[DESCRIPTION]

[TITLE OF INVENTION]

VEHICLE ON-BOARD DEVICE, SERVER, VEHICLE MOTION DETECTION METHOD, AND PROGRAM

[Technical Field]

[0001]

The present invention relates to a vehicle on-board device, a server, a vehicle motion detection method, and a program.

[Background Art]

[0002]

In recent years, the number of vehicles on which vehicle on-board devices are mounted has increased due to charging processes of toll roads, safe driving evaluation processes, and the like being performed. Sensors such as an acceleration sensor and a gyro sensor are provided in such vehicle on-board devices and can detect acceleration, angular velocity, and the like according to a motion of the vehicle (see, for example, Patent Document 1). Using these sensors, the vehicle on-board device can detect motions of the vehicle on which the vehicle on-board device is mounted (a forward or backward movement, a right or left turn, and the like).

[Citation List]

[Patent Document]

[0003]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2016-128985

[Summary of Invention]

[Technical Problem]

[0004]

A vehicle on-board device is not necessarily attached to a vehicle at a fixed attitude (position and angle). For example, a forward or backward direction and a left or right direction of the vehicle on-board device after the attachment may not match a forward or backward direction and a left or right direction of the vehicle. As a result, there is a possibility that the vehicle on-board device may not be able to accurately detect the actual forward or backward movement and right or left turns of the vehicle. Thus, a process of accurately detecting motions of the vehicle regardless of an attitude of the vehicle on-board device attached to the vehicle is required.

[Solution to Problem]

[0005]

According to an aspect of the present disclosure, there is provided a vehicle on-board device mounted on a vehicle, the vehicle on-board device including: a sensor information acquisition unit configured to acquire triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor; an identification unit configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; an attitude detection unit configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and a conversion unit configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[0006]

According to an aspect of the present disclosure, there is provided a server including: a sensor information acquisition unit configured to acquire triaxial

acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system detected by a vehicle on-board device mounted on a vehicle through an acceleration sensor; an identification unit configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; an attitude detection unit configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and a conversion unit configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[0007]

According to an aspect of the present disclosure, there is provided a vehicle motion detection method including steps of: acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor; identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.

[0008]

According to an aspect of the present disclosure, there is provided a program for causing a computer of a vehicle on-board device mounted on a vehicle to execute steps of: acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor; identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device

coordinate system from the triaxial acceleration information; identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.

[Advantageous Effects of Invention]

[0009]

According to at least the above-described aspect, it is possible to accurately detect a motion of a vehicle regardless of an attitude of a vehicle on-board device attached to the vehicle.

[Brief Description of Drawings]

[0010]

FIG. 1 is a diagram showing an overall configuration of a vehicle motion detection system according to a first embodiment of the present disclosure.

FIG. 2 is a diagram showing a functional configuration of the vehicle motion detection system according to the first embodiment of the present disclosure.

FIG. 3 is a flowchart showing an example of a process of a vehicle on-board device according to the first embodiment of the present disclosure.

FIG. 4 is a first diagram showing an example of a triaxial acceleration distribution according to the first embodiment of the present disclosure.

FIG. 5 is a second diagram showing an example of the triaxial acceleration distribution according to the first embodiment of the present disclosure.

FIG. 6 is a diagram showing a functional configuration of the vehicle motion detection system according to a second embodiment of the present disclosure.

[Description of Embodiments]

[0011]

<First embodiment>

A vehicle motion detection system 1 according to a first embodiment of the present disclosure will be described below with reference to FIGS. 1 to 5.

[0012]

(Overall configuration of vehicle motion detection system)

FIG. 1 is a diagram showing an overall configuration of a vehicle motion detection system according to the first embodiment of the present disclosure.

As shown in FIG. 1, the vehicle motion detection system 1 includes a vehicle on-board device 2 and a server 3.

[0013]

The vehicle on-board device 2 is mounted on each of a plurality of vehicles. Also, a vehicle according to the present embodiment is, for example, a four-wheeled vehicle. The vehicle on-board device 2 acquires sensor values capable of detecting motions of the vehicle (a travel position, a forward or backward movement, a right or left turn, and the like) from built-in sensors (details will be described below). Also, the vehicle on-board device 2 may be attached at any position inside of the vehicle, for example, the vehicle on-board device 2 may be attached onto a dashboard of the vehicle as shown in FIG. 1. At this time, the vehicle on-board device coordinate system (coordinates indicated by XYZ in FIG. 1) indicating a forward or backward direction, a left or right direction, and an upward or downward direction detected by the vehicle on-board device 2 may not match the vehicle coordinate system indicating the forward or backward direction, the left or right direction, and the upward or downward direction of the vehicle (coordinates indicated by X'Y'Z' in FIG. 1). Thus, the vehicle on-board device 2 according to the present embodiment has a function of automatically detecting

the attachment attitude of the device itself (how much the vehicle on-board device coordinate system deviates from the vehicle coordinate system) and converts an acquired sensor value into the vehicle coordinate system.

[0014]

The server 3 is communicatively connected to the vehicle on-board device 2 and collects information (vehicle motion information) capable of detecting the motion of the vehicle on which the vehicle on-board device 2 is mounted. The server 3 also executes a process of charging a toll fare of a toll road for the vehicle, a process of determining whether or not the vehicle is being safely driven, and the like, on the basis of the collected vehicle motion information.

[0015]

(Hardware configuration of vehicle motion detection system)

FIG. 2 is a diagram showing a functional configuration of the vehicle motion detection system according to the first embodiment of the present disclosure.

As shown in FIG. 2, the vehicle on-board device 2 of the vehicle motion detection system 1 includes a CPU 20, an acceleration sensor 21, an angular velocity sensor 22, a GNSS receiver 23, and a storage medium 24.

[0016]

The CPU 20 is a processor that controls the overall operation of the vehicle on-board device 2. Details of the functions of the CPU 20 will be described below.

[0017]

The acceleration sensor 21 is a sensor that detects acceleration associated with the motion of the vehicle on which the vehicle on-board device 2 is mounted or the vehicle on-board device 2 itself.

[0018]

The angular velocity sensor 22 is a sensor (a gyro sensor) that detects an angular velocity and acceleration associated with the motion of the vehicle on which the vehicle on-board device 2 is mounted or the vehicle on-board device 2 itself.

[0019]

The GNSS receiver 23 detects a position (latitude and longitude) of the vehicle on-board device 2, a moving speed, and the like on the basis of signals (satellite signals) received from satellites constituting a global navigation satellite system (GNSS).

[0020]

The storage medium 24 is a so-called auxiliary storage device, such as a hard disk drive (HDD) or a solid-state drive (SSD). In the storage medium 24, sensor values detected by the acceleration sensor 21, the angular velocity sensor 22, and the GNSS receiver 23, information about the attachment attitude of the vehicle on-board device 2 detected by the CPU 20, and the like are stored and accumulated.

[0021]

Also, as shown in FIG. 2, the server 3 includes a CPU 30 and a storage medium 31.

[0022]

The CPU 30 is a processor that controls an overall operation of the server 3. Details of the functions of the CPU 30 will be described below.

[0023]

The storage medium 31 is a so-called auxiliary storage device such as a hard disk drive (HDD) or a solid-state drive (SSD). In the storage medium 31, information (vehicle motion information) for detecting the motion of the vehicle acquired from the vehicle on-board device 2 is stored and accumulated.

[0024]

(Functional configuration of vehicle on-board device)

Next, functions of the vehicle on-board device 2 will be described. The CPU 20 of the vehicle on-board device 2 functions as a sensor information acquisition unit 201, an identification unit 202, an attitude detection unit 203, a conversion unit 204, and a motion detection unit 205 by performing an operation in accordance with a prescribed program.

[0025]

The sensor information acquisition unit 201 acquires triaxial acceleration information indicating a time series of triaxial acceleration in the vehicle on-board device coordinate system from the acceleration sensor 21. Also, the sensor information acquisition unit 201 acquires angular velocity information indicating a time series of angular velocities in the vehicle on-board device coordinate system from the angular velocity sensor 22. Furthermore, the sensor information acquisition unit 201 acquires movement trajectory information indicating a time series of positional information of the vehicle on-board device 2 (vehicle) from the GNSS receiver 23.

[0026]

The identification unit 202 identifies bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information acquired by the sensor information acquisition unit 201.

[0027]

The attitude detection unit 203 identifies deviation between the vehicle on-board device coordinate system (XYZ coordinates in FIG. 1) and the vehicle coordinate system (X’Y’Z’ coordinates in FIG. 1) (deviation in the attachment attitude of the vehicle on-board device 2 for the vehicle) in accordance with the bias in the distribution of the triaxial acceleration identified by the identification unit 202.

[0028]

The conversion unit 204 converts the acquired triaxial acceleration into that of the vehicle coordinate system using the deviation identified by the attitude detection unit 203 and outputs the converted triaxial acceleration.

[0029]

The motion detection unit 205 detects a motion of the vehicle on the basis of the sensor information obtained from the angular velocity sensor 22 and the GNSS receiver 23 and the triaxial acceleration converted into that of the vehicle coordinate system by the conversion unit 204. The motion of the vehicle includes the behavior of the vehicle such as stopping, a forward or backward movement, a right or left turn, a travel position of the vehicle on a road, a moving speed, and the like. The motion detection unit 205 may further execute a process on the basis of the detected motion of the vehicle. For example, the motion detection unit 205 may detect dangerous behavior such as sudden braking or sudden start of the vehicle and output a message for prompting the driver to drive safely.

[0030]

Also, the motion detection unit 205 also transmits vehicle motion information including the detected motion of the vehicle to the server 3. Also, the motion detection unit 205 may transmit vehicle motion information including sensor information acquired from the angular velocity sensor 22 and the GNSS receiver 23 and the triaxial acceleration converted into that of the vehicle coordinate system by the conversion unit 204 to the server 3.

[0031]

(Functional configuration of server)

Next, functions of the server 3 will be described. The CPU 30 functions as a

server-side processing unit 301 by performing an operation according to a prescribed program.

[0032]

The server-side processing unit 301 executes various types of processes on the basis of vehicle motion information acquired from the vehicle on-board device 2. For example, the server-side processing unit 301 performs safe driving evaluation of the vehicle (evaluation based on the presence/absence of sudden braking, sudden start, sharp curve, appropriate acceleration/deceleration, and the like) on the basis of the vehicle motion information. Also, the server-side processing unit 301 may identify a travel route of the vehicle on the basis of the vehicle motion information and perform a process of charging a toll fare when the vehicle travels on a toll road.

[0033]

(Processing flow of vehicle on-board device)

FIG. 3 is a flowchart showing an example of a process of the vehicle on-board device according to the first embodiment of the present disclosure.

Hereinafter, the process of the vehicle on-board device 2 will be described in detail with reference to FIG. 3.

[0034]

First, as shown in FIG. 3, the sensor information acquisition unit 201 acquires sensor information (step S101). In the present embodiment, the sensor information acquisition unit 201 acquires triaxial acceleration information (triaxial acceleration and a detection date and time) indicating a time series of triaxial acceleration, angular velocity information (angular velocity and detection date and time) indicating a time series of angular velocities, and movement trajectory information (positional information, moving speed, and detection date and time) indicating a time series of positional information

from the acceleration sensor 21, the angular velocity sensor 22, and the GNSS receiver 23. The sensor information acquisition unit 201 stores and accumulates the acquired sensor information in the storage medium 24. Also, when the sensor information accumulated in the storage medium 24 exceeds the prescribed number of samples, the sensor information acquisition unit 201 erases the oldest sensor information and stores newly acquired sensor information.

[0035]

Subsequently, the identification unit 202 determines whether or not sensor information of a prescribed number of samples or more has been collected (step S102). In place of the prescribed number of samples, the identification unit 202 may be configured to determine whether or not a sampling period from an initial state (the time of initial activation of the vehicle on-board device 2 or the time of initialization of sensor information) has elapsed.

[0036]

When the identification unit 202 has not collected sensor information of the prescribed number of samples or more (step S102: NO), the process returns to step S101. On the other hand, when the sensor information for the prescribed number of samples or more has been collected (step S103: YES), the identification unit 202 identifies bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system (XYZ coordinates in FIG. 1) from the triaxial acceleration information (step S103).

[0037]

FIG. 4 is a first diagram showing an example of a triaxial acceleration distribution according to the first embodiment of the present disclosure.

In FIG. 4, an example in which the triaxial acceleration information stored in the storage medium 24 is plotted on the vehicle on-board device coordinate system (XYZ

coordinates) is shown. When the vehicle is moving straight forward (the forward or backward movement), the triaxial acceleration is distributed along the X'-axis (the forward or backward direction) of the vehicle coordinate system, the triaxial acceleration tends to be distributed along the Y'-axis (the left or right direction) of the vehicle coordinate system during yawing (a turn around the Z'-axis of the vehicle coordinate system at the time of a turn such as a right or left turn). Also, because the vehicle travels on the road plane, rolling (a turn around the X'-axis of the vehicle coordinate system) and pitching (a turn around the Y'-axis of the vehicle coordinate system) do not have a large influence on the bias in the distribution of the triaxial acceleration. That is, the acceleration during the traveling of the vehicle tends to be biased so that the acceleration is distributed in two directions along the X'-axis and the Y'-axis of the vehicle coordinate system. For this reason, when the triaxial acceleration is plotted on the vehicle on-board device coordinate system as shown in FIG. 4, the bias in the distribution of the triaxial acceleration appears in directions different from the X-axis and the Y-axis of the vehicle on-board device coordinate system. Based on such a tendency, the identification unit 202 identifies the bias in the distribution of the triaxial acceleration in the vehicle on-board device coordinate system as information for detecting each axis in the vehicle coordinate system.

[0038]

First, the identification unit 202 detects the Z'-axis of the vehicle coordinate system. Deviation between the Z-axis (the upward or downward direction) of the vehicle on-board device coordinate system and the Z'-axis of the vehicle coordinate system can be detected from gravitational acceleration. For example, the identification unit 202 detects the Z'-axis of the vehicle coordinate system from the triaxial acceleration (gravitational acceleration) when the vehicle is stationary (when the moving

speed included in the movement trajectory information is zero).

[0039]

Subsequently, the identification unit 202 projects the distribution of triaxial acceleration in FIG. 4 onto the plane seen from the Z'-axis (i.e., an XY plane) to obtain the distribution of acceleration on the XY plane of the vehicle on-board device coordinate system. The identification unit 202 identifies the bias in the distribution of acceleration on the XY plane.

[0040]

FIG. 5 is a second diagram showing an example of a triaxial acceleration distribution according to the first embodiment of the present disclosure.

For example, as shown in FIG. 5, the identification unit 202 may identify a first principal component and a second principal component obtained in principal component analysis on the triaxial acceleration information as the deviation of the acceleration distribution. Vectors of the first principal component and the second principal component can be associated with directions in which the variation in acceleration increases, i.e., the X'- and Y'-axes of the vehicle coordinate system.

[0041]

Also, at this time, the identification unit 202 may perform the principal component analysis by assigning a larger weight to newer data within the triaxial acceleration information. Thereby, for example, even if the attachment attitude (XYZ-axes) of the vehicle on-board device 2 is slightly changed due to vehicle vibration, the driver's operation, or the like, a direction of bias in the distribution of acceleration follows the change in the attitude.

[0042]

Subsequently, the attitude detection unit 203 identifies the deviation between the

vehicle on-board device coordinate system and the vehicle coordinate system in accordance with the bias in the distribution of the triaxial acceleration identified by the identification unit 202 (step S104). Specifically, the attitude detection unit 203 detects the Y'-axis of the vehicle coordinate system on the basis of a correlation between the angular velocity information and the bias in the distribution of the triaxial acceleration and identifies the deviation from the Y-axis of the vehicle on-board device coordinate system.

[0043]

At the time of a turn when the vehicle turns right or left, or the like, an angular velocity becomes large and triaxial acceleration is distributed along the Y'-axis (the left or right direction) of the vehicle coordinate system. The attitude detection unit 203 detects that the direction of the bias in the distribution of the triaxial acceleration measured when the angular velocity is greater than a prescribed reference value is the Y'-axis of the vehicle coordinate system from the above-described correlation between the angular velocity and the bias in the distribution of the triaxial acceleration.

[0044]

For example, when the first principal component and the second principal component indicating the direction of the bias in the triaxial acceleration are identified in the principal component analysis in step S103, it is difficult to determine which of the X'-axis and the Y'-axis is associated with each of the vectors of the first principal component and the second principal component only from the triaxial acceleration information. Thus, the attitude detection unit 203 detects which of the vectors of the first principal component and the second principal component is the Y'-axis of the vehicle coordinate system on the basis of the correlation with the angular velocity. In the example of FIG. 5, it is assumed that the attitude detection unit 203 detects the

direction of the second principal component as the Y'-axis of the vehicle coordinate system. Then, the attitude detection unit 203 detects the direction of the remaining first principal component as the X'-axis of the vehicle coordinate system.

[0045]

When the X'-axis and the Y'-axis of the vehicle coordinate system are detected, the attitude detection unit 203 identifies the deviation from each of the X-axis and the Y-axis of the vehicle on-board device coordinate system. In the example of FIG. 5, the attitude detection unit 203 identifies an angle between the vector of the first principal component in the vehicle on-board device coordinate system and the detected X'-axis of the vehicle coordinate system as the deviation of the X-axis. Also, the attitude detection unit identifies an angle between the vector of the second principal component in the vehicle on-board device coordinate system and the detected Y'-axis of the vehicle coordinate system as the deviation of the Y-axis. The attitude detection unit 203 also identifies the deviation between the Z-axis of the vehicle on-board device coordinate system and the Z'-axis of the vehicle coordinate system detected by the identification unit 202 in a similar way. The attitude detection unit 203 can detect an attachment attitude of the vehicle on-board device 2 on the basis of the deviation of the vehicle on-board device coordinate system identified as described above. Also, the deviation of each axis detected by the attitude detection unit 203 is stored and accumulated in the storage medium 24.

[0046]

Subsequently, the attitude detection unit 203 determines whether or not the attachment attitude of the vehicle on-board device 2 has been decided on (step S105). For example, the storage medium 24 stores attitude decision information indicating whether or not the attachment attitude has been decided on. In an initial state, the

attitude decision information is “undecided.” When the attitude decision information is “undecided” (step S105: NO), the attitude detection unit 203 overwrites the attitude decision information with “decided” (step S106).

[0047]

Also, when the attitude decision information is “decided” (step S105: YES), the attitude detection unit 203 determines whether or not the attachment attitude has changed from the previous time (step S107).

[0048]

For example, the attitude detection unit 203 determines that the attachment attitude of the vehicle on-board device 2 has changed when a difference between the previously identified deviation between the vehicle coordinate system and the corresponding axis of the vehicle on-board device coordinate system and the deviation between the vehicle coordinate system and the corresponding axis of the vehicle on-board device coordinate system newly identified in step S104 is greater than or equal to a prescribed amount (step S107: NO). Also, the attitude detection unit 203 may make a determination on the basis of a difference between a movement average of previous deviations stored in the storage medium 24 and the deviation identified in step S104. Furthermore, the attitude detection unit 203 may determine that the attachment attitude has changed when the triaxial acceleration or angular velocity acquired in step S101 exceeds a prescribed threshold value (step S107: NO). The threshold value is set to an appropriate value so that it can be detected that the acceleration or angular velocity exceeds the acceleration or angular velocity (vehicle motion limit) that can be generated when the vehicle is traveling on a road.

[0049]

When the attitude detection unit 203 determines that the attachment attitude has

changed (step S107: NO), the vehicle on-board device 2 outputs a display or sound signal indicating that the attachment attitude has changed to provide a notification to the driver (step S108). Also, the attitude detection unit 203 may notify the server 3 that the attachment attitude of the vehicle on-board device 2 has changed. Thereby, the server 3 can detect that the vehicle on-board device 2 has been moved, removed, or the like. Furthermore, the attitude detection unit 203 erases (initializes) the sensor information accumulated in the storage medium 24, overwrites the attitude fixation information with "undecided" (step S109), and returns to step S101. Then, the vehicle on-board device 2 stops processes of converting into the vehicle coordinate system and outputting a conversion result by the conversion unit 204 (the processing of step S110 to be described below), and performs a series of processing steps (the processing of steps S101 to S106) by re-collecting sensor information in a new attitude in the sensor information acquisition unit 201, the identification unit 202, and the attitude detection unit 203, and re-detecting an attachment attitude.

[0050]

Also, when the attitude detection unit 203 detects and decides on a new attachment attitude (step S106) or determines that the attachment attitude has not changed (step S107: YES), the conversion unit 204 converts the triaxial acceleration acquired in step S101 into the vehicle coordinate system to output the converted triaxial acceleration using the previously identified deviation between the vehicle on-board device coordinate system and the vehicle coordinate system (step S110).

[0051]

Also, when the new attachment attitude is detected and decided on (step S106), the attitude detection unit 203 may create a coordinate conversion formula from the vehicle on-board device coordinate system into the vehicle coordinate system on the

basis of the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system identified in step S104 and output the coordinate conversion formula as information of the deviation between the coordinate systems to the conversion unit 204. Thus, the conversion unit 204 converts the triaxial acceleration acquired in step S101 into the vehicle coordinate system using the coordinate conversion formula created by the attitude detection unit 203 to output the converted triaxial acceleration (step S110).

[0052]

On the other hand, when the attachment attitude has not changed (step S107: YES), the attitude detection unit 203 does not update the coordinate transformation formula. Thus, the conversion unit 204 converts the triaxial acceleration acquired in step S101 into the vehicle coordinate system using the coordinate conversion formula previously created by the attitude detection unit 203 (step S106) and outputs the converted triaxial acceleration (step S110).

[0053]

The motion detection unit 205 executes various types of processes (sensor information processing) based on the triaxial acceleration converted into that of the vehicle coordinate system (step S111). For example, the motion detection unit 205 detects vehicle behavior such as sudden braking or sudden acceleration on the basis of the triaxial acceleration converted into that of the vehicle coordinate system and outputs a warning or a message for prompting the driver to perform safe driving to the driver. Furthermore, the motion detection unit 205 may determine whether or not the movement trajectory of the vehicle acquired from the GNSS receiver 23 matches the triaxial acceleration and angular velocity converted into those of the vehicle coordinate system and notify the driver and the server 3 that an abnormality (a failure, improper signal

reception, or the like) has occurred in the GNSS receiver 23 when they do not match. After a series of processing steps are executed, the vehicle on-board device 2 returns to step S101 and iteratively executes the above-described process.

[0054]

Also, the motion detection unit 205 may transmit vehicle motion information including sensor information (an angular velocity, positional information, a moving speed, or the like of the vehicle) acquired from the angular velocity sensor 22 and the GNSS receiver 23 and the triaxial acceleration converted into that of the vehicle coordinate system by the conversion unit 204 to the server 3. Then, the server-side processing unit 301 of the server 3 performs safe driving evaluation of the vehicle, a toll fare charging process, and the like on the basis of the vehicle motion information acquired from the vehicle on-board device 2.

[0055]

(Operation and effects)

As described above, in the vehicle motion detection system 1 according to the present embodiment, the vehicle on-board device 2 identifies the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system from the bias in the distribution of the triaxial acceleration in the vehicle on-board device coordinate system and converts the triaxial acceleration into that of the vehicle coordinate system to output the converted triaxial acceleration. By doing so, the vehicle on-board device 2 can automatically detect its own attachment attitude and accurately convert the triaxial acceleration acquired from the acceleration sensor 21 into the vehicle coordinate system to output the converted triaxial acceleration. Thereby, the vehicle on-board device 2 can accurately detect the motion of the vehicle regardless of an attitude of the vehicle on-board device 2 attached to the vehicle.

[0056]

Also, the vehicle on-board device 2 identifies the deviation from the vehicle on-board device coordinate system by associating the vectors of the first principal component and the second principal component obtained in the principal component analysis on the triaxial acceleration information with the two coordinate axes (the X'-axis and the Y'-axis) of the vehicle coordinate system. By doing so, because the vehicle on-board device 2 can accurately identify the bias in the distribution of the triaxial acceleration, the attachment attitude of the vehicle on-board device 2 (the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system) can be more accurately detected.

[0057]

Also, the vehicle on-board device 2 determines deviation between the coordinate axis (the Y-axis) of the vehicle on-board device coordinate system in the left or right direction and the coordinate axis (the Y'-axis) of the vehicle coordinate system in the left or right direction on the basis of a correlation between the bias in the distribution of the triaxial acceleration and the angular velocity information. By doing so, because the vehicle on-board device 2 can accurately detect the Y'-axis of the vehicle coordinate system, the attachment attitude of the vehicle on-board device 2 (the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system) can be more accurately detected.

[0058]

Also, when a difference between the previously identified deviation of the vehicle on-board device coordinate system and the newly identified deviation is less than a prescribed amount, the vehicle on-board device 2 uses the previously identified deviation of the vehicle on-board device coordinate system to convert the triaxial

acceleration into that of the vehicle coordinate system and output the converted triaxial acceleration. Also, when the difference is greater than or equal to the prescribed amount, the vehicle on-board device 2 determines that the attachment attitude of the vehicle on-board device 2 has changed and initializes the acquired sensor information and the acquired attitude decision information. By doing so, the vehicle on-board device 2 can automatically detect a change in an attachment attitude and suppress converting and outputting triaxial acceleration on the basis of an incorrect attachment attitude.

[0059]

Also, when a motion exceeding a motion limit of the vehicle has been detected from the triaxial acceleration information or the angular velocity information, the vehicle on-board device 2 stops converting and outputting the triaxial acceleration. By doing so, when the acceleration or angular velocity that is impossible for the motion of the vehicle has been detected, the vehicle on-board device 2 can suppress automatically detecting a change in the attachment attitude due to movement or removal of the vehicle on-board device 2 or the like and converting and outputting the triaxial acceleration on the basis of the incorrect attachment attitude.

[0060]

<Second embodiment>

Next, a vehicle motion detection system 1 according to a second embodiment of the present disclosure will be described with reference to FIG. 6. Components identical to those of the first embodiment are denoted by the same reference signs and a detailed description thereof is omitted.

[0061]

Although a mode in which the vehicle on-board device 2 detects its own

attachment attitude (deviation between the vehicle on-board device coordinate system and the vehicle coordinate system) and converts the triaxial acceleration acquired from the acceleration sensor 21 into the vehicle coordinate system to output the converted triaxial acceleration has been described in the first embodiment, the present disclosure is not limited thereto. As an example of another mode, in the second embodiment, a mode in which a server 3 detects an attachment attitude of a vehicle on-board device 2 on the basis of sensor information acquired from the vehicle on-board device 2 and converts triaxial acceleration in a vehicle on-board device coordinate system acquired from the vehicle on-board device 2 into triaxial acceleration in the vehicle coordinate system will be described.

[0062]

(Functional configuration of vehicle on-board device)

FIG. 6 is a diagram showing a functional configuration of the vehicle motion detection system according to the second embodiment of the present disclosure.

First, the functional configuration of the vehicle on-board device 2 according to the present embodiment will be described with reference to FIG. 6. As shown in FIG. 6, a CPU 20 of the vehicle on-board device 2 functions as a sensor information transmission unit 206.

[0063]

The sensor information transmission unit 206 sequentially acquires triaxial acceleration information (triaxial acceleration in the vehicle on-board device coordinate system and a detection date and time), angular velocity information (an angular velocity and a detection date and time), and movement trajectory information (positional information, a moving speed, and a detection date and time) from each of an acceleration sensor 21, an angular velocity sensor 22, and a GNSS receiver 23 and transmits the

acquired triaxial acceleration information to the server 3.

[0064]

(Functional configuration of server)

Next, a functional configuration of the server 3 according to the present embodiment will be described. As shown in FIG. 6, the CPU 30 of the server 3 functions as a sensor information acquisition unit 302, an identification unit 303, and an attitude detection unit 304 in addition to a server-side processing unit 301.

[0065]

The sensor information acquisition unit 302 has a function similar to that of the sensor information acquisition unit 201 of the vehicle on-board device 2 of the first embodiment. The sensor information acquisition unit 302 acquires sensor information (triaxial acceleration information, angular velocity information, and movement trajectory information) from the vehicle on-board device 2 attached to each of a plurality of vehicles. Sensor information acquired from each of the plurality of vehicle on-board devices 2 is stored and accumulated in the storage medium 31 for each vehicle on-board device. Specifically, the sensor information acquisition unit 302 performs the processing of step S101 of FIG. 3 like the sensor information acquisition unit 201 of the vehicle on-board device 2 according to the first embodiment.

[0066]

The identification unit 303 has a function similar to that of the identification unit 202 of the vehicle on-board device 2 of the first embodiment. The identification unit 303 identifies bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system of each of the plurality of vehicle on-board devices 2 from the triaxial acceleration information acquired by the sensor information acquisition unit 302. Specifically, the identification unit 303 executes the processing of steps S102 and S103

in FIG. 3 like the identification unit 202 of the vehicle on-board device 2 according to the first embodiment.

[0067]

The attitude detection unit 304 has a function similar to that of the attitude detection unit 203 of the vehicle on-board device 2 of the first embodiment. The attitude detection unit 304 identifies deviation between the vehicle on-board device coordinate system (XYZ coordinates in FIG. 1) and the vehicle coordinate system (X'Y'Z' coordinates in FIG. 1) in accordance with bias in the distribution of the triaxial acceleration identified by the identification unit 303 with respect to each of the plurality of vehicle on-board devices 2. The deviation identified by the attitude detection unit 304 is stored and accumulated in the storage medium 31 for each vehicle on-board device. Specifically, the attitude detection unit 304 performs the processing of steps S104 to S109 in FIG. 3 like the attitude detection unit 203 of the vehicle on-board device 2 according to the first embodiment.

[0068]

The conversion unit 305 has a function similar to that of the conversion unit 204 of the vehicle on-board device 2 of the first embodiment. The conversion unit 305 converts the triaxial acceleration acquired from each of the plurality of vehicle on-board devices 2 into the vehicle coordinate system using the deviation for each vehicle on-board device identified by the attitude detection unit 203 and outputs the converted triaxial acceleration. Specifically, the conversion unit 305 executes the processing of step S110 in FIG. 3 like the conversion unit 204 of the vehicle on-board device 2 according to the first embodiment.

[0069]

The server-side processing unit 301 detects a motion of the vehicle on which

each vehicle on-board device has been mounted on the basis of the angular velocity information and movement trajectory information acquired by the sensor information acquisition unit 302 and the triaxial acceleration converted into that of the vehicle coordinate system by the conversion unit 305. The processing is similar to the processing (step S111 in FIG. 3) of the motion detection unit 205 of the vehicle on-board device 2 according to the first embodiment. Also, the server-side processing unit 301 performs safe driving evaluation, a charging process, and the like for each vehicle on the basis of the detected motion of the vehicle, as in the first embodiment. Also, the server-side processing unit 301 may determine whether or not a movement trajectory of the vehicle identified from the movement trajectory information matches the triaxial acceleration and angular velocity converted into those of the vehicle coordinate system and notify the vehicle on-board device 2 that an abnormality has occurred in the GNSS receiver 23 of the vehicle on-board device 2 when they do not match.

[0070]

(Operation and effects)

As described above, in the vehicle motion detection system 1 according to the present embodiment, the server 3 identifies deviation between the vehicle on-board device coordinate system and the vehicle coordinate system from bias in the distribution of the triaxial acceleration in the vehicle on-board device coordinate system with respect to a plurality of vehicle on-board devices 2 and converts triaxial acceleration into that of the vehicle coordinate system of the vehicle on which the vehicle on-board device 2 has been mounted to output the converted triaxial acceleration. By doing so, the server 3 can accurately detect the motion of the vehicle by performing conversion into triaxial acceleration in the vehicle coordinate system of the vehicle to which each of the vehicle on-board devices 2 is attached regardless of an attitude of each of the plurality of vehicle

on-board devices 2 attached thereto.

[0071]

Although embodiments of the present disclosure have been described in detail above, the present disclosure is not limited thereto and some design changes and the like are also possible without deviating from the technical idea of the present invention.

[0072]

Although an aspect in which, for example, the attitude detection unit 203 of the vehicle on-board device 2 detects the Y'-axis of the vehicle coordinate system on the basis of the correlation with the angular velocity in the above-described first embodiment, the present invention is not limited thereto. In another embodiment, the attitude detection unit 203 may detect the X'-axis and the Y'-axis of the vehicle coordinate system on the basis of a correlation with movement trajectory information. In this case, the attitude detection unit 203 detects a direction in which the distribution of the triaxial acceleration is biased during a period in which the vehicle is traveling straight (the movement trajectory is linear at a plurality of times) as the X'-axis of the vehicle coordinate system. Also, the attitude detection unit 203 detects a direction in which the distribution of the triaxial acceleration is biased during a period in which the vehicle is turning (the movement trajectory is arc-shaped at a plurality of times) as the Y'-axis of the vehicle coordinate system.

[0073]

Although an aspect in which the identification unit 202 of the vehicle on-board device 2 identifies the bias in the distribution of the triaxial acceleration using all of the triaxial acceleration information accumulated in the storage medium 24 has been described in the above-described first embodiment, the present invention is not limited thereto. In another embodiment, the identification unit 202 may be configured to

classify information into triaxial acceleration information when the vehicle travels straight (forward and backward) and triaxial acceleration information when the vehicle turns (turns right or left or the like) on the basis of the angular velocity information or the movement trajectory information and identify two types of bias, i.e., bias in the distribution of the triaxial acceleration during straight traveling and bias in the distribution of the triaxial acceleration during a turn. In this case, the attitude detection unit 203 associates the bias in the distribution of the triaxial acceleration during straight traveling (the first principal component when principal component analysis is performed) with the X'-axis of the vehicle coordinate system. Likewise, the attitude detection unit 203 associates the bias in the distribution of the triaxial acceleration during a turn (the first principal component when principal component analysis is performed) with the Y'-axis of the vehicle coordinate system.

[0074]

<Appendixes>

A vehicle on-board device, a server, a vehicle motion detection method, and a program according to the above-described embodiments are ascertained, for example, as follows.

[0075]

According to a first aspect of the present disclosure, there is provided a vehicle on-board device (2) mounted on a vehicle, the vehicle on-board device including: a sensor information acquisition unit (201) configured to acquire triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor (21); an identification unit (202) configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; an attitude

detection unit (203) configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and a conversion unit (204) configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[0076]

Thereby, the vehicle on-board device can automatically detect its own attachment attitude, accurately convert the triaxial acceleration acquired from the acceleration sensor into the vehicle coordinate system, and output the converted triaxial acceleration. Thereby, the vehicle on-board device can accurately detect the motion of the vehicle regardless of an attitude of the vehicle on-board device attached to the vehicle.

[0077]

According to a second aspect of the present disclosure, in the vehicle on-board device (2) according to the first aspect, the identification unit (202) identifies a first principal component and a second principal component obtained by performing principal component analysis on the triaxial acceleration information, and the attitude detection unit (203) identifies deviation from the vehicle on-board device coordinate system by associating a vector of the first principal component and a vector of the second principal component with two coordinate axes of the vehicle coordinate system.

[0078]

Thereby, because the vehicle on-board device can accurately identify the bias in the distribution of the triaxial acceleration, the attachment attitude of the vehicle on-board device (the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system) can be detected more accurately.

[0079]

According to a third aspect of the present disclosure, in the vehicle on-board device (2) according to the first or second aspect, the sensor information acquisition unit (201) further acquires angular velocity information indicating a time series of angular velocities from an angular velocity sensor, and the attitude detection unit (203) identifies deviation between a coordinate axis of a left or right direction of the vehicle on-board device coordinate system and a coordinate axis of a left or right direction of the vehicle coordinate system on the basis of a correlation between the bias and the angular velocity information.

[0080]

Thereby, because the vehicle on-board device can accurately detect the coordinate axis (Y'-axis) of the left or right direction of the vehicle coordinate system, the attachment attitude of the vehicle on-board device (the deviation between the vehicle on-board device coordinate system and the vehicle coordinate system) can be detected more accurately.

[0081]

According to a fourth aspect of the present disclosure, in the vehicle on-board device (2) according to any one of the first to third aspects, the conversion unit (204) converts the triaxial acceleration into that of the vehicle coordinate system using previously identified deviation when a difference between the previously identified deviation and newly identified deviation is less than a prescribed amount and outputs the converted triaxial acceleration.

[0082]

By doing so, the vehicle on-board device can automatically detect a change in the attachment attitude and can suppress conversion and output of the triaxial

acceleration on the basis of an incorrect attachment attitude.

[0083]

According to a fifth aspect of the present disclosure, in the vehicle on-board device (2) according to any one of the first to fourth aspects, the conversion unit (204) stops converting and outputting the triaxial acceleration when a motion exceeding a motion limit of the vehicle has been detected from the triaxial acceleration information.

[0084]

By doing so, when the vehicle on-board device detects the acceleration or angular velocity that is impossible for the motion of the vehicle, the vehicle on-board device can automatically detect changes in the attachment attitude due to movement or removal of the vehicle on-board device and can suppress conversion and output of the triaxial acceleration on the basis of an incorrect attachment attitude.

[0085]

According to a sixth aspect of the present disclosure, there is provided a server (3) including: a sensor information acquisition unit (302) configured to acquire triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system detected by a vehicle on-board device (2) mounted on a vehicle through an acceleration sensor (21); an identification unit (303) configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; an attitude detection unit (304) configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and a conversion unit (305) configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[0086]

By doing so, the server can perform conversion into the triaxial acceleration in the vehicle coordinate system of the vehicle to which each vehicle on-board device is attached and accurately detect the motion of the vehicle regardless of an attitude of each of a plurality of vehicle on-board devices 2 attached to the vehicle.

[0087]

According to a seventh aspect of the present disclosure, there is provided a vehicle motion detection method comprising steps of: acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor (21); identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.

[0088]

According to an eighth aspect of the present disclosure, there is provided a program for causing a computer of a vehicle on-board device (2) mounted on a vehicle to execute steps of: acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor (21); identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information; identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.

[Industrial Applicability]

[0089]

According to at least the above-described aspect, it is possible to accurately detect a motion of a vehicle regardless of an attitude of a vehicle on-board device attached to the vehicle.

[Reference Signs List]

[0090]

1 Vehicle motion detection system

2 Vehicle on-board device

20 CPU

201 Sensor information acquisition unit

202 Identification unit

203 Attitude detection unit

204 Conversion unit

205 Motion detection unit

206 Sensor information transmission unit

21 Acceleration sensor

22 Angular velocity sensor

23 GNSS receiver

24 Storage medium

3 Server

30 CPU

301 Server-side processing unit

302 Sensor information acquisition unit

303 Identification unit

304 Attitude detection unit

305 Conversion unit

31 Storage medium

[CLAIMS]

[Claim 1]

A vehicle on-board device mounted on a vehicle, the vehicle on-board device comprising:

a sensor information acquisition unit configured to acquire triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor;

an identification unit configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information;

an attitude detection unit configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and

a conversion unit configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[Claim 2]

The vehicle on-board device according to claim 1,

wherein the identification unit identifies a first principal component and a second principal component obtained by performing principal component analysis on the triaxial acceleration information, and

wherein the attitude detection unit identifies deviation from the vehicle on-board device coordinate system by associating a vector of the first principal component and a vector of the second principal component with two coordinate axes of the vehicle coordinate system.

[Claim 3]

The vehicle on-board device according to claim 1 or 2,

wherein the sensor information acquisition unit further acquires angular velocity information indicating a time series of angular velocities from an angular velocity sensor, and

wherein the attitude detection unit identifies deviation between a coordinate axis of a left or right direction of the vehicle on-board device coordinate system and a coordinate axis of a left or right direction of the vehicle coordinate system on the basis of a correlation between the bias and the angular velocity information.

[Claim 4]

The vehicle on-board device according to any one of claims 1 to 3, wherein the conversion unit converts the triaxial acceleration into that of the vehicle coordinate system using previously identified deviation when a difference between the previously identified deviation and newly identified deviation is less than a prescribed amount and outputs the converted triaxial acceleration.

[Claim 5]

The vehicle on-board device according to any one of claims 1 to 4, wherein the conversion unit stops converting and outputting the triaxial acceleration when a motion exceeding a motion limit of the vehicle has been detected from the triaxial acceleration information.

[Claim 6]

A server comprising:

a sensor information acquisition unit configured to acquire triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system detected by a vehicle on-board device mounted on a vehicle through

an acceleration sensor;

an identification unit configured to identify bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information;

an attitude detection unit configured to identify deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and

a conversion unit configured to convert the triaxial acceleration into that of the vehicle coordinate system using the deviation and output the converted triaxial acceleration.

[Claim 7]

A vehicle motion detection method comprising steps of:

acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor;

identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information;

identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and

converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.

[Claim 8]

A program for causing a computer of a vehicle on-board device mounted on a vehicle to execute steps of:

acquiring triaxial acceleration information indicating a time series of triaxial acceleration in a vehicle on-board device coordinate system from an acceleration sensor;

identifying bias in a distribution of the triaxial acceleration in the vehicle on-board device coordinate system from the triaxial acceleration information;

identifying deviation between the vehicle on-board device coordinate system and a vehicle coordinate system in accordance with the bias; and

converting the triaxial acceleration into that of the vehicle coordinate system using the deviation and outputting the converted triaxial acceleration.