US012392191B2

(12) **United States Patent**
**Kaneda et al.**

(10) **Patent No.: US 12,392,191 B2**
(45) **Date of Patent: Aug. 19, 2025**

(54) **DOOR OPENING AND CLOSING ASSISTING APPARATUS**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 184 days.

(21) Appl. No.: **18/174,885**

(22) Filed: **Feb. 27, 2023**

(65) **Prior Publication Data**

US 2023/0287726 A1 Sep. 14, 2023

(30) **Foreign Application Priority Data**

Mar. 10, 2022 (JP) ..... 2022-037199

(51) **Int. Cl.**
***E05F 15/75*** (2015.01)
***E05F 15/622*** (2015.01)

(52) **U.S. Cl.**
CPC ..... ***E05F 15/75*** (2015.01); ***E05F 15/622*** (2015.01); *E05Y 2400/3015* (2024.05);
(Continued)

(58) **Field of Classification Search**
CPC ..... E05F 15/75; E05F 15/622; E05F 15/611; E05F 15/70; E05Y 2400/3015;
(Continued)

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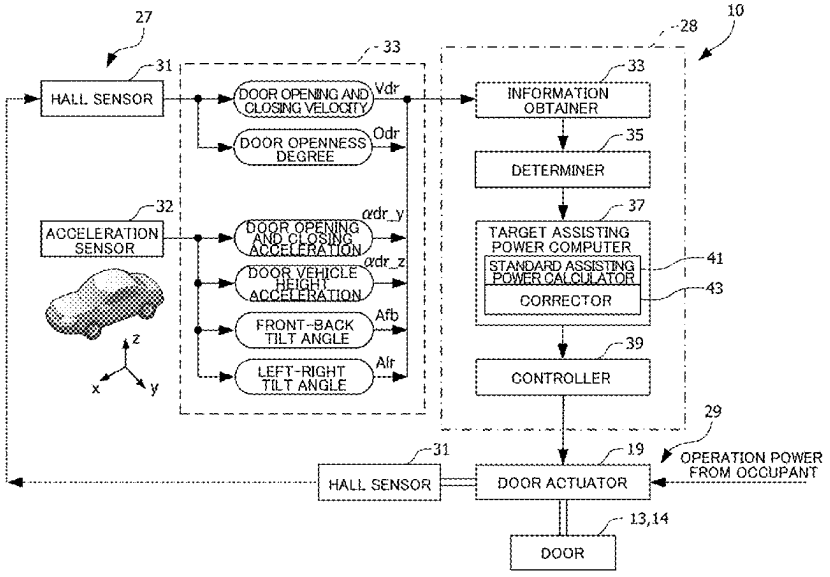
(57) **ABSTRACT**

A door opening and closing assisting apparatus that assists an opening and closing operation of a door on a vehicle is provided. The door opening and closing assisting apparatus includes: an information obtainer that obtains information on an opening and closing acceleration of the door; a door actuator that performs driving for assisting the opening and closing operation of the door; a target assisting power computer that computes a target assisting power for assisting the opening and closing operation of the door; and a controller that performs driving control for the door actuator based on the target assisting power. The controller starts the driving control for the door actuator at a timing at which the information obtainer obtains the opening and closing acceleration of the door.

**4 Claims, 9 Drawing Sheets**



(52) **U.S. Cl.**
CPC ..... *E05Y 2400/326* (2013.01); *E05Y 2400/37* (2024.05); *E05Y 2900/531* (2013.01)

(58) **Field of Classification Search**
CPC ..... E05Y 2400/326; E05Y 2400/36; E05Y 2900/531; E05Y 2400/32
See application file for complete search history.

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FIG. 1A

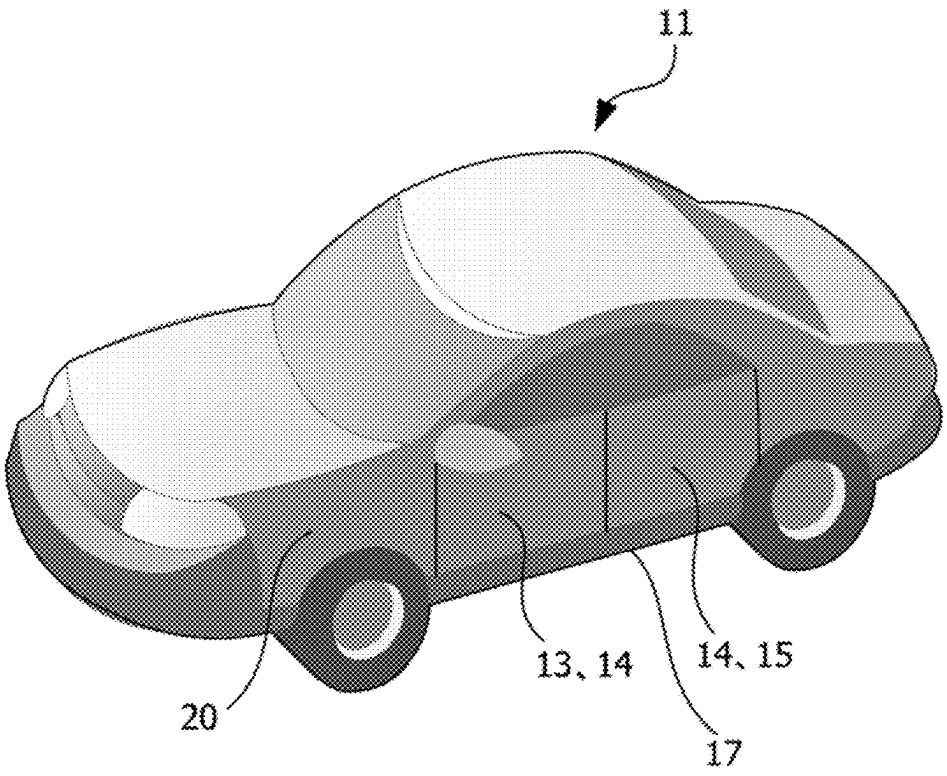


FIG. 1B

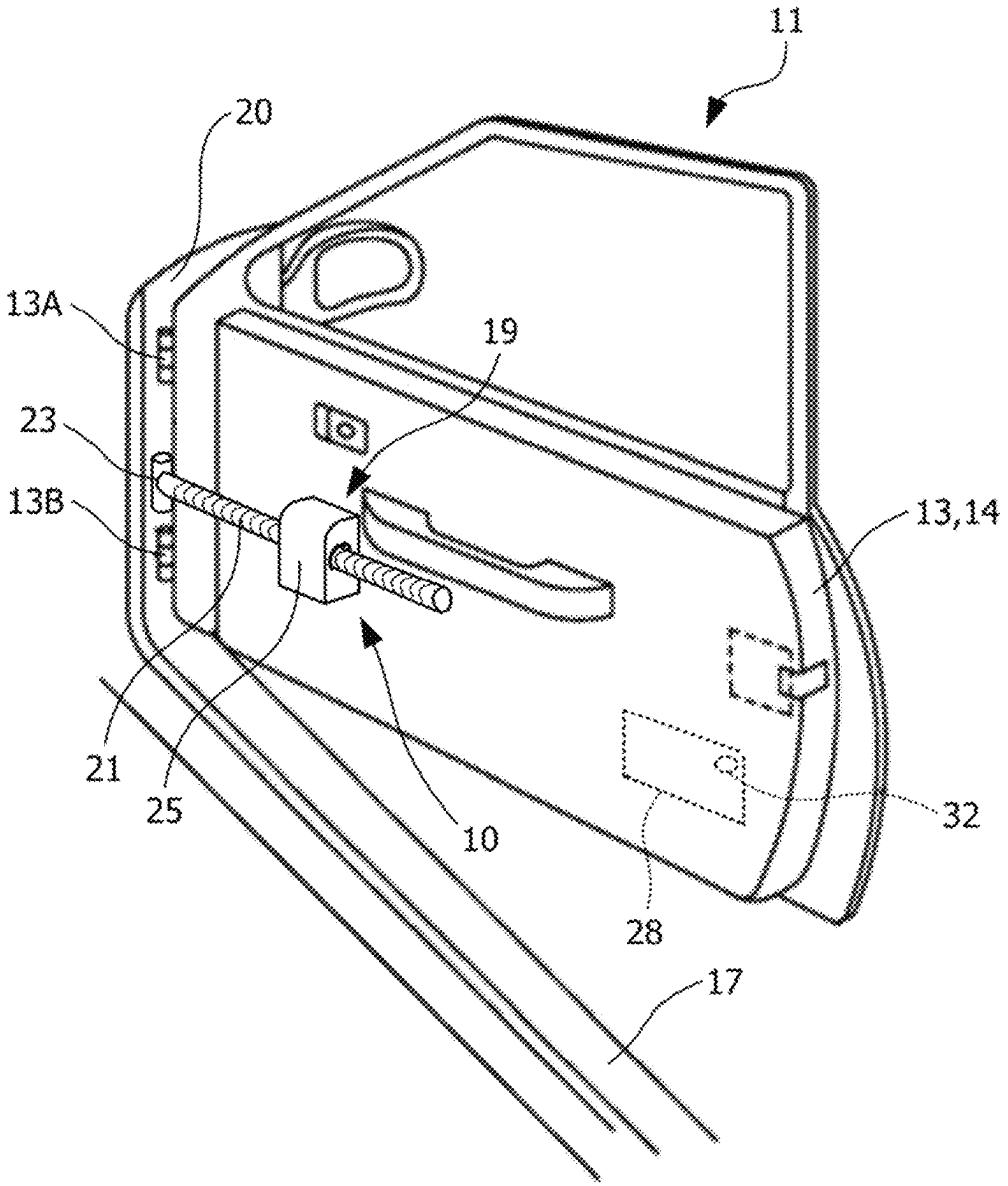


FIG. 2

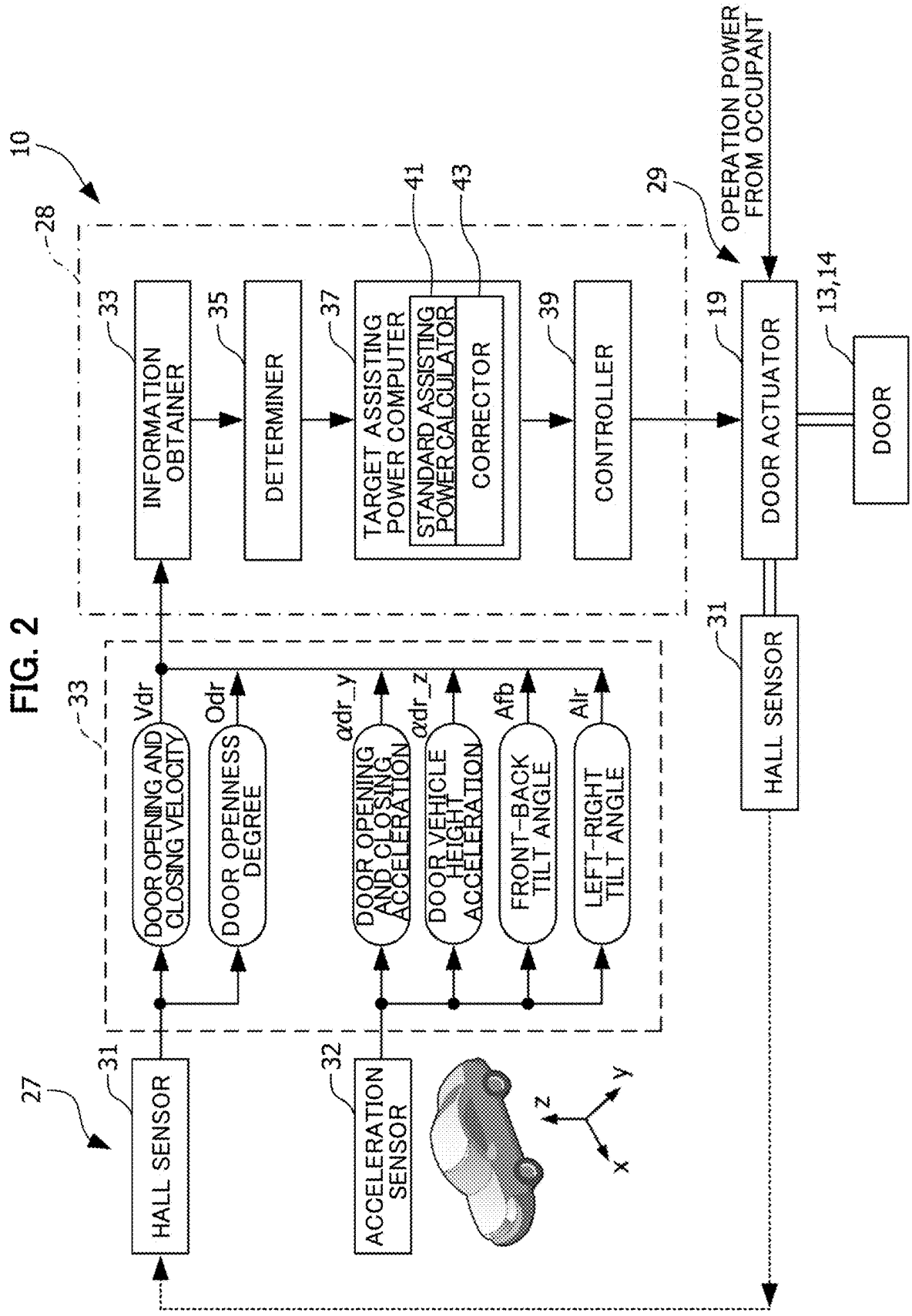
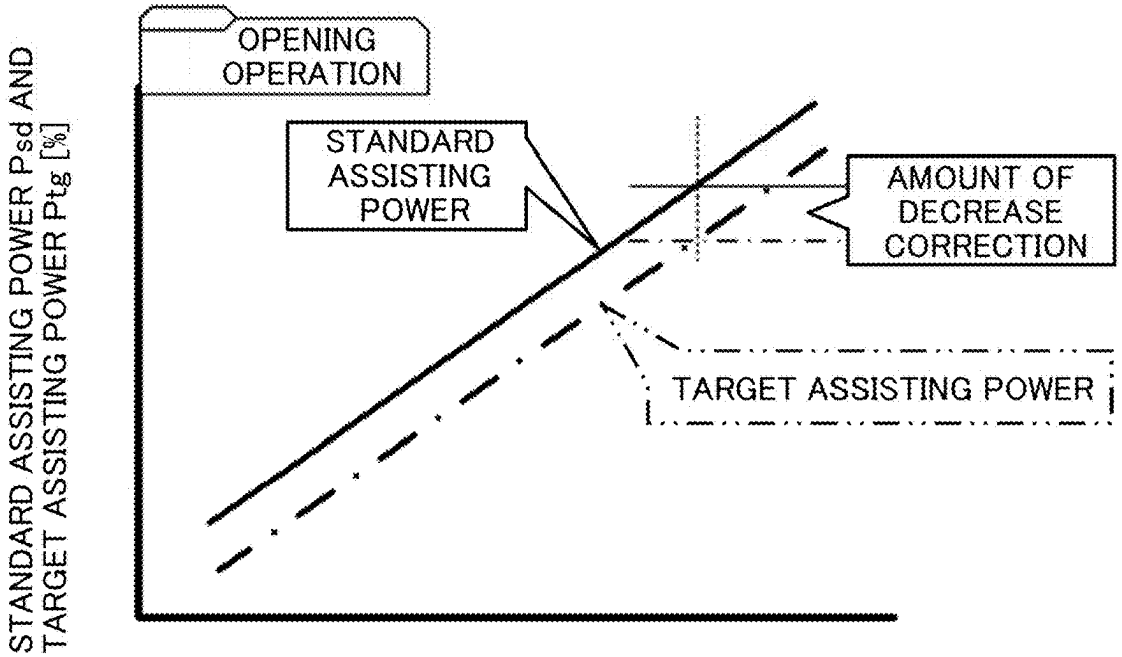

10
28
33
INFORMATION OBTAINER
35
DETERMINER
37
TARGET ASSISTING POWER COMPUTER
41
STANDARD ASSISTING POWER CALCULATOR
43
CORRECTOR
39
CONTROLLER
29
OPERATION POWER FROM OCCUPANT
19
DOOR ACTUATOR
13,14
DOOR
31
HALL SENSOR
33
Vdr
DOOR OPENING AND CLOSING VELOCITY
Odr
DOOR OPENNESS DEGREE
αdr_y
DOOR OPENING AND CLOSING ACCELERATION
αdr_z
DOOR VEHICLE HEIGHT ACCELERATION
Afb
FRONT-BACK TILT ANGLE
Alr
LEFT-RIGHT TILT ANGLE
27
31
HALL SENSOR
32
ACCELERATION SENSOR
z
y
x

FIG. 3A

(a) OPENING OPERATION




(b) CLOSING OPERATION

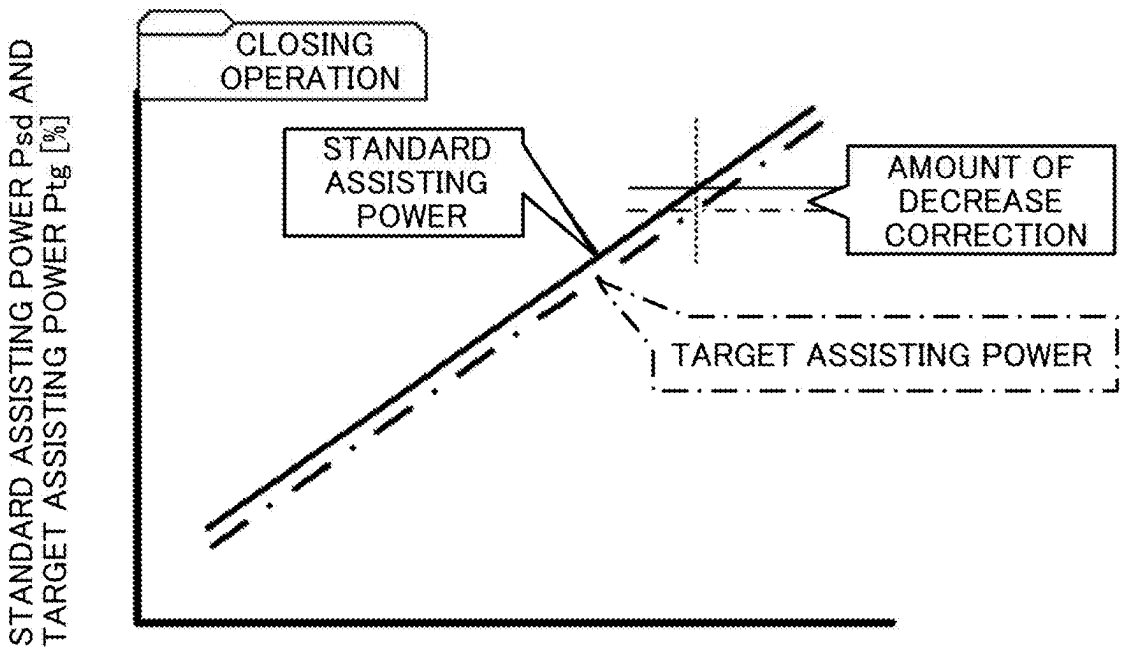


FIG. 3B

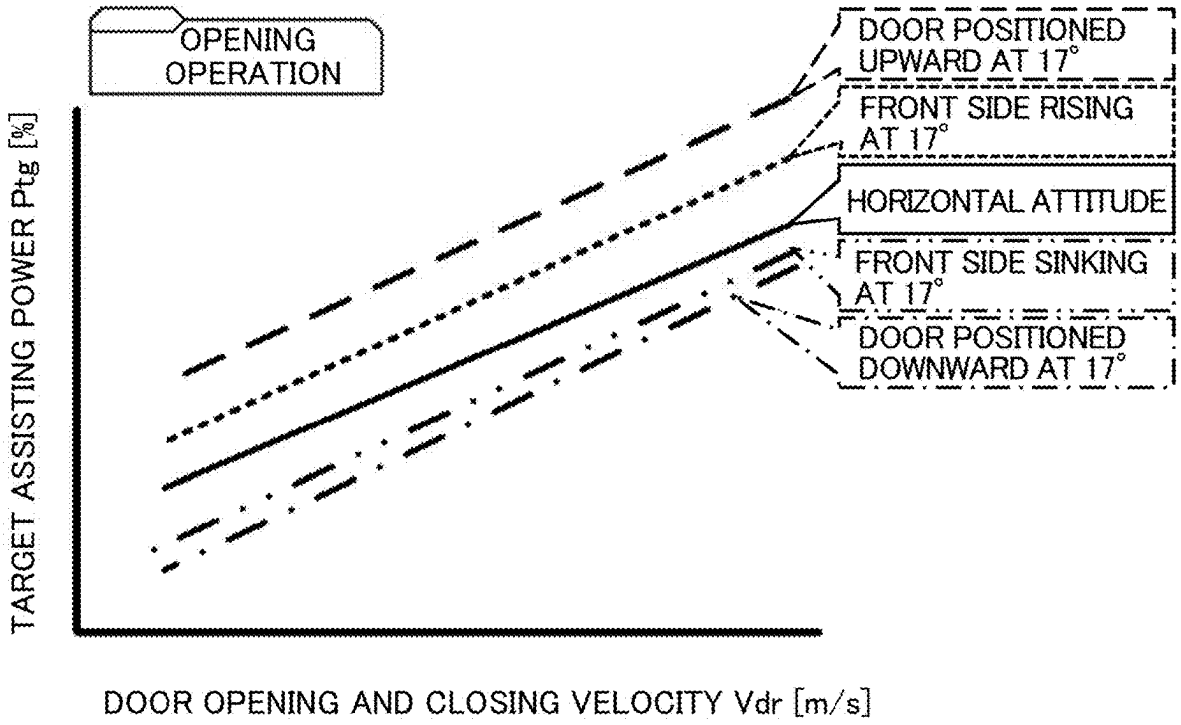

OPENING OPERATION
DOOR POSITIONED UPWARD AT 17°
FRONT SIDE RISING AT 17°
HORIZONTAL ATTITUDE
FRONT SIDE SINKING AT 17°
DOOR POSITIONED DOWNWARD AT 17°
TARGET ASSISTING POWER Ptg [%]
DOOR OPENING AND CLOSING VELOCITY Vdr [m/s]

FIG. 3C

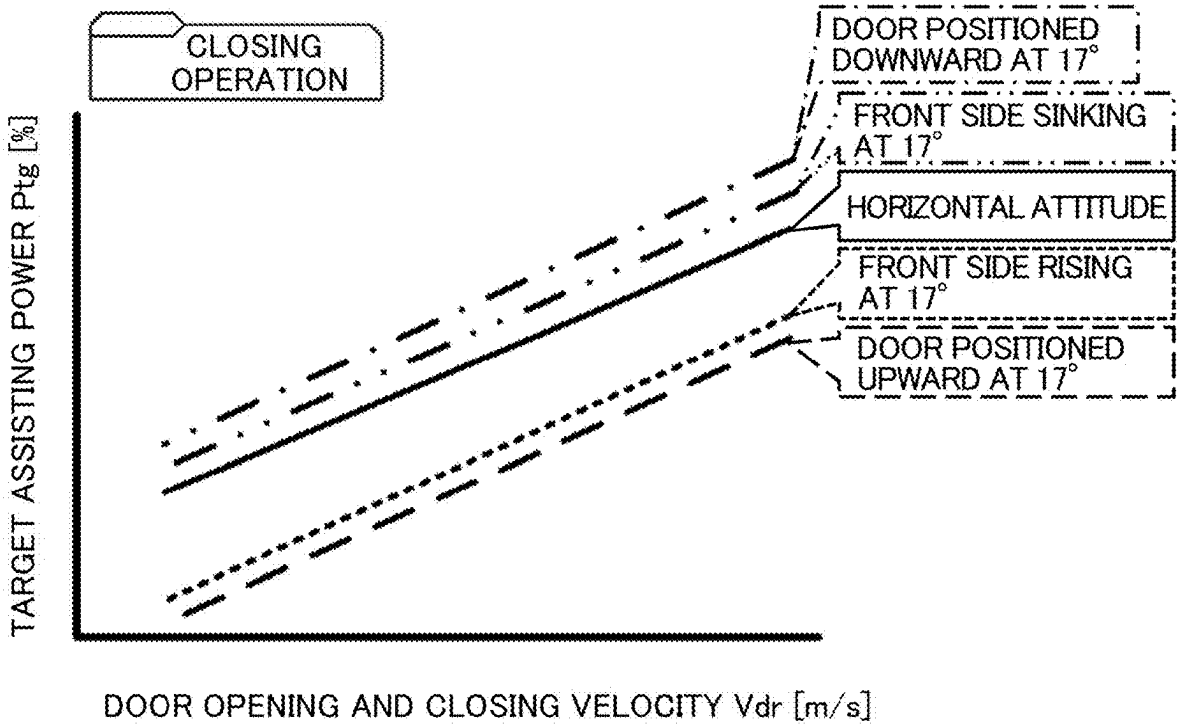

CLOSING OPERATION
DOOR POSITIONED DOWNWARD AT 17°
FRONT SIDE SINKING AT 17°
HORIZONTAL ATTITUDE
FRONT SIDE RISING AT 17°
DOOR POSITIONED UPWARD AT 17°
TARGET ASSISTING POWER Ptg [%]
DOOR OPENING AND CLOSING VELOCITY Vdr [m/s]

FIG. 3D

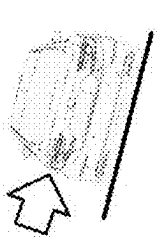
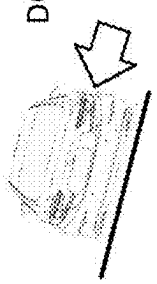
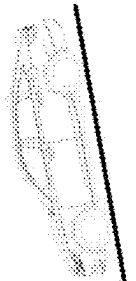
| | | OPENING OPERATION | CLOSING OPERATION |
|---|---|---|---|
| SLOPE TILTING IN VEHICLE WIDTH DIRECTION | DOOR POSITIONED UPWARD  | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ LARGER ACCORDING TO LEFT-RIGHT TILT ANGLE AND DOOR OPENNESS DEGREE | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ SMALLER ACCORDING TO LEFT-RIGHT TILT ANGLE AND DOOR OPENNESS DEGREE |
| | DOOR POSITIONED DOWNWARD  | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ SMALLER ACCORDING TO LEFT-RIGHT TILT ANGLE AND DOOR OPENNESS DEGREE | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ LARGER ACCORDING TO LEFT-RIGHT TILT ANGLE AND DOOR OPENNESS DEGREE |
| SLOPE TILTING IN VEHICLE LENGTH DIRECTION | FRONT SIDE RISING  | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ LARGER ACCORDING TO FRONT-BACK TILT ANGLE AND DOOR OPENNESS DEGREE | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ SMALLER ACCORDING TO FRONT-BACK TILT ANGLE AND DOOR OPENNESS DEGREE |
| | FRONT SIDE SINKING  | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ SMALLER ACCORDING TO FRONT-BACK TILT ANGLE AND DOOR OPENNESS DEGREE | MAKE CORRECTION TO MAKE TARGET ASSISTING POWER $P_{tg}$ LARGER ACCORDING TO FRONT-BACK TILT ANGLE AND DOOR OPENNESS DEGREE |

FIG. 4A

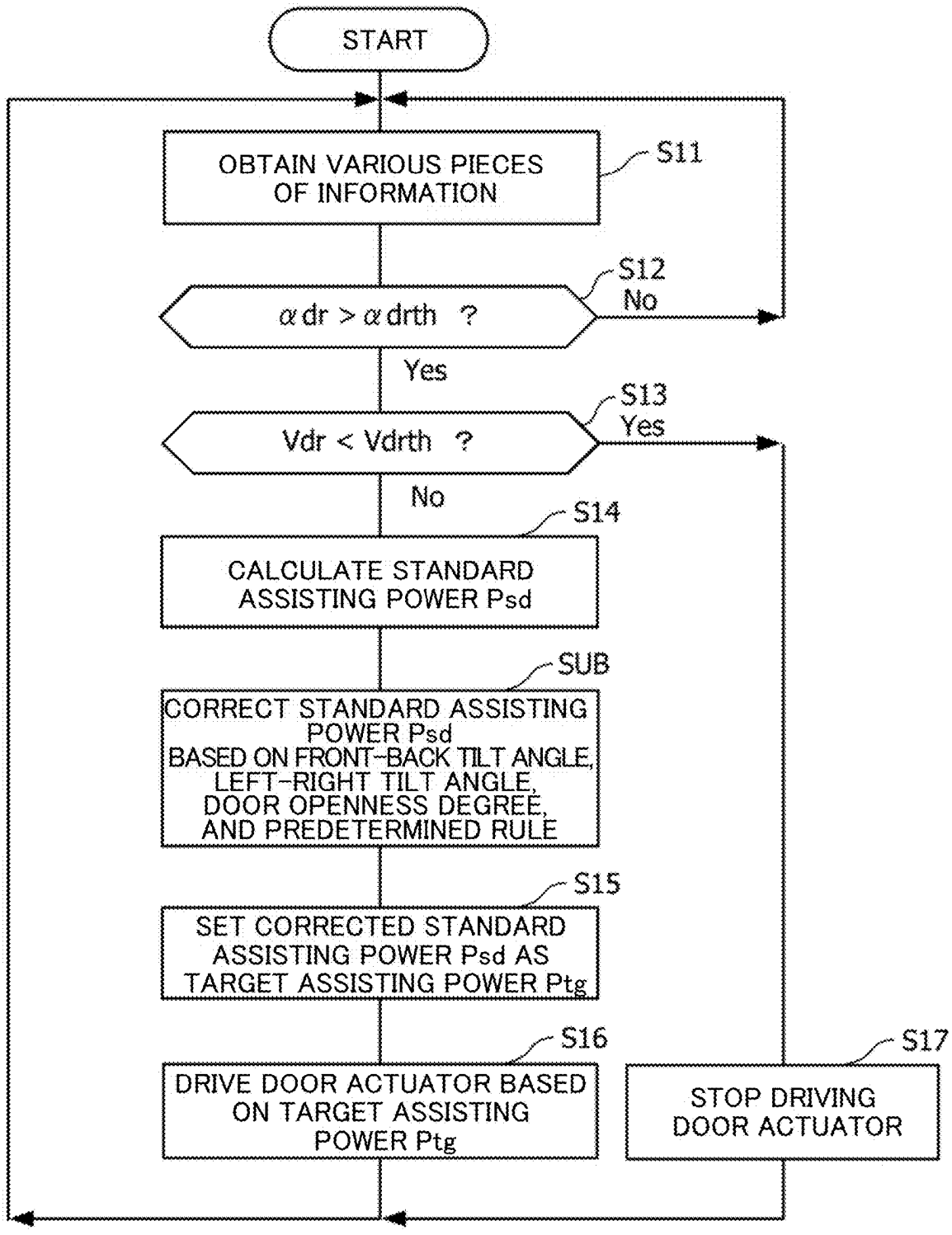

START
OBTAIN VARIOUS PIECES OF INFORMATION
S11
αdr > αdrth ?
S12
No
Yes
Vdr < Vdrth ?
S13
Yes
No
CALCULATE STANDARD ASSISTING POWER Psd
S14
CORRECT STANDARD ASSISTING POWER Psd BASED ON FRONT-BACK TILT ANGLE, LEFT-RIGHT TILT ANGLE, DOOR OPENNESS DEGREE, AND PREDETERMINED RULE
SUB
SET CORRECTED STANDARD ASSISTING POWER Psd AS TARGET ASSISTING POWER Ptg
S15
DRIVE DOOR ACTUATOR BASED ON TARGET ASSISTING POWER Ptg
S16
STOP DRIVING DOOR ACTUATOR
S17

FIG. 4B

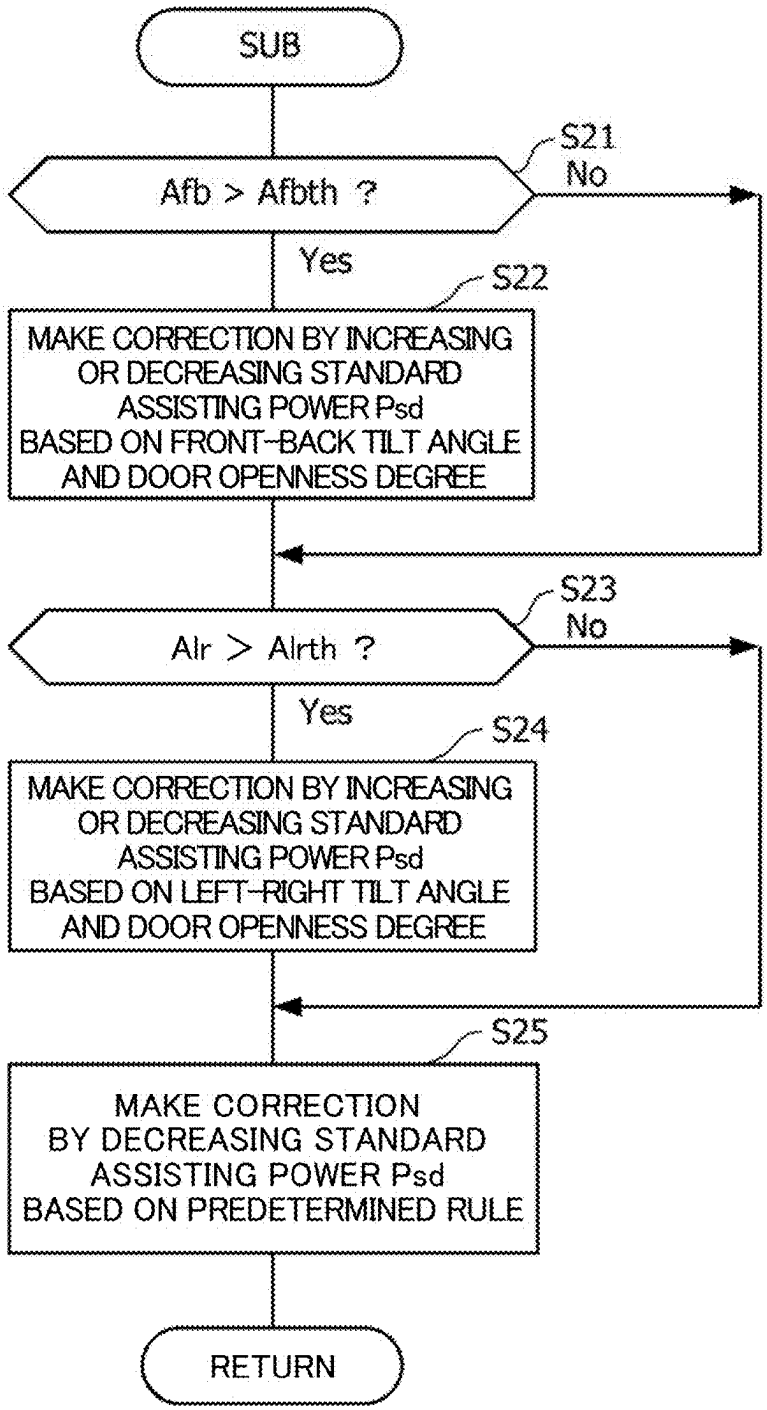
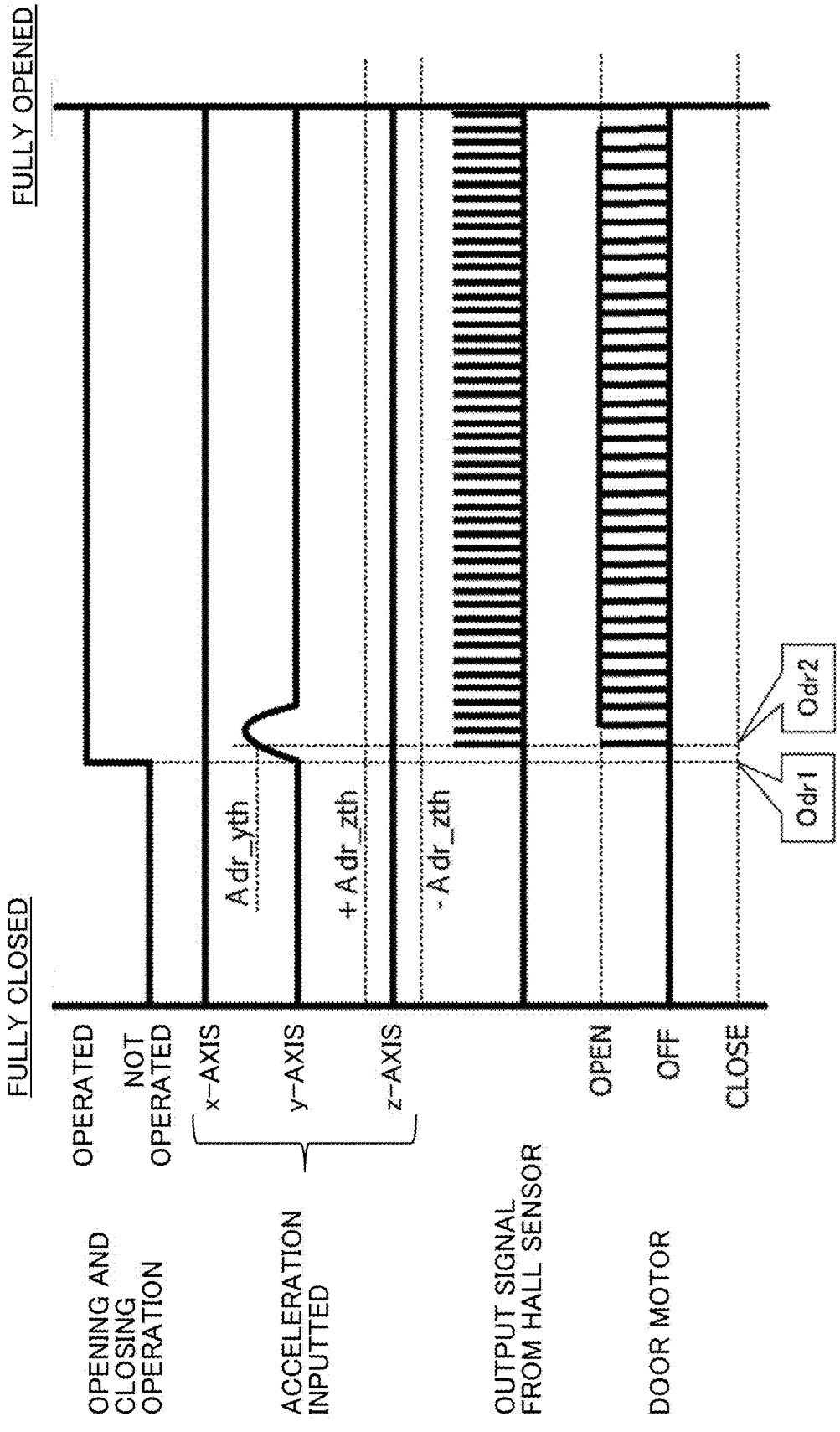

SUB
S21
Afb > Afbth ?
No
Yes
S22
MAKE CORRECTION BY INCREASING OR DECREASING STANDARD ASSISTING POWER Psd BASED ON FRONT-BACK TILT ANGLE AND DOOR OPENNESS DEGREE
S23
Alr > Alrth ?
No
Yes
S24
MAKE CORRECTION BY INCREASING OR DECREASING STANDARD ASSISTING POWER Psd BASED ON LEFT-RIGHT TILT ANGLE AND DOOR OPENNESS DEGREE
S25
MAKE CORRECTION BY DECREASING STANDARD ASSISTING POWER Psd BASED ON PREDETERMINED RULE
RETURN

FIG. 5


FULLY OPENED
FULLY CLOSED
OPERATED
NOT OPERATED
x-AXIS
y-AXIS
z-AXIS
OPENING AND CLOSING OPERATION
ACCELERATION INPUTTED
OUTPUT SIGNAL FROM HALL SENSOR
DOOR MOTOR
OPEN
OFF
CLOSE
A dr_yth
+ A dr_zth
- A dr_zth
Odr1
Odr2

# DOOR OPENING AND CLOSING ASSISTING APPARATUS

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of foreign priority to Japanese Patent Application No. 2022-037199, filed on Mar. 10, 2022, which is incorporated by reference in its entirety.

## TECHNICAL FIELD

The present invention relates to a door opening and closing assisting apparatus that assists in opening and closing of a door on a vehicle.

## BACKGROUND

There is conventionally known a door opening and closing assisting apparatus that assists in opening and closing of a door by applying an assisting power to a door opening and closing operation power exerted by an operator of a vehicle (see JP2007-238014A). The door opening and closing assisting apparatus according to JP2007-238014A includes a torque sensor that detects a door opening and closing operation power exerted to a door knob on a vehicle, a velocity sensor that detects the velocity of opening and closing of the door, a motor that assists the door opening and closing operation power, and a controller that controls the motor using an assisting power instruction value computed from the door opening and closing operation power and the opening and closing velocity. The controller computes the assisting power instruction value based on the mass of the door, a viscous friction coefficient determined by the relation between a viscous friction force acting on the door and a moving velocity, and a virtual mass and a virtual viscosity friction coefficient for attaining ideal operability.

The door opening and closing assisting apparatus according to JP2007-238014A computes the assisting power instruction value based on the opening and closing operation power and opening and closing velocity of the door and controls the motor based on the assisting power instruction value obtained as a result of the computation. Thus, the control logic is established with a small number of parameters, and therefore, setting, development, and the like can be done readily with a clear configuration.

Meanwhile, in order for a door opening and closing assisting apparatus like the one disclosed in JP2007-238014A to be used widely, not only favorable operability for opening and closing the door, but also simplicity of the configuration of the apparatus is demanded.

In this regard, the door opening and closing assisting apparatus according to JP2007-238014A has room for improvement in terms of achieving favorable operability for opening and closing a door with a simple apparatus configuration.

The present invention has been made to solve the above problem and has an object to provide a door opening and closing assisting apparatus capable of achieving favorable operability for door opening and closing with a simple apparatus configuration.

## SUMMARY

To achieve the above object, one aspect of the present invention is mainly characterized as a door opening and closing assisting apparatus that assists an opening and closing operation of a door on a vehicle, the door opening and closing assisting apparatus including: an information obtainer that obtains information on an opening and closing acceleration of the door; a door actuator that performs driving for assisting the opening and closing operation of the door; a target assisting power computer that computes a target assisting power for assisting the opening and closing operation of the door; and a controller that performs driving control for the door actuator based on the target assisting power, in which the controller starts the driving control for the door actuator at a timing at which the information obtainer obtains the opening and closing acceleration of the door.



## BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present invention in any way.

FIG. **1**A is a perspective view of an outer appearance of a vehicle equipped with a door opening and closing assisting apparatus according to an embodiment of the present invention.

FIG. **1**B is a perspective view showing how the door opening and closing assisting apparatus is attached to a door.

FIG. **2** is a functional block configuration diagram of the door opening and closing assisting apparatus according to the embodiment of the present invention.

FIG. **3**A includes a diagram (a) conceptually showing, in contradistinction, the relation between a standard assisting power and a target assisting power in a door opening operation with the door opening and closing velocity being changed and a diagram (b) conceptually showing, in contradistinction, the relation between the standard assisting power and the target assisting power in a door closing operation with the door opening and closing velocity being changed.

FIG. **3**B is a diagram conceptually showing, in contradistinction, the relation of the target assisting power to the opening and closing velocity of the door for each of variously changed attitudes of the vehicle in a door opening operation.

FIG. **3**C is a diagram conceptually showing, in contradistinction, the relation of the target assisting power to the opening and closing velocity of the door for each of variously changed attitudes of the vehicle in a door closing operation.

FIG. **3**D is a diagram conceptually showing suitable increase or decrease corrections made on a standard assisting power for various attitudes of a vehicle in each of a door opening operation and a door closing operation.

FIG. **4**A is a flowchart used to describe the operation of the door opening and closing assisting apparatus according to the embodiment of the present invention.

FIG. **4**B is a flowchart illustrating a procedure for a segment of the operation of the door opening and closing assisting apparatus, the segment being correcting the standard assisting power into the target assisting power.

FIG. **5** is a diagram conceptually showing how driving control of the actuator is started at a timing at which the opening and closing acceleration is generated by a door opening and closing operation.

## DETAILED DESCRIPTION

Referring to the drawings as needed, the following provides a detailed description of a door opening and closing assisting apparatus according to an embodiment of the present invention.

Note that throughout the drawings to be referred to below, members having the same function are denoted by the same reference sign. Also, the size and shape of a member may be schematically shown and may be modified or exaggerated for explanatory convenience.

When a description is given using directions, the directions are based on the front and rear, left and right, and up and down as seen from a driver sitting in the driver's seat (the front right seat) unless otherwise noted. In other words, a "front-back direction" corresponds to a "vehicle length direction," a "left and right direction" corresponds to a "vehicle width direction," and an "up-down direction" corresponds to a "vehicle height direction."

In the description of a vehicle **11** equipped with a door opening and closing assisting apparatus **10** according to the embodiment of the present invention, a plurality of members forming the vehicle body of the vehicle **11** are formed using a metal material such as a steel plate, unless otherwise noted.

[Configuration of Door Opening and Closing Assisting Apparatus **10**]

First, the configuration of the vehicle **11** equipped with the door opening and closing assisting apparatus **10** according to the embodiment of the present invention is described with reference to FIGS. **1**A and **1**B as needed.

FIG. **1**A is a perspective view of an outer appearance of the vehicle **11** equipped with the door opening and closing assisting apparatus **10** according to the embodiment of the present invention. FIG. **1**B is a perspective view showing how the door opening and closing assisting apparatus **10** is attached to a door **13**. FIG. **2** is a functional block configuration diagram of the door opening and closing assisting apparatus **10**. In FIG. **3**A, (a) is a diagram conceptually showing, in contradistinction, the relation between a standard assisting power Psd and a target assisting power Ptg in a door opening operation with the door opening and closing velocity being changed, and (b) is a diagram conceptually showing, in contradistinction, the relation between the standard assisting power Psd and the target assisting power Ptg in a door closing operation with the door opening and closing velocity being changed. FIG. **3**B is a diagram conceptually showing, in contradistinction, the relation of the target assisting power Ptg to an opening and closing velocity Vdr of a door **14** for each of variously changed attitudes of the vehicle **11** in an opening operation of the door **14**. FIG. **3**C is a diagram conceptually showing, in contradistinction, the relation of the target assisting power Ptg to the opening and closing velocity Vdr of the door **14** for each of variously changed attitudes of the vehicle **11** in a closing operation of the door **14**. FIG. **3**D is a diagram conceptually showing suitable increase or decrease corrections made on the standard assisting power Psd for various attitudes of a vehicle **11** in each of door opening and closing operations of the door **14**.

As shown in FIG. **1**A, the vehicle **11** equipped with the door opening and closing assisting apparatus **10** according to the embodiment of the present invention includes, on its sides, left and right front seat doors **13**, left and right rear seat doors **15**, and left and right side sills **17**. Note that the front seat doors **13** and the rear seat doors **15** are collectively called "doors **14**" in the following description unless a distinction therebetween is necessary.

As shown in FIG. **1**B, the front seat doors **13** (the doors **14**) are each swingably attached to a vehicle body **20** via a pair of hinge mechanisms **13**A and **13**B arranged in the vehicle height direction, so that the front seat door **13** is freely openable and closable. The doors **14** are each provided with a door actuator **19** of the door opening and closing assisting apparatus **10**, the door actuator **19** performing driving for assisting an opening and closing operation of the door **14**.

As shown in FIG. **1**B, the door actuator **19** is configured including a spindle screw **21** having a screw groove axially formed in its outer circumference and a door motor **25** having a spindle nut (not shown) having a screw groove formed in its inner circumference to threadably engage with the screw groove on the spindle screw **21**, the spindle nut being connected to a rotor (not shown) via a speed reduction mechanism (not shown).

One end of the spindle screw **21** is pivotally supported via a joint mechanism **23** provided on the vehicle body **20**. The other end of the spindle screw **21** is provided with the door motor **25**. The door motor **25** is fixedly provided on the inner side of the front seat door **13** (the door **14**).

In the door opening and closing assisting apparatus **10** according to the embodiment of the present invention, when an operator performs an operation for opening and closing the door **14**, the door actuator **19** starts driving, triggered by the opening or closing movement of the door **14** caused by the opening or closing operation.

For instance, in a case where an operator performs an operation for opening the door **14**, the door **14** undergoes opening movement caused by the opening operation.

In response to the opening movement of the door **14**, the rotor of the door motor **25** provided at the free end of the spindle screw **21** is mechanically driven and rotated. When no electric power is being fed to the door motor **25**, the door motor **25** serves to hinder the opening movement of the door **14** as a power generation device. In this state, the operator experiences a resistance against the opening or closing operation of the door **14** and is therefore unable to have favorable operability for opening or closing the door **14**.

Thus, when the door **14** is opened, a door ECU **28** provided at the front seat door **13** (the door **14**) determines whether a condition to start driving of the door actuator **19** (to be detailed later) is satisfied. Driving of the door actuator **19** is started if it is determined that the condition to start driving of the door actuator **19** is satisfied.

Once driving of the door actuator **19** is started, the door motor **25** is supplied with electric power so that the opening movement of the door **14** may be performed. Assisting power enabled by this power supply is added to the operation power of the operator. This reduces resistance that the operator feels when performing an operation for opening and closing the door **14**, providing them with favorable operability for opening and closing the door **14**.

When the condition to start driving of the door actuator **19** is satisfied, the door opening and closing assisting apparatus **10** according to the embodiment of the present invention calculates, based on the opening and closing velocity Vdr of the door **14**, the standard assisting power Psd which is assisting power required to maintain the opening and closing velocity Vdr, and corrects the calculated standard assisting power Psd in order to improve the operability for opening or closing the door **14** and to have favorable operability comparable to that in a case where the vehicle **11** has a horizontal attitude.

More specifically, when the attitude of the vehicle **11** (including tilts in the front-back direction and the left-right direction) is horizontal, the door opening and closing assisting apparatus **10** makes the correction by decreasing the calculated standard assisting power Psd based on a predetermined rule and sets the standard assisting power Psd thus corrected by being decreased as a target assisting power Ptg.

Meanwhile, when the attitude of the vehicle **11** is not horizontal, the door opening and closing assisting apparatus **10** makes the correction by increasing or decreasing the calculated standard assisting power Psd according to the attitude of the vehicle and the openness degree Odr of the door **14** so as to be able to attain favorable operability comparable to that in a case where the vehicle **11** has a horizontal attitude, and sets the standard assisting power Psd thus corrected by being increased or decreased as the target assisting power Ptg.

Favorable operability for opening and closing the door **14** can thereby be achieved with a simple apparatus configuration. Details of this will be described sequentially.

To implement the functions described above, the door opening and closing assisting apparatus **10** according to the embodiment of the present invention is configured including, as shown in FIG. **2**, functional units belonging to each of an input system **27**, an information processing system (door ECU) **28**, and an output system **29**.

The functional units belonging to the input system **27** are configured including a Hall sensor **31** and an acceleration sensor **32**.

The Hall sensor **31** outputs detection signals including chronological information on the rotation position and rotation velocity of the rotor of the door motor **25** belonging to the door actuator **19**.

Output signals from the Hall sensor **31** are sequentially sent to an information obtainer **33** belonging to the door ECU **28**. The Hall sensor **31** corresponds to the "openness degree sensor" of the present invention.

The acceleration sensor **32** outputs a detection signal indicative of a roll angle, a detection signal indicative of a pitch angle, and a detection signal indicating of a yaw angle. When the front-back direction, the left-right direction (the vehicle width direction), and the up-down direction (the vehicle height direction) of the horizontal and stationary vehicle **11** are an x-axis direction, a y-axis direction, and a z-axis direction, respectively, the roll angle is a rotation angle about the x-axis as a rotary axis, the pitch angle is a rotation angle about the y-axis as a rotary axis, and the yaw angle is a rotational angle about the z-axis as a rotary axis.

As shown in FIG. **1**B, the acceleration sensor **32** is mounted on a board (not shown) of the door ECU **28**.

The output signals (a roll angle, a pitch angle, and a yaw angle) from the acceleration sensor **32** are sequentially sent to the information obtainer **33** belonging to the door ECU **28**.

Functional units belonging to the information processing system (door ECU) **28** are configured including the information obtainer **33**, a determiner **35**, a target assisting power computer **37**, and a controller **39**.

The information obtainer **33** converts the output signals sent from the Hall sensor **31** into chronological information on the opening and closing velocity Vdr and the openness degree Odr of the door **14**.

The information obtainer **33** also converts the output signals (a roll angle, a pitch angle, and a yaw angle) sent from the acceleration sensor **32** into chronological information on a front-back tilt angle Afb and a left-right tilt angle Alr.

The information obtainer **33** further converts each of the output signals (a roll angle, a pitch angle, and a yaw angle) sent from the acceleration sensor **32** into chronological information on an opening and closing acceleration αdr_y and a vehicle height acceleration αdr_z of the door **14**.

The information obtainer **33** thereby obtains the chronological information on the opening and closing velocity Vdr and the openness degree Odr of the door **14** based on the output signals sent from the Hall sensor **31** as well as the chronological information on the front-back tilt angle Afb and the left-right tilt angle Alr and the chronological information on the opening and closing acceleration αdr_y and the vehicle height acceleration αdr_z of the door **14** based on the output signals from the acceleration sensor **32**.

Note that as the openness degree Odr of the door **14**, the current position of the door **14** in a relative coordinate system can be expressed by, for example, setting a definition range by allocating a numeric value "0" to a fully closed (closed) state and a numeric value "100" to a fully opened state (a state where the door is opened to the utmost limit) and assigning appropriate numeric values 1 to 99 to the current open/close positions.

As the front-back tilt angle Afb, the attitude (tilt angle) of the vehicle **11** in the front-back direction in a relative coordinate system can be expressed by, for example, assigning a numeric value "0" to the horizontal state, a positive numeric value to a frontward tilting state, and a negative numeric value to a rearward tilting state.

Similarly, as the left-right tilt angle Alr, the attitude (tilt angle) of the vehicle **11** in the left-right direction in a relative coordinate system can be expressed by, for example, assigning a numeric value "0" to the horizontal state, a positive numeric value to a leftward tilting state, and a negative numeric value to a rightward tilting state.

The opening and closing acceleration αdr_y of the door **14** is an acceleration acting in the left-right direction (the vehicle width direction: the y-axis direction) of the door **14**.

Also, the vehicle height acceleration αdr_z of the door **14** is an acceleration acting in the up-down direction (the vehicle height direction: the z-axis direction) of the door **14**.

The chronological information obtained by the information obtainer **33**, namely the chronological information on the opening and closing velocity Vdr and the openness degree Odr of the door **14**, the chronological information on the front-back tilt angle Afb and the left-right tilt angle Alr, and the chronological information on the opening and closing acceleration αdr_y and the vehicle height acceleration αdr_z of the door **14**, are sent to the determiner **35**.

The determiner **35** not only determines the direction of the opening and closing operation of the door **14**, but also determines whether the opening and closing acceleration αdr_y of the door **14** is above a predetermined opening and closing acceleration threshold αdr_yth, whether the vehicle height acceleration αdr_z of the door **14** is below a predetermined vehicle height acceleration threshold αdr_zth, and whether the opening and closing velocity Vdr of the door **14** is below a predetermined velocity threshold Vdrth.

Of the items determined by the determiner **35**, "whether the vehicle height acceleration αdr_z of the door **14** is below the predetermined vehicle height acceleration threshold αdr_zth" may be omitted.

The direction of the opening and closing operation of the door **14** may be obtained based on whether the sign of the difference between the openness degrees Odr that are a certain temporal interval apart from each other in the chronological information on the openness degree Odr of the door **14** is positive or negative.

The determination result on the direction of the opening and closing operation of the door **14** obtained by the determiner **35** is sent to the target assisting power computer **37**.

Also, the acceleration-related determination results obtained by the determiner **35**, namely whether the opening and closing acceleration αdr_y of the door **14** is above the

predetermined opening and closing acceleration threshold αdr_yth and whether the vehicle height acceleration αdr_z of the door **14** is below the predetermined vehicle height acceleration threshold αdr_zth, are sent to the controller **39**.

If the opening and closing acceleration αdr_y of the door **14** is not above the predetermined opening and closing acceleration threshold αdr_yth or the vehicle height acceleration αdr_z of the door **14** is equal to or above the predetermined vehicle height acceleration threshold αdr_zth, it is highly probable that the values of the opening and closing acceleration αdr_y of the door **14** and the vehicle height acceleration αdr_z of the door **14** are a result of error detection. If driving of the door actuator **19** is started in such a case, the operator may experience a strange feeling as if the door **14** is moving against their will.

Thus, in the door opening and closing assisting apparatus **10** according to the embodiment of the present invention, driving of the door actuator **19** is started only when acceleration requirements are satisfied, the acceleration requirements being the opening and closing acceleration αdr_y of the door **14** being above the predetermined opening and closing acceleration threshold αdr_yth and the vehicle height acceleration αdr_z of the door **14** being below the predetermined vehicle height acceleration threshold αdr_zth.

A situation where the operator may experience a strange feeling as if the door **14** is moving against their will is thereby avoided.

Thus, values set as the predetermined opening and closing acceleration threshold αdr_yth and the predetermined vehicle height acceleration threshold αdr_zth may be any appropriate values (except for zero) indicating that the values of the opening and closing acceleration αdr_y of the door **14** and the vehicle height acceleration αdr_z of the door **14** are not a result of error detection.

In addition, the determination result obtained by the determiner **35** regarding whether the opening and closing velocity Vdr of the door **14** is below the predetermined velocity threshold Vdrth is sent to the controller **39**.

If, during the driving of the door actuator **19**, assisting power from the door actuator **19** continues to be applied until the opening and closing velocity Vdr of the door **14** becomes zero, the operator may experience a strange feeling as if the door **14** is coasting against their will.

Thus, in the door opening and closing assisting apparatus **10** according to the embodiment of the present invention, driving control of the door actuator **19** is stopped at a timing at which the opening and closing operation of the door **14** is expected to end soon, such as when the opening and closing velocity Vdr of the door **14** falls below the predetermined velocity threshold Vdrth.

A situation where the operator may experience a strange feeling as if the door **14** is coasting against their will is thereby avoided.

Thus, as the predetermined velocity threshold Vdrth, for example, a value of the opening and closing velocity Vdr of the door **14** (except for zero) indicating that the opening and closing movement of the door **14** is expected to end soon may be appropriately set.

The determiner **35** also determines whether the front-back tilt angle Afb of the vehicle **11** is above a predetermined front-back tilt angle threshold Afbth and whether the left-right tilt angle Alr of the vehicle **11** is above a predetermined left-right tilt angle threshold Alrth.

The determination results obtained by the determiner **35** on whether the front-back tilt angle Afb of the vehicle **11** is above the predetermined front-back tilt angle threshold Afbth and whether the left-right tilt angle Alr of the vehicle **11** is above the predetermined left-right tilt angle threshold Alrth are sent to the target assisting power computer **37**.

Note that the determiner **35** may be configured to determine that the opening and closing velocity Vdr of the door **14** is below the predetermined velocity threshold Vdrth when the opening and closing velocity Vdr of the door **14** stays below the predetermined velocity threshold Vdrth for a predetermine period of time.

This configuration is expected to offer an effect of avoiding a situation where driving control of the door actuator **19** is erroneously stopped precociously by mistiming the end of the opening or closing movement of the door **14**.

The target assisting power computer **37** computes the target assisting power Ptg for assisting an opening or closing operation of the door **14**.

To be more specific, the target assisting power computer **37** is configured including a standard assisting power calculator **41** that calculates the standard assisting power Psd based on the opening and closing velocity Vdr of the door **14** obtained by the information obtainer **33**, the standard assisting power Psd being assisting power required to maintain the opening and closing velocity Vdr; and a corrector **43** that corrects the standard assisting power Psd calculated by the standard assisting power calculator **41** in order to improve the operability for opening and closing the door **14** and to attain favorable operability comparable to that in a case where the vehicle **11** has a horizontal attitude even if the vehicle **11** does not have a horizontal attitude.

The standard assisting power calculator **41** of the target assisting power computer **37** calculates the standard assisting power Psd based on the opening and closing velocity Vdr of the door **14** obtained by the information obtainer **33**, the standard assisting power Psd being assisting power required to maintain the opening and closing velocity Vdr.

The corrector **43** of the target assisting power computer **37** performs correction processing on the standard assisting power Psd calculated by the standard assisting power calculator **41**, the correction processing being different depending on whether the vehicle **11** has a horizontal attitude or does not have a horizontal attitude (the vehicle **11** is tilted in the front-back and/or left-right direction).

Specifically, when the attitude of the vehicle **11** (including tilts in the front-back and left-right directions) is horizontal, the corrector **43** of the target assisting power computer **37** makes the correction by decreasing the standard assisting power Psd calculated by the standard assisting power calculator **41** based on a predetermined rule and sets the standard assisting power Psd thus corrected by being decreased as a target assisting power Ptg.

In this way, in a case of performing driving control of the door actuator **19** when the vehicle **11** has a horizontal attitude, the standard assisting power Psd thus corrected by being decreased is set as the target assisting power Ptg. Thus, compared to a case where the target assisting power Ptg is a standard assisting power Psd without the decrease correction, assisting power is applied so that the door **14** moves to follow the opening and closing operation performed by the operator with a delay.

As a result, the operator's power of opening and closing the door **14** can be assisted properly, not too much or too little, and thus, the operability for opening and closing the door **14** can be improved.

Meanwhile, when the vehicle **11** does not have a horizontal attitude (when the vehicle **11** is tilting in the front-back or left-right direction), the corrector **43** of the target assisting power computer **37** makes the correction by

increasing or decreasing the standard assisting power Psd calculated by the standard assisting power calculator **41** based on the attitude of the vehicle **11** and the openness degree Odr of the door **14** (details will be described later) so as to offer favorable operability comparable to that in a case where the vehicle **11** has a horizontal attitude, and sets the standard assisting power Psd thus corrected by being increased or decreased as the target assisting power Ptg.

In this case, in a case of performing driving control of the door actuator **19** when the vehicle **11** does not have a horizontal attitude, the standard assisting power Psd calculated by the standard assisting power calculator **41** is corrected by being increased or decreased based on the attitude of the vehicle **11** and the openness degree Odr of the door **14**, and the standard assisting power Psd thus corrected by being increased or decreased is set as the target assisting power Ptg. Thus, even if the magnitude of gravity acting on the door **14** changes depending on the attitude of the vehicle **11** and the openness degree Odr of the door **14**, assisting power applied can be of a magnitude that eliminates the affect by this change, compared to a case where the target assisting power Ptg is not a standard assisting power Psd corrected by being increased or decreased based on the attitude of the vehicle **11** and the openness degree Odr of the door **14**.

As a result, the operator's operation power for opening and closing the door **14** can be properly assisted not too much or not too little, and thus, the operability for opening and closing the door **14** can be improved.

The target assisting power Ptg which is the computation result obtained by the target assisting power computer **37** is sent to the controller **39**.

Here, the correction by decreasing the standard assisting power Psd based on the predetermined rule is, for example, a concept including both of a mode of obtaining the target assisting power Ptg which is decreased by multiplication of the standard assisting power Psd by a predetermined decrease rate (e.g., approximately 3% to 20%) and a mode of obtaining the target assisting power Ptg which is decreased by subtraction of a predetermined value (e.g., a value corresponding to approximately 3% to 20%) from the standard assisting power Psd.

Note that there are no particular limitations for the standard assisting power Psd and the target assisting power Ptg, but for example, they can be obtained using a mode involving an output duty ratio [%].

Also, as shown in, for example, (a) and (b) of FIG. **3**A in contradistinction, the corrector **43** belonging to the target assisting power computer **37** makes a correction so that the amount of the decrease correction may be smaller for a closing operation of the door **14** than for an opening operation of the door **14**.

Thus, a situation where the door **14** hits the next vehicle in the opening operation of the door **14** is less likely to occur, and an experience of speedy closing of the door **14** can be offered in the closing operation of the door **14**.

The corrector **43** belonging to the target assisting power computer **37** further makes a correction by increasing or decreasing the standard assisting power Psd based on the information on the attitude of the vehicle **11** including front-back and left-right tilts.

To be more specific, as shown in FIGS. **3**B and **3**D, in a case where a force that hinders the open state of the door **14** is exerted in the opening operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned upward at 17 degrees; the front side rising at 17 degrees), a correction is made so that the target assisting power Ptg may be larger than in a case where the vehicle **11** has a horizontal attitude. This correction is made by increasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Note that "the door positioned upward at 17 degrees" means that the target is a door located at an upper side when the vehicle **11** is on a slope tilting in the vehicle width direction (at a tilt angle of 17°).

Meanwhile, "the front side rising at 17 degrees" means that the target is a door on the vehicle **11** being on a slope tilting in the vehicle length direction (at a tilt angle of 17°) in such a manner that the front of the vehicle **11** is directed upward.

By contrast, in a case where a force that promotes the open state of the door **14** is exerted in the opening operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned downward at 17 degrees; the front side sinking at 17 degrees), a correction is made so that the target assisting power Ptg may be smaller than in a case where the vehicle **11** has a horizontal attitude. This correction is made by decreasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Note that "the door positioned downward at 17 degrees" means that the target is a door located at a lower side when the vehicle **11** is on a slope tilting in the vehicle width direction (at a tilt angle of 17°).

Meanwhile, "the front side sinking at 17 degrees" means that the target is a door on the vehicle **11** being on a slope tilting in the vehicle length direction (at a tilt angle of 17°) in such a manner that the front of the vehicle **11** is directed downward.

Also, as shown in FIGS. **3**C and **3**D, in a case where a force that hinders the closed state of the door **14** is exerted in the closing operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned downward at 17 degrees; the front side sinking at 17 degrees), a correction is made so that the target assisting power Ptg may be larger than in a case where the vehicle **11** has a horizontal attitude. This correction is made by increasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

By contrast, in a case where a force that promotes the closed state of the door **14** is exerted in the closing operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned upward at 17 degrees; the front side rising at 17 degrees), a correction is made so that the target assisting power Ptg may be smaller than in a case where the vehicle **11** has a horizontal attitude. This correction is made by decreasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Note that the correction for making the target assisting power Ptg larger or smaller due to a change in the attitude of the vehicle **11** may be made using a combined correction amount obtained by adding and combining a correction amount for the front-back tilt angle Afb and a correction amount for the left-right tilt angle Alr that have been independently obtained.

For the correction made by increasing or decreasing the standard assisting power Psd, in actuality, characteristics tables (or conversion formulae) for the target assisting power Ptg that changes according to a change in the opening and closing velocity Vdr of the door **14** are prepared in advance according to operation modes (opening and closing) of the door **14** and according to changes in the attitude of the vehicle **11**. The characteristics tables (conversion formulae) to be referred to are switched and used for each individual

case (such as, for example, the door **14** is being operated to be open, the door **14** is positioned upward, and the vehicle **11** has a front rising attitude).

Favorable operability for opening and closing the door **14** is thus achieved with a simple apparatus configuration.

Because the corrector **43** belonging to the target assisting power computer **37** thus makes a correction by increasing or decreasing the standard assisting power Psd based on information on the attitude of the vehicle **11** including front-back and left-right tilts, driving control of the door actuator **19** is performed using the target assisting power Ptg of a magnitude suited to the change in the attitude of the vehicle **11**. As a result, even if the attitude of the vehicle **11** changes, favorable operability for opening and closing the door **14** can be achieved with a simple apparatus configuration.

When there is a change in the attitude of the vehicle **11** including front-back and left-right tilts, the magnitude of gravity acting on the door **14** changes depending on whether the openness degree Odr of the door **14** is large or small. In other words, there is a close relation between the openness degree Odr of the door **14** and the operability for opening and closing the door **14**.

Thus, the corrector **43** belonging to the target assisting power computer **37** makes a correction by increasing or decreasing the standard assisting power Psd based on information on the attitude of the vehicle **11** including front-back and left-right tilts and on the openness degree Odr of the door **14**.

To be more specific, as shown in FIGS. **3**B and **3**D, in a case where a force that hinders the open state of the door **14** is exerted in the opening operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned upward at 17 degrees; the front side rising at 17 degrees), a correction is made so that the target assisting power Ptg may be larger than in a case where the vehicle **11** has a horizontal attitude. This correction is made by increasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Specifically, the amount of correction made here on the standard assisting power Psd can be expressed as follows: [(the front-back tilt angle Afb*a tilt coefficient β)*the door openness degree Odr]. The larger the front-back tilt angle Afb and the larger the door openness degree Odr, the larger the above correction amount. Here, (the front-back tilt angle Afb*the tilt coefficient β) means an output (a duty ratio) necessary at the time of starting actuation of the door **14** (this is true hereinbelow as well).

By contrast, in a case where a force that promotes the open state of the door **14** is exerted in the opening operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned downward at 17 degrees; the front side sinking at 17 degrees), a correction is made so that the target assisting power Ptg may be smaller than in a case where the vehicle **11** has a horizontal attitude. This correction is made by decreasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Specifically, the amount of correction made here on the standard assisting power Psd can be expressed as follows: [(the front-back tilt angle Afb*the tilt coefficient β)*(the door openness degree Odr of the door fully opened−the door openness degree Odr)]. The larger the front-back tilt angle Afb, the larger the above correction amount, whereas the larger the door openness degree Odr, the smaller the above correction amount.

Also, as shown in FIGS. **3**C and **3**D, in a case where a force that hinders the closed state of the door **14** is exerted in the closing operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned downward at 17 degrees; the front side sinking at 17 degrees), a correction is made so that the target assisting power Ptg may be larger than in a case where the vehicle **11** has a horizontal attitude. This correction is made by increasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Specifically, the amount of correction made here on the standard assisting power Psd can be expressed as follows: [(the front-back tilt angle Afb*the tilt coefficient β)*the door openness degree Odr]. The larger the front-back tilt angle Afb and the larger the door openness degree Odr, the larger the above correction amount.

By contrast, in a case where a force that promotes the closed state of the door **14** is exerted in the closing operation of the door **14** due to a change in the attitude of the vehicle **11** (the door positioned upward at 17 degrees; the front side rising at 17 degrees), a correction is made so that the target assisting power Ptg may be smaller than in a case where the vehicle **11** has a horizontal attitude. This correction is made by decreasing the amount of correction on the standard assisting power Psd compared to that in a case where the vehicle **11** has a horizontal attitude.

Specifically, the amount of correction made here on the standard assisting power Psd can be expressed as follows: [(the front-back tilt angle Afb*the tilt coefficient β)*(the door openness degree Odr of the door fully opened−the door openness degree Odr)]. The larger the front-back tilt angle Afb, the larger the above correction amount, whereas the larger the door openness degree Odr, the smaller the above correction amount.

Such a configuration helps prevent a change in the attitude of the vehicle **11**, if any, from affecting the operability for opening and closing the door **14** and also helps prevent the openness degree Odr of the door **14** at that time from affecting the operability for opening and closing the door **14**. As a result, the operability for opening and closing the door **14** can be made to be favorable furthermore.

The controller **39** performs driving control for the door actuator **19** based on the target assisting power Ptg, which is the computation result obtained by the target assisting power computer **37**. Favorable operability for opening and closing the door **14** is thus achieved with a simple apparatus configuration.

Also, the controller **39** performs driving control for the door actuator **19** is started only when the acceleration requirements are satisfied, the acceleration requirements being the opening and closing acceleration αdr_y of the door **14** being above the predetermined opening and closing acceleration threshold αdr_yth and the vehicle height acceleration αdr_z of the door **14** being below the predetermined vehicle height acceleration threshold αdr_zth. Not starting driving of the door actuator **19** unless the acceleration requirements are satisfied can help prevent a situation where the operator may experience a strange feeling as if the door **14** is moving against their will.

Further, the controller **39** performs control so that the driving of the door actuator **19** stops once the opening and closing velocity Vdr of the door **14** falls below the predetermined velocity threshold Vdrth. Stopping the driving of the door actuator **19** once the opening and closing velocity Vdr of the door **14** falls below the predetermined velocity threshold Vdrth can help prevent a situation where the operator may experience a strange feeling as if the door **14** is coasting against their will.

[Operation of Door Opening and Closing Assisting Apparatus **10**]

Next, the operation of the door opening and closing assisting apparatus **10** according to the embodiment of the present invention is described with reference to FIGS. **4**A, **4**B, and **5** as needed. FIG. **4**A is a flowchart used to describe the operation of the door opening and closing assisting apparatus **10** according to the embodiment of the present invention. FIG. **4**B is a flowchart illustrating a procedure for a segment of the operation of the door opening and closing assisting apparatus **10**, the segment being correcting the standard assisting power Psd into the target assisting power Ptg. FIG. **5** is a diagram conceptually showing how driving control of the door actuator **19** is started at a timing at which the opening and closing acceleration αdr_y is generated by an opening and closing operation of the door **14**.

The following premises are made: the door **14** of the vehicle **11** is open and located at a door position Odr1, the door **14** is positioned upward (for example, the right door of the vehicle **11** that is tilted leftward), and the vehicle **11** has a front rising attitude (directed in the climbing direction on a slope). An operator starts an operation of opening the door **14** with the opening and closing velocity Vdr of the door **14** being equal to or above the predetermined velocity threshold Vdrth.

In Step S**11** shown in FIG. **4**A, the information obtainer **33** belonging to the door ECU **28** obtains chronological information on the opening and closing velocity Vdr and the openness degree Odr of the door **14** based on output signals from the Hall sensor **31** as well as chronological information on the front-back tilt angle Afb and the left-right tilt angle Alr and chronological information on the opening and closing acceleration αdr_y and the vehicle height acceleration αdr_z of the door **14** based on output signals from the acceleration sensor **32**.

In Step S**12**, the determiner **35** belonging to the door ECU **28** determines whether the opening and closing acceleration αdr_y of the door **14** is above a predetermined opening and closing acceleration threshold αdr_yth.

If it is determined in Step S**12** that the opening and closing acceleration αdr_y of the door **14** is not above the predetermined opening and closing acceleration threshold αdr_yth (No in Step S**12**), the door ECU **28** returns to the start of the processing to repeat the subsequent processing sequentially.

Meanwhile, if it is determined in Step S**12** that the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth (Yes in Step S**12**), the door ECU **28** proceeds to the next Step S**13**.

In the example shown in FIG. **5**, at a point where the door **14** reaches a door openness degree Odr2, the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth. Thus, the door ECU **28** proceeds to the next Step S**13**. Note that in the example shown in FIG. **5**, at the point where the door **14** reaches the door openness degree Odr2, the vehicle height acceleration αdr_z of the door **14** is also within a predetermined vehicle height acceleration threshold |αdz_yth|.

In Step S**13**, the determiner **35** belonging to the door ECU **28** determines whether the opening and closing velocity Vdr of the door **14** is below a predetermined velocity threshold Vdrth.

If it is determined in Step S**13** that the opening and closing velocity Vdr of the door **14** is equal to or above the predetermined velocity threshold Vdrth, the door ECU **28** proceeds to the next Step S**14**.

Meanwhile, if it is determined in Step S**13** that the opening and closing velocity Vdr of the door **14** is below the predetermined velocity threshold Vdrth, the door ECU **28** jumps to Step S**17**.

The example shown in FIG. **5** satisfies the prerequisite (the operation of opening the door **14** is started with the opening and closing velocity Vdr of the door **14** being equal to or above the predetermined velocity threshold Vdrth). Thus, the door ECU **28** proceeds to Step S**14**.

In Step S**14**, based on the opening and closing velocity Vdr of the door **14** obtained by the information obtainer **33**, the standard assisting power calculator **41** of the target assisting power computer **37** belonging to the door ECU **28** calculates a standard assisting power Psd which is assisting power required to maintain the opening and closing velocity Vdr.

In a subroutine SUB, the corrector **43** of the target assisting power computer **37** belonging to the door ECU **28** corrects the standard assisting power Psd based on the front-back tilt angle Afb, the left-right tilt angle Alr, the door openness degree Odr, and a predetermined rule.

Now, the subroutine SUB is described with reference to FIG. **4**B.

In Step S**21** in the subroutine SUB shown in FIG. **4**B, the determiner **35** belonging to the door ECU **28** determines whether the front-back tilt angle Afb of the vehicle **11** is above a predetermined front-back tilt angle threshold Afbth.

If it is determined in Step S**21** that the front-back tilt angle Afb of the vehicle **11** is above the predetermined front-back tilt angle threshold Afbth (Yes in Step S**21**), the door ECU **28** proceeds to the next Step S**22**.

Meanwhile, if it is determined in Step S**21** that the front-back tilt angle Afb of the vehicle **11** is not above the predetermined front-back tilt angle threshold Afbth (No in Step S**21**), the door ECU **28** jumps to Step S**23**.

In Step S**22** of the subroutine SUB, the corrector **43** of the target assisting power computer **37** belonging to the door ECU **28** makes a correction by increasing or decreasing the standard assisting power Psd based on the front-back tilt angle Afb and the door openness degree Odr.

Considering the premises (the door **14** of the vehicle **11** is operated to be open, the door **14** is positioned upward, and the vehicle **11** has a front rising attitude), the corrector **43** makes the correction by increasing the standard assisting power Psd based on the front-back tilt angle Afb and the door openness degree Odr.

In Step S**23** of the subroutine SUB, the determiner **35** belonging to the door ECU **28** determines whether the left-right tilt angle Alr of the vehicle **11** is above a predetermined left-right tilt angle threshold Alrth.

If it is determined in Step S**23** that the left-right tilt angle Alr of the vehicle **11** is above the predetermined left-right tilt angle threshold Alrth (Yes in Step S**23**), the door ECU **28** proceeds to the next Step S**24**.

Meanwhile, if it is determined in Step S**23** that the left-right tilt angle Alr of the vehicle **11** is not above the predetermined left-right tilt angle threshold Alrth (No in Step S**23**), the door ECU **28** jumps to Step S**25**.

In Step S**24** of the subroutine SUB, the corrector **43** of the target assisting power computer **37** belonging to the door ECU **28** makes a correction by increasing or decreasing the standard assisting power Psd based on the left-right tilt angle Alr and the door openness degree Odr.

Considering the premises (the door **14** of the vehicle **11** is operated to be open, the door **14** is positioned upward, and

the vehicle **11** has a front rising attitude), the corrector **43** makes the correction by increasing the standard assisting power Psd based on the left-right tilt angle Alr and the door openness degree Odr.

In Step **S25** of the subroutine SUB, the corrector **43** of the target assisting power computer **37** belonging to the door ECU **28** makes a correction by decreasing the standard assisting power Psd based on a predetermined rule.

Then, the door ECU **28** returns to the main routine shown in FIG. **4**A. The following continues the description of the main routine.

In Step **S15** shown in FIG. **4**A, the target assisting power computer **37** belonging to the door ECU **28** sets the standard assisting power Psd which has been corrected in the subroutine SUB, as the target assisting power Ptg. In the present embodiment, the target assisting power computer **37** sets the standard assisting power Psd corrected taking the above-described premises into account as the target assisting power Ptg.

In Step **S16**, the controller **39** belonging to the door ECU **28** performs driving control for the door actuator **19** based on the target assisting power Ptg, which is a computation result obtained by the target assisting power computer **37** (see the OPEN operation of the door motor and an output signal from the Hall sensor **31** at a door openness degree beyond the openness degree Odr2 shown in FIG. **5**).

Consequently, favorable operability for opening and closing the door **14** can be achieved with a simple apparatus configuration.

After the processing in Step **S16** ends, the door ECU **28** returns to Step **S11** and repeats the subsequent processing.

When the opening and closing velocity Vdr of the door **14** falls below the predetermined velocity threshold Vdrth, in Step **S17**, the controller **39** belonging to the door ECU **28** performs control to stop driving of the door actuator **19**.

Stopping driving of the door actuator **19** once the opening and closing velocity Vdr of the door **14** falls below the predetermined velocity threshold Vdrth can help prevent a situation where the operator may experience a strange feeling as if the door **14** is coasting against their will.

After the processing in Step **S17** ends, the door ECU **28** returns to Step **S11** and repeats the subsequent processing.

[Advantageous Effects by Door Opening and Closing Assisting Apparatus **10**]

Next, advantageous effects offered by the door opening and closing assisting apparatus according to the embodiment of the present invention are described.

A door opening and closing assisting apparatus based on a first aspect is on the basis of the door opening and closing assisting apparatus **10** that assists an opening and closing operation of the door **14** on the vehicle **11**.

The door opening and closing assisting apparatus **10** based on the first aspect includes the information obtainer **33** that obtains information on the opening and closing acceleration αdr_y of the door **14**, the door actuator **19** that performs driving for assisting the opening and closing operation of the door **14**, the target assisting power computer **37** that computes the target assisting power Ptg for assisting the opening and closing operation of the door **14**, and the controller **39** that performs driving control for the door actuator **19** based on the target assisting power Ptg.

The controller **39** is configured to start the driving control for the door actuator **19** at a timing at which the information obtainer **33** obtains the opening and closing acceleration αdr_y of the door **14**.

In the door opening and closing assisting apparatus **10** based on the first aspect, the controller **39** starts the driving control for the door actuator **19** at a timing at which the information obtainer **33** obtains the opening and closing acceleration αdr_y of the door **14**. Thus, the door opening and closing assisting apparatus **10** can start the driving control for the door actuator **19** by detecting an operator's operation of opening and closing the door **14** promptly and precisely.

The door opening and closing assisting apparatus **10** based on the first aspect can start the driving control for the door actuator **19** by detecting an operator's operation of opening or closing the door **14** promptly and precisely. Also, in a case where the direction of the opening and closing operation of the door **14** is inverted, the driving control for the door actuator **19** can be started by detecting the timing of the inversion promptly and precisely through the opening and closing acceleration αdr_y of the door **14**.

Thus, favorable operability that does not make the operator feel the weight of the door **14** when performing the opening and closing operation can be achieved with a simple apparatus configuration.

In addition, a door opening and closing assisting apparatus **10** based on a second aspect is the door opening and closing assisting apparatus **10** based on the first aspect, which may be configured as follows: the door is a swing door **14** that opens and closes, pivotally supported by the hinge mechanisms **13**A and **13**B provided on the vehicle body **20** of the vehicle **11**, the door opening and closing assisting apparatus **10** further includes the acceleration sensor **32** that is provided on the door **14** and that detects the opening and closing acceleration αdr_y of the door **14** and the vehicle height acceleration αdr_z of the door **14** which is an acceleration in the vehicle height direction and the determiner **35** that determines the magnitudes of the opening and closing acceleration αdr_y and the vehicle height acceleration αdr_z of the door **14**, the information obtainer **33** further obtains information on the vehicle height acceleration αdr_z of the door **14**, and the controller **39** starts the driving control for the door actuator **19** at a timing at which the determiner **35** determines that the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth and also the vehicle height acceleration αdr_z of the door **14** is below the predetermined vehicle height acceleration threshold αdr_zth.

Even when the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth, if the vehicle height acceleration αdr_z of the door **14** is equal to or above the predetermined vehicle height acceleration threshold αdr_zth, it is probable that not an operator's opening and closing operation, but an external perturbation, such as shaking of the vehicle body **20** as a whole, has been detected. If the door actuator **19** is started to be driven in such a case, the operator may experience a strange feeling as if the door **14** is moving against their will.

Thus, in the door opening and closing assisting apparatus **10** based on the second aspect, the controller **39** starts the driving control for the door actuator **19** at a timing at which the determiner **35** determines that the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth and also that the vehicle height acceleration αdr_z of the door **14** is below the predetermined vehicle height acceleration threshold αdr_zth.

This helps prevent a situation where the operator may experience a strange feeling as if the door **14** is moving against their will.

A value set as the predetermined vehicle height acceleration threshold αdr_zth may be any appropriate value (except for zero) indicating that the value of the opening and closing acceleration αdr_y of the door **14** is not a result of error detection.

According to the door opening and closing assisting apparatus **10** based on the second aspect, the controller **39** starts controlling driving of the door actuator **19** at a timing at which the determiner **35** determines that the opening and closing acceleration αdr_y of the door **14** is above the predetermined opening and closing acceleration threshold αdr_yth and also that the vehicle height acceleration αdr_z of the door **14** is below the predetermined vehicle height acceleration threshold αdr_zth. This can help prevent a situation where the operator may experience a strange feeling as if the door **14** is moving against their will.

Thus, as is similar to the door opening and closing assisting apparatus **10** based on the first aspect, favorable operability that does not make the operator feel the weight of the door **14** when performing the opening and closing operation can be achieved with a simple apparatus configuration.

Further, a door opening and closing assisting apparatus **10** based on a third aspect is the door opening and closing assisting apparatus **10** based on the first or second aspect, which may be configured as follows: the information obtainer **33** further obtains information on the opening and closing velocity Vdr of the door **14**, and the target assisting power computer **37** calculates, based on the opening and closing velocity Vdr of the door **14** obtained by the information obtainer **33**, the standard assisting power Psd which is assisting power required to maintain the opening and closing velocity Vdr, makes a correction by decreasing the calculated standard assisting power Psd according to a predetermined rule, and sets the standard assisting power Psd thus corrected by being decreased, as the target assisting power Ptg.

In the door opening and closing assisting apparatus **10** based on the third aspect, the target assisting power computer **37** calculates, based on the opening and closing velocity Vdr of the door **14** obtained by the information obtainer **33**, the standard assisting power Psd which is assisting power required to maintain the opening and closing velocity Vdr, makes a correction by decreasing the calculated standard assisting power Psd according to a predetermined rule, and sets the standard assisting power Psd thus corrected by being decreased as the target assisting power Ptg. An occupant, when performing an operation of opening and closing the door **14**, can actually feel, with a certain response, that the door **14** is opened and closed in accordance with their will because of the assisting power having a moderate magnitude as a result of a decrease correction.

In the door opening and closing assisting apparatus **10** based on the third aspect, the standard assisting power Psd is calculated based on the opening and closing velocity Vdr of the door **14**, a correction is made by decreasing the calculated standard assisting power Psd according to a predetermined rule, and the standard assisting power Psd thus decreased and corrected is set as the target assisting power Ptg. Accordingly, favorable operability that does not make the operator feel the weight of the door **14** when performing the opening and closing operation can be achieved with a simple apparatus configuration, as is similar to the door opening and closing assisting apparatus **10** based on the first or second aspect.

Also, a door opening and closing assisting apparatus **10** based on a fourth aspect is the door opening and closing assisting apparatus **10** based on the third aspect, which may be configured as follows: the door is a swing door **14** that opens and closes, pivotally supported by the hinge mechanisms **13**A and **13**B provided on the vehicle body **20** of the vehicle **11**, the door opening and closing assisting apparatus **10** further includes the acceleration sensor **32** that is provided on the door **14** to detect accelerations in three-dimensional directions including the vehicle length direction, the vehicle width direction, and the vehicle height direction, the information obtainer **33** further obtains, based on the accelerations in the three-dimensional directions detected by the acceleration sensor **32**, information on the attitude of the vehicle **11** including front-back and left-right tilts, and the target assisting power computer **37** pre-stores information on the attitude of the vehicle **11** when the door **14** is fully closed, and when the door **14** is open, makes a correction to make the target assisting power Ptg larger or smaller based on the pre-stored attitude of the vehicle **11**.

In a case where the acceleration sensor **32** is provided on the door **14** and information on the attitude of the vehicle **11** is obtained based on information detected by the acceleration sensor **32**, the attitude of the vehicle **11** may have error depending on the open or close position of the door **14**.

In this regard, the door opening and closing assisting apparatus **10** based on the fourth aspect pre-stores information on the attitude of the vehicle **11** when the door **14** is fully closed, and when the door **14** is open, makes a correction to make the target assisting power Ptg larger or smaller based on the pre-stored attitude of the vehicle **11**. Thus, information on the attitude of the vehicle **11** can be obtained with high precision irrespective of the open/close position of the door **14**.

Also, because the target assisting power computer **37** makes a correction to make the target assisting power Ptg larger or smaller based on the precise attitude of the vehicle **11**, even if the attitude of the vehicle **11** changes, the affect that this attitude change has on the operability for opening and closing the door **14** can be reduced properly.

Also, a door opening and closing assisting apparatus **10** based on a fifth aspect is the door opening and closing assisting apparatus **10** based on the fourth aspect, which may be configured as follows: the door opening and closing assisting apparatus **10** further includes the Hall sensor (openness degree sensor) **31** provided on the door actuator **19** to detect the openness degree Odr of the door **14**, the information obtainer **33** further obtains information on the openness degree Odr of the door **14** via the Hall sensor (openness degree sensor) **31**, and the target assisting power computer **37** makes a correction to make the target assisting power Ptg larger or smaller based on the attitude of the vehicle **11** and the openness degree Odr of the door **14**.

According to the door opening and closing assisting apparatus **10** based on the fifth aspect in which the target assisting power computer **37** makes a correction by increasing or decreasing the standard assisting power Psd based on the attitude of the vehicle **11** and the openness degree Odr of the door **14**. Thus, even if the attitude of the vehicle **11** changes, the affect that this attitude change has on the operability for opening and closing the door **14** can be reduced properly, and also, the affect that the openness degree Odr of the door **14** at that time has on the operability for opening or closing the door **14** can be reduced.

As a result, operability for opening and closing the door **14** can be made to be even more favorable.

## OTHER EMBODIMENTS

A plurality of embodiments described above show examples of how the present invention is embodied. Thus,

those embodiments should not be interpreted as limiting the technical scope of the present invention. The present invention can be carried out in various modes without departing from the gist thereof or main features thereof.

What is claimed is:

**1**. A door opening and closing assisting apparatus that assists an opening and closing operation of a swing door pivotally supported by a hinge mechanism provided on a vehicle, the door opening and closing assisting apparatus comprising:

an acceleration sensor provided on the swing door to detect an opening and closing acceleration of the swing door and a vehicle height acceleration of the swing door which is an acceleration in a vehicle height direction;

a door actuator that performs driving for assisting the opening and closing operation of the swing door; and

an ECU (electronic control unit) configured to function as:

an information obtainer that obtains information on the opening and closing acceleration and the vehicle height acceleration of the swing door;

a determiner that determines magnitudes of the opening and closing acceleration and the vehicle height acceleration of the swing door;

a target assisting power computer that computes a target assisting power for assisting the opening and closing operation of the swing door; and

a controller that performs driving control for the door actuator based on the target assisting power, wherein

the controller starts the driving control for the door actuator at a timing at which the information obtainer obtains the opening and closing acceleration and the vehicle height acceleration of the swing door and at a timing at which the determiner determines the opening and closing acceleration of the swing door is above a predetermined opening and closing acceleration threshold and the vehicle height acceleration of the swing door is below a predetermined vehicle height acceleration threshold.

**2**. The door opening and closing assisting apparatus according to claim **1**, wherein

the information obtainer further obtains information on an opening and closing velocity of the swing door, and

the target assisting power computer calculates, based on the opening and closing velocity of the swing door obtained by the information obtainer, a standard assisting power which is an assisting power required to maintain the opening and closing velocity, makes a correction by decreasing the calculated standard assisting power according to a predetermined rule, and sets the standard assisting power thus corrected by being decreased, as the target assisting power.

**3**. The door opening and closing assisting apparatus according to claim **2**, wherein

the acceleration sensor detects accelerations in three-dimensional directions including a vehicle length direction, a vehicle width direction, and the vehicle height direction,

the information obtainer further obtains, based on the accelerations in the three-dimensional directions detected by the acceleration sensor, information on an attitude of the vehicle including front-back and left-right tilts, and

the target assisting power computer pre-stores information on the attitude of the vehicle when the swing door is fully closed, and when the swing door is open, makes a correction to make the target assisting power larger or smaller based on the pre-stored attitude of the vehicle.

**4**. The door opening and closing assisting apparatus according to claim **3**, further comprising an openness degree sensor provided on the door actuator to detect a degree of openness of the swing door, wherein

the information obtainer further obtains information on the degree of openness of the swing door through the openness degree sensor, and

the target assisting power computer makes a correction to make the target assisting power larger or smaller based on the attitude of the vehicle and the degree of openness of the swing door.

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