(57) [CLAIMS]

1. An automatic driving control device mounted on a vehicle, the automatic driving control device comprising:

a surrounding information acquisition unit configured to acquire surrounding information, which is information of the surrounding of the vehicle;

a driving mode setting unit configured to set a driving mode of the vehicle to either one of an advanced automation mode in which at least some of a plurality of types of driving operations necessary for traveling of the vehicle is automatically executed based on the surrounding information and a basic mode in which a type of automatic driving operation which is the driving operation to be automatically executed is less than the advanced automation mode or is zero;

an automatic control unit configured to execute, based on the driving mode set by the driving mode setting unit, the automatic driving operation set in the driving mode; and

an impact detection unit configured to detect an impact applied to the vehicle from outside the vehicle; wherein

the automatic control unit is configured to stop the execution of at least one of the automatic driving operations set for execution when the impact is detected by the impact detection unit while the driving mode is set to at least the advanced automation mode.

2. The automatic driving control device according to claim 1, wherein
the automatic control unit is configured to stop all the automatic driving operations to be executed in the driving mode when the impact is detected by the impact detection unit while the driving mode is set to a driving mode having at least one automatic driving operation to be executed.
3. The automatic driving control device according to claim 1 or 2, further comprising a switch operated to set the driving mode; wherein
the driving mode setting unit is configured to set the driving mode to the advanced automation mode or the basic mode in response to an operation of the switch;
a notification unit configured to, when the impact is detected by the impact detection unit, notify an occupant of the vehicle of an advance notice to stop the execution of at least one of the automatic driving operations set for execution, and
a cancel permission determination unit configured to determine whether or not a specific cancel permission operation different from an operation of the switch is performed by an occupant of the vehicle after the notification by the notification unit are further provided; and

the automatic control unit is configured to stop the execution of the automatic driving operation whose execution is to be stopped when the cancel permission determination unit determines that the cancel permission operation is performed, and execute a predetermined automatic stopping process for stopping the traveling of the vehicle when the cancel permission determination unit does not determine that the cancel permission operation is performed.

DETAILED DESCRIPTION OF THE INVENTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]

The present international application claims priority based on Japanese Patent Application No. 2014 -234665 filed to the Japanese Patent Office on November 19, 2014, and the entire contents of Japanese Patent Application No. 2014 - 234665 are incorporated herein by reference.

[Technical Field]

[0002]

The present disclosure relates to an automatic driving control device capable of automatically performing at least a part of various driving operations of a driver necessary for causing a vehicle to travel, such as various determinations and operations by the driver, without requiring an operation or the like by the driver.

Description of the Related Art

[0003]

Various techniques for realizing automatic driving of a vehicle have been proposed and some have been put into practical use. Patent Literature 1 below discloses an automatic driving vehicle capable of automatic driving travel according to a preset travel plan.

PRIOR ART DOCUMENT

Patent Literature

[0004]

Patent Literature 1: Japanese Laid-Open Patent Publication No. 2012-59274

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005]

One of the final goals of automatic driving technology is to merely set a destination, and thereafter allow the occupant to reach the destination without any involvement in traveling. However, in the present situation, the level of reliability high enough to realize the above has not yet been reached.

[0006]

In addition, as the automatic driving technology becomes more advanced, it is desirable to be able to take an appropriate response to an abnormality of the in-vehicle computer for realizing the automatic driving. Specifically, in a case where the automatic driving technology is adopted, it is desirable that at least a part of the control being automatically executed is invalidated and entrusted to the driver's operation, or the behavior of the vehicle can be forcibly controlled in a safe direction, as necessary.

[0007]

In one aspect of the present disclosure, in a vehicle capable of automatically executing at least a part of various driving controls necessary for traveling without requiring an operation of a driver, it is desirable to be able to forcibly stop at least a part of the control being automatically executed at an appropriate timing.

[Means for Solving the Problem]

[0008]

An automatic driving control device according to one aspect of the present disclosure is mounted on a vehicle, and includes a surrounding information acquisition unit, a driving mode setting unit, an automatic control unit, and a cancellation required event determination unit.

The surrounding information acquisition unit acquires surrounding information which is information around the vehicle. More specifically, the surrounding information is information indicating a state around the vehicle and is information necessary for automatically executing a plurality of types of driving operations necessary for traveling of the vehicle without requiring an operation of the driver.

[0009]

The driving mode setting unit sets the driving mode of the vehicle to either an advanced automation mode or a basic mode. The advanced automation mode is a driving mode in which at least a part of the plurality of types of driving operations necessary for traveling of the vehicle is automatically executed based on the surrounding information. The basic mode is a driving mode in which the type of automatic driving operations, which are driving operations to be automatically executed, is less than that in the advanced automation mode or is zero.

[0010]

Based on the driving mode set by the driving mode setting unit, the automatic control unit executes the automatic driving operation set in the driving mode. The cancellation required event determination unit determines whether or not a predetermined cancellation required event has occurred at least when the driving mode is set to the advanced automation mode. The cancellation required event is a predetermined event in which at least one of the automatic driving operations set to be executed is to be canceled (stop execution).

[0011]

When the driving mode is set to at least the advanced automation mode, the automatic control unit stops the execution of at least one of the automatic driving operations set for execution when the cancellation required event determination unit determines that the cancellation required event has occurred.

[0012]

According to the automatic driving control device configured as described above, when the driving mode is set to at least the advanced automation mode (that is, when at least one automatic driving operation is set for execution) and the cancellation required event has occurred, at least one of the automatic driving operations to be originally executed is canceled from the execution target and is not executed by the automatic control unit.

[0013]

Therefore, even if a cancellation required event occurs in which the automatic driving operation may not be normally performed, it is possible to suppress unintentional unstable traveling of the vehicle.

In a case where the driving mode is set to a driving mode having at least one automatic driving operation to be executed, the automatic control unit may stop all the automatic driving operations to be executed in the driving mode when the cancellation required event determination unit determines that the cancellation required event has occurred. That is, when the cancellation required event occurs, the automatic driving operation by the automatic control unit is not performed. In this way, even if a cancellation required event occurs in which the automatic driving operation may not be normally performed, it is possible to more reliably suppress unintentional unstable traveling of the vehicle.

[0014]

Here, a notification unit and a cancel permission determination unit may be provided. When the cancellation required event determination unit determines that the cancellation required event has occurred, the notification unit notifies the occupant of the vehicle that the cancellation required event has occurred. The cancel permission determination unit determines whether or not a specific cancel permission operation is performed by the occupant of the vehicle after the notification by the notification unit. When the cancel permission determination unit determines that the cancel permission operation has been performed, the automatic control unit may stop the execution of the automatic driving operation whose execution is to be stopped. Then, when the cancel permission determination unit does not determine that the cancel permission operation has been performed, the automatic control unit may execute predetermined automatic stopping process for stopping the traveling of the vehicle.

[0015]

In the automatic driving control device configured as described above, when the cancellation required event occurs, the execution of the automatic driving operation is not unconditionally stopped, but the notification is made in advance. When an occupant of the vehicle displays an intention in response to the notification, the execution of the automatic driving operation is stopped. In this way, it is possible to suppress the traveling state of the vehicle from becoming unstable due to the stop of the execution of the automatic driving operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1A is a side view of a vehicle according to an embodiment, and FIG. 1B is a top view of the vehicle according to the embodiment.

FIG. 2 is a block diagram illustrating an electrical configuration of the vehicle according to a first embodiment.

FIG. 3A is an explanatory diagram illustrating an automatic driving level of each driving mode, and FIG. 3B is an explanatory diagram illustrating that control contents at each automatic driving level may be arbitrarily set.

FIG. 4 is an explanatory diagram for describing an outline of automatic driving.

FIG. 5 is a flowchart of an automatic driving level setting process.

FIG. 6 is a flowchart illustrating details of an automatic driving cancellation confirmation process in the automatic driving level setting process of FIG. 5.

FIG. 7 is a flowchart illustrating details of a system monitoring process in the automatic driving cancellation confirmation process of FIG. 6.

FIG. 8 is a flowchart illustrating details of an inside-outside behavior monitoring process in the automatic driving cancellation confirmation process of FIG. 6.

FIG. 9 is a flowchart showing details of an environment monitoring process in the automatic driving cancellation confirmation process of FIG. 6.

FIG. 10A is a flowchart of a travel history recording process, and FIG. 10B is a flowchart illustrating details of a self-diagnosis process in the automatic driving cancellation confirmation process of FIG. 6.

FIG. 11 is a block diagram illustrating an electrical configuration of a vehicle according to a second embodiment.

FIG. 12 is a flowchart of a control state monitoring process according to the second embodiment.

[Description of Reference Numerals]

[0017]

1 vehicle

2 front camera

3 rear camera

4 left-side camera

5 right-side camera

6 indoor camera

9 front window

10 steering wheel

11 front radar device

12 rear radar device

13 left radar device

14 right radar device

16 solar sensor

17 rainfall sensor

18 wheel speed sensor

19 current sensor

20 steering amount sensor

21 in-vehicle contact sensor

22 engine room temperature sensor

23 engine room sound sensor

24 tire pressure sensor

25 suspension sensor

26 vehicle exterior sound sensor

27 impact sensor

30, 101 automatic driving control device

30a, 101a, 102a control unit

30b, 101b, 102b memory

31 GPS communication unit

32 vehicle-to-vehicle communication unit

33 road-to-vehicle communication unit

34 pedestrian-to-vehicle communication unit

35 LTE communication unit

36 operation unit

37 display unit

38 speaker

41 automatic driving switch

42 level setting operation unit

43 emergency stop lever

44 cancellation reset switch

46 travel driving control unit

47 brake control unit

48 steering control unit

81 on-road communication device

82 camera

100 network

102 monitoring device

111 detection means group

112 communication means group

DESCRIPTION OF EMBODIMENTS

[0018]

Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the drawings.

[First Embodiment]

(1) Configuration diagram of vehicle 1

FIG. 1A is a side view of a vehicle 1 according to the present embodiment, and FIG. 1B is a top view of the vehicle 1. However, FIGS. 1A and 1B simply illustrate arrangement states of various cameras, radars, sensors, and the like mainly in the vehicle 1 for the purpose of clearly indicating the arrangement states thereof.

[0019]

As illustrated in FIGS. 1A and 1B, the vehicle 1 includes at least a front camera 2, a rear camera 3, a left-side camera 4, a right-side camera 5 and an indoor camera 6 as cameras for photographing the inside and outside of the vehicle 1. Each of the cameras 2 to 6 is a camera capable of photographing color images and moving images. Each camera 2 to 6 may be a monocular camera, or may be a stereo camera including a plurality of lenses so as to be able to acquire information in the depth direction as well.

[0020]

The front camera 2 is provided so as to face the front side on the front end side of the ceiling in the vehicle interior. The front camera 2 can photograph the front side of the vehicle 1 in a wide range. The rear camera 3 is provided so as to face the rear side on the rear end side of the ceiling in the vehicle interior. The rear camera 3 can photograph the rear side of the vehicle 1 in a wide range.

[0021]

The left-side camera 4 is provided so as to face the left side at the left side surface of the vehicle 1. The left-side camera 4 can photograph the left side of the vehicle 1 in a wide range. The right-side camera 5 is provided so as to face the right side at the right side surface of the vehicle 1. The right-side camera 5 can photograph the right side of the vehicle 1 in a wide range.

[0022]

The indoor camera 6 is provided so as to face the rear side (vehicle interior) on the front end side of the ceiling in the vehicle interior. The indoor camera 6 can photograph at least the upper body of the driver (driver) in the vehicle interior.

[0023]

As illustrated in FIGS. 1A and 1B, the vehicle 1 includes a front radar device 11, a rear radar device 12, a left radar device 13, and a right radar device 14. In the present embodiment, each radar device 11 to 14 is a millimeter-wave radar. As is well known, a millimeter-wave radar is a radar that transmits a millimeter-wave radio wave and receives its reflected wave by a plurality of receiving antennas, thereby detecting target information on a target around the vehicle 1 based on a relationship between a transmitting wave and each of the receiving waves and a relationship between the respective receiving waves. Target information detectable by each radar device 11 to 14 includes presence or absence of a target in a detecting direction, distance to the target, direction of the target with respect to the vehicle 1, moving speed of the target (relative speed with respect to the vehicle 1), and the like.

[0024]

Specifically, the front radar device 11 is provided at the front end of the vehicle 1, and transmits and receives a millimeter-wave having a predetermined frequency with respect to the front side of the vehicle 1. The front radar device 11 can acquire target information on a target on the front side of the vehicle 1. The rear radar device 12 is provided at the rear end of the vehicle 1, and transmits and receives a millimeter-wave having a predetermined frequency with respect to the rear side of the vehicle 1. The rear radar device 12 can acquire target information on a target on the rear side of the vehicle 1.

The left radar device 13 is provided on the left side surface of the vehicle 1, and transmits and receives a millimeter-wave having a predetermined frequency with respect to the left side of the vehicle 1. The left radar device 13 can acquire target information on a target on the left side of the vehicle 1. The right radar device 14 is provided on the right side surface of the vehicle 1, and transmits and receives a millimeter-wave having a predetermined frequency with respect to the right side of the vehicle 1. The right radar device 14 can acquire target information on a target on the right side of the vehicle 1.

[0025]

As illustrated in FIGS. 1A and 1B, the vehicle 1 includes a solar sensor 16 and a rainfall sensor 17. The solar sensor 16 is installed at a lower portion of a front window 9 in the front side of the vehicle interior. The solar sensor 16 can detect a solar radiation amount with respect to the vehicle 1, and thus the brightness around the vehicle 1. The rainfall sensor 17 is installed at an upper portion of the inner side of the vehicle interior in the front window 9. The rainfall sensor 17 can detect the presence or absence of rainfall and the amount of rainfall.

[0026]

(2) Electrical configuration of vehicle 1

An electrical configuration of the vehicle 1 will be specifically described with reference to FIG. 2. As illustrated in FIG. 2, vehicle 1 includes an automatic driving control device 30. The automatic driving control device 30 mainly has a mode switching function and an automatic driving function. The mode switching function is a function of setting the driving mode of the vehicle 1 to either the advanced automation mode or the basic mode. The automatic driving function is a function that executes automatic driving corresponding to an automatic driving level of the set driving mode (see FIG. 3A. Details will be described later.). As will be described later, the automatic driving control device 30 appropriately switches the driving mode of the vehicle 1 according to various factors such as the traveling state of the vehicle 1, the surrounding situation of the vehicle 1, and the state of the driver of the vehicle 1.

[0027]

Types of automatic driving of the vehicle include partial automatic driving, fully automatic driving, and the like. The partial automatic driving is automatic driving in which a part of various driving operations of the driver necessary for traveling the vehicle is automated. Here, automation means that it can be executed without requiring an operation or the like of the driver. The fully automatic driving is automatic driving in which traveling to a set destination is entirely automated without requiring an operation or the like of the driver to the destination. A parameter indicating the degree of type and number of driving operations automated in the automatic driving is hereinafter referred to as an automatic driving level. The fully automatic driving has a higher automatic driving level than the partial automatic driving. In addition, there are various levels of partial automated driving according to the type and number of automated driving operations.

[0028]

The vehicle 1 of the present embodiment is configured to be able to perform not only partial automatic driving but also fully automatic driving by the automatic driving control device 30. In the present embodiment, it is configured such that the driver can arbitrarily change the setting of the automatic driving level, that is, which operation is to be automated and which operation is to be performed by the driver among the various driving operations necessary for traveling.

[0029]

More specifically, in the present embodiment, there are seven types of main automatic control functions for realizing fully automatic driving, automatic start/stop control, lane keeping control, inter-vehicle distance control, lane change control, right/left turn control, collision prevention control, and parking control. The automatic driving control device 30 can execute these seven types of automatic control functions, and can realize fully automatic driving by executing all of these seven types of automatic control functions.

[0030]

On the contrary, the partial automatic driving is realized by executing six or less arbitrary automatic control functions among the seven types of automatic control functions. In the present embodiment, which of the seven types of automatic control functions is to be executed in the advanced automation mode can be arbitrarily set.

[0031]

Specific contents of the seven types of automatic control functions will be described later in detail.

The automatic driving level becomes higher as the number of functions to be executed among the seven types of automatic control functions increases. Specifically, the automatic driving level when none of the seven types of automatic control functions is executed is level 0. The automatic driving level when n types of the seven types of automatic control functions are executed is level n.

Therefore, in the driving mode of level 0, it is necessary for the driver to determine and operate on their own the control operation corresponding to the seven types of automatic control functions. On the other hand, the driving modes of levels 1 to 6 are driving modes in which partial automatic driving is performed. The driving mode of level 7 is a driving mode in which fully automatic driving is performed.

[0032]

In the present embodiment, the advanced automation mode is a driving mode in which the automatic driving at the automatic driving level of level 1 or higher is performed. On the other hand, the basic mode is a driving mode in which the automatic driving level is relatively low with respect to the advanced automation mode. For example, when the advanced automation mode is level n, the basic mode can be set to any one of level n-1 to level 0.

[0033]

In the present embodiment, in order to simplify and make the description easy to understand, the basic mode will be described assuming that the automatic driving level is set to level 0. The level 0 is a level at which all the seven types of automatic control functions are not executed and the driver needs to perform most of various driving operations necessary for traveling.

[0034]

The automatic driving control device 30 includes a control unit 30a and memory 30b. Specifically, the memory 30b includes a ROM, a RAM, and other various storage media (e.g., EEPROM and flash memory). The arithmetic unit 30a realizes various functions including the mode switching function and the automatic driving function described above by executing various programs stored in the memory 30b. The control unit 30a includes at least a CPU.

[0035]

The various programs stored in the memory 30b include a program (so-called security software) capable of detecting an external unauthorized operation, a computer virus, unauthorized software, data, and the like (hereinafter collectively referred to as an “unauthorized factor”). The control unit 30a monitors the presence or absence of an unauthorized factor at any time by having the security software reside during the starting. When the unauthorized factor occurs, various types of unauthorized handling processes are executed. The unauthorized handling process includes a process of forcibly setting the automatic driving level to level 0 so as not to activate the automatic control function at all. In addition, various specific contents of the unauthorized handling processes are conceivable, and for example, a warning by voice or the like may be output to the driver, or the vehicle 1 may be forcibly decelerated or stopped. Furthermore, the connection between the control unit 30a and each communication unit 31 to 35 may be physically cut off so that access from the outside to the automatic driving control device 30 via wireless communication cannot be made.

[0036]

Each camera 2 to 6, each radar device 11 to 14, and each sensor 21 to 23 illustrated in FIGS. 1A and 1B are connected to the automatic driving control device 30. The control unit 30a of the automatic driving control device 30 individually controls the operation of each camera 2 to 6, and acquires a photographing result (image data) from each camera 2 to 6 and stores the photographing result in memory 30b. The image data is repeatedly acquired and stored at every predetermined time.

[0037]

The control unit 30a can recognize various situations inside and outside the vehicle on the basis of the image data of each camera 2 to 6. For example, the motion, the expression, the line-of-sight, the state of the eye, and the like of the occupant (mainly the driver) can be recognized from the image data of the indoor camera 6.

[0038]

Thus, the control unit 30a can determine whether or not the driver shows an abnormal behavior based on the image data of the indoor camera 6. Here, the abnormal behavior of the driver means any of a state in which the driver may not be able to normally operate the vehicle 1, and a state in which the driver feels uneasy about the operation of the vehicle 1 because the automatic driving function is not normally operating. Specific examples of the former include looking aside too much, dozing, or fainting. Specific examples of the latter include the driver expressing surprise, anxiety, or fear.

[0039]

Furthermore, based on the image data of the front camera 2, the control unit 30a can recognize a front vehicle, an oncoming vehicle, a vehicle in an adjacent lane traveling diagonally ahead, a lane dividing line, a pedestrian crossing, a pedestrian, an intersection, entry of another vehicle into a crossway at an intersection, contents of a road sign, a traffic light, a signboard, and the like in an advancing direction, a rainfall situation, a snowfall situation, a fog generating situation, surrounding brightness, and other objects around the vehicle by various types of image recognition process. Note that the recognizable road sign also includes characters, marks, and the like drawn on the road surface of the road.

[0040]

Thus, the control unit 30a can recognize the behavior of the pedestrian, the behavior and the line-of-sight of the pedestrian, the presence or absence of passing from the oncoming vehicle, the weather condition, and the like on the basis of the image data of the front camera 2. More specifically, it is possible to recognize that there is rain or snow of a predetermined amount or more, that thick fog is generated, and the like as the weather condition. From the behavior of the pedestrian, it is possible to recognize whether or not the pedestrian is feeling uneasy about the vehicle 1. More specifically, in a case where the pedestrian is looking at the vehicle 1 and the expression thereof represents a specific emotion such as surprise, anxiety, or fear, it can be determined that the pedestrian is feeling uneasy about the vehicle 1. In addition, it is possible to recognize that there is a possibility that the vehicle 1 is not normally operating when the line-of-sight of a predetermined number or more pedestrians is directed to the vehicle 1.

[0041]

Furthermore, based on the image data of the front camera 2, the control unit 30a can recognize a distance and a relative speed from the front vehicle, recognize a traveling state of the own vehicle with respect to the traveling road, and recognize contents of a road sign and a signboard. Therefore, it is possible to recognize various types of sign information such as a speed limit, necessity of temporary stop, and advisability of parking and stopping based on the recognition result of the contents of the road sign and the signboard. In addition, for example, it is also possible to recognize an accident-prone area, a school zone, or another specific environment (e.g., an area where an animal appears at high frequency).

[0042]

Furthermore, based on the image data of the rear camera 3, the control unit 30a can recognize a following vehicle, a vehicle in an adjacent lane traveling diagonally behind, surrounding brightness, a pedestrian, sign information drawn on a road surface of a road, and other objects around the vehicle by various types of image recognition process.

[0043]

Thus, the control unit 30a can recognize, for example, the relative distance and the relative speed between the own vehicle and the following vehicle, and the presence or absence of passing from the following vehicle based on the image data of the rear camera 3. In addition, similarly to the image data of the front camera 2, the behavior of the pedestrian, the behavior and line-of-sight of the pedestrian, the weather condition, and the like can also be recognized by the image data of the rear camera 3.

[0044]

Furthermore, based on the image data of the left-side camera 4 and the right-side camera 5, the control unit 30a can recognize a vehicle on the side of the own vehicle (left front, left rear, right front, and right rear vehicles are also included), a road sign on the side of the own vehicle traveling road, a lane mark, a pedestrian, surrounding brightness, and other objects around the vehicle by various types of image recognition process.

[0045]

Thus, the control unit 30a can recognize, for example, the relative distance and the relative speed between the own vehicle and the side vehicle based on the image data of each of the side cameras 4 and 5. In addition, similarly to the image data of the front camera 2, the behavior of the pedestrian, the behavior and line-of-sight of the pedestrian, the weather condition, and the like can also be recognized by the image data of each side camera 4 and 5.

[0046]

In addition, the control unit 30a of the automatic driving control device 30 individually controls each radar device 11 to 14, acquires a target detection result from each radar device 11 to 14, and stores the target detection result in the memory 30b. The detection result from each radar device 11 to 14 is repeatedly acquired and stored at every predetermined time. The control unit 30a can calculate and acquire the presence or absence of a target, the distance to the target, the direction of the target, the relative speed of the target viewed from the vehicle 1, and the like based on the detection result of each radar device 11 to 14.

[0047]

Note that, from the detection result of the front radar device 11, it is possible to mainly acquire information of a target ahead of the vehicle (including diagonally forward left and right). From the detection result of the rear radar device 12, it is possible to mainly acquire information of a target behind the vehicle (including diagonally rearward left and right). From the detection result of the left radar device 13, it is possible to mainly acquire information on a target on the left side of the vehicle (including the left front and the left rear). From the detection result of the right radar device 14, it is possible to mainly acquire information of a target on the right side of the vehicle (including the right front and the right rear).

[0048]

In addition, the control unit 30a of the automatic driving control device 30 can determine the brightness of the traveling environment based on the detection signal from the solar sensor 16, and determine whether or not it is the brightness at night or in a situation similar thereto (hereinafter, simply referred to as "night"). Note that the vehicle 1 includes a headlight (not illustrated). The headlight can be turned on and off by a driver's operation, and can be automatically turned on and off by setting the light mode to the auto mode. In a case where the light mode is set to the auto mode, the control unit 30a automatically turns on the headlight when determined as night based on the detection signal from the solar sensor 16, and automatically turns off the headlight when determined as not night. Further, in the present embodiment, when the driving mode is set to the advanced automation mode, the light mode is forcibly set to the auto mode.

[0049]

Furthermore, the control unit 30a of the automatic driving control device 30 can determine the presence or absence of rainfall and the amount of rainfall based on the detection signal from the rainfall sensor 17.

In addition, as illustrated in FIG. 2, the vehicle 1 includes, as components connected to the automatic driving control device 30, a wheel speed sensor 18, a current sensor 19, a steering amount sensor 20, an in-vehicle contact sensor 21, an engine room temperature sensor 22, an engine room sound sensor 23, a tire pressure sensor 24, a suspension sensor 25, a vehicle exterior sound sensor 26, and an impact sensor 27.

[0050]

The wheel speed sensor 18 is provided on each of four front, rear, left, and right wheels of the vehicle 1, and outputs a detection signal (wheel speed signal) indicating the rotation speed of the corresponding wheel. Each wheel speed signal from each wheel speed sensor 18 is input to the automatic driving control device 30.

[0051]

The control unit 30a can detect the rotation speed of each wheel based on the wheel speed signal from each wheel speed sensor 18. Then, from the detection result, for example, whether or not slip has occurred can be detected.

[0052]

The current sensor 19 is provided for one or a plurality of a large number of electric wiring provided in the vehicle 1, and outputs a detection signal (current detection signal) indicating a current flowing through the electric wiring. The current detection signal from the current sensor 19 is input to the automatic driving control device 30.

[0053]

The control unit 30a can detect the current of the corresponding electric wiring based on the current detection signal from the current sensor 19. Then, from the detection result, for example, whether or not an overcurrent is flowing through a specific electric wiring can be detected. The overcurrent here is a large current that does not theoretically flow in a state where the vehicle 1 is operating normally, and for example, a large current or a surge current that may be generated by a lightning strike can be considered.

[0054]

Note that the current sensor 19 may be provided in the vehicle body of the vehicle 1 to detect the current flowing through the vehicle body. By doing so, when a lightning strike occurs in the vehicle 1, a large current flowing through the vehicle 1 to the ground can be detected. How and where the current sensor 19 is installed may be appropriately determined so that it is possible to detect that a lightning strike has occurred in the vehicle 1.

[0055]

The steering amount sensor 20 is provided to directly or indirectly detect the steering amount of the turning wheel. The steering amount sensor 20 may be provided, for example, on a column shaft connecting the steering wheel 10 (see FIGS. 1A and 1B) and a steering mechanism. However, the vehicle 1 of the present embodiment includes an electric power steering device capable of controlling the steering of the turning wheels by a motor, and includes a rotation sensor for detecting a rotation position (and furthermore, a steering state) of the motor for steering control. Therefore, the steering amount sensor 20 may not be provided alone, and the rotation sensor may be used as the steering amount sensor 20. That is, the specific configuration, installing location, and the like of the steering amount sensor 20 may be appropriately determined so that the steering amount can be detected.

[0056]

The control unit 30a can detect the steering amount of the turning wheels based on the detection signal from the steering amount sensor 20. Then, from the detection result, for example, a change state or a change rate of the steering amount can be detected. Accordingly, when the driving level is set such that the steering is automatically performed (i.e., the driving level is set such that at least one of the lane keeping control, the lane change control, and the right/left turn control is executed), whether or not the automatic control of the steering is appropriately performed can be determined. Specifically, for example, when the change rate of the steering amount is greater than or equal to a predetermined value (that is, when the change rate is excessively large), it can be determined that the automatic control of steering is not normally performed. Alternatively, it can also be determined that the automatic control of steering is not normally performed when the vehicle is not traveling along the lane (e.g., the vehicle goes beyond the lane mark), when the vehicle travels straight where the vehicle should turn right or left, and the like.

[0057]

The in-vehicle contact sensor 21 is a sensor for detecting that an occupant of the vehicle 1 has touched a specific part in the vehicle, and is provided at the specific part (hereinafter also referred to as “in-vehicle specific contact part”). The in-vehicle specific contact part can be appropriately determined, and for example, a specific part in the seating seta of the driver, the steering wheel 10 or the vicinity thereof, and the like can be considered.

[0058]

As will be described later, the in-vehicle contact sensor 21 is provided so that the driver can quickly (urgently) cancel the automatic driving when the automatic driving level of the vehicle 1 is set to level 1 or higher. That is, in a case where the driver wishes to cancel the automatic driving for some reason when the automatic driving level is set to level 1 or higher, the automatic driving is forcibly canceled when the driver touches the in-vehicle specific contact part. Therefore, the specific configuration and installing location of the in-vehicle contact sensor 21 may be appropriately determined so that it is possible to detect that the driver has touched the in-vehicle specific contact part.

[0059]

In the present embodiment, "cancellation" of the automatic driving means to set the automatic driving level to level 0. However, this is merely an example. For example, stopping at least one of the currently executed automatic control functions may be defined as "cancellation" of the automatic driving. For example, forcibly stopping one or a plurality of automatic control functions including at least the automatic control function may be defined as "cancellation" of the automatic driving when the driver feels that there is a possibility that the automatic control function is not normally operating and touches the in-vehicle specific contact part while the automatic control function is operating.

[0060]

The engine room temperature sensor 22 is provided at a predetermined portion in the engine room of the vehicle 1 or in the vicinity of the engine room, and outputs a detection signal corresponding to the temperature of the engine room. The control unit 30a can detect the temperature of the engine room based on the detection signal from the engine room temperature sensor 22. Then, when the detected temperature of the engine room is excessively large (e.g., when higher than or equal to a predetermined temperature threshold value), it can be determined that some abnormality has occurred in the engine or the periphery thereof.

[0061]

The engine room sound sensor 23 is provided at a predetermined portion in the engine room of the vehicle 1 or in the vicinity of the engine room mainly for the purpose of detecting sound generated in the engine room, and outputs a detection signal corresponding to a volume around the installing portion. The control unit 30a can detect sound generated in the engine room based on a detection signal from engine room sound sensor 23. Then, in a case where the detected sound in the engine room is excessively large (e.g., when greater than or equal to a predetermined volume threshold value), it can be determined that some kind of abnormality has occurred in the engine or the periphery thereof.

[0062]

The tire pressure sensor 24 is provided on each of the four front, rear, left, and right wheels of the vehicle 1, and outputs a detection signal (air pressure signal) indicating the air pressure of the tire of the corresponding wheel. The air pressure signal from each tire pressure sensors 24 is input to the automatic driving control device 30.

[0063]

The control unit 30a can detect the air pressure of the tire of each wheel based on the air pressure signal from each tire pressure sensor 24. Then, from the detection result, for example, whether or not abnormality (e.g., puncture) has occurred in any tire can be detected.

[0064]

The suspension sensor 25 outputs a detection signal indicating an expansion/contraction amount of a suspension of the vehicle 1 (e.g., an expansion/contraction amount of a shock absorber or a spring). The control unit 30a can detect the behavior (mainly the behavior in the vertical direction) of the vehicle 1 based on the detection signal from the suspension sensor 25. When the automatic driving level of the vehicle 1 is set to level 1 or higher and the automatic control function to be executed is not normally operating, the behavior of the vehicle 1 may become unstable. For example, an unstable behavior such as sudden start, sudden stop, or sudden turn may automatically occur. Such unstable behavior appears as behavior of the suspension. Therefore, the control unit 30a can determine the stability of the behavior of the vehicle 1 based on the detection signal from the suspension sensor 25 (i.e., based on the expansion/contraction amount of the suspension itself or the change rate thereof), and furthermore, can determine whether or not the automatic control function is normally operating when the automatic control function is operating.

[0065]

The vehicle exterior sound sensor 26 is provided mainly for the purpose of detecting sound generated around the vehicle 1. The control unit 30a can detect a type and a volume of a sound generated around vehicle 1 based on a detection signal from vehicle exterior sound sensor 26. For example, when another vehicle is honking the horn, this can be detected.

[0066]

When an impact is applied to the vehicle 1 from the outside of the vehicle 1, the impact sensor 27 outputs a detection signal corresponding to the level of the impact. The control unit 30a can detect the presence or absence and level of an external impact on the vehicle 1 based on a detection signal from the impact sensor 27. The impact to be detected by the impact sensor 27 includes impact of a wide range of level from an impact of relatively large level such as a collision with another vehicle or a road structure to an impact of relatively low level such as an impact caused by a person outside the vehicle 1 hitting the vehicle 1.

[0067]

As illustrated in FIG. 2, the vehicle 1 includes a GPS communication unit 31, a vehicle-to-vehicle communication unit 32, a road-to-vehicle communication unit 33, a pedestrian-to-vehicle communication unit 34, and an LTE communication unit 35 as components connected to the automatic driving control device 30.

[0068]

The GPS communication unit 31 receives radio waves from a plurality of global positioning system (GPS) satellites, and outputs information (GPS information) included in the received radio waves to the automatic driving control device 30. The control unit 30a of the automatic driving control device 30 can calculate the current position of the vehicle 1 based on the information received by the GPS communication unit 31.

[0069]

In addition, the automatic driving control device 30 has a route guidance function which is one of various element functions for realizing the automatic driving function. The route guidance function is a function of calculating an appropriate route from the current position to the destination on the basis of the current position of the vehicle 1 calculated based on the GPS information and the destination set by the driver, and performing guidance control of the vehicle 1 so that the vehicle 1 travels along the route to the destination.

[0070]

The route guidance function also includes a function of recognizing a road situation around the vehicle 1 (e.g., a shape of a route to a destination, a vehicle width, or the like) and a function of recognizing presence or absence of an infrastructure in an advancing direction, an operation state, or the like (e.g., a state of a traffic light in an advancing direction, presence or absence of an intersection, presence or absence of a pedestrian crossing, speed limit, regulation information, and the like.). The control unit 30a realizes the guidance control by also using these various recognition results.

[0071]

The content of the guidance control of the vehicle 1 in the route guidance function varies depending on the automatic driving level. For example, the guidance control when the automatic driving level is set to level 7 of the fully automatic driving is provision of route information (information on which direction and which route the vehicle should travel) necessary for execution of the automatic control functions with respect to a plurality of types (in the present embodiment, seven types as described above) of automatic control functions for realizing the fully automatic driving. Furthermore, for example, the guidance control in a case where the automatic driving level is set to the predetermined level 1 to 6 (partial automatic driving) lower than the level of the fully automatic driving is to provide the route information for the automatic control function necessary for the partial automatic driving among the plurality of types of automatic control functions, and to guide the travel route (e.g., voice guidance) with respect to the driver as necessary.

[0072]

When the automatic driving level is set to any of the levels 1 to 6, that is, when one or more of the seven types of automatic control functions are set to be executed, the control unit 30a provides at least information necessary for the set automatic control function as the guidance control.

[0073]

Map data and various other data necessary for the route guidance function are stored in the memory 30b. The control unit 30a realizes the route guidance function (that is, the guidance control) by executing the program for the route guidance function stored in the memory 30b while referencing the various data.

[0074]

The vehicle-to-vehicle communication unit 32 is a communication module for wirelessly transmitting and receiving various data to and from other vehicles other than the own vehicle. The control unit 30a of the automatic driving control device 30 can acquire information (e.g., a traveling direction, a traveling speed, a position, etc.) of other surrounding vehicles via the vehicle-to-vehicle communication unit 32. Conversely, the information of the own vehicle 1 can be transmitted to another vehicle.

[0075]

The control unit 30a can also know the relative relationship between the own vehicle and the other vehicle amount by acquiring the position and the traveling state of the other vehicle by vehicle-to-vehicle communication. For example, it is also possible to detect a relative distance, a relative speed, and the like between the own vehicle and another vehicle.

[0076]

Further, as information that can be transmitted and received by vehicle-to-vehicle communication, there is information regarding a driving mode. The control unit 30a can also transmit and receive information indicating which one of the advanced automation mode and the basic mode is set as the driving mode and which level is the automatic driving level in the set driving mode.

[0077]

The road-to-vehicle communication unit 33 is a communication module for receiving various types of information wirelessly transmitted from an on-road communication device 81 (see FIG. 4) provided on a road (ground side). Various types of information received by the road-to-vehicle communication unit 33 are input to the automatic driving control device 30.

[0078]

The on-road communication device 81 is connected to a server (not illustrated), receives various types of information from the server, and wirelessly transmits the information to a surrounding predetermined area. Various types of road traffic information such as various types of infrastructure information (e.g., traffic light information, road regulation information, and various types of information related to other traveling roads) and existence information of other vehicles, pedestrians, and the like are aggregated in the server. Based on the aggregated road traffic information, the server transmits, for each of the on-road communication devices 81, individual road information related to the on-road communication device 81. The individual road information is information targeted for vehicles traveling within the communication area of the on-road communication device 81, and includes various types of road traffic information in the communication area, various types of traffic information ahead of the inside of the area (traveling direction side), and the like. Each on-road communication device 81 wirelessly transmits the individual road information transmitted from the server within a predetermined communication area.

[0079]

The control unit 30a of the automatic driving control device 30 can acquire various types of road traffic information regarding the traveling road around the own vehicle and the advancing direction via the road-to-vehicle communication unit 33. The information that can be acquired by the control unit 30a via the road-to-vehicle communication unit 33 includes section information regarding a traveling section requiring caution for driving (hereinafter, also referred to as a “caution required section”), such as an accident-prone area, a school zone, or an area where animals appear and disappear. The control unit 30a can recognize a relative relationship between the caution required section and the vehicle 1, such as whether or not the vehicle 1 is traveling in the caution required section indicated by the section information and how long the vehicle 1 will travel before entering the caution required section, by linking the acquired section information and the route guidance function. As the section information, information regarding other sections or points other than the caution required section may be acquired.

[0080]

Note that a camera 82 is mounted on each of the on-road communication devices 81 illustrated in FIG. 4. Each camera 82 photographs the road side and transmits the photographed data to the server via the network.

[0081]

The server can acquire the road traffic information around the camera from the photographed data transmitted from each camera 82. Specifically, the server can recognize the shape of the road, the lane, and the state of the traffic light from the photographed data. The server can also recognize a traveling state and a number of the traveling vehicle. Furthermore, the server can also determine, based on the photographed data, whether or not the vehicle in the photographed data is traveling normally. For example, when the vehicle passes without stopping even though the traffic light is red, it can be determined that the vehicle is not traveling normally.

[0082]

In addition, various types of information regarding the state of the vehicle 1 can be transmitted from the vehicle 1 via the road-to-vehicle communication unit 33. The transmission information transmitted from the vehicle 1 is received by the on-road communication device 81 and aggregated in a server. The server can individually recognize and manage states of a plurality of vehicles including the vehicle 1, and can notify a specific vehicle of states of other vehicles other than the vehicle as necessary. Therefore, for example, it is also possible to know information such as what level the automatic driving level is set in other vehicles around the own vehicle, that is, how much the automatic control function is activated in other vehicles around the own vehicle.

[0083]

The pedestrian-to-vehicle communication unit 34 is a communication module for performing wireless communication with a communication terminal (e.g., a mobile phone or a smartphone) possessed by a pedestrian on the ground side. When a communication terminal possessed by a pedestrian is configured to be capable of wirelessly transmitting terminal position information indicating the position of the communication terminal (i.e., the position of the pedestrian), the pedestrian-to-vehicle communication unit 34 can receive terminal position information transmitted from the communication terminal. The terminal position information received by the pedestrian-to-vehicle communication unit 34 is input to the automatic driving control device 30. The automatic driving control device 30 can also notify the pedestrian of the position information and the like of the vehicle 1 by wirelessly transmitting various types of information such as the position information of the vehicle 1 from the pedestrian-to-vehicle communication unit 34 to the communication terminal of the pedestrian.

[0084]

The control unit 30a of the automatic driving control device 30 can know the position and movement of the pedestrian based on the terminal position information received via the pedestrian-to-vehicle communication unit 34. The presence or absence and the movement of the pedestrian can also be detected by each of the cameras and the radar devices described above, and in addition, the presence or absence of the pedestrian, the jumping out of the pedestrian, and the like can also be detected from information obtained via the pedestrian-to-vehicle communication unit 34.

[0085]

The LTE communication unit 35 is a communication module for realizing wireless communication by the LTE which is a well-known mobile phone communication standard. The control unit 30a can acquire various types of information necessary for automatic driving of the vehicle 1 or update existing information (e.g., update map data) via the LTE communication unit 35 (i.e., by LTE wirelessly communication). Note that it is not essential to perform such acquisition and updating of various types of information by the LTE wireless communication, and may be performed by using other wireless communication.

[0086]

In addition, as illustrated in FIG. 2, the vehicle 1 includes an operation unit 36, a display unit 37, a speaker 38, an automatic driving switch 41, a level setting operation unit 42, an emergency stop lever 43, and a cancellation reset switch 44 as components connected to the automatic driving control device 30.

[0087]

The operation unit 36 is an input interface for accepting various input operations on the vehicle 1 by an occupant of the vehicle 1 including a driver. The display unit 37 is an output interface for visually providing various types of information to the occupant of the vehicle 1 including the driver. Various types of information including map information in the route guidance function are also displayed on the display unit 37. The speaker 38 outputs sound based on various sound signals output from the automatic driving control device 30.

[0088]

The automatic driving switch 41 is a switch for setting the driving mode of the vehicle 1 to the advanced automation mode. The driver of the vehicle 1 needs to switch the automatic driving switch 41 to the on side in order to set the driving mode to the advanced automation mode and execute the automatic driving. On the other hand, when the automatic driving switch 41 is switched to the off side, the driving mode is set to the basic mode.

[0089]

The emergency stop lever 43 is an operation means for forcibly canceling the automatic driving (that is, forcibly switching the automatic driving level to level 0) when the automatic driving level of the vehicle 1 is level 1 or higher, and is provided at a predetermined portion (e.g., on the top) in the vehicle interior. When the emergency stop lever 43 is operated while the automatic driving level of vehicle 1 is set to level 1 or higher, the automatic driving is forcibly canceled. When the driver recognizes that an unauthorized factor such as a computer virus or an unauthorized operation has occurred, or when the driver recognizes that the automatic control function is not normally operating, the driver operates the emergency stop lever 43 to forcibly cancel the automatic driving and cause the vehicle 1 to travel by the driver's own driving operation.

[0090]

The level setting operation unit 42 is a user interface for accepting an operation of setting an automatic driving level (details will be described later) by the driver.

The cancellation reset switch 44 is a switch for resetting the cancellation state after the automatic driving is forcibly canceled and the automatic driving level is forcibly set to level 0. In the present embodiment, as will be described later, in a case where the automatic driving level is set to level 1 or higher, the automatic driving is forcibly canceled when a predetermined cancellation required event for canceling the automatic driving occurs. Specifically, an automatic driving cancellation flag, described later, is set.

[0091]

When the automatic driving is forcibly canceled, the cancellation state is maintained in principle (the set state of the automatic driving cancellation flag is maintained), but the cancellation state can be reset (the automatic driving cancellation flag can be reset) by pressing the cancellation reset switch 44. When the cancellation state is reset, the driving mode is set to a mode corresponding to the operation state of the automatic driving switch, and the automatic driving level is set to a level corresponding to the set driving mode (a level set by the level setting operation unit 42).

[0092]

As illustrated in FIG. 2, the vehicle 1 includes a travel driving control unit 46, a brake control unit 47, and a steering control unit 48 as components connected to the automatic driving control device 30.

[0093]

The travel driving control unit 46 controls the traveling of the vehicle 1 by controlling an engine and a transmission device (not illustrated) based on various information such as a depression amount of an accelerator pedal (not illustrated), an operation position of a shift lever (not illustrated), a vehicle speed, and an engine speed.

[0094]

On the other hand, when the automatic driving level is set to level 1 or higher, that is, when any one of the seven types of automatic control functions is executed, the automatic driving control device 30 outputs control information necessary for realizing the automatic control function to be executed to the travel driving control unit 46. In this case, even when the accelerator pedal is not depressed, the travel driving control unit 46 automatically controls the engine and the transmission device according to the control information from the automatic driving control device 30. Although the vehicle 1 of the present embodiment includes the engine as the driving source for traveling, the automatic driving control device of the present disclosure can also be applied to a vehicle including a driving source for traveling other than the engine (e.g., electric motor). In this case, the travel driving control unit 46 illustrated in FIG. 2 has a function of controlling the driving source for traveling of the vehicle. In addition, when a driving source for traveling other than the engine is provided, the engine room temperature sensor 22 and the engine room sound sensor 23 described above may be installed for the purpose of detecting the temperature and sound of the driving source for traveling or the periphery thereof.

[0095]

The brake control unit 47 controls a brake device (not illustrated) based on a depression amount of a brake pedal (not illustrated). On the other hand, when the automatic driving level is set to level 1 or higher, that is, when any one of the seven types of automatic control functions is executed, the automatic driving control device 30 outputs control information necessary for realizing the automatic control function to be executed to the travel driving control unit 46. In this case, even if the brake pedal is not depressed, the brake control unit 47 automatically controls the brake device according to the control information from the automatic driving control device 30.

[0096]

The steering control unit 48 mainly has two functions. One is a so-called electric power steering function. That is, the operation of the steering wheel 10 by the driver is assisted by the motor. The other is an automatic steering function that automatically steers a turning wheel (e.g., a front wheel) of the vehicle 1 without requiring a driver's operation. Basically, the steering of the turning wheels is performed by the driver operating the steering wheel 10, but when at least any of the seven types of automatic control functions other than the automatic start/stop control and the inter-vehicle distance control is executed, the steering control unit 48 automatically controls the steering of the turning wheels by controlling the motor according to the control information from the automatic driving control device 30 even if the driver is not operating the steering wheel 10.

[0097]

(3) Description of automatic driving function

In the vehicle 1 of the present embodiment, the automatic driving control device 30 can acquire and detect various types of information necessary for realizing the automatic driving function described above.

[0098]

As information that can be used to realize the automatic driving function, first, there is information (own vehicle information) such as the position and speed of the own vehicle. The own vehicle position can be acquired by calculation based on the GPS information. The own vehicle speed can be acquired by calculation based on a vehicle speed signal from a vehicle speed sensor (not illustrated), a detection signal from the steering amount sensor 20, a yaw rate signal from a yaw rate sensor (not illustrated), and the like. The own vehicle speed can also be calculated from a change rate of the own vehicle position.

[0099]

Furthermore, the information that can be used to realize the automatic driving function includes information regarding surrounding objects. Specifically, the information is information related to a relative position, distance, and speed with respect to the own vehicle of various objects (including people and animals) present around the own vehicle, such as a front vehicle, a rear vehicle, a side vehicle, an oncoming vehicle, a vehicle crossing an intersection of an approaching destination, a pedestrian, a bicycle, a building or a fixed installation on a road, and an obstacle.

[0100]

The information on these surrounding objects can be acquired based on the photographed data of each camera 2 to 5, detection results by each radar device 11 to 14, and the like. Various techniques for recognizing surrounding objects based on the photographed data and the detection result of a radar device have been proposed and put into practical use, and thus description thereof will be omitted here.

[0101]

The information on the surrounding object can also be acquired by vehicle-to-vehicle communication, road-to-vehicle communication, and pedestrian-to-vehicle communication. For example, by performing vehicle-to-vehicle communication with the surrounding vehicle, it is possible to recognize not only the position and movement of the surrounding vehicle visible from the own vehicle but also the position and movement of the surrounding vehicle existing in a place that is in a blind spot from the own vehicle and is not directly visible. In the road-to-vehicle communication, as described above, existence information of surrounding vehicles, pedestrians, and the like can be acquired. In the pedestrian-to-vehicle communication, as described above, the position and movement of the pedestrian can be known based on the terminal position information received via the pedestrian-to-vehicle communication unit 34.

[0102]

By any one or a plurality of the vehicle-to-vehicle communication, the road-to-vehicle communication, and the pedestrian-to-vehicle communication, for example, it is possible to acquire oncoming vehicle information at the time of normal traveling (particularly a curve) or right turn in order to prevent a frontal collision with an oncoming vehicle, to acquire two-wheeled vehicle information on the left side or the rear side in order to prevent two-wheeled vehicle winding at the time of left turn, to acquire information of a vehicle on the side (rear side) at the time of lane change, to acquire front vehicle information in order to prevent a rear-end collision or suppress rear-end collision, to acquire information of another vehicle traveling on the crossway side in order to prevent a head-to-head collision at an intersection, and to acquire information of a pedestrian or the like in order to prevent a collision with a pedestrian or the like.

[0103]

In addition, as information that can be used to realize the automatic driving function, there are also information regarding various road displays directly drawn on the road, such as a lane division line (including a parking division line), a pedestrian crossing, and a temporary stop line. Examples of the information regarding the road display include the position and content of the road display. The information regarding the road display can be acquired based on the photographed data of each camera 2 to 6. Various techniques for recognizing the road display from the photographed data have been proposed and put into practical use, and thus description thereof will be omitted here.

[0104]

The information on the road display in the advancing direction can also be acquired by the road-to-vehicle communication. Although the vehicle 1 of the present embodiment is not provided, it is also possible to acquire information regarding various road displays using a laser radar.

[0105]

In addition, examples of the information that can be used for

In addition, as information that can be used to realize the automatic driving function, there are information on a traffic light, a railroad crossing, a sign (including a signboard), an intersection, a merging/separating point, a sidewalk, an obstacle, a dangerous site, other ground structures, and the like (hereinafter collectively referred to as “infrastructure-related information”). The infrastructure-related information includes, in addition to the presence or absence and the position of the various objects described above, information on the color in the case of a traffic light, the operation state in the case of a railroad crossing, the display content in the case of a sign, a signboard, or the like. The infrastructure-related information can also be recognized and acquired based on the photographed data of each camera 2 to 6, and can also be acquired by the road-to-vehicle communication. Furthermore, various types of infrastructure information can also be acquired from the above-described route guidance function based on the GPS information, map data, and the like.

[0106]

Furthermore, as information that can be used to realize the automatic driving function, there is regulation information. For example, when traveling regulation due to construction, an accident, a natural disaster, or the like is implemented in the advancing direction, the regulation information can be acquired by the road-to-vehicle communication.

[0107]

Among the various types of information necessary for realizing the automatic driving function (in the present embodiment, realizing the seven types of automatic control functions described above), such as the information regarding the surrounding objects, the information regarding the road display, the infrastructure-related information, and the regulation information described above, in particular, the information regarding the surroundings of the vehicle 1 corresponds to an example of the surrounding information of the present disclosure.

[0108]

The automatic driving control device 30 acquires the various types of information described above, and controls the travel driving control unit 46, the brake control unit 47, the steering control unit 48, and other necessary in-vehicle devices and the like based on the information, thereby realizing automatic driving. Specifically, the above-described seven types of automatic control functions can be executed. As described above, the seven types of automatic control functions in the present embodiment are automatic start/stop control, lane keeping control, inter-vehicle distance control, lane change control, right/left turn control, collision prevention control, and parking control.

[0109]

The automatic start/stop control is a control to automatically stop the vehicle 1 when a condition to stop is satisfied during traveling, and to automatically start the vehicle 1 when the condition to stop is canceled after the stop. This control is performed using information regarding the surrounding objects obtained from each camera 2 to 5 and each radar sensor 11 to 14, infrastructure-related information and regulation information obtained by the road-to-vehicle communication, and the like, in addition to the own vehicle information. According to this automatic start/stop control, for example, control is performed to cause the vehicle to travel as it is when the color of the traffic light is blue at an intersection or the like, and to stop when the color is red or yellow; to stop when the crossing is recognized ahead and it is recognized that the crossing is descending; to temporary stop and then again started when the crossing is not descending. In addition, when an obstacle or the like is recognized in front of the vehicle, the vehicle is automatically stopped.

[0110]

The lane keeping control is a control configured to automatically steer the turning wheels so that the own vehicle travels along the lane without deviating from the lane mark. This control is performed in cooperation with the route guidance function using information regarding the road displays (particularly, vehicle dividing lines) obtained from each camera 2 to 5 and each radar sensor 11 to 14 in addition to the own vehicle information.

[0111]

The inter-vehicle distance control is a control that performs a speed control so as to keep an inter-vehicle distance from another vehicle at a constant distance when another vehicle is traveling in front of the own vehicle, and causes the vehicle to travel at a set vehicle speed when no other vehicle is present in front of the own vehicle. This control is mainly performed using, in addition to the own vehicle information, information on surrounding objects (particularly, front vehicle) obtained from each camera 2 to 5 and each radar sensor 11 to 14.

[0112]

The lane change control is a control in which, when a lane change (steering for lane change) is required, another vehicle in the adjacent lane to be changed is detected, and the lane change is automatically performed while the driving force, the braking force, and the steering are controlled so as not to collide with another vehicle according to the presence or absence, the position, the speed, and the like of the other vehicle. This control is performed using, in addition to the own vehicle information, information regarding surrounding objects (particularly, other vehicles in the adjacent lane) and information regarding vehicle dividing lines obtained from each camera 2 to 5 and each radar sensor 11 to 14, information regarding other vehicles (traveling vehicles in the adjacent lane) obtained by the vehicle-to-vehicle communication, and the like.

[0113]

The right/left turn control is a control to automatically make a right turn or a left turn without colliding with an oncoming vehicle, a vehicle traveling on a crossway, a vehicle around the own vehicle, a pedestrian, or the like when a right turn or a left turn is required. This control is performed using information regarding surrounding objects obtained from each camera 2 to 5 and each radar sensor 11 to 14, information regarding other vehicles obtained by vehicle-to-vehicle communication, information regarding pedestrians and the like obtained by pedestrian-to-vehicle communication, and the like, in addition to the own vehicle information.

[0114]

The collision prevention control is a control for automatically steering, braking, stopping, or the like the vehicle so as not to collide with an obstacle when the obstacle exists on a road in the vehicle advancing direction. Information on surrounding objects obtained from each camera 2 to 5 and each radar sensor 11 to 14, infrastructure-related information and regulation information obtained by road-to-vehicle communication, and the like are used.

[0115]

The parking control is a control in which, when a specific target parking position (e.g., in a parking section of a specific parking lot) is set as a destination, calculates a traveling track to the target parking position, and controls the driving force, braking force, and steering of the vehicle along the traveling track to automatically park the vehicle.

[0116]

A driver or the like can arbitrarily set which one of the seven types of control functions to execute, that is, the automatic driving level. Specifically, as illustrated in FIG. 3A, the automatic driving level can be arbitrarily set in both the advanced automation mode and the basic mode. However, for the basic mode, level 7 cannot be set, and any one of level 0 to level 6 can be set. On the other hand, for the advanced automation mode, level 0 cannot be set, and any one of levels 1 to 7 can be set. Furthermore, the level of the basic mode can be set within a range of levels lower than the level of the advanced automation mode. Conversely, the level of the advanced automation mode can be set within a range of levels higher than the level of the basic mode.

[0117]

In the present embodiment, as illustrated in FIG. 3A, control A (e.g., lane keeping control) is executed at level 1. At level 2, control B (e.g., inter-vehicle distance control) is executed in addition to control A. At level 3, control C (e.g., automatic start/stop control) is executed in addition to controls A and B. At level 4, control D (e.g., collision prevention control) is executed in addition to controls A, B, and C. At the level, control E (e.g., lane change control) is executed in addition to controls A, B, C, and D. At level 6, control F (e.g., right/left turn control) is executed in addition to controls A, B, C, D, and E. At level 7, control G (e.g., parking control) is executed in addition to controls A, B, C, D, E, and F. That is, as the level becomes higher, the number of types of automatic control functions to be executed increases, and fully automatic driving is performed at level 7.

[0118]

The level setting for each driving mode can be performed by individually operating a level setting operation unit 42 provided in the vicinity of the driver's seat for each driving mode. In the present embodiment, the automatic driving level of the basic mode is set to level 0 by default, and the automatic driving level of the advanced automation mode is set to level 1 by default. Then, the currently set automatic driving level can be arbitrarily set and changed for each driving mode. For example, when the basic mode is set to level 0, the advanced automation mode can be arbitrarily set and changed between levels 1 to 7. Furthermore, for example, in a case where the basic mode is set to level 1, the advanced automation mode can be arbitrarily set and changed between levels 2 to 7. For example, when the advanced automation mode is set to level 4, the basic mode can be arbitrarily set and changed between level 0 and level 3.

[0119]

Which automatic control function is to be executed at which level is not limited to the content illustrated in FIG. 3A. For example, it is not essential that the automatic control function to be executed is increased by one every time the level is raised by one. Which automatic control function is to be executed at which level may be appropriately determined.

[0120]

In addition, as illustrated in FIG. 3B, the driver or the like may arbitrarily set the contents of control A to control G on the assumption that the automatic control function executed each time the level is raised by one increases by one, as illustrated in FIG. 3A.

[0121]

In the vehicle 1 of the present embodiment, when the automatic driving switch 41 is turned off, the driving mode is set to the basic mode. On the other hand, when the automatic driving switch 41 is turned on, the driving mode becomes the advanced automation mode under a certain condition. When the lane change control, the right/left turn control, and the parking control are set to be executed, the destination (the target parking position in the case of the parking control) needs to be set. Specifically, a route guidance function may be activated, and a destination may be input via a touch panel. The automatic driving when the destination is set is basically performed along the calculated route to the destination while confirming the position of the own vehicle in cooperation with the route guidance function.

[0122]

Various control examples in the advanced automation mode when the automatic driving level of the advanced automation mode is set to level 7 will be described with reference to FIG. 4. Each of the vehicles 61 to 67 illustrated in FIG. 4 has the same configuration as the vehicle 1 illustrated in FIGS. 1 and 2. The vehicle traveling within the communication area of the on-road communication device 81 can receive the individual road information from the on-road communication device 81. At least four vehicles 61, 65, 66, and 67 among the vehicles in FIG. 4 can receive individual road information from at least two on-road communication devices 81a and 81b in the vicinity thereof. Specifically, information on the traffic light 71 ahead, information on the oncoming vehicle 62, information on the pedestrian 76, and the like can be acquired.

[0123]

In addition, at least the vehicle 63 can receive individual road information from at least the on-road communication device 81c in the vicinity thereof. Specifically, information such as that there is a temporary stop sign 73 (that is, a temporary stop should be made), that another vehicle 64 is approaching from the right side, and the like can be acquired.

[0124]

In addition, at least the vehicle 64 can receive individual road information from at least the on-road communication device 81d in the vicinity thereof. Specifically, information such as that another vehicle 63 is approaching from the left side can be acquired.

[0125]

Furthermore, at least the vehicle 62 can receive individual road information from at least the on-road communication device 81e in the vicinity thereof. Specifically, information such as information of a traffic light 72 ahead, the existence of an oncoming vehicle 61 that is about to turn right, the presence of a pedestrian crossing in the left turning direction, and the presence of a pedestrian 76 at the pedestrian crossing can be acquired.

[0126]

In addition, each vehicle 61 to 66 can also obtain various types of information from each camera 2 to 6 and each radar device 11 to 14 provided therein, and can also obtain various types of information by vehicle-to-vehicle communication and pedestrian-to-vehicle communication. For example, the vehicle 65 can detect the vehicle 67 in front and the vehicle 66 on the right side by the camera or the radar device, and thus, can travel while appropriately maintaining the inter-vehicle distance with the vehicle 67 in front, or can change the lane at an appropriate timing while considering the positional relationship with the vehicle 66 on the right side when a lane change is necessary. Furthermore, the vehicle 65 can also detect the jumping out of the pedestrian 77 by a camera or a radar device, and in that case, it is possible to perform appropriate deceleration control so as not to collide with the pedestrian 77 while considering the distance to the vehicle 65 behind.

[0127]

As a result, each vehicle 61 to 66 can appropriately automatically travel on the travel route to the destination while using various types of information such as various types of information obtained by the own vehicle and various types of information obtained from the road side. Specifically, by automatically controlling mainly the travel driving control unit 46, the brake control unit 47, and the steering control unit 48, each vehicle 61 to 66 can appropriately automatically travel along the travel route so as not to come into contact with other vehicles, pedestrians, and other road structures and so as to follow traffic lights, traffic rules, and the like.

[0128]

(4) Automatic driving level setting process

Next, automatic driving level setting process executed by the control unit 30a of the automatic driving control device 30 will be described with reference to FIG. 5. The automatic driving level setting process of FIG. 5 is a process of switching the driving mode of the vehicle 1 to either the advanced automation mode or the basic mode, and forcibly setting the automatic driving level to level 0 when making a determination on whether or not to cancel the automatic driving and determining that the automatic driving should be canceled in a case where the automatic driving level is level 1 or higher.

[0129]

When the control unit 30a is started by turning on a power switch (not illustrated) (e.g., an ignition switch) of the vehicle 1, the control unit 30a reads a program of the automatic driving level setting process of FIG. 5 from the memory 30b and repeatedly executes the program at a predetermined control cycle.

[0130]

When the automatic driving level setting process of FIG. 5 is started, in S10, the control unit 30a determines whether or not the automatic driving cancellation flag is set. The automatic driving cancellation flag is a flag that is set when it is determined that the automatic driving should be canceled, and is specifically set in S119 of FIG. 6 to be described later.

[0131]

When the automatic driving cancellation flag is set (S10: YES), the automatic driving level is set to level 0 in S70. That is, regardless of whether or not the driving mode is set to the advanced automation mode or the basic mode, the automatic driving level is forcibly set to level 0, and all the seven types of automatic control functions described above are not executed. Then, in S80, a predetermined error notification is made to notify the occupant of the vehicle 1 that the automatic driving is forcibly canceled, and the automatic driving level setting process is terminated.

[0132]

While the automatic driving cancellation flag is set, all the seven types of automatic control functions do not operate, and thus all the driving operations corresponding to the seven types of automatic control functions (driving operations that can be automatically executed by each automatic control function) need to be performed by the driver himself/herself. As described above, the automatic driving cancellation flag can be reset by pressing the cancellation reset switch 44.

[0133]

When it is determined in S10 that the automatic driving cancellation flag has not been set (S10: NO), whether or not the emergency stop flag has been set is determined in S20. The emergency stop flag is a flag that is set when it is determined that the vehicle 1 should make an emergency stop, and specifically, is a flag set in S120 of FIG. 6 to be described later.

[0134]

When the emergency stop flag is set (S20: YES), the emergency stopping process is performed in S90. The emergency stopping process is a process for stopping the vehicle 1 as soon as possible while maintaining safety. As specific processing contents of the emergency stopping process, contents that can stop the vehicle as soon as possible while maintaining safety may be appropriately determined. For example, processing content of moving the vehicle 1 to a road shoulder while decelerating the vehicle

1 and stopping the vehicle 1 while monitoring the vehicle 1 with each camera, each radar device, or the like so as not to come into contact with an object outside the vehicle (including other vehicles, pedestrians, or the like) is conceivable.

[0135]

When it is determined in S20 that the emergency stop flag is not set (S20: NO), whether or not the automatic driving switch 41 is turned on is determined in S30. When the automatic driving switch 41 is turned on (S30: YES), the driving mode is set to the advanced automation mode in S40, and the process proceeds to S60. When the automatic driving switch 41 is turned off (S30: NO), the driving mode is set to the basic mode in S50, and the process proceeds to S60.

[0136]

When the driving mode is set to the advanced automation mode in S40, the control unit 30a executes the automatic control function based on the automatic driving level set as the advanced automation mode in S55. For example, when level 6 is set as the advanced automation mode, six types of automatic control functions (see FIG. 3A) of controls A to F are executed. For example, when level 7 is set as the advanced automation mode, the fully automatic driving is realized by executing all seven types of automatic control functions of controls A to G. In addition, the execution of the automatic control function in S55 is performed based om the acquired various types of information while acquiring various types of information including the above-described surrounding information as necessary.

[0137]

When the driving mode is set to the basic mode in S50, the control unit 30a executes the automatic control function based on the automatic driving level set as the basic mode in S50. For example, when level 1 is set as the basic mode, the automatic control function of control A (see FIG. 3A) is executed. The execution of the automatic control function in this case is also performed based on the acquired various types of information while acquiring various types of information including the above-described surrounding information as necessary. However, when level 0 is set as the basic mode, all the automatic control functions are not executed.

[0138]

In S60, automatic driving cancellation confirmation process is executed. There are mainly two purposes of this automatic driving cancellation confirmation process. One is to determine whether or not it is necessary to forcibly set the automatic driving level to level 0 when the automatic driving level is set to level 1 or higher, and to set the automatic driving cancellation flag when it is necessary to forcibly set the automatic driving level to level 0. Another purpose is to determine whether or not it is necessary to cause the vehicle 1 to make an emergency stop when the automatic driving level is set to level 1 or higher, and to set the emergency stop flag when it is necessary to make an emergency stop.

[0139]

Details of the automatic driving cancellation confirmation process in S60 are as shown in FIG. 6. As the process proceeds to the automatic driving cancellation confirmation process in S60, as shown in FIG. 6, the control unit 30a determines whether or not the automatic driving level set in the current driving mode is level 1 or higher in S111. When the automatic driving level is not level 1 or higher (that is, it is level 0) (S111: NO), the automatic driving cancellation confirmation process in FIG. 6 is terminated, and accordingly, the automatic driving level setting process of FIG. 5 is terminated.

[0140]

When the automatic driving level set in the current driving mode is 1 or higher (S111: YES), a system monitoring process is executed in S112. The system monitoring process of S112 is a process of monitoring the operation state (including the execution state of the automatic control function) of the vehicle 1 and determining whether or not a predetermined event (cancellation required event) for forcibly switching the automatic driving level to level 0 has occurred. Details of the system monitoring process of S112 will be described later with reference to FIG. 7.

[0141]

In S113, inside-outside behavior monitoring process is executed. The inside-outside behavior monitoring process of S113 is a process of monitoring the behavior of the vehicle occupant in the vehicle interior of the vehicle 1, the behavior of the pedestrian or another vehicle outside the vehicle 1, and the like, and determining whether or not a cancellation required event in which the automatic driving level is to be forcibly switched to level 0 has occurred. Details of the inside-outside behavior monitoring process in S113 will be described later with reference to FIG. 8.

[0142]

In S114, an environment monitoring process is executed. The environment monitoring process of S114 is a process of monitoring the environment around the vehicle 1 and determining whether or not a cancellation required event in which the automatic driving level is to be forcibly switched to level 0 has occurred. Details of the environment monitoring process in S114 will be described later with reference to FIG. 9.

[0143]

In S115, self-diagnosis process is executed. The self-diagnosis process in S115 is a process of performing self-diagnosis by comparing whether or not the execution state of the automatic control function by the control unit 30a itself is normal with a past execution result. Details of the self-diagnosis process in S115 will be described later with reference to FIG. 10B.

[0144]

In S116, whether or not it is determined that the cancellation required event has occurred in any one of the processes as a result of the processes of S112 to S115 is determined. When it is not determined at all that a cancellation required event has occurred (S116: NO), the automatic driving cancellation confirmation process in FIG. 6 is terminated. When it is determined that the cancellation required event has occurred in any one of the processes of S112 to S115 (S116: YES), an automatic driving cancellation advance notice notification is made to the occupant of the vehicle 1 in S117. This notification is a notification for notifying the occupant in advance that automatic driving is to be canceled based on occurrence of a cancellation required event in which the automatic driving is to be canceled. This notification may be performed by various methods capable of causing the occupant of the vehicle 1 to recognize that the cancellation required event has occurred and the automatic driving is to be canceled. As a specific notification method, for example, a method of generating a predetermined message by voice, visually transmitting a message to the occupant using the display unit 37, vibrating the seat, or the like may be adopted.

[0145]

In S118, whether or not the automatic driving can be canceled is determined. In other words, this determination is a process of determining whether or not it is a state in which the driver himself/herself can perform the driving operation in a case where the driving operation that has been automatically performed until then is no longer automatically performed due to the cancellation of the automatic driving. On what to base the determination on whether or not the automatic driving can be canceled may be appropriately determined. For example, the determination may be made on the basis of whether or not a specific cancel permission operation is performed by the driver based on the state or behavior of the driver. The cancel permission operation is an operation indicating that the driver is in a state of being able to perform a driving operation by himself/herself. The cancel permission operation also includes a stationary state in which the driver is stationary in a specific state. As the cancel permission operation, for example, at least one of a plurality of operations and states such as that the driver is gripping the steering wheel 10 with at least one hand, that the driver is gripping the steering wheel 10 with both hands, that the eyes of the driver are open, that the line-of-sight of the driver is directed to the front of the vehicle, and that the behavior of the driver is normal (e.g., a state in which affirmative determination is made in the determination process of S204 described later) may be set. The control unit 30a may determine whether or not the cancel permission operation is performed on the basis of, for example, image data of the indoor camera 6.

[0146]

When determined that the automatic driving can be canceled (S118: YES), an automatic driving cancellation flag is set in S119. Accordingly, when the determination process in S10 of FIG. 5 is executed next, an affirmative determination is made and the process proceeds to S70, and the automatic driving level is forcibly set to level 0.

[0147]

When determined that the automatic driving cannot be canceled in S118 (S118: NO), an emergency stop flag is set in S120. Accordingly, when the determination process in S20 of FIG. 5 is executed next, an affirmative determination is made and the process proceeds to S90, and the emergency stopping process is executed.

[0148]

Next, the system monitoring process of S112 in the automatic driving cancellation confirmation process of FIG. 6 will be specifically described with reference to FIG. 7. As the process proceeds to the system monitoring process in S112, as shown in FIG. 7, whether or not the distance to another vehicle is normal is determined in S161. The distance to another vehicle can be detected based on a detection result of another vehicle around the own vehicle by each camera 2 to 5 or each radar device 11 to 14. In addition, it can also be detected based on position information of another vehicle acquired via the vehicle-to-vehicle communication and the own vehicle position information.

[0149]

The determination on whether or not the distance to the other vehicle is normal may be made, for example, by setting a distance threshold value and determining as normal when the distance to the other vehicle is greater than or equal to the threshold value. In this case, the threshold value may be individually set according to the position (e.g., which one of the front, rear, and side of the own vehicle) of the other vehicle with respect to the own vehicle. Of course, whether or not the distance to another vehicle is normal may be determined by a method other than the above example.

[0150]

When the distance to the other vehicle is not normal (S161: NO), the process proceeds to S169. When the distance to another vehicle is not normal, the possibility of collision with another vehicle increases. As a cause thereof, a possibility that the automatic control function is not normally operating can be considered. Therefore, when the distance to the other vehicle is not normal, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the distance to the other vehicle is not normal is one of the cancellation required events.

[0151]

When the distance to the other vehicle is normal (S161: YES), whether or not the relative speed with the other vehicle is normal is determined in S162. The relative speed with the other vehicle can also be detected based on the detection result of the other vehicle around the own vehicle by each camera 2 to 5 and each radar device 11 to 14, similarly to the distance with the other vehicle.

[0152]

The determination on whether or not the relative speed with the other vehicle is normal may be made, for example, by setting a threshold value of the relative speed and determining as normal when the relative speed with the other vehicle is less than or equal to the threshold value. In this case, the threshold value may be individually set according to the position (e.g., which one of the front, rear, and side of the own vehicle) of the other vehicle with respect to the own vehicle. Of course, whether or not the relative speed with the other vehicle is normal may be determined by a method other than the above example.

[0153]

When the relative speed with the other vehicle is not normal (S162: NO), the process proceeds to S169. When the relative speed with the other vehicle is not normal, there is a possibility of collision with the other vehicle. In addition, there is a possibility that the vehicle is not following the flow of surrounding traffic. As a cause thereof, a possibility that the automatic control function is not normally operating can be considered. Therefore, when the relative speed with the other vehicle is not normal, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the relative speed with the other vehicle is not normal is one of the cancellation required events.

[0154]

When the relative speed with the other vehicle is normal (S162: YES), whether or not the behavior of the suspension is normal is determined in S163. The behavior of the suspension can be detected based on the detection result of the suspension sensor 25.

[0155]

The determination on whether or not the behavior of the suspension is normal may be made, for example, by setting a threshold value for the expansion/contraction amount of the suspension and determining as normal when the expansion/contraction amount is less than or equal to the threshold value. Furthermore, for example, a threshold value may be set with respect to the change rate of the expansion/contraction amount, and it may be determined as normal when the change rate of the expansion/contraction is less than or equal to the threshold value. Note that, in a case where a plurality of suspension sensors 25 are provided, how to comprehensively determine on the basis of detection results from the plurality of suspension sensors 25 may be appropriately determined. For example, it may be determined that the behavior of the suspension is abnormal when the expansion/contraction amount exceeds the threshold value in at least one of the plurality of suspension sensors 25.

[0156]

When the behavior of the suspension is not normal (S163: NO), the process proceeds to S169. When the behavior of the suspension is not normal, a possibility that the automatic control function is not normally operating is considered as the cause. That is, when the automatic control function is not normally operating, an unstable behavior such as sudden start, sudden stop, or sudden turn may occur, and the suspension may greatly expand/contract. Therefore, when the behavior of the suspension is not normal, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the behavior of the suspension is not normal is one of the cancellation required events.

[0157]

When the behavior of the suspension is normal (S163: YES), whether or not the engine room is normal is determined in S164. Specifically, whether or not the state in the engine room is a state in which the temperature in the engine room is normal and no abnormal noise has occurred is determined. The temperature in the engine room can be detected based on the detection result of the engine room temperature sensor 22, and the sound generated from the engine room can be detected based on the detection result of the engine room sound sensor 23.

[0158]

The determination on whether or not the engine room is normal may be performed by, for example, setting a temperature threshold value for the temperature in the engine room and setting a volume threshold value for the sound in the engine room, and determining as normal when the temperature in the engine room is lower than or equal to the temperature threshold value and the sound in the engine room is lower than or equal to the volume threshold value. The sound quality of the sound of the engine room may be analyzed, and it may be determined that the engine room is abnormal when sound quality equivalent to the sound quality that may occur at the time of occurrence of abnormality is detected.

[0159]

When the engine room is not normal (S164: NO), the process proceeds to S169. When the engine room is not normal, a possibility that the automatic control function is not normally operating can be considered as the cause. That is, if the automatic control function does not normally operate, the automatic driving control device 30 cannot normally control the travel driving control unit 46, and thus the travel driving control unit 46 cannot normally control the engine, the transmission device, and the like. Therefore, when the engine room is not normal, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the engine room is not normal is one of the cancellation required events.

[0160]

When the engine room is normal (S164: YES), whether or not an abnormal current is generated is determined in S165. The abnormal current here means the overcurrent described above (e.g., an excessively large current that can be generated at the time of a lightning strike). Whether or not an abnormal current is generated can be determined based on a detection result of the current sensor 19. For example, a threshold value may be set for a current to be detected, and it may be determined that an abnormal current has occurred when the detected current is greater than or equal to the threshold value.

[0161]

When the abnormal current is generated (S165: YES), the process proceeds to S169. When the abnormal current is generated, the automatic control function may not normally operate due to the abnormal current. Therefore, when an abnormal current occurs, it is determined that a cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the occurrence of an abnormal current due to various factors such as a lightning strike is one of the cancellation required events.

[0162]

When the abnormal current is not generated (S165: NO), whether or not the puncture of a tire has occurred is determined in S166. Whether or not the puncture of a tire has occurred can be detected based on the detection result of the tire pressure sensor 24.

[0163]

Whether or not the puncture of the tire has occurred can be determined by, for example, setting a threshold value for the air pressure, and determining that the puncture has occurred when the air pressure is less than or equal to the threshold value in any one of the four tires.

[0164]

When the puncture has occurred (S166: YES), the process proceeds to S169. When the puncture has occurred, there is a possibility that the control of the vehicle 1 by the automatic control function cannot be normally performed due to the puncture. Therefore, when the puncture has occurred, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the occurrence of puncture of the tire is one of the cancellation required events.

[0165]

In a case where no puncture of the tire has occurred (S166: NO), whether or not slip has occurred is determined in S167. Whether or not slip has occurred can be detected based on the detection result of the wheel speed sensor 18 of each wheel. For example, the detection results of the wheel speed sensors 18 may be compared, and it may be determined that the slip has occurred when the difference between the largest wheel speed and the smallest wheel speed is greater than or equal to a predetermined threshold value.

[0166]

When the slip has occurred (S167: YES), the process proceeds to S169. When the slip has occurred, there is a possibility that the control of the vehicle 1 by the automatic control function cannot be normally performed due to the slip. Therefore, when the slip has occurred, it is determined that the cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the occurrence of the slip is one of the cancellation required events.

[0167]

When no slip has occurred (S167: NO), whether or not the steering state is normal is determined in S168. The steering state can be detected based on the detection result of the steering amount sensor 20. Whether or not the steering state is normal may be performed by, for example, setting a threshold value for the steering amount having a neutral position as a reference, and determining as normal when the steering amount from the neutral position is less than or equal to the threshold value. Furthermore, for example, a threshold value may be set for the change rate of the steering amount, and it may be determined as normal when the change rate of the steering amount is less than or equal to the threshold value.

[0168]

When the steering state is not normal (S163: NO), the process proceeds to S169. When the steering state is not normal, a possibility that the automatic control function is not normally operating is considered as the cause. Therefore, when the steering state is not normal, it is determined that a cancellation required event has occurred in S169 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the steering state is not normal is one of the cancellation required events.

[0169]

When the steering state is normal (S168: YES), the system monitoring process of FIG. 7 (that is, the process of S112 of FIG. 6) is terminated.

Next, the inside-outside behavior monitoring process in S113 in the automatic driving cancellation confirmation process in FIG. 6 will be specifically described with reference to the drawings. As the process proceeds to the inside-outside behavior monitoring process in S113, as illustrated in FIG. 8, whether or not the contact of the occupant of the vehicle 1 with the in-vehicle specific contact part has been detected is determined in S201. Presence or absence of contact with the in-vehicle specific contact part can be determined on the basis of a detection result of the in-vehicle contact sensor 21.

[0170]

When contact with the in-vehicle specific contact part is detected (S201: YES), the process proceeds to S210. In the instruction manual of the vehicle 1 of the present embodiment, it is described that the automatic driving can be forcibly canceled by touching the in-vehicle specific contact part or operating the emergency stop lever 43 when the driver feels abnormal or anxious about the operation state of the automatic control function. Therefore, when the contact with the in-vehicle specific contact part is detected, it can be determined that the occupant of the vehicle 1 has made an intention to forcibly cancel the automatic driving.

[0171]

Therefore, when the contact with the in-vehicle specific contact part is detected, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the contact with the in-vehicle specific contact part is detected is one of the cancellation required events.

[0172]

When the contact with the in-vehicle specific contact part is not detected (S201: NO), whether or not the emergency stop lever 43 is operated is determined in S202. When the emergency stop lever 43 is operated (S202: YES), the process proceeds to S210. When emergency stop lever 43 is operated, it can be determined that the occupant of vehicle 1 has expressed an intention to forcibly cancel the automatic driving.

[0173]

Therefore, when the emergency stop lever 43 is operated, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the operation of the emergency stop lever 43 is one of the cancellation required events.

[0174]

When the emergency stop lever 43 is not operated (S202: NO), whether or not an external impact is detected is determined in S203. As described above, the external impact includes a large impact such as collision with another vehicle and a small impact such as hitting of the vehicle 1 by an external person such as a pedestrian.

[0175]

Presence/absence of an external impact can be determined based on a detection result of the impact sensor 27. When an external impact is detected (S203: YES), the process proceeds to S210. When an external impact is detected, there is a possibility that the vehicle 1 may be damaged and cannot travel normally. In addition, when the automatic control function of the vehicle 1 does not normally operate and the vehicle 1 causes an abnormal behavior, or when a person outside the vehicle notices that an abnormality has occurred in the driver of the vehicle 1, the person outside the vehicle may hit the vehicle 1 to alert the occupant of the vehicle 1.

[0176]

Therefore, when an external impact is detected, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the detection of an external impact is one of the cancellation required events.

[0177]

When no external impact is detected (S203: NO), whether or not the behavior of the driver is normal is determined in S204. The behavior of the driver can be recognized by analyzing the photographed data of the indoor camera 6. Then, for example, in a case where the driver is continuously looking aside for a certain period of time or more, the driver's eyes are closed for a certain period of time or more, or the driver has an expression of surprise, anxiety, or fear, it can be determined that the behavior of the driver is abnormal. Of course, whether or not the behavior of the driver is normal may be determined on the basis of other determination criteria.

[0178]

When it is determined that the behavior of the driver is not normal (S204: YES), the process proceeds to S210. The determination that the behavior of the driver is not normal is considered to be a possibility that an abnormality has occurred in the driver, a possibility that the automatic control function of the vehicle 1 is not operating normally, or the like.

[0179]

Therefore, when it is determined that the behavior of the driver is not normal, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself or cause the vehicle 1 to make an emergency stop. That is, the determination that the behavior of the driver is not normal is one of the cancellation required events.

[0180]

When it is determined that the behavior of the driver is normal (S204: NO), whether or not the line-of-sight of the pedestrian is directed to the own vehicle is determined in S205. Whether or not the line-of-sight is directed from the pedestrian can be determined by analyzing the photographed data of each camera 2 to 5 as described above.

[0181]

When the line-of-sight is directed from the pedestrian (S205: YES), whether or not the line-of-sight of the predetermined number or more of pedestrians is directed to the own vehicle (that is, whether or not the attention degree from the pedestrian is high) is determined in S208. When the number of pedestrians directing his/her line-of-sight toward the own vehicle is less than the predetermined number (that is, when the attention degree is not high) (S208: NO), the process proceeds to S209.

[0182]

In S209, whether or not the behavior of the pedestrian directing his/her line-of-sight toward the own vehicle is normal is determined. The determination criterion on whether or not the behavior of the pedestrian directing his/her line-of-sight toward the own vehicle is normal may be appropriately determined. For example, the behavior of the pedestrian may be determined to be abnormal when the expression of the pedestrian has a specific expression or action such as surprise, anxiety, or fear.

[0183]

When it is determined that the line-of-sight of the predetermined number or more of pedestrians is directed to the own vehicle in S208 (S208: YES) and when it is determined that the behavior of the pedestrian directing his/her line-of-sight toward the own vehicle is not normal in S209 (S209: NO), the process proceeds to S210.

[0184]

When the line-of-sight of a large number of pedestrians is concentrated on the own vehicle, it is conceivable that the automatic control function of the vehicle 1 is not operating normally and the vehicle 1 is behaving abnormally or an abnormality has occurred in the driver of the vehicle 1. In addition, even if the number of pedestrians directing his/her line-of-sight toward the own vehicle is small, if the behavior of the pedestrians is abnormal, it is conceivable that the automatic control function of the vehicle 1 is not operating normally and the vehicle 1 is behaving abnormally or an abnormality has occurred in the driver of the vehicle 1.

[0185]

Therefore, in a case where the line-of-sight of a large number of pedestrians is concentrated, or in a case where the behavior of the pedestrian directing his/her line-of-sight is abnormal, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself, or to cause the vehicle 1 to make an emergency stop. That is, both the fact that the line-of-sight of a large number pedestrians is concentrated and the fact that the behavior of the pedestrian directing his/her line-of-sight is abnormal are one of the cancellation required events.

[0186]

When the line-of-sight of the pedestrian is not directed to the own vehicle (S205: NO) and when, although the line-of-sight of the pedestrian is directed toward the own vehicle, the number thereof is small and the behavior of the pedestrian is also normal (S209: YES), the process proceeds to S206.

[0187]

In S206, whether or not passing has been performed from another vehicle (mainly an oncoming vehicle or a following vehicle) is determined. Whether or not passing has been performed from another vehicle can be determined mainly by analyzing the photographed data of the front camera 2 and the rear camera 3. When passing has been performed from another vehicle (S206: YES), the process proceeds to S210.

[0188]

When passing has been performed from another vehicle, this may mean that the automatic control function of the vehicle 1 is not operating normally and the vehicle 1 is behaving abnormally, and the driver of the other vehicle who has noticed the abnormal behavior is calling attention. Therefore, when passing is performed from another vehicle, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself, or cause the vehicle 1 to make an emergency stop. That is, passing from another vehicle is one of the cancellation required events.

[0189]

When passing has not been performed from another vehicle (S206: NO), whether or not honking has been performed from another vehicle is determined in S207. Whether or not honking has been performed from another vehicle can be determined mainly based on the detection result of the vehicle exterior sound sensor 26. When honking has been performed from another vehicle (S207: YES), the process proceeds to S210.

[0190]

When honking has been performed from another vehicle, this may mean that the automatic control function of the vehicle 1 is not operating normally and the vehicle 1 is behaving abnormally, and the driver of the other vehicle who has noticed the abnormal behavior is calling attention. Therefore, when honking is performed from another vehicle, it is determined that the cancellation required event has occurred in S210 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself, or cause the vehicle 1 to make an emergency stop. That is, honking from another vehicle is one of the cancellation required events.

[0191]

Next, the environment monitoring process of S114 in the automatic driving cancellation confirmation process of FIG. 6 will be specifically described with reference to FIG. 9. When the process proceeds to the environment monitoring process of S114, as shown in FIG. 9, whether or not the weather around the vehicle 1 is in a heavy rain state is determined in S251. The determination as to whether or not it is a heavy rain state can be made based on the detection signal from the rainfall sensor 17, for example, by setting a threshold value for the detection amount and comparing the detection amount with the threshold value. Of course, whether or not it is a heavy rain state may be determined by another method. For example, the determination may be made by analyzing the amount of rainfall from the photographed data of each camera 2 to 5.

[0192]

When determined as the heavy rain state (S251: YES), the process proceeds to S256. When not determined as the heavy rain state (S251: NO), the process proceeds to S252.

In S252, whether or not the weather around the vehicle 1 is in a heavy snow state is determined. The determination as to whether or not it is a heavy snow state may be made, for example, by analyzing a snowfall amount from the photographed data of each camera 2 to 5. Of course, whether or not it is a heavy snow state may be determined by another method.

[0193]

When determined as the heavy snow state (S252: YES), the process proceeds to S256. When not determined as the heavy snow state (S252: NO), the process proceeds to S253.

In S253, whether or not around the vehicle 1 is in a dense fog state is determined. Similarly to the method for determining the heavy snow state, for example, the determination on whether or not in the dense fog state may be made by analyzing the fog generation state from the photographed data of each camera 2 to 5. Of course, whether or not it is a dense fog state may be determined by another method.

[0194]

When determined as the dense fog state (S253: YES), the process proceeds to S256. When not determined as the dense fog state (S253: NO), the process proceeds to S254.

When determined as a heavy rain state, when determined as a heavy snow state, and when determined as a dense fog state (hereinafter collectively referred to as "bad weather"), there is a possibility that the visibility of the front side of the vehicle is poor and the automatic control function does not normally operate. Therefore, in the case of bad weather, it is determined that the cancellation required event has occurred in S256 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the bad weather is one of the cancellation required events.

[0195]

In S254, whether or not the vehicle 1 is traveling in the caution required section is determined. As described above, the caution required section in the present embodiment includes at least an accident-prone area, a school zone, an area where animals easily appear and disappear, and the like. Whether or not the vehicle is traveling in the caution required section can be determined based on section information obtained through road-to-vehicle communication. Alternatively, when the photographed data from the front camera 2 includes a signboard or a road sign indicating the caution required section, the determination can be made based thereon.

[0196]

When determined that the vehicle 1 is traveling in the caution required section (S254: YES), the process proceeds to S256. When the vehicle 1 is traveling in the caution required section, it may be preferable for the driver himself/herself to perform the driving operation while paying attention to the advancing direction rather than relying on the automatic control function. Therefore, when the vehicle 1 is traveling in the caution required section, it is determined that the cancellation required event has occurred in S256 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the vehicle 1 is traveling in the caution required section is one of the cancellation required events.

[0197]

When the vehicle 1 is not traveling in the caution required section (S254: NO), the process proceeds to S255. In S255, whether or not the average value of the automatic driving levels of other surrounding vehicles (hereinafter referred to as "surrounding average level") is lower than or equal to a predetermined level (e.g., lower than or equal to level 1) is determined. When the surrounding average level is higher than the predetermined level (S255: NO), the environment monitoring process is terminated. On the other hand, when the surrounding average level is lower than or equal to the predetermined level (S255: YES), the process proceeds to S256.

[0198]

The surrounding average level can be derived by acquiring the automatic driving levels set in the other vehicles from the other vehicles traveling around the own vehicle and performing an average calculation of the acquired automatic driving levels. The automatic driving level of another vehicle around the own vehicle can be directly acquired by vehicle-to-vehicle communication or indirectly acquired by road-to-vehicle communication.

[0199]

When the surrounding average level is lower than or equal to the predetermined level, it means that many of the other surrounding vehicles are keeping the automatic driving level low. That is, it can be said that there is a high possibility that drivers of many other vehicles are driving by their own driving operation without relying on the automatic control function. It is conceivable that the fact that many surrounding drivers are driving without relying on the automatic control function means that the area where the vehicle is currently traveling is an area where it is preferable to drive by the driver's own driving operation rather than the automatic driving for some reason.

[0200]

Therefore, when the surrounding average level is lower than or equal to the predetermined level, it is determined that the cancellation required event has occurred in S256 to forcibly cancel the automatic driving and leave the driving operation of the vehicle 1 to the driver himself/herself. That is, the fact that the surrounding average level is lower than or equal to the predetermined level is one of the cancellation required events.

[0201]

Next, the self-diagnosis process of S115 in the automatic driving cancellation confirmation process of FIG. 6 will be described, but prior to the description of the self-diagnosis process, the travel history recording process shown in FIG. 10A will be described first.

[0202]

The travel history recording process of FIG. 10A is a process of storing, as a history, various specific control operations performed when the vehicle 1 travels (however, control operations automatically performed by the automatic control function) in association with positions where the specific control operations are performed. The type and number of specific control operations to be stored as the history may be appropriately determined. For example, an operation of temporarily stopping while traveling, an operation of decelerating although there is no other vehicle ahead, and the like may be determined as the specific control operation.

[0203]

If the automatic control function is normally operating, the vehicle 1 should be automatically stopped at a place where there is a temporary stop road sign or a stop line thereof. In addition, in front of the pedestrian crossing, the vehicle should decelerate for safety even if there is no vehicle in front. On the other hand, when the automatic control function is not normally operating, there is a possibility that the vehicle passes by without stopping even though there is a road sign for temporary stop, or the vehicle passes by without decelerating even if there is a pedestrian crossing. That is, when the automatic control function is not normally operating, even if the vehicle travels in the same place as the place where the vehicle has previously traveled, the vehicle may travel differently from the previous time.

[0204]

Therefore, in the present embodiment, the past travel history is stored in association with the position, and when the vehicle performs a travel operation different from the past as compared with the past operation state when the vehicle travels in the same place the next time (e.g., when the vehicle has temporarily stopped in the past but has passed by without stopping this time) , it is determined that the automatic control function is not operating normally and the automatic driving should be canceled.

[0205]

When starting the operation, the control unit 30a executes the travel history recording process of FIG. 10A in parallel with the automatic driving level setting process of FIG. 5. When starting the travel history recording process of FIG. 10A, the control unit 30a determines whether or not the vehicle 1 has traveled a certain distance in S301. The determination in S301 is continued until the vehicle travels a certain distance. When the vehicle has traveled the certain distance (S301: YES), the process proceeds to S302.

[0206]

In S302, the specific control operation performed in the traveling section for the certain distance is stored as specific control information together with the position information where the specific control operation is performed. When the specific control operation at the same position is already stored, the stored content is updated. After the specific control information performed in the traveling section for the certain distance is stored, the process returns to S301. In this way, every time the vehicle travels a certain distance, the specific control information storing process is performed for the traveling section of the certain distance.

[0207]

Next, the self-diagnosis process in S115 of FIG. 6 will be described with reference to FIG. 10B. When the process proceeds to the self-diagnosis process in S115, as illustrated in FIG. 10B, whether or not the current traveling position has been traveled in the past is determined in S351. This determination can be made by comparing the current position based on the GPS information with the position information associated with the specific control information stored in the memory 30b.

[0208]

When the current traveling position is not associated with any of the specific control information stored in the memory 30b, it is considered that the current traveling position has not been traveled in the past (S351: NO), and the self-diagnosis process is terminated. When the current traveling position coincides with or is close to the position information associated with any one of the specific control information stored in the memory 30b, it is determined that the current traveling position has also been traveled in the past (S351: YES), and the process proceeds to S352.

[0209]

In S352, past specific control information corresponding to the current traveling position is read from the memory 30b. That is, what specific control operation has been performed in the past at the place where the vehicle is currently traveling is confirmed. In S353, whether or not the current traveling state is different from the past traveling state is determined. More specifically, whether or not the specific control operation executed in the past at the same place has also been performed this time is determined. When the vehicle is traveling differently from the past, that is, when the specific control operation performed at the same place in the past is not performed this time (S353: YES), the process proceeds to S354, and it is determined that the cancellation required event has occurred. When the vehicle does not travel differently from the past, that is, when the specific control operation performed at the same place in the past is also performed this time (S353: NO), the self-diagnosis process is terminated.

[0210]

(5) Effects of First Embodiment

According to the vehicle 1 of the present embodiment described above, whether or not a cancellation required event for canceling the automatic driving has occurred is determined (S112 to S115 in FIG. 6) when the automatic driving level is level 1 or higher (that is, when the automatic control function is activated). When the cancellation required event has occurred, the automatic driving level is forcibly set to level 0. That is, when the cancellation required event occurs, all the operations of the automatic control function are stopped regardless of the setting state of the driving mode, and the driving operation of the vehicle 1 is entrusted to the driver.

[0211]

Therefore, when the cancellation required event occurs, the vehicle 1 can be caused to travel by the driver's own driving operation. Thus, it is possible to suppress the occurrence of unstable operation of the vehicle 1 due to malfunction or the like of the automatic control function.

[0212]

In addition, in the present embodiment, assuming a large number of events considered as the cancellation required events, the determination is made for each event one by one.

Specifically, as shown in S161 of FIG. 7, the distance to the other vehicle is determined, and when the distance to the other vehicle is not normal, the automatic driving is forcibly canceled. Therefore, even if the vehicle 1 is about to collide with another vehicle due to malfunction of the automatic control function or the like, it is possible to avoid this by the driver's own driving operation.

[0213]

Furthermore, as shown in S162 of FIG. 7, the relative speed with respect to the other vehicle is determined, and when the relative speed with respect to the other vehicle is not normal, the automatic driving is forcibly canceled. Therefore, even if the vehicle 1 is about to collide with another vehicle due to malfunction of the automatic control function or the like, it is possible to avoid this by the driver's own driving operation. In addition, even when the traveling speed of the vehicle 1 is different from the speeds of many surrounding vehicles and does not follow the flow of surrounding traffic due to malfunction of the automatic control function or the like, this can be avoided by the driver's own driving operation.

[0214]

As shown in S163 of FIG. 7, the behavior of the suspension is determined, and when the behavior is not normal, the automatic driving is forcibly canceled. Therefore, even if the vehicle 1 exhibits an abnormal behavior due to malfunction or the like of the automatic control function, this can be avoided by the driver's own driving operation.

[0215]

Furthermore, as shown in S164 of FIG. 7, the state (temperature and sound) of the engine room is determined, and when the state is not normal, the automatic driving is forcibly canceled. Therefore, when an abnormality occurs in the engine room due to malfunction or the like of the automatic control function, the influence can be suppressed to a minimum by the driver's own driving operation.

[0216]

Furthermore, as shown in S165 of FIG. 7, when abnormal current generates in the electric wiring (however, the electric wiring in which the current sensor 19 is provided) in the vehicle 1, the automatic driving is forcibly canceled. Therefore, even if an excessively large current flows due to a lightning strike or the like, it is possible to prevent the automatic control function from malfunction and the traveling state of the vehicle 1 from becoming unstable.

[0217]

Moreover, as shown in S166 and S167 of FIG. 7, when the tire is punctured or slip occurs, the automatic driving is forcibly canceled. Therefore, when the reliability of traveling by the automatic control function lowers due to a puncture or a slip of the tire, the vehicle 1 can be appropriately operated (e.g., the vehicle stops while slowly decelerating or smoothly returns from the slip state) by the driver's own driving operation.

[0218]

As shown in S168 of FIG. 7, when the steering state of the turning wheels is not normal, the automatic driving is forcibly canceled. Therefore, even if the turning wheels of the vehicle 1 exhibit an abnormal behavior due to malfunction or the like of the automatic control function, it is possible to avoid this by the driver's own driving operation.

[0219]

As illustrated in S201 and S202 in FIG. 8, the automatic driving is forcibly canceled both when the contact of the occupant with the in-vehicle specific contact part is detected and when the emergency stop lever is operated by the occupant. Therefore, when a situation in which the driver desires to cancel the automatic driving occurs, for example, when the behavior of the vehicle 1 becomes unstable, the driver can quickly cancel the automatic driving by his/her own will.

[0220]

Furthermore, as shown in S203 of FIG. 8, when an external impact is detected, the automatic driving is forcibly canceled. Therefore, even if there is a risk that the automatic control function does not normally operate due to the external impact, the vehicle 1 can be appropriately operated by the driver's own driving operation.

[0221]

In addition, as illustrated in S204 of FIG. 8, when the behavior of the driver is not normal (e.g., when the driver shows an expression of surprise or fear), the automatic driving is forcibly canceled. Therefore, even if the traveling state of the vehicle 1 becomes unstable to such an extent that the driver shows an expression of surprise or fear due to malfunction or the like of the automatic control function, this can be quickly avoided by the driver's own driving operation.

[0222]

In addition, as shown in S205, S206, and S207 of FIG. 8, in a case where attention is attracted from a pedestrian, a pedestrian looking at the own vehicle shows abnormal behavior (e.g., the pedestrian points at the own vehicle and shows a surprised expression), a horn is honked by another vehicle, or passing is performed by another vehicle, the automatic driving is forcibly canceled. This is because the fact that some action is made on the own vehicle from a pedestrian or another vehicle as described above indicates that there is a possibility that the traveling state of the own vehicle is unstable, and malfunction of the automatic control function or the like is considered as the cause.

[0223]

As shown in S251 to S253 of FIG. 9, the automatic driving is forcibly canceled in the case of bad weather such as heavy rain, heavy snow, and heavy fog. Therefore, even when there is a possibility that the automatic control function does not normally operate due to bad weather and the traveling of the vehicle 1 becomes unstable, the automatic driving is forcibly canceled so that the vehicle 1 can be appropriately traveled by the driver's own driving operation.

[0224]

Furthermore, as shown in S254 of FIG. 9, when the vehicle 1 is traveling in the caution required section, the automatic driving is forcibly canceled. As a result, it is possible to appropriately travel through the caution required section by the driver's own driving operation without relying on the automatic control function.

[0225]

As illustrated in FIG. 10B, when the vehicle again travels a place where the vehicle has traveled in the past and the specific control operation performed in the past is not performed this time, it is assumed that the automatic control function is not normally operating, and the automatic driving is forcibly canceled. Therefore, it is possible to suppress a problem that may occur due to a malfunction of the automatic control function in advance.

[0226]

In the present embodiment, when the cancellation required event occurs, the occupant is notified of cancelling the automatic driving instead of unconditionally canceling the automatic driving (S117 in FIG. 6). When it is confirmed that a state in which the automatic driving can be canceled is obtained such as when there is a predetermined reaction from the occupant (YES in S118 in FIG. 6), the automatic driving is canceled. Therefore, it is possible to smoothly and appropriately cancel the automatic driving and enable the driving operation by the driver.

[0227]

On the other hand, when there is no predetermined reaction from the occupant even if the occupant is notified of canceling the automatic driving (NO in S118), the vehicle 1 is automatically brought to an emergency stop. Therefore, for example, when the driver falls asleep or faints and it becomes difficult for the driver to drive the vehicle 1, it is possible to quickly and appropriately stop the vehicle 1 and suppress the occurrence of an unexpected situation.

[0228]

Note that the control unit 30a corresponds to an example of a surrounding information acquisition unit, a driving mode setting unit, an automatic control unit, a cancellation required event determination unit, a notification unit, and a cancel permission determination unit. Furthermore, the processes of S40 and S50 in FIG. 5 correspond to an example of the process of the driving mode setting unit. Furthermore, the process of S55 in FIG. 5 corresponds to an example of the process of the surrounding information acquisition unit. Furthermore, the process of S55 in FIG. 5 and the processes of S118 to S120 in FIG. 6 correspond to an example of the process of the automatic control unit. Moreover, the processes of S120 in FIG. 6 particularly corresponds to an example of the automatic stopping process among the process of the automatic control unit. In addition, the processes of S112, S113, S114, and S115 in FIG. 6 corresponds to an example of the process of the cancellation required event determination unit. The process of S117 in FIG. 6 corresponds to an example of the process of the notification unit, and the process of S118 in FIG. 6 corresponds to an example of the process of the cancel permission determination unit.

[0229]

[Second Embodiment]

FIG. 11 illustrates an electrical configuration of the vehicle according to a second embodiment. In FIG. 11, the same components as those of the vehicle 1 of the first embodiment are denoted by the same reference numerals as those of the first embodiment, and a detailed description thereof will be omitted.

[0230]

As illustrated in FIG. 11, the vehicle of the second embodiment includes an automatic driving control device 101 and a monitoring device 102. The automatic driving control device 101 basically has the same configuration and operates similarly as the automatic driving control device 101 of the first embodiment except that it has a function of performing data communication with the monitoring device 102 via the network 100. That is, the control unit 101a of the automatic driving control device 101 executes the automatic driving level setting process (see FIG. 5) similarly to the vehicle 1 of the first embodiment according to various programs stored in the memory 101b. In addition, an automatic control function based on a set automatic driving level is also executed.

[0231]

In FIG. 11, each camera 2 to 6, each radar device 11 to 14, and each sensor 16 to 27 in the vehicle 1 of the first embodiment illustrated in FIG. 2 are collectively illustrated as a detection unit group 111. In FIG. 11, the communication units 31 to 35 in the vehicle 1 of the first embodiment illustrated in FIG. 2 are collectively illustrated as a communication unit group 112.

[0232]

The automatic driving control device 101 of the present embodiment further periodically transmits an execution state (result of control calculation) of the automatic control function corresponding to the automatic driving level to the monitoring device 102 via the network 100 as one piece of control information. In addition, when the cancellation required event occurs as a result of the automatic driving level setting process, the automatic driving control device 101 periodically transmits at least the fact (the fact that the cancellation required event has occurred) to the monitoring device 102 via the network 100 as one piece of control information.

[0233]

The monitoring device 102 is provided to monitor whether or not various controls by the automatic driving control device 101 are normally operating. That is, the monitoring device 102 basically has a configuration similar to that of the automatic driving control device 101, and similarly to the automatic driving control device 101, the control unit 102a executes control calculation of the automatic control function based on the set automatic driving level.

[0234]

That is, although the monitoring device 102 does not actually execute the automatic control function, the control calculation of the automatic control function is performed similarly to the automatic driving control device 101. That is, both the automatic driving control device 101 and the monitoring device 102 execute control calculation necessary for realizing the automatic control function corresponding to the set automatic driving level.

[0235]

Therefore, on the premise that the operation of the monitoring device is normal, if the automatic driving control device 101 is normal, the results of the control calculation of both should be the same. On the other hand, when an abnormality occurs in the automatic driving control device 101 and the automatic control function is not normally operated, the control calculation results of both become different (there is a possibility that the calculation result of the automatic driving control device 101 is not normal.

[0236]

Therefore, the monitoring device 102 compares its own control calculation result with the control calculation result by the automatic driving control device 101, and forcibly cancels the automatic control function by the automatic driving control device 101 when the control calculation results do not match. Specifically, the control unit 102a of the monitoring device 102 executes the control state monitoring process illustrated in FIG. 12.

[0237]

When starting the control state monitoring process of FIG. 12, the control unit 102a of the monitoring device 102 executes the arithmetic process of the automatic control function corresponding to the set automatic driving level in S501. In S502, the calculation result of the control calculation of the automatic control function in the automatic driving control device 101 is acquired from the automatic driving control device 101 via the network 100.

[0238]

In step S503, the own calculation result calculated in step S501 is compared with the calculation result in automatic driving control device 101 acquired in step S502, and whether or not both calculation results match is determined. When the calculation results do not match (S503: NO), it is determined that the calculation result by automatic driving control device 101 is not normal, and in S508, a forced canceling process for forcibly canceling the automatic control function by the automatic driving control device 101 is executed.

[0239]

Various specific contents of the forced canceling process of S508 can be considered. For example, by instructing the travel driving control unit 46, the brake control unit 47, and the steering control unit 48 to ignore the control command by the automatic driving control device 101 from the monitoring device 102, these control units 46 to 48 may operate without depending on the automatic driving control device 101 (that is, the automatic driving may be canceled).

[0240]

Furthermore, the automatic driving control device 101 may be caused to forcibly cancel the automatic driving by transmitting for example, determination information indicating that the calculation results do not match to the automatic driving control device 101 via the network 100.

[0241]

In addition, for example, switches may be provided between the automatic driving control device 101 and the travel driving control unit 46, between the automatic driving control device 101 and the brake control unit 47, and between the automatic driving control device 101 and the steering control unit 48 to conduct and cut-off the electrical connection state. Then, at least one of the switches may be turned off (that is, the electrical connection state may be cut off) so that the automatic driving control device 101 cannot perform control.

[0242]

Furthermore, as a cause of the calculation result by automatic driving control device 101 not being normal, it is conceivable that automatic driving control device 101 is illegally accessed from the outside. Therefore, a switch may be provided between the communication unit group 112 and the automatic driving control device 101 to conduct and cut-off the electrical connection state between the communication unit group and the automatic driving control device, and the switch may be turned off (that is, the electrical connection state may be cut off) so that access cannot be physically made from the outside.

[0243]

When the calculation results match with each other in S503 (S503: YES), whether or not a cancellation required event has occurred is determined in S504. Specifically, whether or not the cancellation required event has occurred is determined by performing processes exactly similar to each process of S112 to S115 in the automatic driving cancellation confirmation process of the first embodiment illustrated in FIG. 6.

[0244]

In S505, based on the determination result of S504, when the cancellation required that determines whether or not the cancellation required event has occurred has not occurred (S505: NO), the control state monitoring process is terminated. When the cancellation required event has occurred (S505: YES), the determination result on the presence or absence of the cancellation required event in the automatic driving control device 101 is acquired from the automatic driving control device 101 via the network 100 in S506.

[0245]

In S507, whether or not the occurrence of the cancellation required event is determined is also determined in the automatic driving control device 101 based on the acquisition result of S506. When the occurrence of the cancellation required event is also determined in the automatic driving control device 101, it is determined that the automatic driving control device 101 is normally operating, and the control state monitoring process is terminated. On the other hand, when the occurrence of the cancellation required event is not determined in the automatic driving control device 101, it is determined that the automatic driving control device 101 is not normally operating for some reason, and the process proceeds to S508 and the forced canceling process is executed as described above.

[0246]

According to the vehicle of the second embodiment described above, the following effects can be further obtained in addition to the effects of the first embodiment. That is, in the second embodiment, the monitoring device 102 is provided separately from the automatic driving control device 101. The monitoring device 102 also performs control calculation substantially similar to that of the automatic driving control device 101, compares the calculation result with the calculation result in the automatic driving control device 101, and determines whether or not the automatic driving control device 101 is normally operating according to whether or not the calculation results match with each other.

[0247]

That is, it is determined whether or not the operation of one computer (here, the automatic driving control device 101) is normal by having each of the two independent computers execute the same control calculation and checking whether or not the calculation results of the two computers match.

[0248]

When the two calculation results do not match with each other, the monitoring device 102 executes the forced canceling process (S508 in FIG. 12) to forcibly cancel the automatic driving. Note that the automatic driving control device 101 canceling the automatic driving by itself when the cancellation required event occurs is similar to the first embodiment. In the second embodiment, in addition, a forced canceling process for canceling the automatic driving is also performed from the monitoring device 102. Therefore, when a situation in which the automatic driving should be canceled occurs, the automatic driving can be canceled more reliably.

[0249]

[Other Embodiments]

Although the embodiment of the present disclosure has been described above, the present disclosure is not limited to the above embodiment, and various forms can be adopted.

[0250]

(1) The specific examples of the cancellation required event described in the above embodiments are merely examples. For other events other than the above where it can be considered that the automatic driving should be canceled, the presence or absence of occurrence thereof is determined, and the automatic driving may be canceled when the other events has occurred.

[0251]

For example, in the first embodiment, the example in which the automatic driving is canceled when the driver behaves abnormally has been described, but the automatic driving may be canceled based on the behavior of other occupant other than the driver.

[0252]

Furthermore, it is not limited to the behavior of the occupant (including the driver), and whether or not to cancel the automatic driving may be determined according to the content of the speech of the occupant. For example, when someone says “An ambulance is approaching from behind!”, the automatic driving may be canceled and left to the driver's driving operation. That is, the automatic driving may be canceled in response to a specific phrase or sentence.

[0253]

In addition, the traveling state of the vehicle may be monitored on the infrastructure side, and when the traveling state is unstable (that is, when there is a possibility that the automatic control function is not normally operating), this fact may be notified to the vehicle via the road-to-vehicle communication or the like. When the notification is received from the infrastructure side, the vehicle side may forcibly cancel the automatic driving.

[0254]

(2) In the above embodiment, the automatic driving level is forcibly set to level 0 if any cancellation required event occurs when the automatic driving level is level 1 or higher, but the automatic driving level may be set to 0 if the cancellation required event occurs when the automatic driving level is a predetermined level n or higher, which is higher than level 1 (that is, ignored when lower than level n). Alternatively, the automatic driving level may be forcibly set to level 0 if a cancellation required event occurs when the driving mode is the advanced automation mode, and the setting of the basic mode may be

maintained even if a cancellation required event occurs when the driving mode is the basic mode.

[0255]

In addition, it is not essential to set the automatic driving level to level 0 when the cancellation required event occurs, and the automatic driving level may be lowered to at least a level lower than the current automatic driving level. For example, when a cancellation required event occurs in the advanced automation mode, the mode may be switched to the basic mode.

[0256]

(3) A camera or a radar device necessary for realizing automatic driving may be provided anywhere in the vehicle 1, and any number of cameras or radar devices may be provided. The installing location and the number of cameras and radar devices may be appropriately determined so that a desired automatic control function can be realized. Furthermore, the in-vehicle device necessary for realizing the automatic driving is not limited to the various devices illustrated in FIGS. 1 and 2.

[0257]

(4) In addition, the functions of one component in the above embodiments may be distributed as a plurality of components, or the functions of a plurality of components may be integrated into one component. Moreover, at least a

part of the configuration of the above embodiment may be replaced with a known configuration having a similar function. Furthermore, a part of the configuration of the above embodiment may be omitted. Moreover, at least a part of the configuration of the above embodiment may be added to or replaced with the configuration of another above embodiment. Note that all aspects included in the technical idea specified only by the wording described in the Claims are embodiments of the present disclosure.

[0258]

[Technical idea grasped from embodiments]

At least the following technical ideas can be grasped from the various embodiments described in detail above.

(A) An automatic driving control device mounted on a vehicle, the automatic driving control device including:

a surrounding information acquisition unit configured to acquire surrounding information, which is information of the surrounding of the vehicle;

a driving mode setting unit configured to set a driving mode of the vehicle to either one of an advanced automation mode in which at least a part of a plurality of types of driving operations necessary for traveling of the vehicle is automatically executed based on the surrounding information and a basic mode in which a type of an automatic driving operation which is the driving operation to be automatically executed is less than the advanced automation mode or is zero;

an automatic control unit configured to execute, based on the driving mode set by the driving mode setting unit, the automatic driving operation set in the driving mode; and

a cancellation required event determination unit configured to, when the driving mode is set to a driving mode having at least one of the automatic driving operations to be executed, determine whether or not a predetermined cancellation required event in which at least one of the automatic driving operations set in the driving mode has occurred; where

when the driving mode is set to a driving mode having at least one of the automatic driving operations to be executed, the automatic control unit stops the execution for at least one of the set automatic driving operations when the cancellation required event determination unit determines that the cancellation required event has occurred.

[0259]

In the automatic driving control device having the above configuration, when the driving mode is set to the advanced automation mode, the cancellation required event determining unit determines whether or not the cancellation required event has occurred, but even when the driving mode is set to the basic mode, the cancellation required event determination unit determines whether or not the cancellation required event has occurred if the basic mode is set to execute at least one of the plurality of types of automatic driving operations.

[0260]

That is, regardless of the type of the set driving mode, the cancellation required event determination unit determines whether or not the cancellation required event has occurred when it is set to execute at least one of the plurality of types of automatic driving operations. Then, when it is determined that the cancellation required event has occurred, at least one of the automatic driving operations to be executed is stopped.

[0261]

The cancellation required event is an event that may occur when that the automatic driving operation being executed is not normally executed, or an event that may hinder the execution of the automatic driving operation when such an even occurs although the automatic driving operation is normally executed at the present time.

[0262]

One or more cancellation required events may be set in advance. In a case where a plurality of cancellation required events are set, the cancellation required event determination unit may determine whether or not all of the plurality of cancellation required events have occurred, or may determine whether or not some of the plurality of cancellation required events have occurred. In the latter case, which of the plurality of cancellation required events is to be determined may be appropriately determined. For example, based on the automatic driving operation set to be executed in the current driving mode, at least one of a cancellation required event that occurs when the automatic driving operation is not normally executed and a cancellation required event that may possibly interfere with the automatic driving operation may be included in the determination target.

[0263]

In addition, the timing at which the cancellation required event determination unit determines the presence or absence of the occurrence of the cancellation required event may be appropriately determined in addition to the above. For example, in accordance with the number and types of automatic driving operations set to be executed in the current driving mode, it may be determined whether or not the cancellation required event determination unit should determine the occurrence of the cancellation required event, and when the determination should be made, at which timing the determination should be made may be specifically determined.

(B) The automatic driving control device according to above (A), where

an operation state of the vehicle being at least one of the operations states of at least one operation state that may possibly occur when there is a possibility that the automatic driving operation set as an execution target is not normally executed, and at least one operation state in which there is possibility that the automatic driving operation set as an execution target may not be normally executed is set as the cancellation required event.

[0264]

In this manner, by appropriately setting the operation state of the vehicle in which the automatic driving operation is not normally executed (or may not be normally executed) as the cancellation required event, it is possible to appropriately determine whether or not to stop the automatic driving operation being executed.

(C) The automatic driving control device according to (A) or (B), where

at least one of a fact that an occupant of the vehicle shows a specific first behavior, a fact that a person around the vehicle shows a specific second behavior, and a fact that another vehicle around the vehicle performs a specific third operation is set as the cancellation required event.

[0265]

When the automatic driving operation being executed is not normally executed, the influence is reflected in the operation state of the vehicle, and in contrast, there is a possibility that an occupant of the vehicle shows a specific behavior (e.g., an expression of surprise or anxiety), a person around the vehicle shows a specific behavior (e.g., line-of-sight of many people is concentrated, a finger is pointed toward the vehicle, or the like), or another vehicle (more specifically, an occupant of another vehicle) performs a specific operation (e.g., honking or passing) with respect to the own vehicle. Therefore, by setting at least one of the first behavior, the second behavior, and the third behavior as the cancellation required event, it is possible to appropriately determine whether or not to stop the automatic driving operation being executed.

(D) The automatic driving control device according to any one of (A) to (C), where

an environment around the vehicle being a preset specific environment is set as the cancellation required event.

[0266]

The specific environment means an environment in which the automatic driving operation being executed may not be normally executed or an environment in which one or a plurality of specific automatic driving operations should not be executed, and for example, bad weather such as heavy rain or dense fog is conceivable. Furthermore, for example, consideration is made to a case in which the vehicle is traveling in an area where it is preferable to entrust the driver's own driving operation rather than automatic driving, such as a school zone or an accident-prone area.

[0267]

It is possible to appropriately determine whether or not to stop the automatic driving operation being executed by setting the existence of the vehicle under such a specific environment as the cancellation required event.