(t)$, depending how much the load on the loading platform 31 weighs. Consequently, when the load placed on the loading platform 31 is replaced with another one, the target speed generating unit 33 can reduce the chance of the user being pulled and pushed by the power-assisted cart 30.

[0086]

It is noted that in order to prevent unstable movement of the power-assisted cart 30 caused by varying inertia of the loading platform 31, either one of the settings, instead of both the settings, may be employed: The power-assist coefficient A is set greater when a load on the loading platform 31 is heavy; and the power-assist deceleration constant GS is set smaller when a load on the loading platform 31 is heavy. Unstable movement of the power-assisted cart 30 can be prevented by at least one of (i) setting the power-assist coefficient A greater and (ii) setting the power-assist deceleration constant GS smaller, even though utilizing one setting is not as effective as both the settings.

[Industrial Applicability]

[0087]

A power-assisted cart according to an implementation of the present invention can be used just like a manual transportation cart. Hence, the power-assisted cart is effective as a cart for transporting a heavy load.

[Reference Signs List]

[0088]

10, 20, and 30 Power-assisted cart

11 Handlebar

12 Cart main body

13 Operating force detecting unit

14 Motor

15 Speed sensor

16, 26, and 33 Target speed generating unit

17 Motor control unit

	18	Wheel	
	19	Sub wheel	
	21	Trailer	
	21a	Trailer wheel	
5	27	Power-assist reducing unit	
	28	Insensible region generating unit	
	29	Acceleration and deceleration limiting unit	
	31	Trailer	
	32	Weight sensor	
10	41, 42, and 43	Control unit	

[CLAIMS]

[Claim 1]

A power-assisted cart comprising:

a cart main body;

5 a handlebar which is provided to the cart main body;

a speed sensor which detects a moving speed and a moving direction of the cart main body;

10 a force detecting unit configured to detect a magnitude and a direction of an operating force which is applied to the handlebar with respect to the moving direction of the cart main body;

a driving source which moves the cart main body;

a target speed generating unit configured to generate a target speed based on the magnitude of the operating force and the moving speed; and

15 a control unit configured to control the driving source based on the target speed,

wherein the target speed generating unit is configured to generate the target speed to be (i) faster than the moving speed in the case where the moving direction and the direction of the operating force are same, and (ii) slower than the moving speed in the case where the moving direction and the direction of the operating force are opposite.

[Claim 2]

The power-assisted cart according to Claim 1,

25 wherein the target speed generating unit is configured to generate the target speed by adding the moving speed and a power-assisted speed which is obtained by multiplying the magnitude of the operating force by a predetermined power-assist coefficient.

30 [Claim 3]

The power-assisted cart according to Claim 2,

wherein the target speed generating unit is configured to generate the target speed by adding the moving speed, the power-assisted speed, and a predetermined power-assist offset

value.

[Claim 4]

The power-assisted cart according to one of Claims 2 and 3,
wherein, in the case where the moving speed is faster than a
5 predetermined speed reference value, the target speed generating
unit is configured to generate the target speed by multiplying the
power-assisted speed by a power-assist reduction rate and adding a
result of the multiplication and the moving speed, the power-assist
reduction rate being smaller than 1.

10 [Claim 5]

The power-assisted cart according to Claim 4, further
comprising

a receiving unit configured to receive information of a weight
which is detected by a weight sensor of a loading platform that is
15 coupled to the cart main body,

wherein the target speed generating unit is configured to
perform at least one of setting the predetermined power-assist
coefficient higher or setting the speed reference value lower for
higher values of the weight detected by the weight sensor.

20 [Claim 6]

The power-assisted cart according to one of Claims 1 to 5,
wherein, in the case where an absolute value of the magnitude
of the operating force is smaller than a predetermined insensible
region threshold value, the target speed generating unit is
25 configured to generate the target speed with the magnitude of the
operating force set to 0.

[Claim 7]

The power-assisted cart according to one of Claims 1 to 6,
wherein the target speed generating unit is configured to (i)
30 decrease the target speed in the case where the target speed
becomes faster than a previous target speed by a predetermined
acceleration and deceleration limitation speed or faster and (ii)
increase the target speed in the case where the target speed
becomes slower than the previous target speed by the predetermined

acceleration and deceleration limitation speed or slower, the previous target speed being an immediately preceding target speed.

[Claim 8]

5 A method for controlling a power-assisted cart including a cart main body, a handlebar which is provided to the cart main body, a speed sensor which detects a moving speed and a moving direction of the cart main body, and a force detecting unit configured to detect a magnitude and a direction of an operating force which is applied to the handlebar with respect to the moving direction of the cart main
10 body, the method comprising:

generating the target speed to be (i) faster than the moving speed in the case where the moving direction and the direction of the operating force are same, and (ii) slower than the moving speed in the case where the moving direction and the direction of the
15 operating force are opposite; and

moving the cart main body based on the target speed.

[Claim 9]

The method for controlling the power-assisted cart according to Claim 8,

20 wherein, in the generating, the target speed is generated by adding the moving speed and a power-assisted speed which is obtained by multiplying the magnitude of the operating force by a predetermined power-assist coefficient.

[Claim 10]

25 The method for controlling the power-assisted cart according to Claim 9,

wherein, in the generating, the target speed is generated by adding the moving speed, the power-assisted speed, and a predetermined power-assist offset value.

30 [Claim 11]

The method for controlling the power-assisted cart according to one of Claims 9 and 10,

wherein, in the case where the moving speed is faster than a predetermined speed reference value in the generating, the target

speed is generated by multiplying the power-assisted speed by a power-assist reduction rate and adding a result of the multiplication and the moving speed, the power-assist reduction rate being smaller than 1.

5 [Claim 12]

The method for controlling the power-assisted cart according to Claim 11, further comprising

receiving information of a weight which is detected by a weight sensor of a loading platform that is coupled to the cart main body,

10 wherein the target speed generating unit is configured to perform at least one of setting the predetermined power-assist coefficient higher or setting the speed reference value lower for higher values of the weight detected by the weight sensor.

[Claim 13]

15 The method for controlling the power-assisted cart according to any one of Claims 8 to 12,

wherein, in the case where an absolute value of the magnitude of the operating force is smaller than a predetermined insensible region threshold value in the generating, the target speed is
20 generated with the magnitude of the operating force set to 0.

[Claim 14]

The method for controlling the power-assisted cart according to any one of Claims 8 to 13,

25 wherein, in the generating, the target speed is (i) decreased in the case where the target speed becomes faster than a previous target speed by a predetermined acceleration and deceleration limitation speed or faster and (ii) increased in the case where the target speed becomes slower than the previous target speed by the predetermined acceleration and deceleration limitation speed or
30 slower, the previous target speed being an immediately preceding target speed.