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(54) **DOOR PINCH DETECTION DEVICE, RAILWAY DOOR DEVICE AND PROGRAM**

(57) A door pinch detection device (1) for detecting door pinch when a door (3R, 3L) is driven in a closing direction by a driving force from a motor (11) includes a position determining unit (32) for determining whether the door (3R, 3L) reaches a predetermined position based on at least one selected from the group consisting of a speed, a distance and a duration of movement made

by the door (3R, 3L) while closed, and a door pinch determining unit (31) for determining whether the door pinch has occurred based on current flowing through the motor (11) in a period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches a fully closed position.

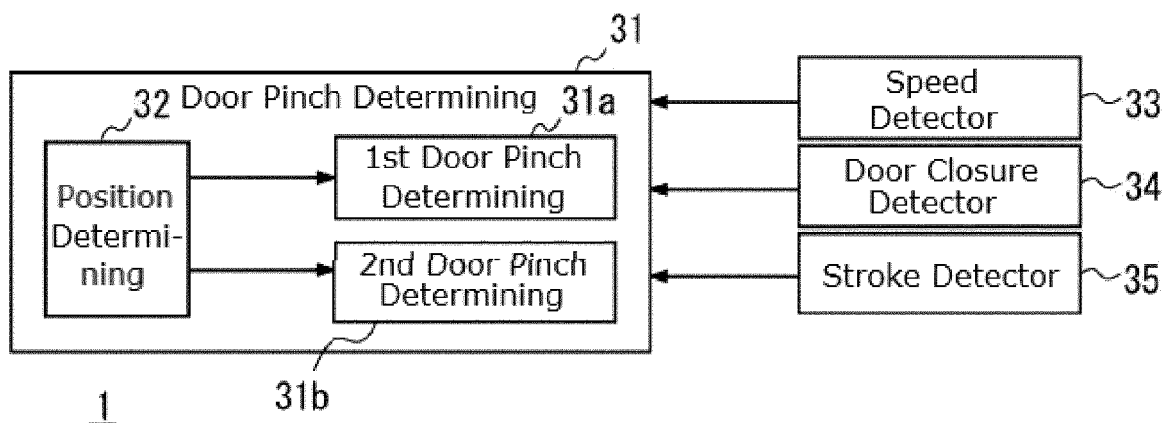


Fig. 4

Description

TECHNICAL FIELD

[0001] Embodiments of the present invention relate to a door pinch detection device, a railway door device, and a program.

BACKGROUND

[0002] Automatic door devices include door pinch detection devices for detecting whether persons or objects touch the leading edge of the door leaves. Conventional door pinch detection devices are classified into two types, one of which is configured to consult the moving speed of the door leaves to detect door pinch, and the other is configured to refer to the current flowing through the motor (hereinafter, referred to as the motor current) for generating a driving force intended for moving the door leaves in order to detect door pinch.

[0003] In a case where the moving speed of the door leaves is referred to in order to detect door pinch, the conventional door pinch detection devices determine that door pinch has occurred if the moving speed of the door leaves becomes zero. In another case where the motor current is referred to in order to detect door pinch, the conventional door pinch detection devices determine that door pinch has occurred if the motor current exceeds a predetermined threshold value. This is because the motor current suddenly increases following the occurrence of door pinch.

[0004] The leading edge of the door leaf has a rubber material attached thereto in order to mitigate the impact on the persons and objects. Accordingly, if persons or objects touch the rubber material, the moving speed of the door leaf does not instantly reach zero and, instead, the door leaf moves at a low speed as long as the rubber material can contract. Similarly, when left and right door leaves are fully closed, the door leaves keep moving at a low speed for a while after the rubber materials of the door leaves touch each other. For the above reasons, whether door pinch has occurred may not be accurately determined only based on the moving speed of the door.

[0005] The motor current, on the other hand, may be also subject change for various factors. The motor current may be compared against a threshold value in an attempt to detect door pinch. If the motor current significantly change, however, it cannot be accurately detected whether door pinch has occurred.

[0006] To address the above problems, embodiments of the present invention are designed to provide a door pinch detection device, a railway door device, and a program capable of detecting whether door pinch has occurred in a simple and accurate manner.

SUMMARY

[0007] To solve the above problems, one embodiment

of the present invention provides a door pinch detection device for detecting door pinch when a door is driven in a closing direction by a driving force from a motor. The door pinch detection device includes a position determining unit for determining whether the door has reached a predetermined position based on at least one selected from the group consisting of a speed, a distance and a duration of movement made by the door while the door is closed, and a door pinch determining unit for determining whether door pinch has occurred based on current flowing through the motor in a period from when the door is determined to have reached the predetermined position to when the door reaches a fully closed position.

[0008] In the period from when the door is determined to have reached the predetermined position to when the door reaches the fully closed position, the door pinch determining unit may determine whether door pinch has occurred based on the speed of the movement made by the door, concurrently with the determination as to whether door pinch has occurred based on the current flowing through the motor.

[0009] The door pinch determining unit may include a first door pinch determining unit for, if the door is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the speed of the movement made by the door or the current flowing through the motor satisfies a first condition, and a second door pinch determining unit for, in the period from when the door is determined to have reached the predetermined position to when the door reaches the fully closed position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.

[0010] The second door pinch determining unit may determine that the door pinch has occurred in at least one of (i) a case where the current is determined to satisfy the second condition in the period from when the door is determined to have reached the predetermined position to when the door reaches the fully closed position or (ii) a case where door pinch is determined to have occurred based on the speed of the door.

[0011] The door pinch detection device may include a first obtaining unit for obtaining a first current value indicating current flowing through the motor in a first period while the door is closed, a threshold setting unit for, based on the obtained first current value, setting a threshold value used to determine whether the door pinch has occurred, and a second obtaining unit for obtaining a second current value indicating current flowing through the motor in a second period following the first period while the door is closed. The second door pinch determining unit may determine whether the second condition is satisfied based on comparing the obtained second current value against the set threshold value.

[0012] The threshold setting unit may set the threshold value based on at least one selected from the group consisting of an average value, a median value, a most fre-

quent value, and an integrated value of values indicating the current flowing through the motor in the first period.

[0013] The door pinch detection device may include a storage unit for storing association between (i) at least one measured value of an average value, a median value, a most frequent value, or an integrated value of values indicating the current flowing through the motor when no door pinch occurs while the door is driven in a closing direction and (ii) a reference threshold value determined by the measured value. The threshold setting unit may set the threshold value based on (i) the association stored in the storage unit and (ii) at least one selected from the group consisting of an average value, a median value, a most frequent value, and an integrated value of values indicating the current flowing through the motor in the first period.

[0014] The threshold setting unit may set the threshold value based on voltage used to drive the motor in the first period.

[0015] Another aspect of the present invention provides a railway door device including a door provided in a railway vehicle, a motor for opening or closing the door, a door opening-closing control unit for controlling the motor, and a door pinch detection device for detecting door pinch when the door is driven by a driving force from the motor in a closing direction. The door pinch detection device includes a position determining unit for, while the door is closed, determining whether the door has reached a predetermined position based on at least one selected from the group consisting of a moving speed of the door, a distance moved by the door and a duration of movement made by the door in the closing direction, a first door pinch determining unit for, if the door is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the moving speed of the door or current flowing through the motor satisfies a first condition, and a second door pinch determining unit for, in a period from when the door is determined to have reached the predetermined position to when the door reaches a fully closed position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.

[0016] Yet another aspect of the present invention provides a program for causing a computer to detect door pinch when a door is driven in a closing direction by a driving force from a motor. The program causes the computer to execute procedures of determining whether the door has reached a predetermined position based on at least one selected from the group consisting of a moving speed of the door, a distance moved by the door and a duration of movement made by the door in the closing direction, while the door is closed, if the door is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the moving speed of the door or current flowing through the motor satisfies a first condition, and in a period from when the door is determined to have reached

the predetermined position to when the door reaches a fully closed position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.

[0017] The threshold setting unit may set the threshold value based on voltage used to drive the motor in the first period.

[0018] A further different aspect of the present invention provides a railway door device including a door, a motor for opening or closing the door, a door opening-closing control unit for controlling the motor, a door pinch detection device for detecting door pinch when the door is driven by a driving force from the motor in a closing direction. The door pinch detection device includes a position determining unit for, while the door is closed, determining whether the door has reached a predetermined position based on at least one selected from the group consisting of a moving speed of the door, a distance moved by the door and a duration of movement made by the door in the closing direction, a first door pinch determining unit for, if the door is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the moving speed of the door or current flowing through the motor satisfies a first condition, and a second door pinch determining unit for, if the door is determined to have reached the predetermined position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.

[0019] An aspect of the present invention provides a program for causing a computer to detect door pinch when a door is driven in a closing direction by a driving force from a motor. The program causes the computer to execute procedures of determining whether the door has reached a predetermined position based on at least one selected from the group consisting of a moving speed of the door, a distance moved by the door and a duration of movement made by the door in the closing direction, while the door is closed, if the door is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the moving speed of the door or current flowing through the motor satisfies a first condition, and if the door is determined to have reached the predetermined position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is an external view showing an automatic door device having a door pinch detection device relating to a first embodiment built therein.

Fig. 2 more specifically shows constituent components in the vicinity of a motor.

Fig. 3 is a block diagram schematically showing the configuration of a control system of the automatic door device of Fig. 1.

Fig. 4 is a block diagram showing the configuration of a door pinch detection device relating to the first embodiment.

Fig. 5 is a graph showing how a stroke, a moving speed and a motor current change.

Fig. 6 is a flow chart showing the series of steps in the procedure performed by the door pinch detection device relating to the first embodiment.

Fig. 7 is a flow chart showing the series of steps in the procedure performed by a door pinch detection device relating to a second embodiment.

Fig. 8 is a block diagram showing the configuration of a door pinch detection device relating to a third embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The following describes embodiments of a door pinch detection device, a railway door device, and a program with reference to the attached drawings. The following description focuses on the main constituent parts of the door pinch detection device, railway door device and program, and the door pinch detection device, railway door device and program may include more constituent parts and functions not shown or described. The following description by no means exclude such constituent parts and functions not shown or described.

<First Embodiment

[0022] Fig. 1 is an external view showing an electric door device 2 having a door pinch detection device 1 relating to a first embodiment built therein. The electric door device 2 shown in Fig. 1 is designed to be installed in railway vehicles. The electric door device 2 according to the present embodiment can be used in a wide range of applications in addition to railway vehicles. For example, the electric door device 2 relating to the present embodiment are applicable to automatic door devices installed in vehicles, buildings, and facilities, and also to doors of private residences. The electric door device 2 described herein is installed mainly in railway vehicles.

[0023] The electric door device 2 shown in Fig. 1 includes a pair of door leaves 3R and 3L constituting a sliding door. The door leaves 3R and 3L are movable in the left-right direction in the drawing. Above the door leaves 3R and 3L, a guide rail 4, a suspension device 5R supporting the right door leaf 3R and a suspension device 5L supporting the left door leaf 3L are provided.

[0024] The suspension device 5R and door leaf 3R are integrally movable along the guide rail 4. Likewise, the suspension device 5L and door leaf 3L are integrally movable along the guide rail 4. As used herein, at least one of the door leaf 3R or the door leaf 3L may be simply

referred to as a door.

[0025] In the suspension devices 5R and 5L, a plurality of rollers 6 are provided, as shown by the dotted lines in Fig. 1. The rollers 6 roll while remaining in contact with the upper or lower surface of the guide rail 4.

[0026] The leading edge of the door leaves 3R and 3L has a rubber material 7 attached thereto, which is made of a soft synthetic rubber material. When the door leaves 3R and 3L are fully closed, their respective rubber materials 7 touch each other and contract to a certain extent while touching each other. After this, the door leaves 3R and 3L stop moving.

[0027] Above the guide rail 4, a right rack gear 8R and a left rack gear 8L are provided and extend in the direction in which the guide rail 4 extends. The right rack gear 8R is coupled with a right bracket 9R. As the right rack gear 8R moves in the left-right direction, the movement causes the right bracket 9R to move in the left-right direction. Similarly, the left rack gear 8L is coupled with a left bracket 9L. As the left rack gear 8L moves in the left-right direction, the movement causes the left bracket 9L to move in the left-right direction. The right bracket 9R is coupled with the suspension device 5R. As the right bracket 9R moves in the left-right direction, the suspension device 5R and door leaf 3R integrally move in the left-right direction. Similarly, the left bracket 9L is coupled with the suspension device 5L. As the left bracket 9L moves in the left-right direction, the suspension device 5L and door leaf 3L integrally move in the left-right direction.

[0028] The right and left rack gears 8R and 8L mesh with a pinion gear 10, so that they are configured to convert the rotation of the pinion gear 10 into linear movement. The pinion gear 10 is rotated when acted upon by a driving force from a motor 11.

[0029] Fig. 2 more specifically shows the constituent parts in the vicinity of the motor 11. The motor 11 has a rotational shaft 12, to which a sun gear 13 is attached, a plurality of planetary gears 14 surround and mesh with the sun gear 13, and the pinion gear 10 serves as an outer gear that is positioned outside the planetary gears 14 and meshes with the planetary gears 14.

[0030] With the above-described configuration, as the motor 11 rotates, the resulting rotational force is transmitted to the rack gears 8R and 8L via the pinion gear 10. As the rack gears 8R and 8L move in the left-right direction as a result of the rotation of the motor 11, the door leaves 3R and 3L move in the left-right direction along the guide rail 4 via the right and left brackets 9R and 9L. The motor 11 is driven by a motor driving unit 23 included in a controller 15 shown in Fig. 3, which will be described below.

[0031] In the above description, the electric door device 2 may be opened or closed using the rack and pinion system, but the present disclosure is not necessarily limited to such. Any other systems (for example, belt, screw and linear motor systems) may be employed.

[0032] Fig. 3 is a block diagram schematically showing the configuration of a control system of the electric door

device 2 of Fig. 1. The control system of the electric door device 2 relating to the present embodiment includes a controller 15 having the door pinch detection device 1 built therein, a power supply unit 16 and a motor monitoring unit 17.

[0033] The power supply unit 16 includes a power unit for converting an alternating-current voltage fed from an overhead line to a direct-current voltage. The controller 15 includes a door opening-closing control unit 18 and an instructing unit 19. The instructing unit 19 outputs, to the door opening-closing control unit 18, an instruction signal for opening or closing the door leaves 3R and 3L. The door opening-closing control unit 18 controls the opening or closing of the door leaves 3R and 3L based on the instruction signal.

[0034] The door opening-closing control unit 18 includes a power-supply voltage detecting unit 21, a PWM control unit 22, a motor driving unit 23 and a Hall signal detector 24.

[0035] The power-supply voltage detecting unit 21 is configured to detect the level of the DC voltage output from the power supply unit 16. The PWM control unit 22 is configured to generate a PWM signal for driving the motor 11 based on the level of the DC voltage detected by the power-supply voltage detecting unit 21 and the instruction signal from the instructing unit 19. More specifically, the PWM control unit 22 generates the PWM signal for controlling the duty ratio of the voltage to be fed to the motor 11, based on a reference voltage instruction pattern indicated by the instruction signal and the voltage level of the DC signal detected by the power-supply voltage detecting unit 21.

[0036] The motor driving unit 23 is configured to turn on or off the transistors configured to drive the motor 11, based on the PWM signal. For example, when the motor 11 is a three-phase motor, the motor driving unit 23 generates gate signals for turning on or off the U-phase, V-phase and W-phase transistors.

[0037] A Hall element 25 is provided in the vicinity of a rotational shaft 12 of the motor 11. The Hall element 25 detects the number of rotations of the motor 11. In the vicinity of the motor 11, the motor monitoring unit 17 is provided. The motor monitoring unit 17 includes, in addition to the above-mentioned Hall element 25, a motor current detector 26 for detecting the motor current and a motor voltage detector 27 for detecting the voltage applied to the motor 11.

[0038] The Hall signal detector 24 is configured to detect the number of rotations of the motor 11 based on the detection signal from the Hall element 25. The motor driving unit 23 can refer to the number of rotations of the motor 11 detected by the Hall signal detector 24 to feed-back control the timing of turning on or off the transistors for driving the motor 11.

[0039] The door pinch detection device 1 is configured to detect occurrence of door pinch between the leading edges of the door leaves 3R and 3L when the driving force from the motor 11 drives the door leaves 3R and

3L in the closing direction.

[0040] The electrical door device 2 relating to the present embodiment may include a sending unit 28. The sending unit 28 is configured to, if the door pinch detection device 1 detects that door pinch has occurred, notify a managing device (not shown), a mobile terminal owned by a maintenance worker or the like of the fact that door pinch has occurred.

[0041] Fig. 4 is a block diagram showing the configuration of the door pinch detection device 1 relating to the first embodiment. As shown in Fig 4, the door pinch detection device 1 includes a door pinch determining unit 31.

[0042] The door pinch determining unit 31 is configured to determine whether door pinch has occurred based on (i) at least one selected from the group consisting of a speed, a distance and a duration of the movement made by the door leaves 3R and 3L while closed and (ii) the current flowing through the motor. Concurrently with the determination as to whether door pinch has occurred between the door leaves 3R and 3L based on the current flowing through the motor, the door pinch determining unit 31 may continuously determine whether door pinch has occurred based on the moving speed of the door leaves 3R and 3L in the period from when the door leaves 3R and 3L start moving in the closing direction to when the door leaves 3R and 3L reach the fully closed position.

[0043] As described above, the door pinch determining unit 31 is configured to perform both a door pinch determining procedure based on the motor current and a door pinch determining procedure based on the moving speed of the door leaves 3R and 3L, so that it can more accurately detect door pinch.

[0044] The door pinch detection device 1 relating to the present embodiment includes a position determining unit 32. The position determining unit 32 determines whether or not the door leaves 3R and 3L have reached a predetermined position based on at least one selected from the group consisting of the moving speed of the door leaves 3R and 3L, the moved distance of the door leaves 3R and 3L and the duration of the movement made by the door leaves 3R and 3L in the closing direction while the door leaves 3R and 3L are closed. The position determining unit 32 is intended to determine whether or not the door leaves 3R and 3L are positioned immediately close to the fully closed position. The predetermined position is designated as a position approximately several centimeters before the fully closed position, for example. The door pinch determining unit 31 determines whether door pinch has occurred between the door leaves 3R and 3L based on the current flowing through the motor 11 in the period from when the door leaves 3R and 3L are determined to have reached the predetermined position to when the door leaves 3R and 3L reach the fully closed position. As noted, the door pinch determining unit 31 consults the motor current in order to determine whether door pinch has occurred if the door leaves 3R and 3L have moved to be positioned immediately close to the

fully closed position.

[0045] The door pinch determining unit 31 may change the door pinch determining procedure depending on whether the door leaves 3R and 3L have reached the predetermined position. For example, as shown in Fig 4, the door pinch determining unit 31 may include a first door pinch determining unit 31a and a second door pinch determining unit 31b.

[0046] The first door pinch determining unit 31a determines whether door pinch has occurred based on whether the moving speed of the door leaves 3R and 3L or the current flowing through the motor satisfies a first condition, if the door leaves 3R and 3L are determined to have not reached the predetermined position.

[0047] The second door pinch determining unit 31b determines whether door pinch has occurred based on whether the current satisfies a second condition different from the first condition, in the period from when the door leaves 3R and 3L are determined to have reached the predetermined position to when the door leaves 3R and 3L reach the fully closed position. The second door pinch determining unit 31b may determine that door pinch has occurred in at least one of (i) a case where the current is determined to satisfy the second condition in the period from when the door leaves 3R and 3L are determined to have reached the predetermined position to when the door leaves 3R and 3L reach the fully closed position, or (ii) a case where door pinch is determined to have occurred between the door leaves 3R and 3L based on the speed of the door leaves 3R and 3L.

[0048] In addition, the door pinch determining unit 31 relating to the present embodiment may include a speed detector 33 for detecting the moving speed of the door leaves 3R and 3L. Furthermore, the door pinch determining unit 31 relating to the present embodiment may include a door closure detector 34 for detecting whether the door leaves 3R and 3L are fully closed. In addition, the door pinch determining unit 31 relating to the present embodiment may include a stroke detector 35 for detecting the moved position (stroke) of the door leaves 3R and 3L.

[0049] Fig. 5 is a graph showing how the stroke w1, moving speed w2, motor current w3a, w3b of the door leaves 3R and 3L change while the door leaves 3R and 3L move from the fully open position to the fully closed position. In Fig. 5, the horizontal axis represents the position of the leading edge of the door leaves 3R and 3L, and the vertical axis represents the amount of the stroke by the waveform w1, the moving speed by the waveform w2 and the motor current by the waveform w3. The amount of the stroke indicates the distance by which the door leaves 3R and 3L have moved. As for the motor current, the waveform w3a shows the motor current observed while no door pinch is occurring, and the waveform w3b shows the motor current observed while door pinch is occurring.

[0050] As indicated by the waveform w2, the moving speed of the door leaves 3R and 3L is increasing imme-

diately after the door leaves 3R and 3L start moving, in other words, rises linearly as the time elapses. Once the moving speed reaches a certain level, the moving speed of the door leaves 3R and 3L remains constant at the level for a predetermined period of time. The moving speed then decreases as the time elapses. While decreasing, the moving speed drops in a stepwise manner. As the moving speed changes, the stroke of the door leaves 3R and 3L changes to draw a non-linear line or curved line, as indicated by the waveform w1.

[0051] The motor current significantly changes as influenced by external disturbances immediately after the door leaves 3R and 3L start moving in the closing direction from the fully open position. After this, the motor current decreases in a stepwise manner. Once the moving speed of the door leaves 3R and 3L start decreasing, the motor current changes drastically temporarily once and then decreases in a stepwise manner. Once the door leaves 3R and 3L reach a position near the fully closed position, the rubber materials of the door leaves 3R and 3L touch each other, so that the motor current suddenly increases.

[0052] The motor current exhibits significantly different values between when door pinch occurs with the door leaves 3R and 3L being positioned near the fully closed position (the waveform w3b) and when no door pinch occurs (the waveform w3a). The motor current exhibits a far greater value when door pinch occurs (the waveform w3b) than when no door pinch occurs (w3a).

[0053] The door pinch detection device 1 relating to the present embodiment makes use of the shapes of the waveforms shown in Fig. 5. More specifically, the door pinch detection device 1 detects whether door pinch has occurred by comparing the motor current against a predetermined threshold value when the door leaves 3R and 3L are positioned near the fully closed position. The threshold value is, for example, set close to the median value between the peak value of the waveform w3a and the peak value of the waveform w3b observed when the door leaves 3R and 3L are positioned close to the fully closed position, which are shown in Fig. 5.

[0054] Fig. 6 is a flow chart showing the series of steps in the procedure performed by the door pinch detection device 1 relating to the first embodiment. The series of steps shown in the flow chart of Fig. 6 starts when the door leaves 3R and 3L start moving in the closing direction. In the first step, it is determined whether the door leaves 3R and 3L have reached the fully closed position (the step S1). Whether or not the door leaves 3R and 3L have reached the fully closed position may be detected based on, for example, the signal from the stroke detector 35. Since the signal from the stroke detector 35 can result in detecting the distance of the movement made by the door leaves 3R and 3L, the signal from the stroke detector 30 can be used to determine whether the door leaves 3R and 3L have reached the fully closed position. Alternatively, the signal from the door closure detector 34 may be used to determine whether the door leaves 3R and

3L are moving. The door closure detector 34 is configured to detect whether the door leaves 3R and 3L have reached the fully closed position.

[0055] If the step S1 determines that the door leaves 3R and 3L have reached the fully closed position, the procedure shown Fig. 6 ends. If the step S1 determines that the door leaves 3R and 3L have not reached the fully closed position, the next step determines whether the moving speed of the door leaves 3R and 3L has become zero (the step S2). The moving speed of the door leaves 3R and 3L is detected by, for example, the speed detector 33. Alternatively, the moving speed of the door leaves 3R and 3L may be detected based on the signal produced by the Hall signal detector 24.

[0056] If the step S2 determines that the moving speed of the door leaves 3R and 3L is not zero, the next step determines whether the door leaves 3R and 3L have reached a predetermined position before the fully closed position (the step S3). The predetermined position before the fully closed position may be approximately several centimeters before the fully closed position, for example.

[0057] If the step S3 determines that the door leaves 3R and 3L have not reached the predetermined position, the flow of the procedure goes back to the step S2. If the step S3 determines that the door leaves 3R and 3L have reached the predetermined position, the next step determines whether the motor current is greater than a predetermined threshold value (the step S4). If the step S4 determines that the motor current is greater than the threshold value, it is determined that door pinch has occurred and door pinch is thus detected (the step S5). In addition, if the step S2 determines that the door leaves 3R and 3L have not reached the fully closed position but the moving speed of the door leaves 3R and 3L have become zero, the flow of the procedure jumps to the step S5 and the step 5 detects that door pinch has occurred. The information indicating that the occurrence of door pinch is detected is transmitted to, for example, a managing device, a mobile terminal owned by a maintenance worker or the like (not shown) via the sending unit 28.

[0058] As described above, in the first embodiment, the door pinch detection device 1 determines that door pinch has occurred if the speed of the door has become zero, in the period from when the door leaves 3R and 3L start moving in the closing direction to when the door leaves 3R and 3L reach the fully closed position. In addition, once the door leaves 3R and 3L reach the predetermined position before the fully closed position, the door pinch detection device 1 compares the motor current against the threshold value. If the motor current exceeds the threshold value, the door pinch detection device 1 determines that door pinch has occurred. As described above, the rubber materials 7 are attached to the leading edges of the door leaves 3R and 3L. Even if a person or object touches the rubber materials 7, the door leaves 3R and 3L keep moving as long as the rubber materials 7 can contract. For the above reasons, whether door pinch has occurred may not be swiftly and accu-

ately detected only based on the speed of the door. To address this issue, the present embodiment refers not only to the speed of the door but also to the motor current in order to detect door pinch. Accordingly, the present embodiment can swiftly and accurately detect whether door pinch has occurred.

<Second Embodiment

[0059] A door pinch detection device 1 relating to a second embodiment has the same block diagram configuration as shown in Fig. 4, but performs a different series of steps than the door pinch detection device 1 relating to the first embodiment.

[0060] Fig. 7 is a flow chart showing the series of steps in the procedure performed by the door pinch detection device 1 relating to the second embodiment. The series of steps shown in the flow chart of Fig. 7 starts when the door leaves 3R and 3L start moving in the closing direction.

[0061] In the first step, it is determined whether the leading edge of the door leaves 3R and 3L has reached a predetermined position (the step S11). The predetermined position is, for example, a position several centimeters before the fully closed position but can be defined in any manner.

[0062] If the step S11 determines that the leading edge of the door leaves 3R and 3L has not reached the predetermined position, the next step determines whether the moving speed of the door leaves 3R and 3L or the current flowing through the motor satisfies a first condition (the step S12). The first condition is satisfied if, for example, the moving speed of the door leaves 3R and 3L or the current flowing through the motor is equal to or greater than a predetermined threshold value.

[0063] The specific details of the first condition can be determined in any manner. If the leading edge of the door leaves 3R and 3L has not reached the predetermined position, the motor current drastically changes as can be seen from the waveforms w3a and w3b indicated in the graph in Fig. 5. For this reason, the threshold value for the motor current may be set low. Furthermore, the door pinch detection device 1 may not depend only on the motor current to determine whether door pinch has occurred, and may also consult whether the moving speed of the door leaves 3R and 3L has become zero in order to determine whether door pinch has occurred.

[0064] If the first condition is not satisfied in the step S12, the door pinch detection device 1 determines that no door pinch has occurred and performs the step S11 again. The door pinch detection device 1 determines whether the current flowing through the motor satisfies a second condition (the step S13) in the period from when the leading edge of the door leaves 3R and 3L is determined to have reached the predetermined position in the step S11 to when the door leaves 3R and 3L reach the fully closed position. According to the specific details of the second condition, the threshold value to be compared

against the motor current is set greater than the threshold value included in the specific details of the first condition. More specifically, the threshold value may be set close to the median value between the peak value of the waveform w3a and the peak value of the wave form w3b, shown in Fig. 5, observed when the door leaves 3R and 3L are positioned close to the fully closed position. The specific details of the second condition may include a condition relating to the speed of the door. Regarding the door speed, the door pinch detection device 1 may determine that door pinch has occurred if the speed of the door has become zero for either the first or second condition, for example. The door pinch detection device 1 determines whether the second condition is satisfied while, for example, the door leaves 3R and 3L are positioned within a predetermined range before the fully closed position (indicated by the arrow in Fig. 5).

[0065] If the step S13 determines that the second condition is not satisfied, the next step determines whether the door has reached the fully closed position (the step S15). If the door has not reached the fully closed position, the step S11 and the subsequent steps are performed again. Once the door has reached the fully closed position, the procedure ends.

[0066] If the step S12 determines that the first condition is satisfied, or if the step S13 determines that the second condition is satisfied, the door pinch detection device 1 determines that door pinch has occurred (the step S15) and performs a predetermined procedure. After this, the procedure shown in Fig. 7 ends. The predetermined procedure includes, for example, a step of notifying a managing device or maintenance worker of the occurrence of the door pinch.

[0067] As described above, the second embodiment uses different criteria to determine whether door pinch has occurred, depending on where the door leaves 3R and 3L are positioned while moving in the closing direction. Accordingly, the door pinch detection device 1 relating to the second embodiment can swiftly and accurately determine whether door pinch has occurred.

<Third Embodiment

[0068] The above-described first and second embodiments determine whether door pinch has occurred by comparing the motor current against the threshold value if the door leaves 3R and 3L are positioned close to the fully closed position. The following third embodiment, however, is configured to optimize the threshold value.

[0069] Fig. 8 is a block diagram showing the configuration of a door pinch detection device 1 relating to the third embodiment. In addition to the constituent parts shown in Fig. 4, the door pinch detection device 1 shown in Fig. 8 further includes a first obtaining unit 36, a threshold setting unit 37, and a second obtaining unit 38.

[0070] The first obtaining unit 36 is configured to obtain a first current value indicating current flowing through the motor in a first period while the door leaves 3R and 3L

are closed. The first period includes, for example, a period in which the moving speed of the door leaves 3R and 3L remains constant, as shown in Fig. 5. As shown in Fig. 5, the motor current relatively stably change in the period in which the moving speed of the door leaves 3R and 3L remains constant. As being configured to obtain the motor current in the constant speed period, the first obtaining unit 36 can obtain a motor current value less influenced by external disturbances.

[0071] The first period may alternatively be defined in the period in which the moving speed is increasing after the door starts moving in the closing direction, or in the period in which the moving speed remains constant after having increased. As shown in Fig. 5, the motor current significantly changes immediately after the moving speed starts increasing. For this reason, it should be avoided to obtain the motor current immediately after the moving speed starts increasing, but the motor current changes less dramatically in the middle and final stages of the period in which the moving speed increases. Accordingly, the first period may overlap part of the period in which the moving speed increases. Similarly, when the moving speed starts decreasing after remaining constant, the motor current is stabilized after a while and changes less dramatically, as shown in Fig. 5. For this reason, the first period may overlap part of the period in which the moving speed of the door leaves 3R and 3L is decreasing.

[0072] The threshold setting unit 37 is configured to, based on the first current value obtained by the first obtaining unit 36, set a threshold value used to determine whether door pinch has occurred. The threshold value set by the threshold setting unit 37 is to be compared against the motor current in the procedures shown in the above-described flow charts of Figs. 6 and 7. More specifically, the threshold value is compared against the motor current observed when the door leaves 3R and 3L are positioned close to the fully closed position. In other words, the threshold setting unit 37 uses the actual value of the motor current observed when the door leaves 3R and 3L have not reached a position close to the fully closed position in order to set the threshold value to be compared against the motor current observed when the door leaves 3R and 3L are positioned close to the fully closed position.

[0073] The threshold setting unit 37 is provided for the following reasons. While the electric door is in operation, the sliding friction may gradually change or the driving force produced by the motor 11 may drop. This means that the motor current is not necessarily the same even if the moving speed of the door leaves 3R and 3L is the same. To address this issue, the actually measured value of the motor current is considered to set the threshold value for the motor current.

[0074] When the threshold setting unit 37 performs a procedure to set the threshold value, the door leaves 3R and 3L may be moved with a plurality of heavy objects having different weights being attached by turns to the

suspension devices 5R and 5L. In this manner, the sliding friction can be artificially changed. As the weight of the heavy object increases, the sliding friction increases. While the sliding friction of the door leaves 3R and 3L is set at a plurality of different levels in the above-described manner, the motor current in the first period may be obtained. Based on the resulting values, the threshold setting unit 37 may set the threshold value.

[0075] The threshold setting unit 37 may set the threshold value based on at least one selected from the group consisting of the average value, median value, most frequent value, and integrated value of the values indicating the current flowing through the motor in the first period. For example, the threshold value may be defined as the value obtained by cumulatively adding together the values of the motor current in the first period, calculating the average value based on the result of the cumulative addition, and multiplying the average value with a predetermined coefficient. The predetermined coefficient is greater than zero and less than one and determined, for example, based on the past operational performance of the electric door device 2. Alternatively, the threshold value may be defined as the value obtained by multiplying the median value of the values indicating the motor current in the first period with a predetermined coefficient. As a further alternative example, the threshold value may be defined as the value obtained by sorting by frequency the values of the motor current in the first period, specifying the most frequent value, and multiplying the most frequent value with a predetermined coefficient. As a yet another alternative example, the threshold value may be defined as the value obtained by cumulatively adding together the values of the motor current in the first period to calculate the integrated value, and multiplying the integrated value with a predetermined coefficient. In this case, the coefficient is less than the coefficient used to calculate the threshold value based on the average value.

[0076] The motor current depends on the sliding friction of the door leaves 3R and 3L or the driving force produced by the motor, and also depends on an environmental condition such as temperature and power-supply voltage. Accordingly, the threshold setting unit 37 may determine which type of value of the motor current is to be compared against the threshold value, considering that the motor current may change in the first period. For example, if the motor current does not change significantly temporarily in the first period, the average value may be calculated. On the other hand, if the motor current changes significantly temporarily in the first period, the average value may inadvertently incorporate the influence of the temporary change of the motor current. In this case, the median or most frequent value is desirable. If the motor current exhibits a small value, the integrated value may be selected.

[0077] The power-supply voltage fed to the motor 11 may change, and this may affect the motor current. The threshold setting unit 37 thus may consider the power-

supply voltage detected by the motor voltage detector 27 to set the threshold value. In other words, the threshold setting unit 37 may set the threshold value based on the voltage used to drive the motor 11 in the first period. As the driving voltage for the motor 11 increases, the motor current generally increases. Accordingly, the threshold setting unit 37 may desirably increase the threshold value as the driving voltage increases.

[0078] The second obtaining unit 38 is configured to obtain a second current value indicating the current flowing through the motor 11 in a second period following the first period while the door leaves 3R and 3L are closed. In the second period, the door leaves 3R and 3L are positioned close to the fully closed position and the motor current suddenly increases, for example, as shown in Fig. 5. The motor current suddenly increases when the door leaves 3R and 3L are at a certain position before the fully closed position, but the certain position differs among individual electric door devices 2. Accordingly, the second period is preferably set for each individual electric door device 2. In the second period, the door leaves 3R and 3L are at a position within a range of several dozen millimeters to several millimeters before the fully closed position, for example.

[0079] The first obtaining unit 36 may obtain the first current value in the first period every time the door leaves 3R and 3L are moved in the closing direction from the fully open position. In this case, the threshold setting unit 37 may set a new threshold value every time the door leaves 3R and 3L are moved in the closing direction from the fully open position, based on the first current value obtained by the first obtaining unit 36. Since a new threshold value is set every time the door leaves 3R and 3L are moved in the closing direction from the fully open position, the threshold value can be optimally set without being influenced by aging deterioration of the electric door device 2.

[0080] The first obtaining unit 36 may obtain the first current value in the first period in a case where the door leaves 3R and 3L are driven in the closing direction immediately following the power-on of the door leaves 3R and 3L. The threshold setting unit 37 may set the threshold value based on the first current value obtained by the first obtaining unit 36 in a case where the door leaves 3R and 3L are driven in the closing direction immediately following the power-on of the door leaves 3R and 3L. In a case where the electric door device 2 is used in railways, some passengers lean on the electric door or are pushed against the electric door due to the crowded situation. The motor current is more susceptible to external disturbances while passengers are on board. To address this issue, the first obtaining unit 36 obtains the motor current while the motor current is less influenced by external disturbances, for example, immediately following the power-on of the door leaves 3R and 3L. In this way, the first obtaining unit 36 can obtain the motor current without being affected by external disturbances.

[0081] The door pinch detection device 1 shown in Fig.

8 may include a storage unit 39. The storage unit 39 stores, in association with each other, (i) at least one measured value of the average value, median value, most frequent value and integrated value of the values indicating the current flowing through the motor 11 when the door is driven in the closing direction without causing door pinch and (ii) a reference threshold value determined by the measured value. The current flowing through the motor 11 depends on the sliding friction of the door leaves 3R and 3L. Accordingly, for example, a plurality of heavy objects having different weights are by turns attached to the suspension devices 5R and 5L, so that the sliding friction is artificially changed. In this way, the association between the motor current and the reference threshold is obtained in advance and stored in the storage unit 39. In this case, the threshold setting unit 37 sets the threshold value based on (i) at least one selected from the group consisting of the average value, median value, most frequent value, and integrated value of the values indicating the current flowing through the motor 11 in the first period and (ii) the association stored in the storage unit 39. The storage unit 39 spares the burden of setting a new threshold value every time the door leaves 3R and 3L are closed, thereby reducing the processing load on the door pinch detection device 1.

[0082] As described above, the third embodiment sets the threshold value based on the motor current obtained in the first period overlapping the period in which the moving speed of the door leaves 3R and 3L remains constant while the door leaves 3R and 3L are moved in the closing direction and detects whether door pinch has occurred by comparing the motor current observed when the door leaves 3R and 3L are positioned near the fully closed position against the threshold value set such. The third embodiment can optimize the threshold value taking into consideration aging deterioration of the sliding friction of the door leaves 3R and 3L, the driving force produced by the motor 11 and the like, thereby accurately detecting whether door pinch has occurred.

[0083] At least some of the constituent parts of the door pinch detection device 1 and railway door device described in the above embodiments may be implemented through hardware or software. If the software is used, at least some of the functions of the door pinch detection device 1 and railway door device are implemented by a program, and the program may be stored on a storage medium such as a flexible disc and a CD-ROM and executed when read by a computer. The storage medium is not limited to detachable ones such as magnetic and optical discs, and may be stationary storage media such as hard disk devices and memory devices.

[0084] Alternatively, at least some of the functions of the door pinch detection device 1 and railway door device may be implemented by a program, and the program may be distributed through communication lines (including wireless communication) such as the Internet. Furthermore, the program may be encrypted, modulated or compressed to be distributed through wired or wireless con-

nections such as the Internet or in the state of being stored on storage media.

[0085] Aspects of the present invention are not limited to the foregoing embodiments and embrace various modifications conceivable to those skilled in the art. Effects of the present invention are also not limited to the above-mentioned contents. That is, various additions, changes, and partial deletions are possible in a range not departing from the conceptual ideas and spirit of the present invention derived from contents defined in the claims and equivalents thereof.

Claims

1. A door pinch detection device (1) for detecting door pinch when a door (3R, 3L) is driven in a closing direction by a driving force from a motor (11), the door pinch detection device (1) comprising:

a position determining unit (32) for determining whether the door (3R, 3L) has reached a predetermined position based on at least one selected from the group consisting of a speed, a distance and a duration of movement made by the door (3R, 3L) while the door is closed; and
a door pinch determining unit (31) for determining whether the door pinch has occurred based on current flowing through the motor (11) in a period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches a fully closed position.

2. The door pinch detection device (1) of claim 1, wherein, in the period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches the fully closed position, the door pinch determining unit (31) determines whether door pinch has occurred based on the speed of the movement made by the door (3R, 3L), concurrently with the determination as to whether door pinch has occurred based on the current flowing through the motor (11).
3. The door pinch detection device (1) of claim 1 or 2, wherein the door pinch determining unit (31) includes:

a first door pinch determining unit (31a) for, if the door (3R, 3L) is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the speed of the movement made by the door (3R, 3L) or the current flowing through the motor (11) satisfies a first condition; and
a second door pinch determining unit (31b) for,

- in the period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches the fully closed position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.
4. The door pinch detection device (1) of claim 3, wherein the second door pinch determining unit (31b) determines that the door pinch has occurred in at least one of (i) a case where the current is determined to satisfy the second condition in the period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches the fully closed position or (ii) a case where door pinch is determined to have occurred based on the speed of the door (3R, 3L).
5. The door pinch detection device (1) of claim 3 or 4, comprising:
- a first obtaining unit for obtaining a first current value indicating current flowing through the motor (11) in a first period while the door (3R, 3L) is closed;
- a threshold setting unit for, based on the obtained first current value, setting a threshold value used to determine whether the door pinch has occurred; and
- a second obtaining unit for obtaining a second current value indicating current flowing through the motor (11) in a second period following the first period while the door (3R, 3L) is closed, wherein the second door pinch determining unit (31b) determines whether the second condition is satisfied based on comparing the obtained second current value against the set threshold value.
6. The door pinch detection device (1) of claim 5, wherein the threshold setting unit sets the threshold value based on at least one selected from the group consisting of an average value, a median value, a most frequent value, and an integrated value of values indicating the current flowing through the motor (11) in the first period.
7. The door pinch detection device (1) of claim 5 or 6, comprising
- a storage unit for storing association between (i) at least one measured value of an average value, a median value, a most frequent value, or an integrated value of values indicating the current flowing through the motor (11) when no door pinch occurs while the door (3R, 3L) is driven in a closing direction and (ii) a reference
- threshold value determined by the measured value,
- wherein the threshold setting unit sets the threshold value based on (i) the association stored in the storage unit and (ii) at least one selected from the group consisting of an average value, a median value, a most frequent value, and an integrated value of values indicating the current flowing through the motor (11) in the first period.
8. The door pinch detection device (1) of any one of claims 5 to 7, wherein the threshold setting unit sets the threshold value based on voltage used to drive the motor (11) in the first period.
9. A railway vehicle door device comprising:
- a door (3R, 3L) provided in a railway vehicle;
- a motor (11) for opening or closing the door (3R, 3L);
- a door opening-closing control unit for controlling the motor (11); and
- a door pinch detection device (1) for detecting door pinch when the door is driven by a driving force from the motor (11) in a closing direction, wherein the door pinch detection device (1) includes:
- a position determining unit (32) for, while the door is closed, determining whether the door (3R, 3L) has reached a predetermined position based on at least one selected from the group consisting of a moving speed of the door (3R, 3L), a distance moved by the door (3R, 3L) and a duration of movement made by the door (3R, 3L) in the closing direction;
- a first door pinch determining unit (31a) for, if the door (3R, 3L) is determined to have not reached the predetermined position, determining whether the door pinch has occurred based on whether the moving speed of the door (3R, 3L) or current flowing through the motor (11) satisfies a first condition; and
- a second door pinch determining unit (31b) for, in a period from when the door (3R, 3L) is determined to have reached the predetermined position to when the door (3R, 3L) reaches a fully closed position, determining whether the door pinch has occurred based on whether the current satisfies a second condition different from the first condition.
10. A program for causing a computer to detect door pinch when a door (3R, 3L) is driven in a closing direction by a driving force from a motor (11), the

program causing the computer to execute procedures of:

determining whether the door (3R, 3L) has
reached a predetermined position based on at
least one selected from the group consisting of
a moving speed of the door (3R, 3L), a distance
moved by the door (3R, 3L) and a duration of
movement made by the door (3R, 3L) in the closing
direction, while the door is closed;
if the door (3R, 3L) is determined to have not
reached the predetermined position, determining
whether the door pinch has occurred based
on whether the moving speed of the door (3R,
3L) or current flowing through the motor (11) satisfies
a first condition; and
in a period from when the door (3R, 3L) is determined
to have reached the predetermined position to when the door
(3R, 3L) reaches a fully closed position, determining
whether the door pinch has occurred based on whether the
current satisfies a second condition different from
the first condition.

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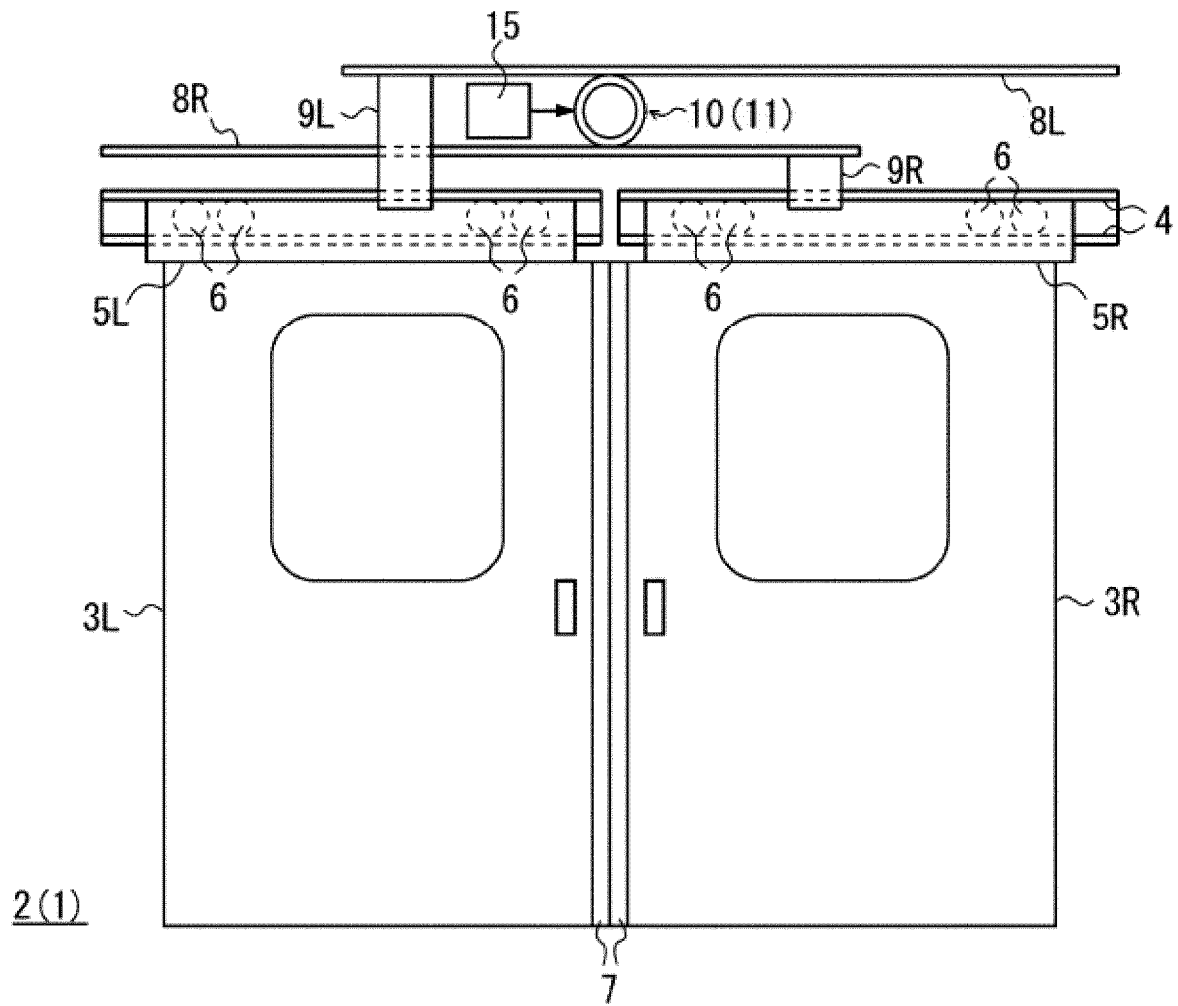


Fig. 1

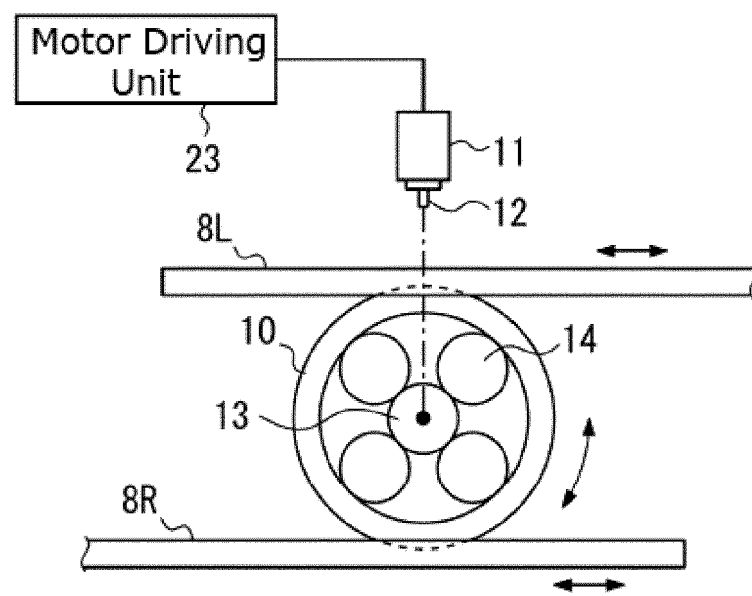


Fig. 2

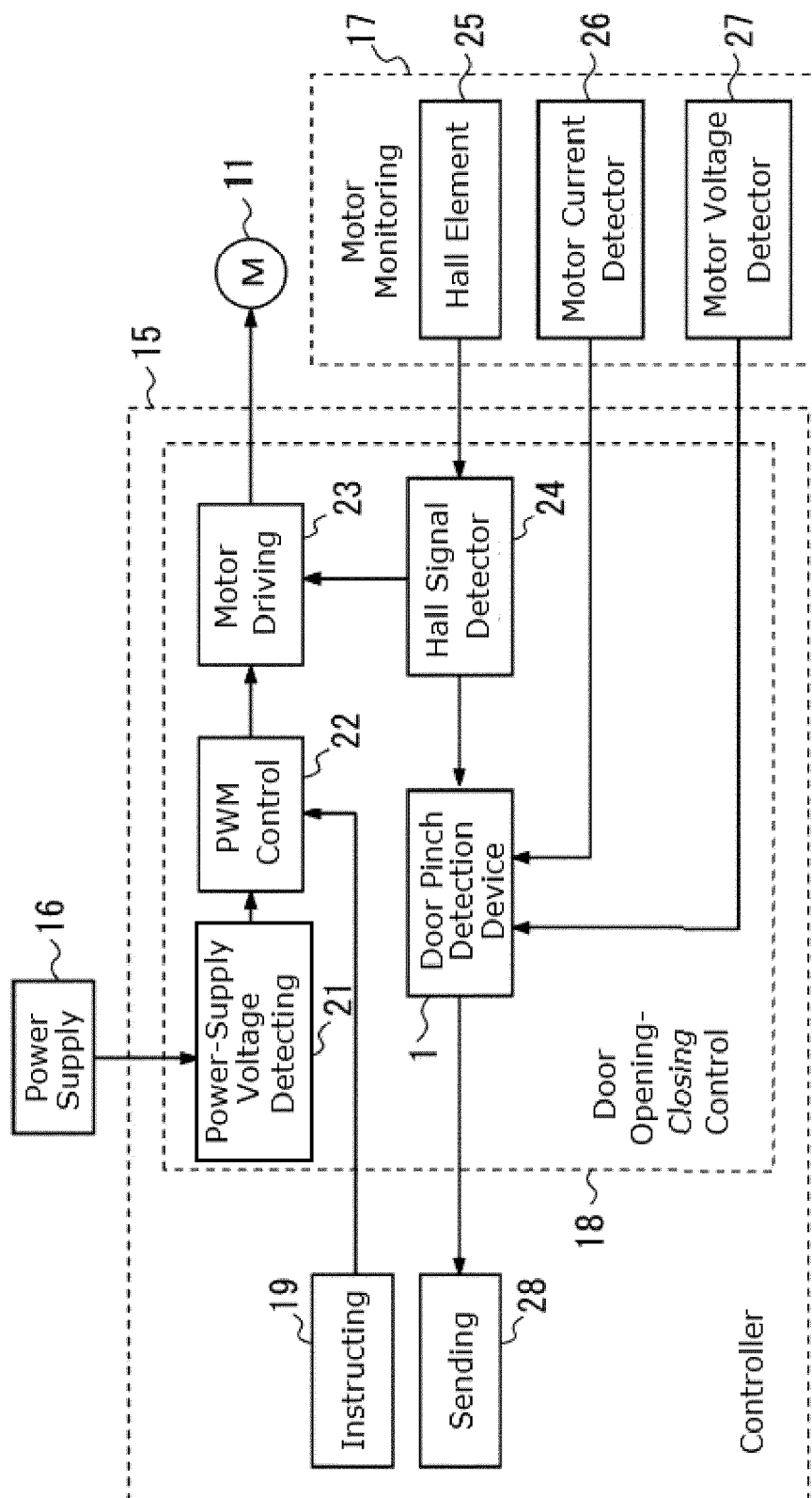


Fig. 3

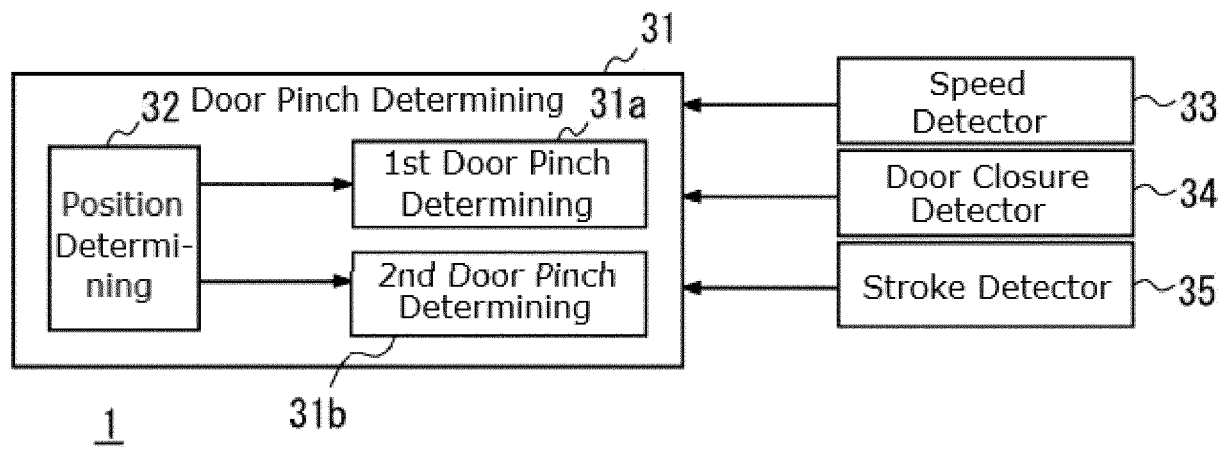


Fig. 4

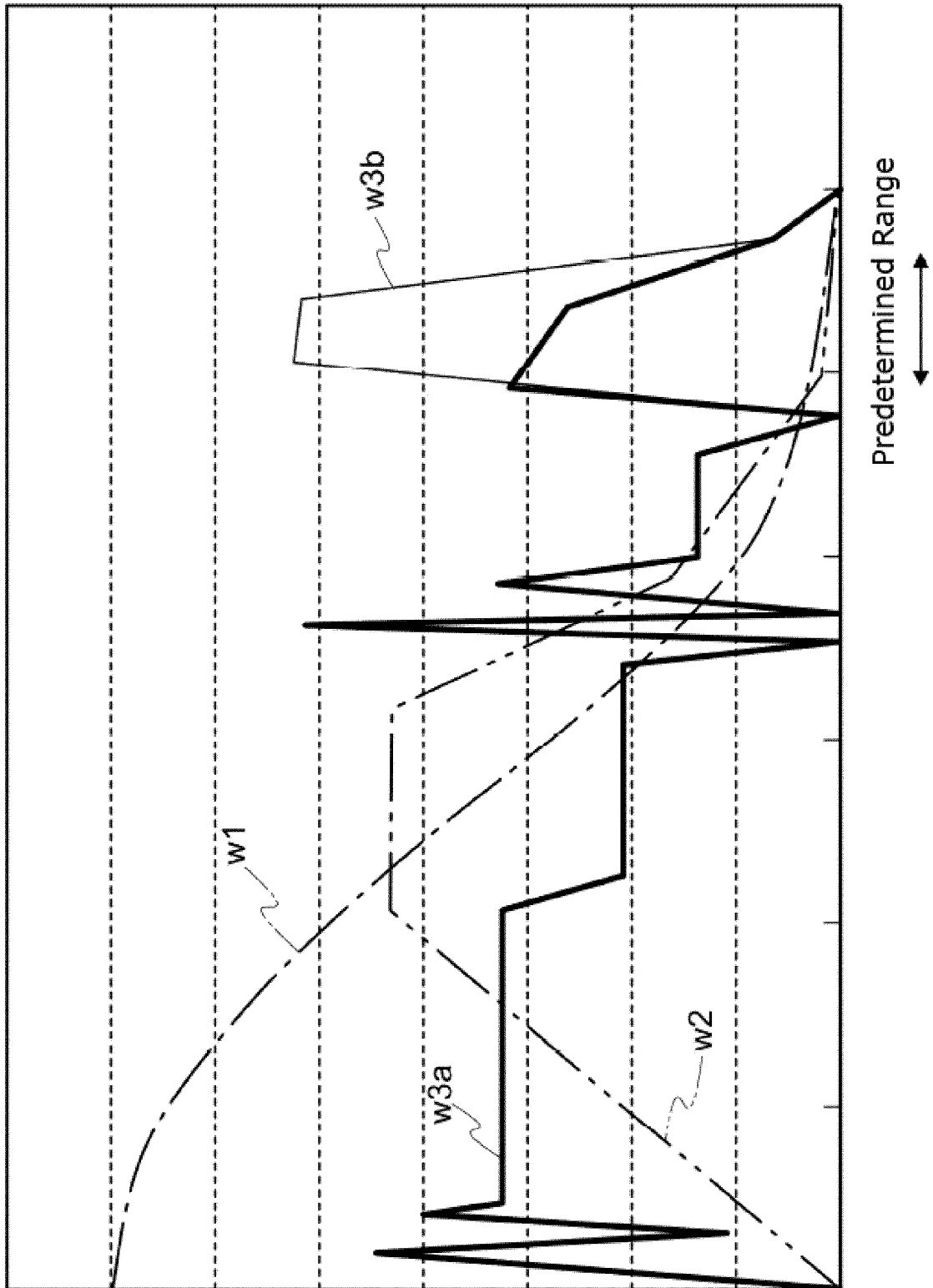


Fig. 5

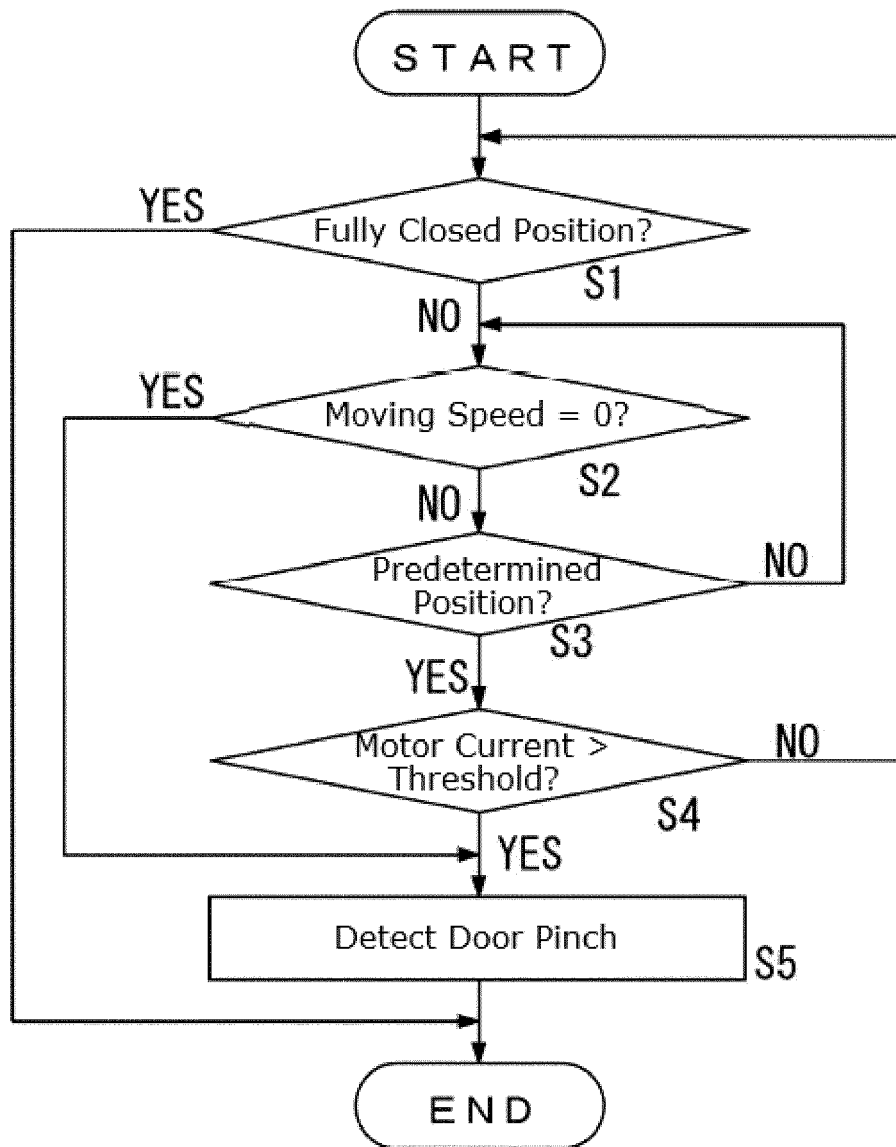


Fig. 6

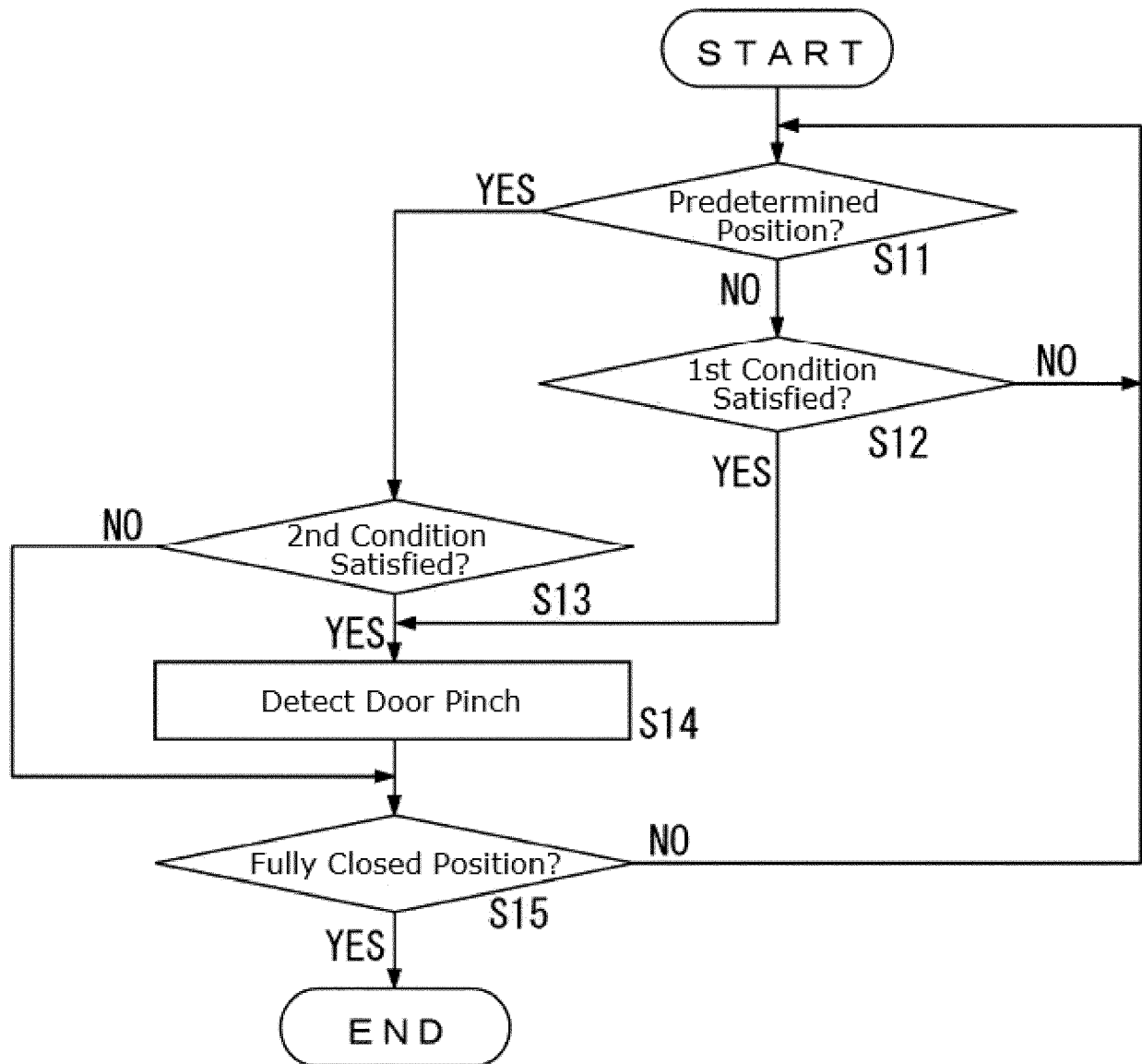


Fig. 7

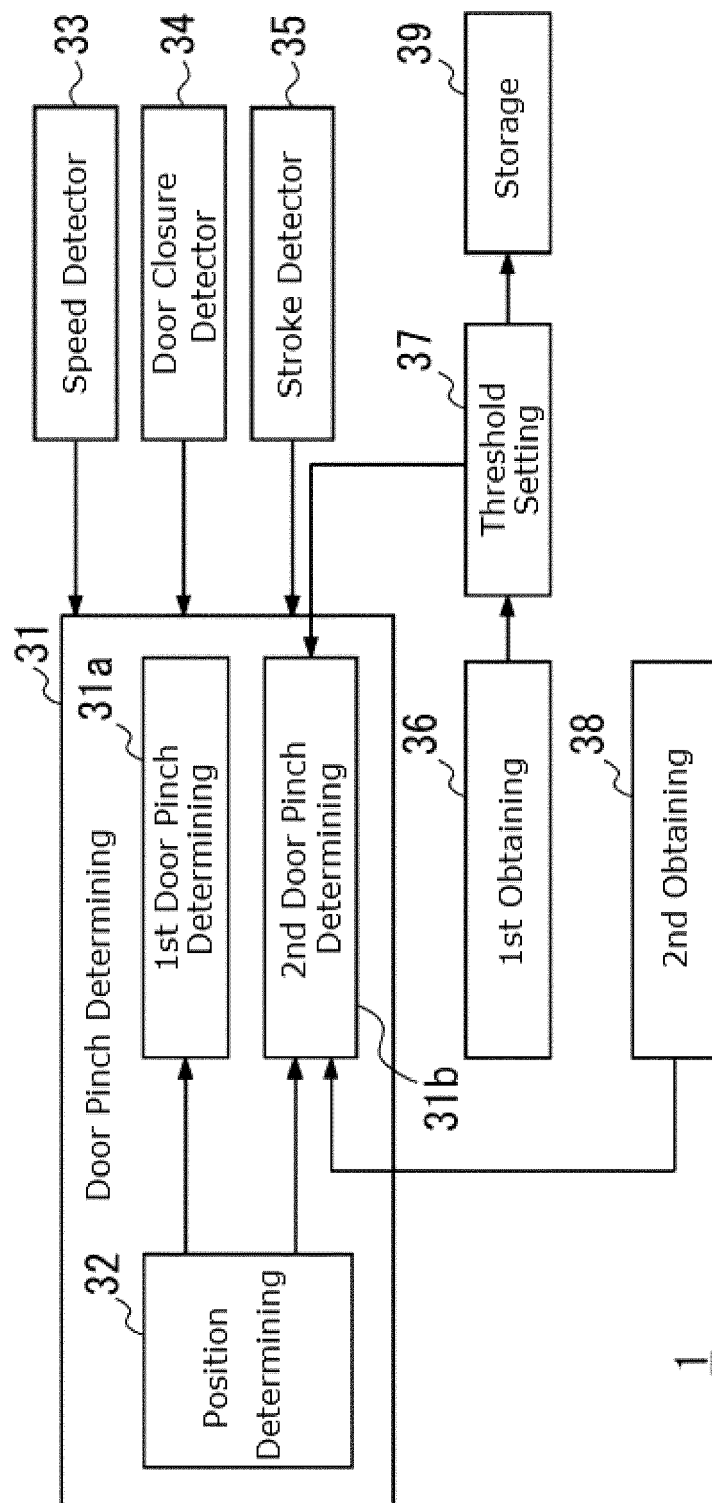


Fig. 8



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Y	* figures 12, 16, 19-23, 36, 40, 44 * * claims 1, 3, 4, 5 * * column 12, line 51 - column 13, line 6 * * column 14, lines 11-50 * * column 17, line 22 - column 21, line 35 * * column 30, line 44 - column 31, line 21 * * column 34, line 7 - column 36, line 9 * * column 37, lines 5-33 * -----	2	E05F15/659
X	EP 1 290 770 B1 (CONTI TEMIC MICROELECTRONIC [DE]) 7 November 2007 (2007-11-07) * paragraphs [0017], [0018], [0025]; claims 1, 6; figures 1-4 * -----	1-6, 8-10	
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A	* figures 2, 4, 8, 9A-9C * * column 5, lines 25-60 * * column 6, lines 33-39 * * column 8, line 13 - column 9, line 40 * -----	1, 3-10	TECHNICAL FIELDS SEARCHED (IPC) E05F
1 The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 2 February 2022	Examiner Klemke, Beate
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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