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VEHICLE CONTROL METHOD AND VEHICLE CONTROL DEVICE

Abstract

A vehicle control method includes detecting occurrence of a driving event specific to a virtual mobility when a reproduction mode for reproducing behavior of the virtual mobility in a driving event of the virtual mobility is selected as a driving mode of a battery electric vehicle, and performing event reproduction control including driving of an in-vehicle device simulating a behavior characteristic of the virtual mobility in the specific driving event and reproduction of a pseudo event sound simulating a sound in the specific driving event, when the occurrence of the specific driving event is detected. In the event reproduction control, the reproduction of the pseudo event sound is started prior to the driving of the in-vehicle device.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-023744 filed on Feb. 20, 2024. The disclosure of the above-identified application, including the specification, drawings, and claims, is incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to a vehicle control method and a vehicle control device applied to a battery electric vehicle using an electric motor as a traveling power device.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2011-215437 (JP 2011-215437 A) discloses a control device installed in a battery electric vehicle. The control device calculates an engine rotation speed of a virtual engine based on traveling information of the battery electric vehicle and a simulation result of an operation of a component of a virtual engine vehicle. In addition, the control device controls a virtual engine sound for a vehicle cabin based on the calculated engine rotation speed. In controlling the virtual engine sound, based on the simulation result of the operation of the component of the virtual engine vehicle, a sound effect corresponding to the operation is decided. Then, the decided sound effect is added to the virtual engine sound.

SUMMARY

[0004] A case where a sound source of the virtual engine sound is a mobility other than an engine vehicle, such as an aircraft, a railroad vehicle, and a ship, is considered. The mobility, such as an aircraft, a railroad vehicle, and a ship, includes a vehicle that uses an engine as a main power source, as with the engine vehicle. Therefore, in a case where the virtual engine sound of such a mobility serving as a sound source is controlled, a sense of realism as if the mobility is being driven can be produced.

[0005] In a case where a virtual mobility that uses an engine as a main power source is a sound source, providing a driver of a battery electric vehicle with information different from a sound, such as a virtual engine sound, is considered. For example, while the battery electric vehicle is turning, a seat surface of a driver's seat is tilted to reproduce turning of the virtual mobility. For example, vibration is generated in the driver's seat to reproduce an impact received when an aircraft lands. For example, vibration is generated in the driver's seat to reproduce an impact of a coupler received when a railroad vehicle with a cargo vehicle departs. Such pseudo-reproduction of driving events is expected to enhance the sense of realism.

[0006] When there is reproduction information of the driving event of the virtual mobility, a sense of realism as if a virtual mobility that does not use an engine as a main power source is being driven can be also produced. For example, a train is considered as the virtual mobility. The train is a mobility that uses a motor as a main power source. Vibration is generated in the driver's seat to reproduce an impact received from a joint of a track when the train travels, whereby a sense of realism as if the train is being driven can be produced.

[0007] The driving events listed above include a driving event common to the battery electric vehicle and the virtual mobility and a driving event specific to the virtual mobility. A representative example of the driving event common to the battery electric vehicle and the virtual mobility is turning of an engine vehicle. A representative example of the driving event specific to the virtual mobility is landing of an aircraft. A significant difference between the driving event common to the battery electric vehicle and the virtual mobility and the driving event specific to the virtual mobility lies in whether the event is caused by a driving operation of the driver or a driving state of the battery electric vehicle. Therefore, in a case where the driving event specific to the virtual mobility is reproduced, the driver who receives the reproduction information may feel uncomfortable or may misunderstand that the battery electric vehicle has failed.

[0008] The present disclosure has been made in consideration of the problem. A first aspect of the present disclosure is to provide a technique of, when a driving event specific to a virtual mobility is reproduced in a battery electric vehicle in a pseudo manner, suppressing erroneous transmission of an intention of the reproduction to a driver of the battery electric vehicle.

[0009] A first aspect of the present disclosure is a vehicle control method applied to a battery electric vehicle that uses an electric motor as a traveling power device and has the following features.

[0010] The vehicle control method includes detecting occurrence of a driving event specific to a virtual mobility when a reproduction mode for reproducing behavior of the virtual mobility in a driving event of the virtual mobility is selected as a driving mode of a battery electric vehicle, and performing event reproduction control including driving of an in-vehicle device simulating a behavior characteristic of the virtual mobility in the specific driving event and reproduction of a pseudo event sound simulating a sound in the specific driving event, when the occurrence of the specific driving event is detected. In the event reproduction control, the reproduction of the pseudo event sound is started prior to the driving of the in-vehicle device.

[0011] In the vehicle control method, the driving of the in-vehicle device may be started after the pseudo event sound reproduced by executing the event reproduction control is detected via an indoor microphone of the battery electric vehicle.

[0012] In the vehicle control method, when a setting state of a sound reproducing device configured to reproduce the pseudo event sound in the battery electric vehicle is a mute state, the mute state may be released before the reproduction of the pseudo event sound is started in the event reproduction control.

[0013] The vehicle control method may further include detecting occurrence of a driving event common to the virtual mobility and the battery electric vehicle when a reproduction mode for reproducing a sound of the virtual mobility in the driving event of the virtual mobility is selected as the driving mode, and performing event reproduction control including at least one of driving of the in-vehicle device simulating a behavior characteristic of the virtual mobility in the common driving event and reproduction of a pseudo event sound simulating a sound in the common driving event, when the occurrence of the common driving event is detected.

[0014] In the vehicle control method, the virtual mobility may include a railroad vehicle with a cargo vehicle. The specific driving event may include a departure event of the railroad vehicle detected by start of the battery electric vehicle and a stop event of the railroad vehicle detected by stop of the battery electric vehicle.

[0015] In the vehicle control method, the virtual mobility may include a railroad vehicle. The specific driving event may include a track traveling event of the railroad vehicle detected by traveling of the battery electric vehicle.

[0016] In the vehicle control method, the virtual mobility may include an aircraft. The specific driving event may include a landing event of the aircraft at a destination, the landing event being detected when a distance from the battery electric vehicle to the destination is within a predetermined distance.

[0017] A second aspect of the present disclosure is a vehicle control device applied to a battery electric vehicle that uses an electric motor as a traveling power device and has the following features.

[0018] The vehicle control device includes a processing circuit that performs various kinds of processing. The processing circuit is configured to detect occurrence of a driving event specific to a virtual mobility when a reproduction mode for reproducing behavior of the virtual mobility in a driving event of the virtual mobility is selected as a driving mode of the battery electric vehicle, perform event reproduction control including driving of an in-vehicle device simulating a behavior characteristic of the virtual mobility in the specific driving event and reproduction of a pseudo event sound simulating a sound in the specific driving event, when the occurrence of the specific driving event is detected. In the event reproduction control, the reproduction of the pseudo event sound is started prior to the driving of the in-vehicle device.

[0019] In the vehicle control device, the processing circuit may be configured to start the driving of the in-vehicle device after the pseudo event sound reproduced by executing the event reproduction control is detected via an indoor microphone of the battery electric vehicle.

[0020] In the vehicle control device, the processing circuit may be configured to, when a setting state of a sound reproducing device configured to reproduce the pseudo event sound in the battery electric vehicle is a mute state, release the mute state before the reproduction of the pseudo event sound is started in the event reproduction control.

[0021] In the vehicle control device, the processing circuit may be further configured to detect occurrence of a driving event common to the virtual mobility and the battery electric vehicle when a reproduction mode for reproducing a sound of the virtual mobility in the driving event of the virtual mobility is selected as the driving mode, and perform event reproduction control including at least one of driving of the in-vehicle device simulating a behavior characteristic of the virtual mobility in the common driving event and reproduction of a pseudo event sound simulating a sound in the common driving event, when the occurrence of the common driving event is detected.

[0022] In the vehicle control device, the virtual mobility may include a railroad vehicle with a cargo vehicle. In this case, the processing circuit may be configured to detect occurrence of a departure event of the railroad vehicle detected by start of the battery electric vehicle and a stop event of the railroad vehicle detected by stop of the battery electric vehicle as the specific driving event.

[0023] In the vehicle control device, the virtual mobility may include a railroad vehicle. In this case, the processing circuit may be configured to detect occurrence of a track traveling event of the railroad vehicle detected by traveling of the battery electric vehicle as the specific driving event.

[0024] In the vehicle control device, the virtual mobility may include an aircraft. In this case, the processing circuit may be configured to detect occurrence of a landing event of the aircraft at a destination as the specific driving event, the landing event being detected when a distance from the battery electric vehicle to the destination is within a predetermined distance.

[0025] According to the present disclosure, when the event reproduction control including the reproduction of the pseudo event sound simulating the sound in the driving event specific to the virtual mobility and the driving of the in-vehicle device simulating the behavior characteristic of the virtual mobility in the same driving event is performed, the reproduction of the pseudo event sound is started prior to the driving of the in-vehicle device. Therefore, when the in-vehicle device is driven, the pseudo event sound is delivered to the driver of the battery electric vehicle before the driving is started. Accordingly, an erroneous transmission of an intention of the driving of the in-vehicle device in the event reproduction control to the driver can be suppressed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0027] FIG. **1** is a conceptual diagram showing a configuration example of a battery electric vehicle to which a vehicle control device according to an embodiment is applied;

[0028] FIG. **2** is a block diagram showing an example of a basic functional configuration of the vehicle control device;
[0029] FIG. **3** is a block diagram showing another example of a basic functional configuration of the vehicle control device;
[0030] FIG. **4** is a block diagram showing an example of a functional configuration of a vehicle control device particularly related to event reproduction control;
[0031] FIG. **5** is a graph illustrating an adjustment example of timing of output of a control command of a reproduction device and event sound data when occurrence of a driving event specific to a virtual mobility is detected;
[0032] FIG. **6** is a flowchart showing a flow of processing particularly related to the embodiment;
[0033] FIG. **7** is a block diagram showing a first configuration example of a power control system of the battery electric vehicle;
[0034] FIG. **8** is a graph showing examples of an engine model, a clutch model, and a transmission model that configure an MT vehicle model;
[0035] FIG. **9** is a graph showing a torque characteristic of an electric motor implemented by motor control using the MT vehicle model as compared with a torque characteristic of the electric motor implemented by normal motor control as the battery electric vehicle; and
[0036] FIG. **10** is a block diagram showing a second configuration example of the power control system of the battery electric vehicle.
DETAILED DESCRIPTION OF EMBODIMENTS
[0037] An embodiment of the present disclosure will be described with reference to the accompanying drawings. In addition, the same or corresponding configurations in each drawing are denoted by the same reference numerals and description thereof will be simplified or will not be repeated. 1. Configuration Example and Reproduction of Virtual Mobility Sound
[0038] FIG. **1** is a conceptual diagram showing a configuration example of a battery electric vehicle including a vehicle control device according to the embodiment of the present disclosure. A vehicle control device **100** according to the embodiment is applied to a battery electric vehicle **10**. The battery electric vehicle **10** includes an electric motor **44**. Examples of the electric motor **44** include a brushless DC motor and a three-phase alternating current synchronous motor. The battery electric vehicle **10** uses the electric motor **44** as a traveling power device.
[0039] In addition, the battery electric vehicle **10** includes various sensors **12**. The various sensors **12** include an operation state sensor, such as an accelerator position sensor, a brake position sensor, and a shift position sensor, and a traveling state sensor, such as a wheel speed sensor, an acceleration sensor, and a rotation speed sensor. The accelerator position sensor detects an operation amount of an accelerator pedal (accelerator operation amount). The brake position sensor detects an operation amount of a brake pedal. The shift position sensor detects a shift position. The wheel speed sensor detects a rotation speed of wheels of the battery electric vehicle **10**. The acceleration sensor detects a lateral acceleration or a longitudinal acceleration of the battery electric vehicle **10**. The rotation speed sensor detects a rotation speed of the electric motor **44**.
[0040] In addition, the various sensors **12** include a position sensor, such as a global navigation satellite system (GNSS) sensor, and a recognition sensor, such as a camera, a radar, and a laser imaging detection and ranging (LIDAR). The GNSS sensor detects a position and a posture of the battery electric vehicle **10**. The camera images at least a region in front of the battery electric vehicle **10**. The radar and the LIDAR recognize a situation around the battery electric vehicle **10**.
[0041] In addition, the battery electric vehicle **10** includes a speaker **14**. The speaker **14** outputs a sound into a vehicle cabin of the battery electric vehicle **10**. The speaker **14** includes, for example, a front speaker provided in front of the vehicle cabin and a rear speaker provided behind the vehicle cabin. The total number of speakers constituting the speaker **14** and a layout of the speaker **14** can be optionally changed.
[0042] The battery electric vehicle **10** further includes a reproduction device **16**. The reproduction

device **16** is a device that reproduces a behavior characteristic of a virtual mobility in a driving event of the virtual mobility in a pseudo manner. Examples of the reproduction device **16** include a seat vibration device that vibrates a driver's seat of the battery electric vehicle **10**, a seat adjustment device that adjusts a height and an inclination of a seat surface of the driver's seat, and a steering vibration device that vibrates a steering wheel. The reproduction device **16** is an in-vehicle device existing in the battery electric vehicle **10** or an in-vehicle device dedicated to reproduction. Another example of the reproduction device **16** is a drive force transmission device, such as the electric motor **40** or a transmission. The electric motor **40** and the transmission are in-vehicle devices existing in the battery electric vehicle **10**, and can vibrate the driver's seat by performing predetermined control.

[0043] In the present disclosure, the virtual mobility refers to a mobility other than the battery electric vehicle **10**. Examples of the mobility other than the battery electric vehicle **10** include an engine vehicle, an aircraft, a railroad vehicle, and a ship. The mobility, such as an aircraft, a railroad vehicle, and a ship, includes a vehicle that uses an engine as a main power source, as with the engine vehicle. In addition, the mobility, such as an aircraft, a railroad vehicle, and a ship, includes a mobility that uses a combination of an engine and a motor or a motor as a main power source.

[0044] In addition, the battery electric vehicle **10** further includes a human machine interface (HMI) unit **18**. The HMI unit **18** is an input/output terminal for providing information to a driver of the battery electric vehicle **10** and receiving information from the driver. The HMI unit **18** includes, for example, an input device, a display device, and a microphone. Examples of the input device include a touch panel, a keyboard, a switch, and a button. The information provided to the driver includes information regarding a traveling state of the battery electric vehicle **10** and information specific to the present disclosure. The specific information specific to the present disclosure includes information regarding a driving mode or a control mode of the battery electric vehicle **10**. The information is provided to the driver by using the display device. The information is received from the driver by using the input device and the microphone.

[0045] The vehicle control device **100** generates a sound related to the virtual mobility (hereinafter, also referred to as a “virtual mobility sound”). In addition, the vehicle control device **100** outputs the generated virtual mobility sound from the speaker **14**. For example, the vehicle control device **100** generates a sound simulating a sound generated from a power source of the virtual mobility (hereinafter, also referred to as “pseudo power source sound”) as the virtual mobility sound, and outputs the sound from the speaker **14**. In another example, the vehicle control device **100** generates a sound simulating a sound simulating a sound in the driving event of the virtual mobility (hereinafter, also referred to as “pseudo event sound”) as the virtual mobility sound, and outputs the sound from the speaker **14**. In addition, in still another example, the vehicle control device **100** generates both the pseudo power source sound and the pseudo event sound, and outputs the pseudo power source sound and the pseudo event sound from the speaker **14**.

[0046] The driving event of the virtual mobility includes a driving event common to the virtual mobility and the battery electric vehicle **10** and a driving event specific to the virtual mobility. Examples of the driving event common to the virtual mobility and the battery electric vehicle **10** (hereinafter, also referred to as a “common driving event”) include a start event, a stop event, a constant speed cruising event, an acceleration event, a deceleration event, a turning event, and a backward event. In the common driving event, a sound is generated from a power source of the virtual mobility, a mobility body, a surrounding environment of the virtual mobility, and the like. The vehicle control device **100** generates the pseudo event sound (excluding the pseudo power source sound) in the common driving event, and outputs the pseudo event sound from the speaker **14**.

[0047] As in the common driving event, even in the driving event specific to the virtual mobility (hereinafter, also referred to as a “specific driving event”), a sound is generated from a power source of the virtual mobility, a mobility body, a surrounding environment of the virtual mobility, and the like. The vehicle control device **100** generates the pseudo event sound (excluding the pseudo power source sound) in the specific driving event, and outputs the pseudo event sound from the speaker **14**. Here, examples of the specific driving event include a landing event of an aircraft at an airport, a start event and a stop event of a railroad vehicle with a cargo vehicle, and a track traveling event of a railroad vehicle. In the landing event of the aircraft, an impact sound is generated by landing of the aircraft. In the start event and the stop event of the railroad vehicle with the cargo vehicle, an impact sound of a coupler between the cargo vehicles is generated. In the track traveling event of the railroad vehicle, an impact sound produced from a joint of a track is generated.

[0048] The entirety of the vehicle control device **100** may be mounted in the battery electric vehicle **10**. As another example, at least a part of the vehicle control device **100** may be included in a management server outside the battery electric vehicle **10**. In this case, the vehicle control device **100** may remotely generate the virtual mobility sound and receive the generated virtual mobility sound to output the generated virtual mobility sound from the speaker **14**.

[0049] In general, the vehicle control device **100** includes at least one processing circuit **102** and at least one storage device **104**. Examples of the processing circuit **102** include at least one of a general purpose processor, a specific purpose processor, an integrated circuit, an application specific integrated circuit (ASIC), a central processing unit (CPU), a conventional circuit, and a combination thereof. The processing circuit **102** is hardware programmed to implement the functions described below or hardware that executes the functions described below. The storage device **104** stores various pieces of information. Examples of the storage device **104** include a volatile memory, a non-volatile memory, a hard disk drive (HDD), and a solid state drive (SSD).

[0050] FIG. **2** is a block diagram showing an example of a basic functional configuration of the vehicle control device **100**. The vehicle control device **100** includes an information acquisition unit **110**, a sound source management unit **120**, a sound generation unit **130**, a sound output controller **140**, and a mode setting unit **150** as functional blocks. These functional blocks are implemented, for example, by cooperation between the processing circuit **102** and the storage device **104**.

[0051] The information acquisition unit **110** acquires information BEV regarding the battery electric vehicle **10**. The information BEV includes information regarding a traveling state of the battery electric vehicle **10**, information regarding a traveling environment of the battery electric vehicle **10**, information regarding a driving mode or a control mode of the battery electric vehicle **10**, and the like. The information BEV is detected by the various sensors **12** and the HMI unit **18**. A part of the information regarding the traveling environment of the battery electric vehicle **10** may be acquired by combining the information detected by the various sensors **12** (for example, position information of the battery electric vehicle **10**) with map data.

[0052] In addition, the information BEV includes a virtual engine rotation speed Ne. Here, it is assumed that the battery electric vehicle **10** uses a virtual engine as a traveling power device. The virtual engine rotation speed Ne is a rotation speed of the virtual engine when assumption is made that the battery electric vehicle **10** is driven by the virtual engine. For example, the information acquisition unit **110** may calculate the virtual engine rotation speed Ne to be increased as the wheel speed is increased. In addition, when the battery electric vehicle **10** has a manual mode (MT mode) described below, the information acquisition unit **110** may calculate the virtual engine rotation speed Ne in the manual mode based on a wheel speed, a total reduction ratio, and a slip ratio of a virtual clutch. Details of the calculation method of the virtual engine rotation speed Ne in the manual mode will be described below.

[0053] The sound source management unit **120** stores sound source data VMS (VMS1, . . . , VMSn) of the virtual mobility used to generate the virtual mobility sound. The sound source management unit **120** is mainly implemented by the storage device **104**. Typically, the sound source data VMS includes a plurality of kinds of sound source data. The sound source data

includes, for example, sound source data of a sound caused by engine combustion (for low rotation speed, for medium rotation speed, and for high rotation speed), sound source data of a sound caused by motor rotation (for low rotation speed, for medium rotation speed, and for high rotation speed), sound source data of a sound caused by an operation of an input device, such as a gear and a clutch (for low rotation speed, for medium rotation speed, and for high rotation speed), and sound source data of a noise sound. Each sound source data is generated in advance through a simulation based on a power source model and a vehicle body model of the virtual mobility. Each sound source data can be flexibly adjusted. That is, at least one of a sound pressure and a frequency of the sound indicated by the sound source data can be flexibly adjusted.
[0054] The sound generation unit **130** (virtual mobility sound simulator) is a simulator that generates the virtual mobility sound. The sound generation unit **130** acquires at least a part of the information BEV from the information acquisition unit **110**. In particular, the sound generation unit **130** acquires information on the virtual engine rotation speed Ne or a vehicle speed from the information acquisition unit **110**. In addition, the sound generation unit **130** reads sound source data VMSk of the virtual mobility (1<k<n) from the sound source management unit **120**. The sound source data VMSk is sound source data of the virtual mobility specified by driving mode data BDM of the battery electric vehicle **10** output from the mode setting unit **150**. The sound generation unit **130** generates a virtual mobility sound corresponding to the driving state (the virtual engine rotation speed Ne or the vehicle speed) of the battery electric vehicle **10** by combining one or more pieces of sound source data included in the sound source data VMSk. Mobility sound data GMS is data indicating the generated virtual mobility sound.
[0055] The generation of the pseudo power source sound is a well-known technique, and a method of generating the pseudo power source sound applicable to the present disclosure is not particularly limited. For example, the pseudo power source sound may be generated by a well-known sound simulator used in a game or the like. A method may be adopted in which a map of the virtual engine rotation speed Ne and a frequency and a map of a virtual engine torque and a sound pressure are prepared, the frequency of the pseudo power source sound is increased or decreased in proportion to the virtual engine rotation speed Ne, and the pseudo power source sound is increased or decreased in proportion to the virtual engine torque.
[0056] The sound output controller **140** receives power source sound data MDS generated by the sound generation unit **130**. Then, the sound output controller **140** outputs the power source sound data MDS from the speaker **14**. When the power source sound data MDS is output, the sound output controller **140** controls the sound pressure of the pseudo power source sound by controlling an amplifier. The sound output controller **140** changes the frequency of the pseudo power source sound by controlling a frequency modulator (FMC).
[0057] FIG. **3** is a block diagram showing another example of a basic functional configuration of the vehicle control device **100**. In the example shown in FIG. **3**, the sound source management unit **120** stores sound source data VES (VES1, . . . , VESm) in the driving event of the virtual mobility. The sound source data VES is generated in advance through a simulation based on a vehicle body model corresponding to the virtual mobility and an environment model of the virtual mobility. The sound source data VES may be generated by separately collecting and editing an environmental sound (for example, a notification sound of a departure bell or an announcement sound by an occupant of the virtual mobility) in the driving event of the virtual mobility. Each sound source data can be flexibly adjusted. That is, at least one of a sound pressure and a frequency of the sound indicated by the sound source data can be flexibly adjusted.
[0058] In the example shown in FIG. **3**, the sound generation unit **130** acquires at least a part of the information BEV from the information acquisition unit **110**. In particular, the sound generation unit **130** acquires information needed to detect the occurrence of the driving event of the virtual mobility from the information acquisition unit **110**. In addition, the sound generation unit **130** reads sound source data VESh of the virtual mobility (1<h<m) from the sound source management unit

120. The sound source data VESh is sound source data of the virtual mobility specified by the driving mode data BDM. The sound generation unit **130** generates a pseudo event sound corresponding to the driving event (that is, the common driving event or the specific driving event) of which generation is detected by combining one or more pieces of sound source data included in the sound source data VESh. Event sound data GES is data indicating the generated pseudo event sound.

2. Event Reproduction Control

[0059] In the embodiment, when the occurrence of the driving event of the virtual mobility is detected, control (event reproduction control) of reproducing the driving event is performed. In the event reproduction control, at least one of the driving of the reproduction device **16** simulating a behavior characteristic of the virtual mobility in the driving event and the reproduction of the pseudo event sound simulating the sound in the driving event is performed.

[0060] FIG. **4** is a block diagram showing an example of a functional configuration of the vehicle control device **100** particularly related to the event reproduction control. In the example shown in FIG. **4**, the vehicle control device **100** includes a reproduction device controller **160** and a control arbitration unit **170** in addition to the functional blocks described in FIGS. **2** and **3**. These functional blocks are implemented, for example, by cooperation between the processing circuit **102** and the storage device **104**.

[0061] The reproduction device controller **160** acquires at least a part of the information BEV from the information acquisition unit **110**. In particular, the reproduction device controller **160** acquires information needed to detect the driving event of the virtual mobility from the information acquisition unit **110**. In addition, the reproduction device controller **160** generates a control command according to a behavior characteristic pattern of the virtual mobility specified by the driving mode data BDM when the occurrence of the driving event is detected. The behavior characteristic pattern is generated in advance through a simulation based on a vehicle body model corresponding to the virtual mobility and an environment model of the virtual mobility. The generated control command is transmitted to the control arbitration unit **170**.

[0062] The control arbitration unit **170** receives the control command from the reproduction device controller **160** and outputs the control command to the reproduction device **16**. In addition, the control arbitration unit **170** receives the event sound data GES from the sound output controller **140** and outputs the event sound data GES to the speaker **14**. When both the control command from the reproduction device controller **160** and the event sound data GES are received, the control arbitration unit **170** determines whether or not output of the control command and the event sound data GES is possible based on the information BEV. For example, in a situation in which emergency vehicle control in which a safety device is operated is being performed, the output of the control command and the event sound data GES is prohibited. When the output of the control command and the event sound data GES is not particularly prohibited, the control arbitration unit **170** adjusts timing of the output.

[0063] The timing of the output of the control command and the event sound data GES is particularly significant when the occurrence of the specific driving event is detected. The occurrence of the common driving event is caused by a driving operation by the driver or a driving state of the battery electric vehicle **10**. In contrast, the specific driving event occurs without being caused by the driving operation or the driving state. Therefore, when the control of the reproduction device **16** is started with the detection of the occurrence of the specific driving event, the control of the reproduction device **16** may cause the driver to feel uncomfortable or to misunderstand that the battery electric vehicle **10** has failed.

[0064] Therefore, in the embodiment, when the occurrence of the specific driving event is detected, the output of the event sound data GES is started prior to the start of the control of the reproduction device **16**. FIG. **5** is a graph illustrating an adjustment example of the timing of the output of the control command by the control arbitration unit **170** and the event sound data GES. In the example shown in FIG. **5**, the mobility sound data GMS is also output. The output of the mobility sound data GMS continues from time T**1**.

[0065] As described above, when the occurrence of the specific driving event is detected, the event sound data GES is generated and output from the speaker **14**. In the example shown in FIG. **5**, with the detection of the occurrence of the specific driving event, the output of the event sound data GES continues between time T**2** and time T**3**. The control of the reproduction device **16** is started at time T**4**. Time T**4** is after time T**2**, and the adjustment of time T**4** is performed by the control arbitration unit **170**. The control of the reproduction device **16** is started at time T**4**, whereby it is possible to suppress erroneous transmission of an intention of the driving of the reproduction device **16** in the event reproduction control to the driver.

[0066] In the example shown in FIG. **5**, data of an announcement sound is included in the event sound data GES output between time T**2** and time T**4**. The announcement sound is a sound for notifying of the start of the control of the reproduction device **16**. The announcement sound may be an environmental sound (for example, a notification sound of a departure bell or an announcement sound by an occupant of the virtual mobility) generated in the specific driving event, or may be a separately generated alert sound. It is expected that the above effects are enhanced by reproducing the announcement sound.

[0067] Time T**4** at which the control of the reproduction device **16** is started may be after the control arbitration unit **170** detects the output of the event sound data GES in the vehicle cabin. In this case, the output of the event sound data GES is detected by using an indoor microphone of the battery electric vehicle **10**. Then, time T**4** is set based on a detection signal included in the information BEV. It is expected that the above effects are enhanced by setting time T**4** after the output of the event sound data GES is confirmed.

[0068] As a case where the output of the event sound data GES is not performed in the vehicle cabin, a case where a setting state of the speaker **14** is set to a mute state (including a small sound state close to the mute state) is assumed. Therefore, it is desirable to detect the setting state of the speaker **14** based on the information BEV and to release the mute state before time T**2** when the setting state is the mute state. The mute state is released, whereby the event sound data GES can be reliably output from the speaker **14**. The mute state is released, for example, by the control arbitration unit **170**.

3. Processing Example

[0069] FIG. **6** is a flowchart showing a flow of computer processing particularly related to the embodiment. The flowchart shown in FIG. **6** is repeatedly executed in a predetermined control period of the processing circuit **102** shown in FIG. **1**.

[0070] In the routine shown in FIG. **6**, first, the information BEV is acquired (step S**11**). As described above, the information BEV is information regarding the battery electric vehicle **10**, and includes information regarding the traveling state of the battery electric vehicle **10**, information regarding the traveling environment of the battery electric vehicle **10**, information regarding the driving mode or the control mode of the battery electric vehicle **10**, the virtual engine rotation speed Ne, and the like.

[0071] Subsequently to the process of step S**11**, it is determined whether or not the driving mode of the battery electric vehicle **10** is set to a reproduction mode (step S**12**). The determination in step S**12** is made based on the driving mode data BDM included in the information BDV. Here, the driving mode data BDM includes selection data of a basic mode and a reproduction mode. A difference between the basic mode and the reproduction mode lies at least in whether or not the virtual mobility sound is reproduced. When the reproduction mode is selected by the driver, a determination result in step S**12** is affirmative.

[0072] When the determination result in step S**12** is affirmative, the generation of the mobility sound data GMS is started (step S**13**). Then, it is determined whether or not the occurrence of the driving event has been detected (step S**14**). Whether or not the occurrence of the driving event has been detected is determined based on a combination of the information BEV and the virtual mobility specified by the driving mode data BDM.

[0073] For example, a start event and a stop event (common driving event) for the engine vehicle, the railroad vehicle, the aircraft, and the ship are detected by an operation of an ignition switch of the battery electric vehicle **10**. A turning event (common driving event) of the engine vehicle, the aircraft, and the ship is detected by a change in steering angle of the battery electric vehicle **10**. A station departure event of the railroad vehicle, a takeoff event of the aircraft, and a departure event of the ship from a shore (common driving event) are detected by a start operation of the battery electric vehicle **10**. A station arrival event of the railroad vehicle and a docking event of the ship (common driving event) are detected when a distance from a destination of the battery electric vehicle **10** is within a predetermined distance.

[0074] A start event (specific driving event) of the railroad vehicle with the cargo vehicle is detected by a start operation of the battery electric vehicle **10**, and a stop event (specific driving event) of the railroad vehicle is detected by a stop operation of the battery electric vehicle **10**. A track traveling event (specific driving event) of the railroad vehicle is detected by traveling of the battery electric vehicle **10**. A landing event (specific driving event) of the aircraft is detected when the distance from the destination of the battery electric vehicle **10** is within a predetermined distance.

[0075] When a determination result of step S**14** is negative, the output control of the mobility sound data GMS is performed (step S**15**). In the process of step S**15**, the mobility sound data GMS is output from the speaker **14**. In the process of step S**15**, control arbitration is appropriately performed to prohibit the output of the mobility sound data GMS in a situation in which the emergency vehicle control is performed.

[0076] When the determination result of step S**14** is affirmative, it is determined whether or not the driving event corresponds to the specific driving event (step S**21**). A determination target of the process of step S**21** is the driving event detected in the process of step S**14**. The determination in step S**21** is made based on the content of the driving event detected in the process of step S**14**.

[0077] When a determination result of step S**21** is negative, the generation of the event sound data GES is started (step S**22**), and the output control of the event sound data GES is performed (step S**23**). In the process of step S**23**, the event sound data GES is output from the speaker **14**. In the process of step S**23**, control arbitration is appropriately performed to prohibit the output of the event sound data GES in a situation in which the emergency vehicle control is performed.

[0078] Subsequently to the process of step S**23**, it is determined whether or not the driving event has ended (step S**24**). A determination target of the process of step S**24** is the driving event detected in the process of step S**14**. The determination in step S**24** is made, for example, by detecting cancellation of the driving operation or the vehicle state detected in the process of step S**14**. When a determination result of step S**24** is negative, the process progresses to the process of step S**22**.

[0079] When the determination result of step S**21** is affirmative, the generation of the event sound data GES is started (step S**25**). Then, the control of the reproduction device **16** and the output control of the event sound data GES are performed (step S**26**). In the process of step S**26**, the event sound data GES is output from the speaker **14**. In addition, in the process of step S**26**, control arbitration is performed in which the output of the event sound data GES is started before the control of the reproduction device **16**. Further, in the process of step S**26**, control arbitration is appropriately performed to prohibit the output of the event sound data GES and the control of the reproduction device **16** in a situation in which the emergency vehicle control is performed.

[0080] Subsequently to the process of step S**26**, it is determined whether or not the driving event has ended (step S**27**). The content of the process of step S**27** is the same as the content of the process of step S**24**. When a determination result of step S**27** is negative, the process progresses to the process of step S**25**.

4. Application to Battery Electric Vehicle Having Manual Mode (MT Mode)

[0081] An electric motor used as a traveling power device in a general battery electric vehicle has a torque characteristic that is significantly different from a torque characteristic of an internal combustion engine used as a traveling power device in a conventional vehicle (CV). Due to the difference in torque characteristic of the power device, a transmission is indispensable for the CV, whereas the battery electric vehicle is generally not equipped with a transmission. Of course, a general battery electric vehicle is not equipped with a manual transmission (MT) that switches a gear ratio via a manual operation of the driver. Therefore, there is a significant difference in driving sensation between driving of a conventional vehicle with the MT (hereinafter, also referred to as an "MT vehicle") and driving of the battery electric vehicle.
[0082] On the other hand, the electric motor can relatively easily control a torque by controlling an applied voltage or a magnetic field. Accordingly, with appropriate control, it is possible for the electric motor to obtain a desired torque characteristic within an operation range of the electric motor. By utilizing this feature, it is possible to control the torque of the battery electric vehicle and simulate a torque characteristic specific to the MT vehicle. In addition, the battery electric vehicle can be provided with a pseudo shifter so that the driver can get driving sensation like the MT vehicle. Whereby, it is possible to simulate the MT vehicle in the battery electric vehicle.
[0083] That is, the battery electric vehicle controls the output of the electric motor to simulate the torque characteristic specific to the MT vehicle. The driver operates the pseudo shifter to perform a pseudo manual gear shift operation. In response to the pseudo manual gear shift operation of the driver, the battery electric vehicle changes the torque characteristic by simulating the MT vehicle. As a result, the driver of the battery electric vehicle can have a feeling as if he or she is driving the MT vehicle. As described above, the control mode of the electric motor for simulating the manual gear shift operation of the MT vehicle is hereinafter also referred to as a "manual mode" or an "MT mode".
[0084] The battery electric vehicle **10** according to the present disclosure may have such a manual mode (MT mode). In the MT mode, the battery electric vehicle **10** generates a pseudo engine sound in response to the driving operation of the driver, and outputs the pseudo engine sound from the speaker **70**. Since an engine sound of the MT vehicle is reproduced as well as the driving operation of the MT vehicle, a degree of satisfaction of the driver who seeks realism increases.
[0085] Hereinafter, a configuration example of the battery electric vehicle **10** having the manual mode (MT mode) will be described.
4-1. First Configuration Example
[0086] FIG. **7** is a block diagram showing a first configuration example of a power control system of the battery electric vehicle **10**. The battery electric vehicle **10** includes the electric motor **44**, a battery **46**, and an inverter **42**. The electric motor **44** is a traveling power device. The battery **46** stores electric energy for driving the electric motor **44**. That is, the battery electric vehicle **10** is a battery electric vehicle (BEV) that travels with electric energy stored in the battery **46**. The inverter **42** converts a direct current electric power input from the battery **46** during acceleration into a drive electric power of the electric motor **44**. In addition, the inverter **42** converts a regenerative electric power input from the electric motor **44** during deceleration into a direct current electric power, which is used to charge the battery **46**.
[0087] The battery electric vehicle **10** includes an accelerator pedal **22** for the driver to input an acceleration request to the battery electric vehicle **10**. An accelerator position sensor **32** for detecting an accelerator operation amount is provided in the accelerator pedal **22**.
[0088] The battery electric vehicle **10** includes a pseudo shift paddle **24**. The pseudo shift paddle **24** is a dummy different from an original paddle-type shifter. The pseudo shift paddle **24** has a structure simulating a shift paddle provided in a clutch pedal-less MT vehicle. The pseudo shift paddle **24** is attached to the steering wheel. The pseudo shift paddle **24** includes an upshift switch and a downshift switch that decide an operation position. The upshift switch issues an upshift signal **34***u* when pulled forward, and the downshift switch issues a downshift signal **34***d* when

pulled forward.

[0089] Wheels **26** of the battery electric vehicle **10** are provided with a wheel speed sensor **36**. The wheel speed sensor **36** is used as a vehicle speed sensor for detecting a vehicle speed of the battery electric vehicle **10**. In addition, the electric motor **44** is provided with a rotation speed sensor **38** for detecting a rotation speed of the electric motor **44**.

[0090] The battery electric vehicle **10** includes a control device **50**. The control device **50** is typically an electronic control unit (ECU) mounted in the battery electric vehicle **10**. The control device **50** may be a combination of a plurality of ECUs. The control device **50** includes an interface, a memory, and a processor. An in-vehicle network is connected to the interface. The memory includes a RAM that temporarily records data and a ROM that stores a program executable by the processor and various data related to the program. The program is formed of a plurality of instructions. The processor reads out and executes a program or data from the memory, and generates a control signal based on a signal acquired from each sensor.

[0091] For example, the control device **50** controls the electric motor **44** through PWM control of the inverter **42**. The control device **50** receives signals from the accelerator position sensor **32**, the pseudo shift paddle **24**, the wheel speed sensor **36**, and the rotation speed sensor **38** (the signals from the pseudo shift paddle **24** are the upshift signal **34***u* and the downshift signal **34***d*). The control device **50** processes these signals and calculates a motor torque command value for PWM control of the inverter **42**.

[0092] The control device **50** includes an automatic mode (EV mode) and a manual mode (MT mode) as a control mode. The automatic mode is a normal control mode for driving the battery electric vehicle **10** as a general battery electric vehicle. The automatic mode is programmed to continuously change the output of the electric motor **44** in response to an operation of the accelerator pedal **22**. Meanwhile, the manual mode is a control mode for driving the battery electric vehicle **10** in the same manner as the MT vehicle. The manual mode is programmed to change an output characteristic of the electric motor **44** for the operation of the accelerator pedal **22** in response to an upshift operation and a downshift operation for the pseudo shift paddle **24**. That is, the manual mode is control mode in which the output of the electric motor **44** can be changed in response to a driving operation of a vehicle component other than the accelerator pedal **22** or the brake pedal. The automatic mode (EV mode) and the manual mode (MT mode) are switchable.

[0093] The control device **50** includes an automatic mode torque calculation unit **54** and a manual mode torque calculation unit **56**. Each of the units **54**, **56** may be an independent ECU, or may have an ECU function obtained by the program recorded in the memory being executed by the processor.

[0094] The automatic mode torque calculation unit **54** has a function of calculating a motor torque when the electric motor **44** is controlled in the automatic mode. The automatic mode torque calculation unit **54** stores a motor torque command map. The motor torque command map is a map for deciding a motor torque from the accelerator operation amount and the rotation speed of the electric motor **44**. The signal of the accelerator position sensor **32** and the signal of the rotation speed sensor **38** are input to each parameter of the motor torque command map. A motor torque corresponding to these signals is output from the motor torque command map. Therefore, in the automatic mode, even when the driver operates the pseudo shift paddle **24**, the operation is not reflected in the motor torque.

[0095] The manual mode torque calculation unit **56** includes an MT vehicle model. The MT vehicle model is a model for calculating a drive wheel torque to be obtained by operating the accelerator pedal **22** and the pseudo shift paddle **24** when the battery electric vehicle **10** is assumed to be an MT vehicle.

[0096] The MT vehicle model included in the manual mode torque calculation unit **56** will be described with reference to FIG. **8**. As shown in FIG. **8**, the MT vehicle model includes an engine model **561**, a clutch model **562**, and a transmission model **563**. The engine, the clutch, and the transmission that are virtually implemented by the MT vehicle model are referred to as a virtual engine, a virtual clutch, and a virtual transmission, respectively. In the engine model **561**, the virtual engine is modeled. In the clutch model **562**, the virtual clutch is modeled. In the transmission model **563**, the virtual transmission is modeled.

[0097] The engine model **561** calculates a virtual engine rotation speed Ne and a virtual engine output torque Teout. The virtual engine rotation speed Ne is calculated based on a wheel rotation speed Nw, a total reduction ratio R, and a slip ratio Rslip of the virtual clutch. For example, the virtual engine rotation speed Ne is represented by Formula (1).

$$Ne=Nw\times R/(1-R\mathrm{slip})\qquad \text{Formula (1):}$$

[0098] The virtual engine output torque Teout is calculated from the virtual engine rotation speed Ne and an accelerator operation amount Pap. As shown in FIG. **8**, a map in which a relationship between the accelerator operation amount Pap, the virtual engine rotation speed Ne, and the virtual engine output torque Teout is defined is used for calculating the virtual engine output torque Teout. In this map, the virtual engine output torque Teout with respect to the virtual engine rotation speed Ne is given for each accelerator operation amount Pap. The torque characteristic shown in FIG. **8** can be set to a characteristic assumed for a gasoline engine or can be set to a characteristic assumed for a diesel engine. In addition, the torque characteristic can be set to a characteristic assumed for a naturally aspirated engine or can be set to a characteristic assumed for a supercharge engine.

[0099] The clutch model **562** calculates a torque transmission gain k. The torque transmission gain k is a gain for calculating a degree of torque transmission of the virtual clutch corresponding to a virtual clutch operation amount Pc. The virtual clutch operation amount Pc is normally 0%, and is temporarily increased to 100% in conjunction with switching of a virtual gear stage of the virtual transmission. The clutch model **562** has a map as shown in FIG. **8**. In the map, the torque transmission gain k is given with respect to the virtual clutch operation amount Pc. In FIG. **8**, Pc0 corresponds to a position where the virtual clutch operation amount Pc is 0%, and Pc3 corresponds to a position where the virtual clutch operation amount Pc is 100%. A range from Pc0 to Pc1 and a range from Pc2 to Pc3 are dead zones in which the torque transmission gain k does not change regardless of the virtual clutch operation amount Pc. The clutch model **562** calculates a clutch output torque Tcout using the torque transmission gain k. The clutch output torque Tcout is a torque output from the virtual clutch. For example, the clutch output torque Tcout is given by a product of the virtual engine output torque Teout and the torque transmission gain k (Tcout=Teout×k).

[0100] In addition, the clutch model **562** calculates the slip ratio Rslip. The slip ratio Rslip is used to calculate the virtual engine rotation speed Ne in the engine model **561**. In the calculation of the slip ratio Rslip, a map in which the slip ratio Rslip is given with respect to the virtual clutch operation amount Pc can be used, as in a case of the torque transmission gain k.

[0101] The transmission model **563** calculates a gear ratio r. The gear ratio r is a gear ratio determined by a virtual gear stage GP in the virtual transmission. The virtual gear stage GP is upshifted by one stage in response to the upshift operation of the pseudo shift paddle **24**. On the other hand, the virtual gear stage GP is downshifted by one stage in response to the downshift operation of the pseudo shift paddle **24**. The transmission model **563** has a map as shown in FIG. **8**. In the map, the gear ratio r is given to the virtual gear stage GP such that the gear ratio r decreases as the virtual gear stage GP increases. The transmission model **563** calculates a transmission output torque Tgout by using the gear ratio r and the clutch output torque Tcout obtained from the map. For example, the transmission output torque Tgout is given by a product of the clutch output torque Tcout and the gear ratio r (Tgout=Tcout×r). The transmission output torque Tgout discontinuously changes in response to the switching of the gear ratio r. The change in the discontinuous transmission output torque Tgout generates a gear shift shock, and a sense of realism typical of a vehicle including a stepped transmission is created.

[0102] The MT vehicle model calculates a drive wheel torque Tw by using a predetermined reduction ratio rr. The reduction ratio rr is a fixed value determined by the mechanical structure

from the virtual transmission to the drive wheels. The value obtained by multiplying the gear ratio r by the reduction ratio rr is the total reduction ratio R. The MT vehicle model calculates the drive wheel torque Tw from the transmission output torque Tgout and the reduction ratio rr. For example, the drive wheel torque Tw is given by a product of the transmission output torque Tgout and the reduction ratio rr (Tw=Tgout×rr).
[0103] The control device **50** converts the drive wheel torque Tw calculated by the MT vehicle model into a requested motor torque Tm. The requested motor torque Tm is a motor torque needed to implement the drive wheel torque Tw calculated by the MT vehicle model. For the conversion of the drive wheel torque Tw into the requested motor torque Tm, the reduction ratio from an output shaft of the electric motor **44** to the drive wheels is used. Then, the control device **50** controls the inverter **42** in accordance with the requested motor torque Tm to control the electric motor **44**.
[0104] FIG. **9** is a graph showing the torque characteristic of the electric motor **44** implemented by the motor control using the MT vehicle model as compared with the torque characteristic of the electric motor **44** implemented by normal motor control as an electric vehicle (EV). With the motor control using the MT vehicle model, as shown in FIG. **9**, the torque characteristic (solid line in FIG. **9**) that simulates the torque characteristic of the MT vehicle can be implemented according to the virtual gear stage set by the pseudo shift paddle **24**. In FIG. **9**, the number of gear stages is six.
4-2. Second Configuration Example
[0105] FIG. **10** is a block diagram showing a second configuration example of the power control system of the battery electric vehicle **10**. Here, solely a configuration different from the first configuration example will be described. Specifically, in the second configuration example, the battery electric vehicle **10** includes a pseudo shift lever **27** and a pseudo clutch pedal **28** instead of the pseudo shift paddle **24** provided in the first configuration example. The pseudo shift lever **27** and the pseudo clutch pedal **28** are merely dummies different from the original shift lever and clutch pedal.
[0106] The pseudo shift lever **27** has a structure that simulates a shift lever provided in the MT vehicle. The disposition and the operation feeling of the pseudo shift lever **27** are the same as the disposition and the operation feeling of the actual MT vehicle. The pseudo shift lever **27** has positions corresponding to each gear stage, for example, first gear, second gear, third gear, fourth gear, fifth gear, sixth gear, reverse, and neutral. The pseudo shift lever **27** is provided with a shift position sensor **27***a* that detects the gear stage by discriminating the position of the pseudo shift lever **27**.
[0107] The pseudo clutch pedal **28** has a structure that simulates a clutch pedal provided in the MT vehicle. The disposition and the operation feeling of the pseudo clutch pedal **28** are the same as the disposition and the operation feeling of the actual MT vehicle. The pseudo clutch pedal **28** is operated when the pseudo shift lever **27** is operated. That is, the driver depresses the pseudo clutch pedal **28** when the driver wishes to change the gear stage settings by using the pseudo shift lever **27**, and in a case where the gear stage settings have been changed, the driver releases and returns the pseudo clutch pedal **28** to the original position. The pseudo clutch pedal **28** is provided with a clutch position sensor **28***a* for detecting a depression amount of the pseudo clutch pedal **28**.
[0108] The control device **50** receives signals from the accelerator position sensor **32**, the shift position sensor **27***a*, the clutch position sensor **28***a*, the wheel speed sensor **36**, and the rotation speed sensor **38**. The control device **50** processes these signals and calculates a motor torque command value for PWM control of the inverter **42**.
[0109] The control device **50** includes an automatic mode and a manual mode as a control mode, as in the first configuration example. The automatic mode is programmed to continuously change the output of the electric motor **44** in response to an operation of the accelerator pedal **22**. Meanwhile, the manual mode is a control mode for driving the battery electric vehicle **10** in the same manner as the MT vehicle. The manual mode is programmed to change the output of the electric motor **44** for the operation of the accelerator pedal **22** in response the operation of the pseudo clutch pedal **28**

and the pseudo shift lever **27**. That is, the manual mode is control mode in which the output of the electric motor **44** can be changed in response to a driving operation of a vehicle component other than the accelerator pedal **22** or the brake pedal.

[0110] The vehicle model included in the manual mode torque calculation unit **56** is the same as the vehicle model shown in FIG. **8**. Note that the virtual clutch operation amount Pc is replaced with the depression amount of the pseudo clutch pedal **28** detected by the clutch position sensor **28***a*. In addition, the virtual gear stage GP is decided by the position of the pseudo shift lever **27** detected by the shift position sensor **27***a*.

Claims

1. A vehicle control method that is applied to a battery electric vehicle that uses an electric motor as a traveling power device, the vehicle control method comprising: detecting occurrence of a driving event specific to a virtual mobility when a reproduction mode for reproducing behavior of the virtual mobility in a driving event of the virtual mobility is selected as a driving mode of the battery electric vehicle; and performing event reproduction control including driving of an in-vehicle device simulating a behavior characteristic of the virtual mobility in the specific driving event and reproduction of a pseudo event sound simulating a sound in the specific driving event, when the occurrence of the specific driving event is detected, wherein, in the event reproduction control, the reproduction of the pseudo event sound is started prior to the driving of the in-vehicle device.

2. The vehicle control method according to claim 1, wherein the driving of the in-vehicle device is started after the pseudo event sound reproduced by executing the event reproduction control is detected via an indoor microphone of the battery electric vehicle.

3. The vehicle control method according to claim 1, wherein, when a setting state of a sound reproducing device configured to reproduce the pseudo event sound in the battery electric vehicle is a mute state, the mute state is released before the reproduction of the pseudo event sound is started in the event reproduction control.

4. The vehicle control method according to claim 1, further comprising: detecting occurrence of a driving event common to the virtual mobility and the battery electric vehicle when a reproduction mode for reproducing a sound of the virtual mobility in the driving event of the virtual mobility is selected as the driving mode; and performing event reproduction control including at least one of driving of the in-vehicle device simulating a behavior characteristic of the virtual mobility in the common driving event and reproduction of a pseudo event sound simulating a sound in the common driving event, when the occurrence of the common driving event is detected.

5. The vehicle control method according to claim 1, wherein: the virtual mobility includes a railroad vehicle with a cargo vehicle; and the specific driving event includes a departure event of the railroad vehicle detected by start of the battery electric vehicle and a stop event of the railroad vehicle detected by stop of the battery electric vehicle.

6. The vehicle control method according to claim 1, wherein: the virtual mobility includes a railroad vehicle; and the specific driving event includes a track traveling event of the railroad vehicle detected by traveling of the battery electric vehicle.

7. The vehicle control method according to claim 1, wherein: the virtual mobility includes an aircraft; and the specific driving event includes a landing event of the aircraft at a destination, the landing event being detected when a distance from the battery electric vehicle to the destination is within a predetermined distance.

8. A vehicle control device that is applied to a battery electric vehicle that uses an electric motor as a traveling power device, the vehicle control device comprising: a processing circuit configured to perform various kinds of processing, wherein the processing circuit is configured to detect occurrence of a driving event specific to a virtual mobility when a reproduction mode for reproducing behavior of the virtual mobility in a driving event of the virtual mobility is selected as a driving mode of the battery electric vehicle, perform event reproduction control including driving of an in-vehicle device simulating a behavior characteristic of the virtual mobility in the specific driving event and reproduction of a pseudo event sound simulating a sound in the specific driving event, when the occurrence of the specific driving event is detected, and start the reproduction of the pseudo event sound prior to the driving of the in-vehicle device in the event reproduction control.

9. The vehicle control device according to claim 8, wherein the processing circuit is configured to start the driving of the in-vehicle device after the pseudo event sound reproduced by executing the event reproduction control is detected via an indoor microphone of the battery electric vehicle.

10. The vehicle control device according to claim 8, wherein the processing circuit is configured to, when a setting state of a sound reproducing device configured to reproduce the pseudo event sound in the battery electric vehicle is a mute state, release the mute state before the reproduction of the pseudo event sound is started in the event reproduction control.

11. The vehicle control device according to claim 8, wherein the processing circuit is further configured to detect occurrence of a driving event common to the virtual mobility and the battery electric vehicle when a reproduction mode for reproducing a sound of the virtual mobility in the driving event of the virtual mobility is selected as the driving mode, and perform event reproduction control including at least one of driving of the in-vehicle device simulating a behavior characteristic of the virtual mobility in the common driving event and reproduction of a pseudo event sound simulating a sound in the common driving event, when the occurrence of the common driving event is detected.

12. The vehicle control device according to claim 8, wherein: the virtual mobility includes a railroad vehicle with a cargo vehicle; and the processing circuit is configured to detect occurrence of a departure event of the railroad vehicle detected by start of the battery electric vehicle and a stop event of the railroad vehicle detected by stop of the battery electric vehicle as the specific driving event.

13. The vehicle control device according to claim 8, wherein: the virtual mobility includes a railroad vehicle; and the processing circuit is configured to detect occurrence of a track traveling event of the railroad vehicle detected by traveling of the battery electric vehicle as the specific driving event.

14. The vehicle control device according to claim 8, wherein: the virtual mobility includes an aircraft; and the processing circuit is configured to detect occurrence of a landing event of the aircraft at a destination as the specific driving event, the landing event being detected when a distance from the battery electric vehicle to the destination is within a predetermined distance.