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(54) **DETERMINING DEVICE, STORAGE MEDIUM STORING COMPUTER PROGRAM FOR DETERMINATION, AND DETERMINING METHOD**

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(57) **ABSTRACT**

A determining device has a processor configured to detect a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle, to set a rollover determination scale based on the detected first roll angle, and to determine whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing the rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

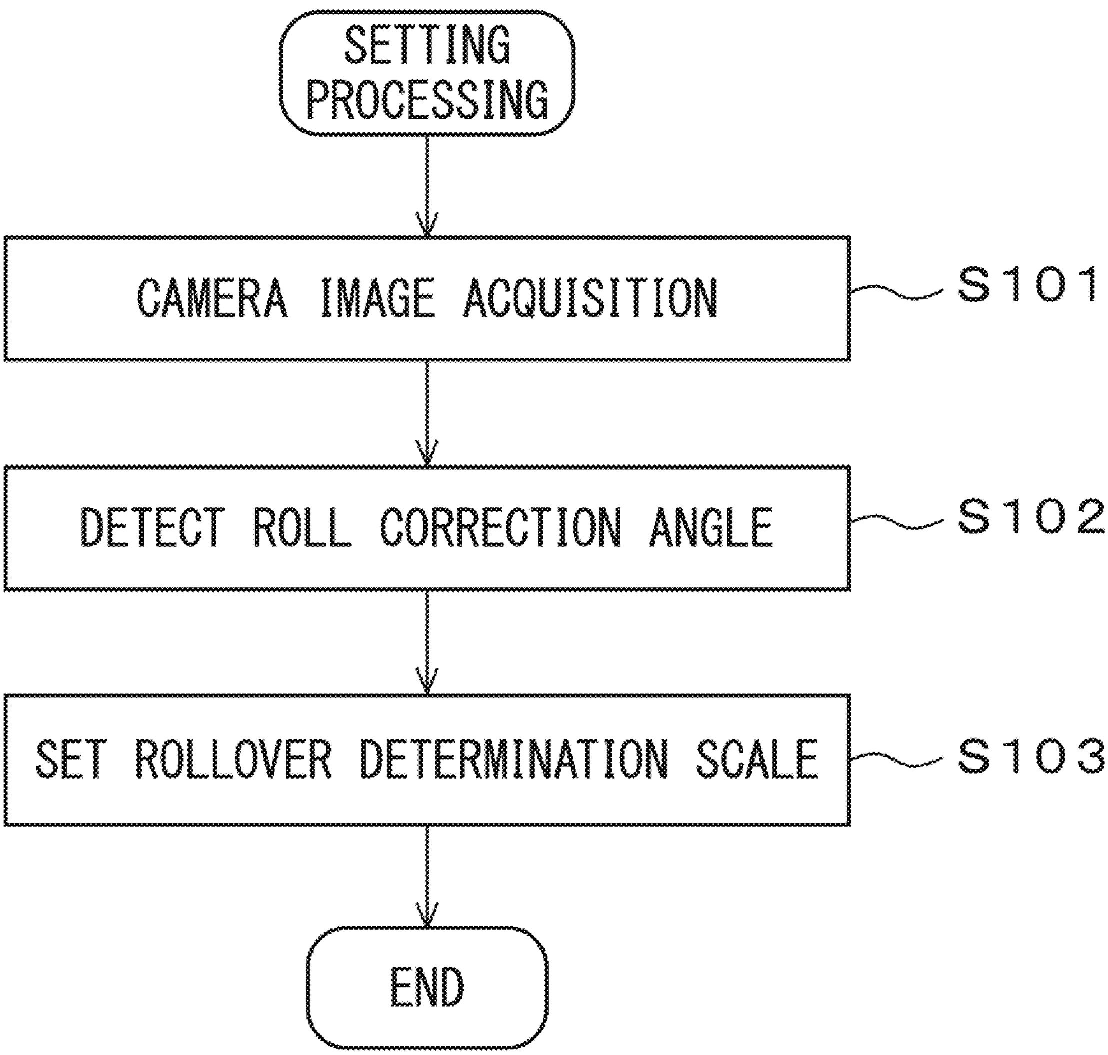


FIG. 1

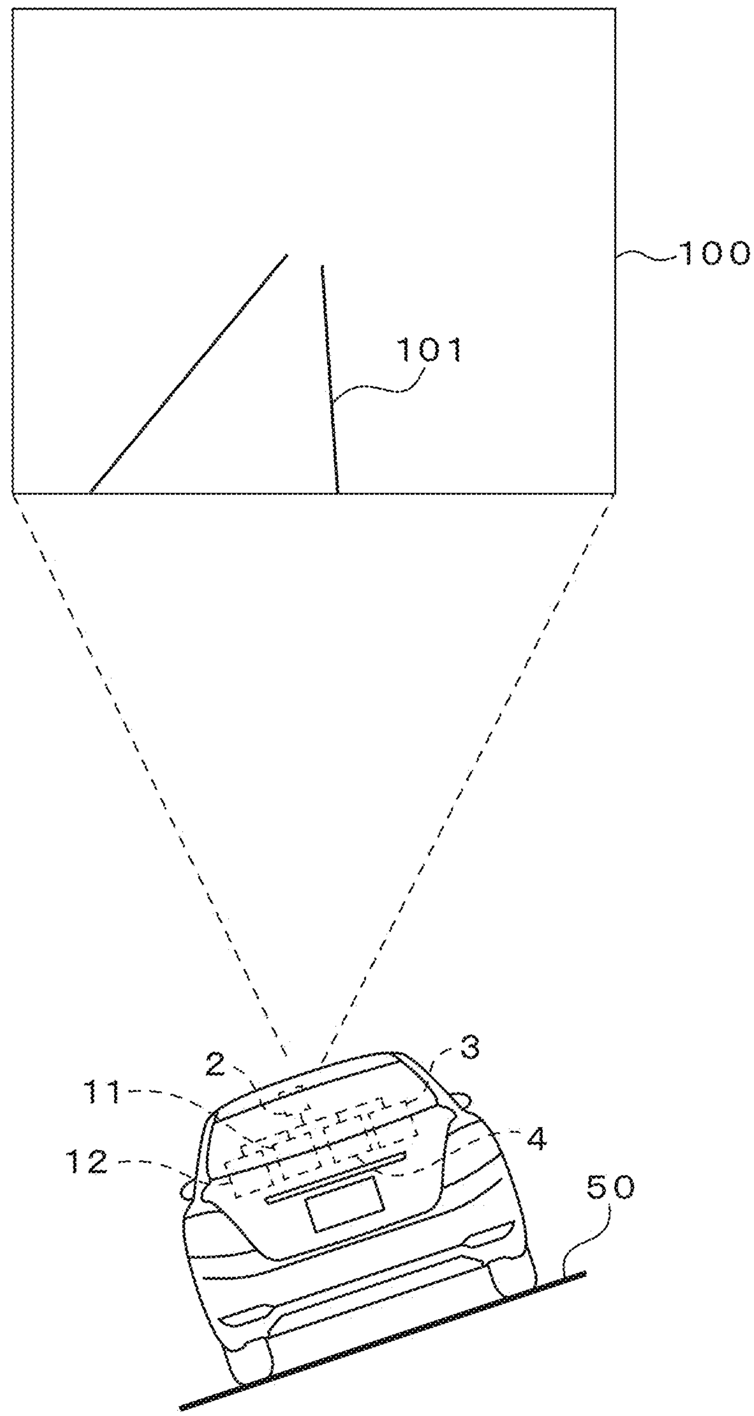


FIG. 2

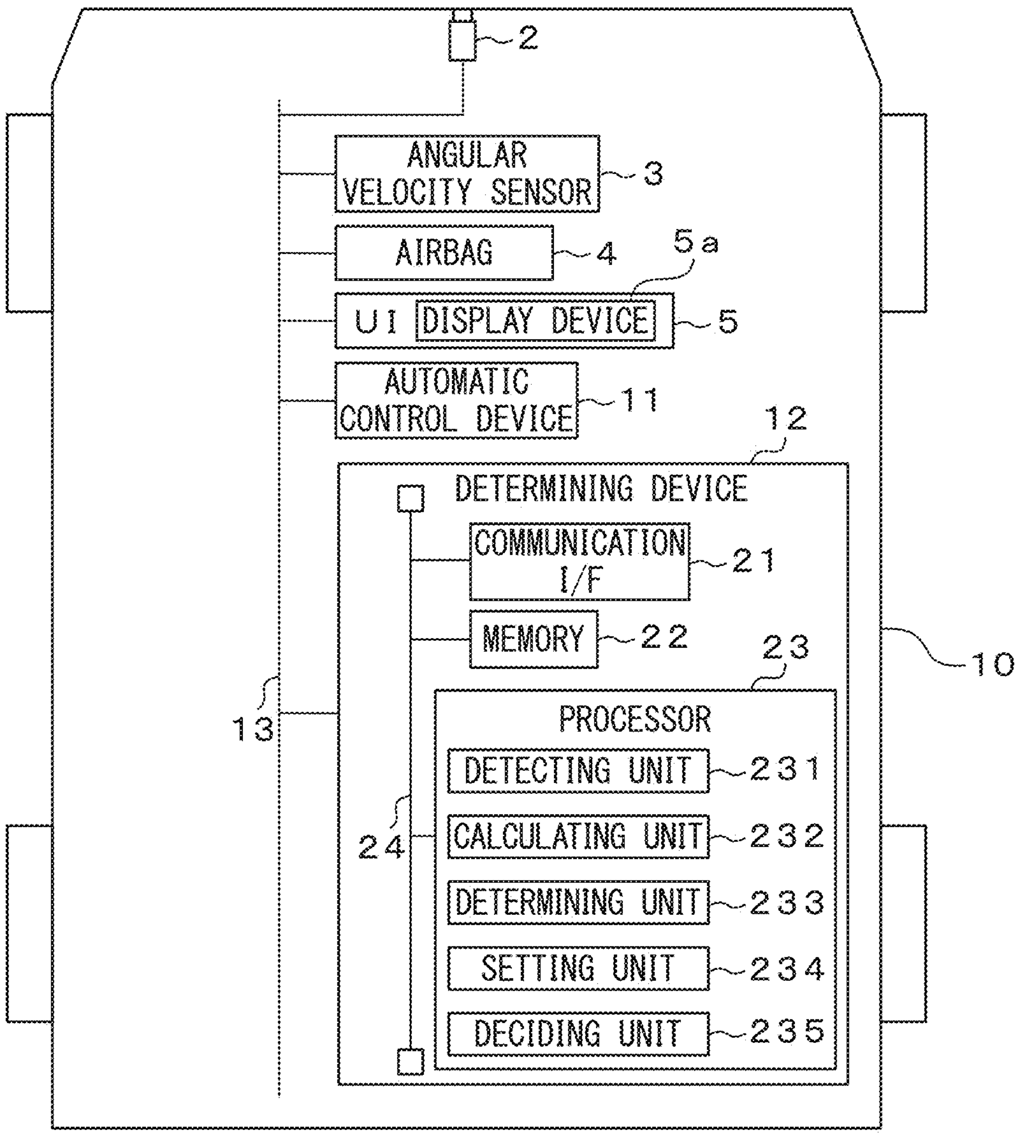

2
ANGULAR VELOCITY SENSOR
3
AIRBAG
4
5a
UI
DISPLAY DEVICE
5
AUTOMATIC CONTROL DEVICE
11
12
DETERMINING DEVICE
COMMUNICATION I/F
21
MEMORY
22
23
10
13
PROCESSOR
DETECTING UNIT
231
24
CALCULATING UNIT
232
DETERMINING UNIT
233
SETTING UNIT
234
DECIDING UNIT
235

FIG. 3

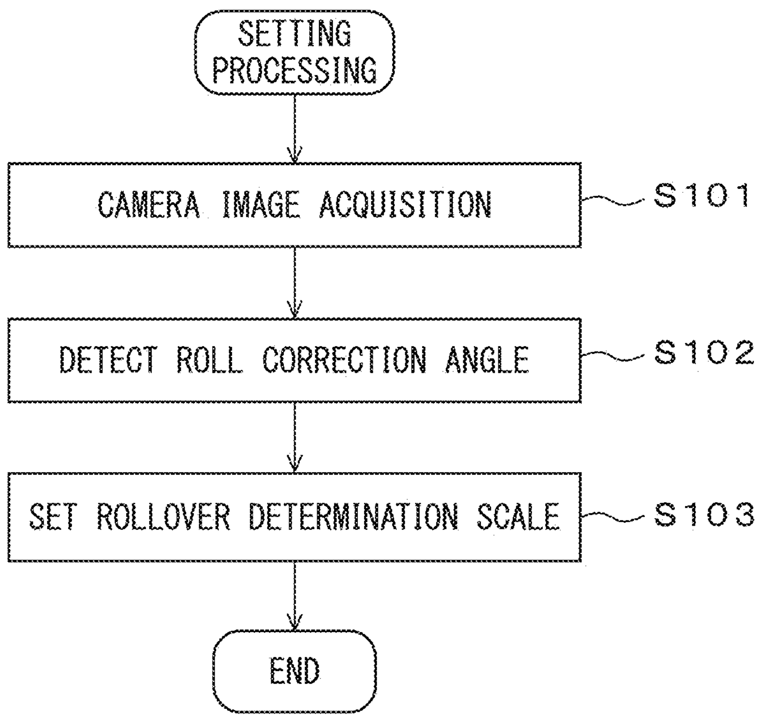

SETTING PROCESSING
CAMERA IMAGE ACQUISITION
S101
DETECT ROLL CORRECTION ANGLE
S102
SET ROLLOVER DETERMINATION SCALE
S103
END

FIG. 4

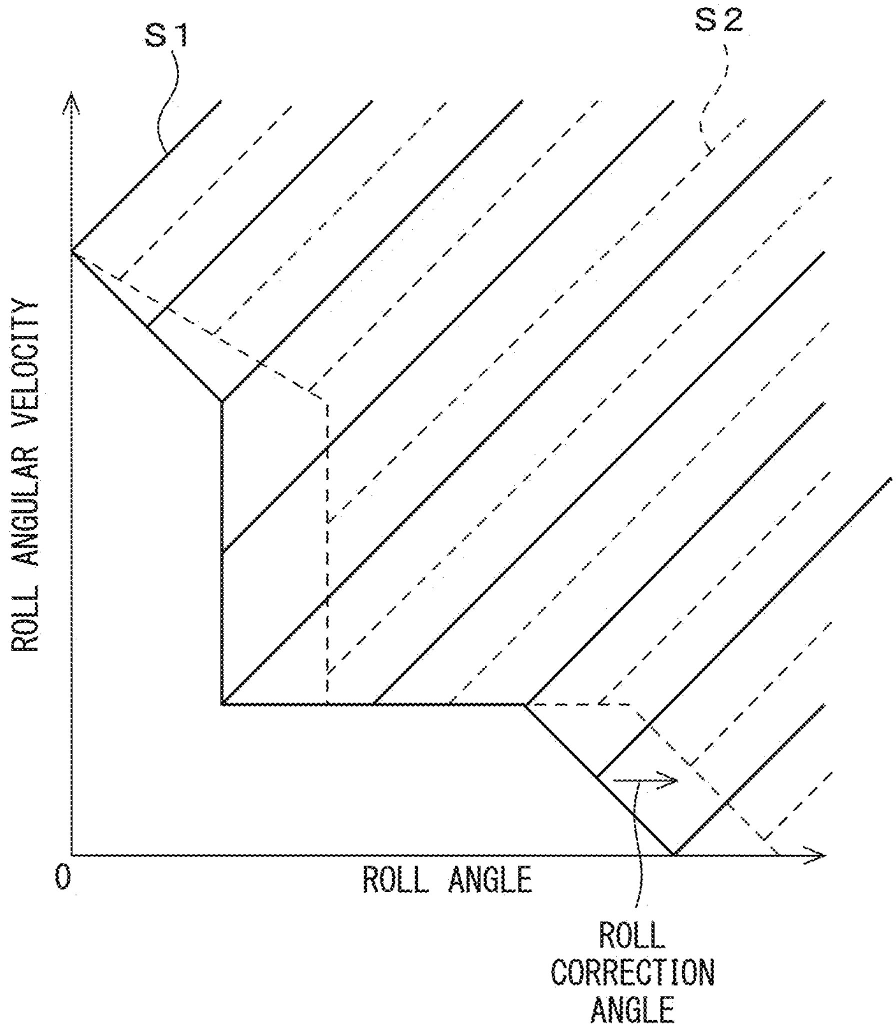

S1
S2
ROLL ANGULAR VELOCITY
0
ROLL ANGLE
ROLL CORRECTION ANGLE

FIG. 5

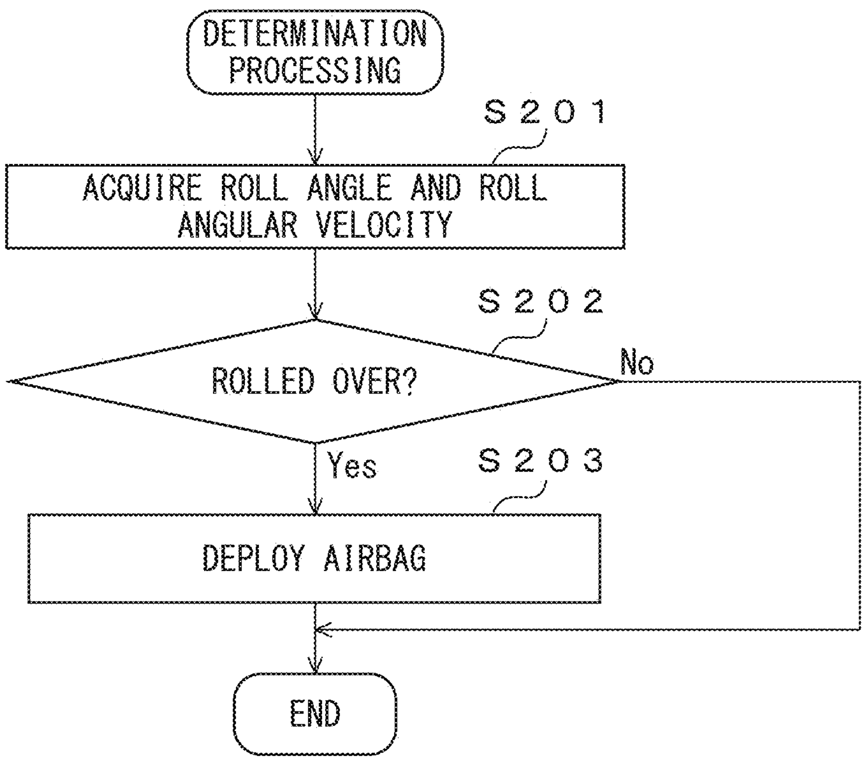
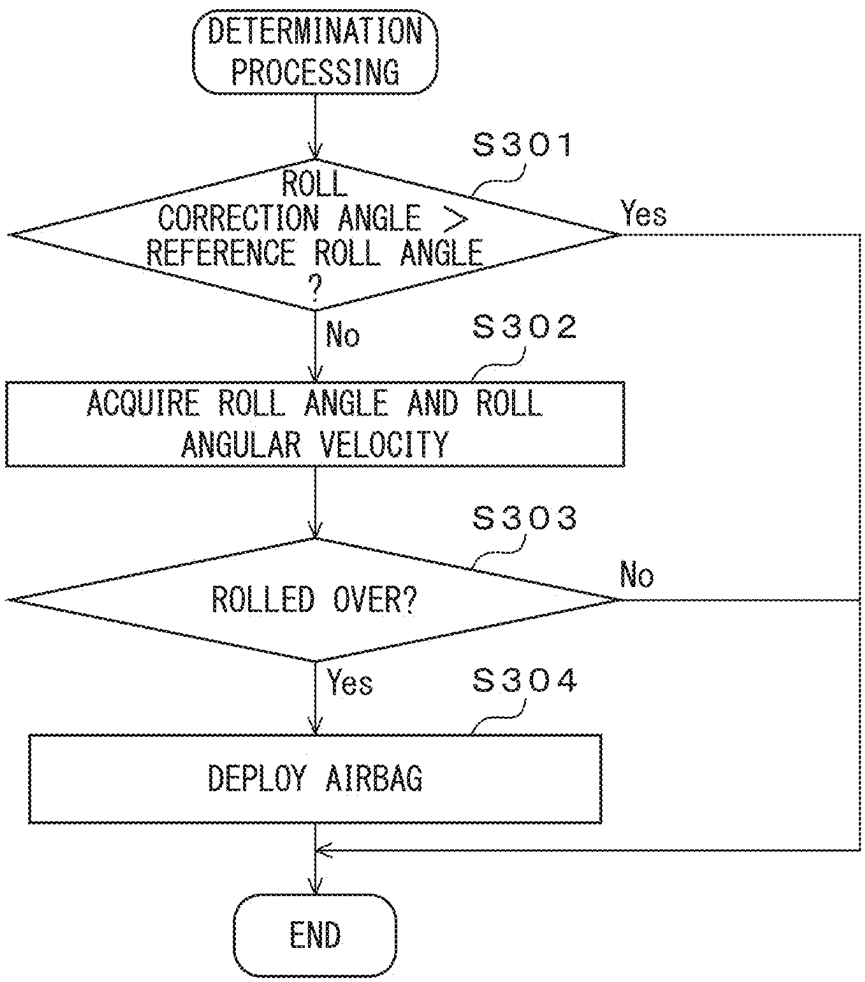

DETERMINATION PROCESSING
S201
ACQUIRE ROLL ANGLE AND ROLL ANGULAR VELOCITY
S202
ROLLED OVER?
No
Yes
S203
DEPLOY AIRBAG
END

FIG. 6


DETERMINATION PROCESSING
S301
ROLL CORRECTION ANGLE > REFERENCE ROLL ANGLE ?
Yes
No
S302
ACQUIRE ROLL ANGLE AND ROLL ANGULAR VELOCITY
S303
ROLLED OVER?
No
Yes
S304
DEPLOY AIRBAG
END

DETERMINING DEVICE, STORAGE MEDIUM STORING COMPUTER PROGRAM FOR DETERMINATION, AND DETERMINING METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Japanese Patent Application No. 2024-024492 filed Feb. 21, 2024, the entire contents of which are herein incorporated by reference.

FIELD

[0002] The present disclosure relates to a determining device, a storage medium storing a computer program for determination, and a determining method.

BACKGROUND

[0003] A vehicle may be equipped with a determining device that determines when the vehicle rolls over. Such a determining device detects the roll angular velocity using a roll angular velocity sensor that indicates the rotational speed around the front-rear axis of the vehicle, and determines whether or not the vehicle has rolled over based on the roll angular velocity and the roll angle obtained by integrating the roll angular velocity.

[0004] When the determining device determines that the vehicle has rolled over, an airbag is deployed to cover the side of the head of the driver in order to protect the driver.

[0005] The roll angle is determined by integrating the roll angular velocity, with zero as the initial value when the vehicle has started. Therefore, in cases where the vehicle has stopped on the road with an inclination in the lateral direction at the time the vehicle has started, it has not been possible to calculate the correct roll angle.

[0006] Japanese Unexamined Patent Publication No. 2004-268699 proposes correcting the roll angular velocity-integrated roll angle by the tilt angle detected using a tilt sensor, and determining rollover based on the corrected roll angle.

SUMMARY

[0007] However, since tilt sensors are not normally installed in vehicles, newly installing a tilt sensor in a vehicle increases production cost for the vehicle.

[0008] It is an object of the present disclosure to provide a determining device that can accurately determine rollover of a vehicle without increasing production cost for the vehicle.

[0009] (1) According to one embodiment, the present disclosure provides a determining device. The determining device has a processor configured to detect a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle, set a rollover determination scale based on the first roll angle, and determine whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

[0010] (2) In the determining device of (1), the processor is further configured to set the rollover determination scale based on the first roll angle detected while the vehicle is traveling.

[0011] (3) In the determining device of embodiment (1) or (2), the rollover determination scale is represented as a rollover region in a coordinate plane in which a first axis represents a roll angle and a second axis represents a roll angular velocity, the roll angle and the roll angular velocity being equal to or greater than predetermined reference values, and the processor is further configured to set the rollover determination scale by moving the rollover region in the direction of the first axis from a reference position by an amount of the detected first roll angle.

[0012] (4) In the determining device of any one of embodiments (1) to (3), the processor is further configured to determine whether or not the detected first roll angle exceeds a predetermined reference roll angle, and halt determination of whether or not the vehicle has rolled over when it has been determined that the first roll angle exceeds the reference roll angle.

[0013] (5) In the determining device of embodiment (4), the processor is further configured to use a smaller reference roll angle when the vehicle is being manually driven than when the vehicle is being self-driven.

[0014] (6) According to another embodiment, a storage medium storing a computer program for determination is provided. The computer program for determination includes detecting a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle, setting a rollover determination scale based on the first roll angle, and determining whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

[0015] (7) According to yet another embodiment of the present disclosure, a determining method is provided. The determining method includes detecting a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle, setting a rollover determination scale based on the first roll angle, and determining whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

[0016] The determining device of the disclosure can accurately determine rollover of a vehicle without increasing production cost for the vehicle.

[0017] The object and advantages of the present disclosure will be realized and attained by the elements and combinations particularly specified in the claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the present disclosure, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

[0018] FIG. **1** is a diagram illustrating operation of a determining device of the embodiment in overview.

[0019] FIG. **2** is a hardware configuration diagram for a vehicle in which the determining device of the embodiment is mounted.
[0020] FIG. **3** is an example of an operation flow chart for setting processing for a determining device according to the embodiment.
[0021] FIG. **4** is a diagram illustrating a rollover determination scale.
[0022] FIG. **5** is an example of an operation flow chart for determination processing by a determining device according to the embodiment.
[0023] FIG. **6** is an example of an operation flow chart showing a modified example of determination processing by a modified example of a determining device according to the embodiment.

DESCRIPTION OF EMBODIMENTS

[0024] FIG. **1** is a diagram illustrating operation of a determining device of the embodiment in overview. Operation relating to determination processing by the determining device **12** disclosed herein will now be described in overview with reference to FIG. **1**.
[0025] A vehicle **10** is on a road **50** which is inclined with respect to the horizontal, in the direction perpendicular to the traveling direction of the vehicle **10**. The vehicle **10** is therefore in a state of rotation around the front-rear direction of the vehicle **10** as the center, as compared to being on a horizontal road.
[0026] The vehicle **10** has a camera **2**, an angular velocity sensor **3**, an airbag device **4**, an automatic control device **11** and a determining device **12**. The airbag device **4** is mounted on the top of the door of the driving seat of the vehicle **10**. When the vehicle **10** has rolled over, the airbag device **4** deploys the airbag so as to cover the side of the head of the driver, thus alleviating impact onto the head.
[0027] The camera **2** acquires camera images representing the environment in the region ahead of the vehicle **10**. The automatic control device **11** controls operation of the vehicle **10** based on camera images acquired by the camera **2**, etc. The vehicle **10** may also be a self-driving vehicle.
[0028] The determining device **12** determines whether or not the vehicle **10** has rolled over using a predetermined rollover determination scale, based on the roll angular velocity representing the rotational speed around the front-rear axis of the vehicle **10**, and the roll angle calculated by integrating the roll angular velocity. When it has determined that the vehicle **10** has rolled over, the determining device **12** deploys the airbag of the airbag device **4**.
[0029] The road **101** on which the vehicle **10** is traveling is represented in the camera image **100** acquired by the camera **2**. The road **101** is shown to be inclined from the horizontal in the camera image **100**.
[0030] Based on the camera image, the determining device **12** detects a roll correction angle around the front-rear axis of the vehicle **10** as the center. The roll correction angle represents the angle the vehicle **10** has rotated around the front-rear axis of the vehicle **10** as the center (the roll angle), compared to when the vehicle **10** is on a horizontal road. Since the vehicle **10** is on an inclined road in the example shown in FIG. **1**, the determining device **12** detects a non-zero roll correction angle.
[0031] The determining device **12** sets the rollover determination scale based on the roll correction angle. By setting the rollover determination scale based on the roll correction angle, the assessment scale for the roll angle is corrected by the degree of the roll angle corresponding to the inclination of the road on which the vehicle **10** is located. The determining device **12** uses the set rollover determination scale to determine whether or not the vehicle **10** has rolled over.
[0032] The camera image is used as information to control the vehicle **10** by the automatic control device **11**. The determining device **12** uses the camera **2** already mounted on the vehicle **10** to carry out accurate rollover determination.
[0033] As explained above, the determining device **12** can accurately determine rollover of the vehicle **10** without increasing production cost for the vehicle **10**.
[0034] FIG. **2** is a hardware configuration diagram for the vehicle **10** in which the determining device **12** of the embodiment is mounted. The vehicle **10** has a camera **2**, an angular velocity sensor **3**, an airbag device **4**, a user interface (UI) **5**, an automatic control device **11** and a determining device **12**. The vehicle **10** may also have a LiDAR sensor, as a distance sensor (not shown) for measurement of the distance of the vehicle **10** to surrounding objects.
[0035] The camera **2**, angular velocity sensor **3**, airbag device **4**, UI **5**, automatic control device **11** and determining device **12** are connected in a communicable manner via an in-vehicle network **13** conforming to the Controller Area Network standard.
[0036] The camera **2** is mounted inside the vehicle **10** and directed toward the front of the vehicle **10**. For accurate detection of the roll correction angle, in some embodiments, the camera **2** is attached with the optical axis oriented parallel to the front-rear axis of the vehicle **10**.
[0037] The camera **2**, for example, acquires a camera image in which the environment of a predetermined region ahead of the vehicle **10** is shown, at a predetermined cycle. The camera image can show the road in the predetermined region ahead of the vehicle **10**, and road features such as surface lane marking lines on the road. The camera image may also include other vehicles which are located ahead of the vehicle **10**. The camera **2** has a 2D detector composed of an array of photoelectric conversion elements with visible light sensitivity, such as a CCD or C-MOS, and an imaging optical system that forms an image of the photographed region on the 2D detector. The camera image is an example of an image representing the environment surrounding the vehicle **10**. Camera images may be acquired in a cycle of 0.1 seconds to 0.5 seconds, for example.
[0038] Each time a camera image is acquired, the camera **2** outputs the camera image and the camera image acquisition time at which the camera image was acquired, through the in-vehicle network **13** to the automatic control device **11** and determining device **12**, etc. At the automatic control device **11**, the camera image is used for processing to detect objects surrounding the vehicle **10**. The camera image is used for rollover determination scale setting processing by the determining device **12**. The vehicle **10** may also have another camera mounted in the vehicle **10** and directed toward the rear of the vehicle **10**.
[0039] The angular velocity sensor **3** detects the roll angular velocity representing the
[0040] rotational speed around the front-rear axis of the vehicle **10**, and outputs information representing the roll angular velocity to the automatic control device **11** and determining device **12**, etc. via the in-vehicle network **13**. The angular velocity sensor **3** may use a piezoelectric or

electrical capacitance-type sensor. The reference used for the front-rear axis of the vehicle **10** may be a line connecting the roll centers of the front and rear suspensions of the vehicle **10**, for example. The automatic control device **11** acquires the roll angular velocity of the vehicle **10** and controls the vehicle **10**, based on the information representing the roll angular velocity. The determining device **12** acquires the roll angular velocity of the vehicle **10** and carries out rollover determination scale setting processing, based on the information representing the roll angular velocity.

[0041] When the vehicle **10** rolls over, the airbag device **4** deploys an airbag to protect the side of the head of the driver. The airbag device **4** is controlled by the determining device **12**. When a deploy signal is input from the determining device **12**, the airbag device **4** sends a current to a squib disposed inside the airbag, the heat generated by the squib causing ignition of an adjacent detonator. Gas is generated in the airbag by a chemical reaction using the explosive heat of the detonator, causing the airbag to inflate. Airbag devices may also be disposed on tops of the doors of the passenger seat and back seats. An airbag device may also be situated to protect the front of the driver.

[0042] The UI **5**, controlled by the automatic control device **11** and determining device **12**, notifies the driver of the vehicle **10** traveling information and warnings, etc. The vehicle **10** traveling information includes the current location of the vehicle **10**, and notifications to the driver. The UI **5** has a display device **5***a* such as a liquid crystal display or touch panel, for display of the traveling information. The UI **5** may also have an acoustic output device (not shown) to notify the driver of traveling information.

[0043] The UI **5** also creates an operation signal in response to operation of the vehicle **10** by the driver. The UI **5** also has a touch panel or operating button, for example, as an input device for inputting operation information from the driver to the vehicle **10**. The operation information may be, for example, a destination location, transit points, vehicle speed and a control transfer request. The control transfer request is made for transfer of control of the vehicle **10** from self-driving mode to manual driving mode, or from manual driving mode to self-driving mode. The UI **5** outputs the input operation information to the automatic control device **11** or determining device **12**, etc. via the in-vehicle network **13**.

[0044] The automatic control device **11** controls operation including traveling of the vehicle **10**. The automatic control device **11** has two driving modes with different degrees of participation of the driver for driving. The automatic control device **11** controls the operation of the vehicle **10** according to the driving mode.

[0045] For example, the automatic control device **11** has a self-driving mode in which the degree to which the driver participates in driving is low (for example, driving mode with levels **3** to **5**) and a manual driving mode in which the degree to which the driver participates in driving is high (for example, driving mode with levels 0 to 2). In self-driving mode, the vehicle **10** is driven primarily by the automatic control device **11**. In manual driving mode, the vehicle **10** is driven primarily by the driver.

[0046] In the driving mode in which the degree to which the driver participates in driving is low, all or some of the driving operations necessary for traveling of the vehicle **10** are executed automatically, while in the driving mode in which the degree to which the driver participates in driving is high, the types of driving operations executed automatically are less than in the driving mode in which the degree to which the driver participates in driving is low, or are zero.

[0047] In self-driving mode, the automatic control device **11** generates a driving plan to control actions such as steering, engine actuation and braking based on map information and on detection information from sensors (not shown) mounted in the vehicle **10**. The automatic control device **11** outputs the automatic control signal based on the driving plan, to an actuator (not shown) that controls the steering wheel, a drive unit (not shown), or the brake (not shown), via the in-vehicle network **13**.

[0048] In manual driving mode, the automatic control device **11** generates a manual control signal to control operation of the vehicle **10** such as steering, actuation and braking based on operation by the driver, and outputs the manual control signal to an actuator for actuation of the steering wheel, and to a drive unit or brake, via the in-vehicle network **13**.

[0049] The automatic control device **11** outputs mode information representing the current driving mode to the determining device **12**, via the in-vehicle network **13**.

[0050] The automatic control device **11** can drive the vehicle **10** in self-driving mode in regions where self-driving mode is permitted (for example, regions where a high-precision map has been prepared for control of the vehicle **10**). In regions where self-driving mode is not permitted, the automatic control device **11** controls the vehicle **10** in manual driving mode. In response to a request by the driver, the automatic control device **11** switches from self-driving mode to manual driving mode or from manual driving mode to self-driving mode. The automatic control device **11** also switches from self-driving mode to manual driving mode when it has determined that the vehicle **10** cannot be safely driven in self-driving mode.

[0051] The determining device **12** carries out detection processing, calculation processing, determination processing, setting processing and decision processing. For this purpose, the determining device **12** has a communication interface (IF) **21**, a memory **22** and a processor **23**. The communication interface **21**, memory **22** and processor **23** are connected via signal wires **24**. The communication interface **21** has an interface circuit to connect the determining device **12** with the in-vehicle network **13**.

[0052] The memory **22** is an example of a storage unit, and it has a volatile semiconductor memory and a non-volatile semiconductor memory, for example. The memory **22** stores an application computer program and various data to be used for information processing carried out by the processor **23** of each device.

[0053] All or some of the functions of the determining device **12** are functional modules driven by a computer program operating on the processor **23**, for example. The processor **23** has a detecting unit **231**, a calculating unit **232**, a determining unit **233**, a setting unit **234** and a deciding unit **235**. The processor **23** has one or more CPUs (Central Processing Units) and their peripheral circuits. The processor **23** may also have other computing circuits such as a logical operation unit, numerical calculation unit or graphics processing unit. Alternatively, the functional module of the processor **23** may be a specialized computing circuit in the processor **23**. The determining device **12** is an electronic control unit (ECU), for example.

[0054] The calculating unit **232** inputs information representing the roll angular velocity, integrates the roll angular velocity, and calculates the roll angle. The roll angle calculated by the calculating unit **232** is an example of a second roll angle.

[0055] The roll angle may also use the opposite direction from the vertical as 0°. When the vehicle **10** is on a horizontal road, the roll angle is 0°. The roll angle may be represented as 180° clockwise with the opposite direction from the vertical as 0°, or as −180° counterclockwise with the opposite direction from the vertical as 0°. This is merely an example of representing the roll angle, and the roll angle may be represented based on a different reference. The rest of the operation of the determining device **12** is described in detail below.

[0056] For FIG. **2**, the automatic control device **11** and the determining device **12** were described as separate devices, but all of the devices may also be constructed as a single device.

[0057] FIG. **3** is an example of an operation flow chart for setting processing by the determining device **12** of this embodiment **12**. Setting processing by the determining device **12** will now be explained with reference to FIG. **3**. The determining device **12** carries out setting processing according to the operation flow chart shown in FIG. **3**, at a setting processing time set with a predetermined cycle. The first setting processing is carried out at a first setting processing time after the vehicle **10** is started. The determining device **12** also carries out setting processing at the setting processing time while the vehicle **10** is traveling.

[0058] First, the detecting unit **231** acquires a camera image (step S**101**). The detecting unit **231** acquires the latest camera image from among multiple camera images output from the camera **2**, for example.

[0059] Based on the camera image, the detecting unit **231** detects a roll correction angle around the front-rear axis of the vehicle **10** as the center (step S**102**). The roll correction angle is an example of a first roll angle.

[0060] The detecting unit **231** has a classifier trained to classify vehicle roll angles from images. The detecting unit **231** detects the vehicle roll angle by inputting camera images into the classifier. The classifier is trained using images and teacher data labeled with vehicle roll angles when the images have been acquired. The roll angle may be represented as 180° clockwise and −180° counterclockwise, with the opposite direction from the vertical as 0°. In some embodiments, the camera images used for training of the classifier are acquired using a camera having its optical axis mounted in a parallel orientation with respect to the front-rear axis of the vehicle **10**, similar to the camera **2**. In some embodiments, when the camera images input to the classifier are images of the front of the vehicle **10**, the images used for training of the classifier are also images of the front of the vehicle.

[0061] The detecting unit **231** may also use a different method for detection of the roll correction angle of the vehicle **10** based on camera images. For example, when the window of a building is shown in the camera image and the upper and lower frames of the window are parallel, it may be the case that a window in front of the camera is visible in the camera image. The upper and lower frames are assumed to be parallel to the ground. Since the inclinations of straight lines representing the upper frame and lower frame in the camera image correspond to the roll angle of the vehicle, the detecting unit **231** can detect the roll angle of the vehicle based on the inclination of the straight line representing the upper frame or lower frame in the camera image.

[0062] The detecting unit **231** detects the region representing the window in the camera image

[0063] and determines whether or not the upper and lower frames are parallel. The region representing the window frame in the camera image is detected using a machine learned classifier, for example. When the upper and lower frames are parallel, the detecting unit **231** calculates the roll angle as the arctan between the number of pixels representing the shift of the y-coordinate at both ends of the straight line representing the upper frame or lower frame in the camera image, and the number of pixels in the x-direction representing the length of the straight line.

[0064] The detecting unit **231** may also detect a roll correction angle for each of the most recently acquired multiple camera images, and calculate the average of the multiple roll correction angles. For example, the detecting unit **231** may detect a roll correction angle from each of multiple camera images acquired within the most recent 0.5 seconds to 1 second.

[0065] The setting unit **234** then sets a rollover determination scale based on the roll correction angle detected by the detecting unit **231** (step S**103**), and the series of processing steps is complete. FIG. **4** is a diagram illustrating a rollover determination scale. When the roll correction angle is zero, the rollover determination scale may be represented as a reference rollover region S**1** indicating values at or above predetermined reference values for the roll angle and roll angular velocity, in a coordinate plane with the abscissa representing the roll angle and the ordinate representing the roll angular velocity.

[0066] Since the detection signal for angular velocity includes a bias, the angular velocity sensor **3** adds an offset component to the roll angle obtained by integration of the roll angular velocity, as time progresses. By setting the rollover determination scale while the vehicle **10** is traveling it is possible to eliminate the effect of the offset component.

[0067] The rollover determination scale shown in FIG. **4** is an example in which the roll angle is between 0° and 180°, and the rollover region is located in the first quadrant of the coordinates. When the roll angle is between 0° and −180°, a rollover determination scale is used in which the rollover region is located in the fourth quadrant of the coordinates.

[0068] The setting unit **234** moves the reference rollover region S**1** in the direction of the abscissa by the amount of the roll correction angle detected by the detecting unit **231**. The rollover determination scale after movement is represented as the rollover region S**2**. When the roll correction angle is zero, the rollover determination scale is represented as the reference rollover region S**1**.

[0069] When the roll angle is between 0° and 180°, the reference rollover region S**1** moves in the positive direction on the abscissa. When the roll angle is between 0° and −180°, the reference rollover region S**1** moves in the negative direction on the abscissa.

[0070] FIG. **5** is an example of an operation flow chart for determination processing by the determining device **12** according to the embodiment. Determination processing by the determining device **12** will now be explained with reference to FIG. **5**. The determining device **12** carries out determination processing according to the operation flow chart shown in FIG. **5**, at a determining time set with a predetermined cycle. The determining device **12** carries out determination processing at the determining time both when the vehicle **10** is stopped and when it is traveling.

[0071] First, the determining unit **233** acquires the roll angle and roll angular velocity (step S**201**). The determining unit **233** acquires the roll angle which has been calculated by the calculating unit **232**. The determining unit **233** also acquires the roll angular velocity based on information representing the roll angular velocity. The determining unit **233** may also use the most recent average roll angular velocity as the current roll angular velocity. The current roll angular velocity may be, for example, the average value for the roll angular velocity within the most recent 0.5 seconds to 1 second. The determining unit **233** is an example of the first determining unit.

[0072] The determining unit **233** then determines whether or not the vehicle **10** has rolled over, using the rollover determination scale set by the setting unit **234**, based on the roll angular velocity representing the rotational speed around the front-rear axis of the vehicle **10**, and the roll angle calculated by integrating the roll angular velocity (step S**202**). When a point represented by the roll angular velocity and roll angle is included in the rollover region S**2**, the determining unit **233** determines that the vehicle **10** has rolled over. When a point represented by the roll angular velocity and roll angle is not included in the rollover region S**2**, on the other hand, the determining unit **233** determines that the vehicle **10** has not rolled over.

[0073] When it has determined that the vehicle **10** has rolled over (step S**202**—Yes), the deciding unit **235** decides to deploy the airbag (step S**203**), and the series of processing steps is complete. The deciding unit **235** outputs to the airbag device **4** a deploy signal for deployment of the airbag, via the in-vehicle network **13**. When a deploy signal is input from the determining device **12**, the airbag device **4** deploys the airbag to cover the side of the head of the driver in order to protect the driver.

[0074] When it has been determined that the vehicle **10** has not rolled over, on the other hand (step S**202**—No), the series of processing steps is complete.

[0075] As explained above, the determining device can accurately determine rollover of a vehicle without increasing production cost for the vehicle.

[0076] A modified example of the determining device **12** of this embodiment will now be described with reference to FIG. **6**. FIG. **6** is an example of an operation flow chart related to determination processing by a modified example of the determining device of the embodiment. This modified example differs from the determination processing shown in FIG. **5** in

[0077] that the processing of step S**301** is added. The processing in steps S**302** to S**304** are the same as in steps S**201** to S**203** described above.

[0078] First, the determining unit **233** determines whether or not the roll correction angle detected by the detecting unit **231** exceeds a predetermined reference roll angle (step S**301**). The determining unit **233** is an example of a second determining unit. The reference roll angle may be 60° to −60°, for example.

[0079] When the absolute value of the roll correction angle is greater than 60°, the determining unit **233** determines that the roll correction angle exceeds the reference roll angle. When the absolute value of the roll correction angle is 60° or smaller, on the other hand, the determining unit **233** determines that the roll correction angle does not exceed the reference roll angle.

[0080] When the roll correction angle exceeds the reference roll angle (step S**301**—Yes), the series of processing steps is complete. The roll correction angle exceeding the reference roll angle signifies an unusual value for the inclination of the road. The detecting unit **231** that has detected such a roll correction angle may not be functioning properly. When the vehicle **10** is on such an inclined road, this also constitutes an unusual situation. The determining device **12** therefore halts determination. In this case, the determining unit **233** also notifies the driver via the UI **5** that rollover determination processing for the vehicle **10** is unusual. Because determination is halted, the airbag is not deployed.

[0081] When the vehicle **10** is being manually driven, the determining unit **233** may use a smaller reference roll angle than when the vehicle **10** is being self-driven. When the mode information input from the automatic control device **11** indicates manual driving mode, the determining unit **233** determines that the vehicle **10** is being manually driven. When the mode information input from the automatic control device **11** indicates self-driving mode, on the other hand, the determining unit **233** determines that the vehicle **10** is being self-driven.

[0082] When the driver is manually driving the vehicle **10**, sudden steering operation on an inclined road can potentially result in rollover. The reference roll angle is therefore reduced when the vehicle **10** is being manually driven. The driver may also be warned of rollover by a driver notification indicating that rollover determination processing for the vehicle **10** is unusual.

[0083] When the roll correction angle does not exceed the reference roll angle (step S**301**—No), on the other hand, processing proceeds to step S**302**.

[0084] According to this modified example, the determining device **12** halts rollover determination when the magnitude of the roll correction angle is unusual, thus helping to prevent deployment of the airbag by erroneous determination.

[0085] The determining device, computer program for determination and determining method according to the embodiments described in the present disclosure may incorporate appropriate modifications that still fall within the gist of the disclosure. Moreover, the technical scope of the disclosure is not limited to these embodiments, and includes the present disclosure and its equivalents as laid out in the Claims.

[0086] For example, setting the rollover determination scale according to the embodiment described above is merely an example, and not to be construed as limiting the method of setting the rollover determination scale. For example, the setting unit may correct the information representing the roll angular velocity output from the roll angular velocity sensor by the degree of the roll correction angle to calculate the corrected roll angular speed. The calculating unit calculates the roll angle by integrating the corrected roll angular speed. The determining unit carries out rollover determination based on the corrected roll angle and the corrected roll angular speed. Setting of the rollover determination scale includes such a method.

[0087] When rain or snow is present in the surrounding environment of the vehicle, the setting unit may be configured to not set the rollover determination scale based on the roll correction angle detected by the detecting unit. This is because it may not be possible to detect an accurate roll correction angle based on camera images acquired in a rainy or snowy environment. In such cases the rollover determination scale is represented as the reference rollover region **S1**.

1. A determining device comprising:

a processor configured to

detect a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle,

set a rollover determination scale based on the first roll angle, and

determine whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

2. The determining device according to claim **1**, wherein the processor is further configured to set the rollover determination scale based on the first roll angle detected while the vehicle is traveling.

3. The determining device according to claim **1**, wherein

the rollover determination scale is represented as a rollover region in a coordinate plane in which a first axis represents a roll angle and a second axis represents a roll angular velocity, the roll angle and the roll angular velocity being equal to or greater than predetermined reference values, and

the processor is further configured to set the rollover determination scale by moving the rollover region in the direction of the first axis from a reference position by an amount of the detected first roll angle.

4. The determining device according to claim **1**, wherein the processor is further configured to

determine whether or not the detected first roll angle exceeds a predetermined reference roll angle, and

halt determination of whether or not the vehicle has rolled over when it has been determined that the first roll angle exceeds the reference roll angle.

5. The determining device according to claim **4**, wherein the processor is further configured to use a smaller reference roll angle when the vehicle is being manually driven than when the vehicle is being self-driven.

6. A computer-readable, non-transitory storage medium storing a computer program for determination, which causes a processor to execute a process, and the process comprises:

detecting a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle;

setting a rollover determination scale based on the first roll angle; and

determining whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

7. A determining method which is carried out by a determining device and the method comprises:

detecting a first roll angle by which a vehicle has rotated around a front-rear axis of the vehicle as a center, based on an image representing surrounding environment of the vehicle;

setting a rollover determination scale based on the first roll angle; and

determining whether or not the vehicle has rolled over, using the rollover determination scale, based on a roll angular velocity representing a rotational speed around the front-rear axis of the vehicle and a second roll angle calculated by integrating the roll angular velocity.

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