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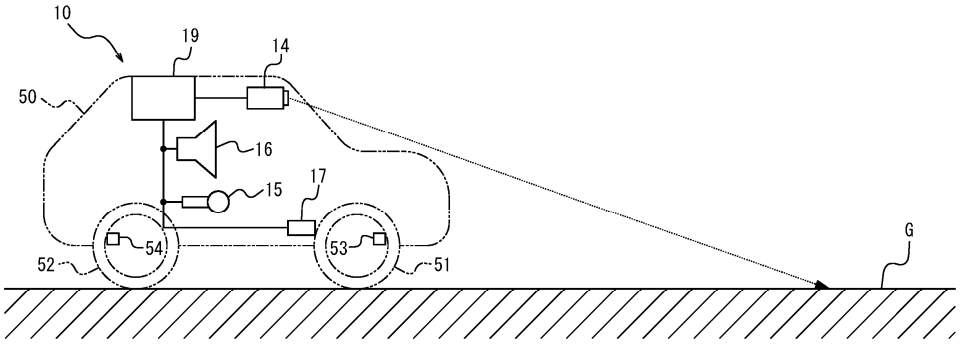
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(54) INFORMATION PROCESSING DEVICE, CONTROL METHOD THEREFOR, AND PROGRAM

(57) Discomfort of vehicle occupants caused by noise when a road surface condition switches is more effectively reduced. An information processing apparatus (10) includes a controller (11) configured to acquire audio information on noise, detected by a microphone (15), generated during traveling of a vehicle (50), generate a cancellation sound for canceling road noise, the road noise occurring due to unevenness of a road surface (G) on which the vehicle (50) is traveling, based on the acquired audio information, and cause a speaker (16) to output the generated cancellation sound. The controller (11) is configured to acquire road surface information indicating a condition of the road surface (G) in a direction in which the vehicle (50) is traveling, detect a switching point at which a condition of unevenness of the road surface (G) switches based on the acquired road surface information, and, in response to detecting the switching point, cause the speaker (16) to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface before or after the vehicle (50) passes the switching point during traveling is smaller.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an information processing apparatus, a control method therefor, and a program.

BACKGROUND

[0002] In order to reduce noise generated accompanying the traveling of a vehicle, it is known to output a cancellation sound for canceling noise. For example, PTL 1 describes adjusting a cancellation sound for canceling road noise that enters the vehicle cabin according to the road surface condition ahead of the vehicle.

CITATION LIST

Patent Literature

[0003] PTL 1: JP 2018-169525 A

SUMMARY

(Technical Problem)

[0004] However, in conventional configurations, there has been room for improvement in terms of reducing discomfort of occupants caused by noise generated near the tires when the road surface condition switches during vehicle travel.

[0005] An object of the present disclosure is to more effectively reduce discomfort of occupants caused by noise when the road surface condition switches.

(Solution to Problem)

[0006]

(1) An information processing apparatus according to one embodiment of the present disclosure includes:

a controller configured to
acquire audio information on noise, detected by a microphone, generated during traveling of a vehicle;
generate, based on the acquired audio information, a cancellation sound for canceling road noise occurring due to unevenness of a road surface on which the vehicle is traveling;
cause a speaker to output the generated cancellation sound;
acquire road surface information indicating a condition of the road surface in a direction in which the vehicle is traveling;
detect, based on the acquired road surface information, a switching point at which a condition of unevenness of the road surface switches; and
in response to detecting the switching point, cause the speaker to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface before or after the vehicle passes the switching point during travel is smaller.

(2) In one embodiment of the present disclosure, in (1),
the controller may be configured either to reduce a volume of the cancellation sound to be outputted by the speaker or to stop outputting the cancellation sound in the transition section.

(3) In one embodiment of the present disclosure, in (1) or (2),
when it is detected, based on the acquired road surface information, that the vehicle is traveling from a section with a smaller degree of unevenness of the road surface to a section with a greater degree of unevenness before and after the switching point, the controller may be configured to cause the speaker to output the noise sound in the transition section before passing the switching point.

(4) In one embodiment of the present disclosure, in (3),
the controller may be configured to cause the speaker to output the noise sound with a greater volume as the vehicle approaches the switching point while traveling in the transition section.

(5) In one embodiment of the present disclosure, in any one of (1) to (4),
when it is detected, based on the acquired road surface information, that the vehicle is traveling from a section with a greater degree of unevenness of the road surface to a section with a smaller degree of unevenness before and after the switching point, the controller may be configured to cause the speaker to output the noise sound in the transition section after passing the switching point.

(6) In one embodiment of the present disclosure, in (5),
the controller may be configured to cause the speaker to output the noise sound with a smaller volume as the vehicle moves away from the switching point while traveling in the transition section.

(7) In one embodiment of the present disclosure, in any one of (1) to (6),

the controller may be configured to
acquire, as the road surface information, a captured image of the road surface in the direction in which the vehicle is traveling; and
detect the switching point at which the condi-

tion of the unevenness of the road surface switches by analyzing the captured image.

(8) In one embodiment of the present disclosure, in any one of (1) to (7),

the controller may be configured to
acquire, as the road surface information, the audio information detected by the microphone; and
detect the switching point at which the condition of the unevenness of the road surface switches by analyzing the audio information.

(9) A control method for an information processing apparatus according to one embodiment of the present disclosure is
a control method for an information processing apparatus including a controller, the method comprising:

acquiring, by the controller, audio information on noise, detected by a microphone, generated during traveling of a vehicle;
generating, by the controller, a cancellation sound for canceling road noise occurring due to unevenness of a road surface on which the vehicle is traveling, based on the acquired audio information; and
causing, by the controller, a speaker to output the generated cancellation sound;
wherein the controller
acquires road surface information indicating a condition of the road surface in a direction in which the vehicle is traveling;
detects a switching point at which a condition of unevenness of the road surface switches, based on the acquired road surface information; and
in response to detecting the switching point, causes the speaker to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface before or after the vehicle passes the switching point during travel is smaller.

(10) A program according to one embodiment of the present disclosure is
a program configured to cause a computer to operate as the information processing apparatus according to any one of (1) to (8).

(Advantageous Effect)

[0007] According to one embodiment of the present disclosure, discomfort of occupants caused by noise when the road surface condition switches can be more effectively reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the accompanying drawings:

FIG. 1: is a diagram illustrating an example of a vehicle equipped with an information processing apparatus according to one embodiment;
FIG. 2: is a block diagram illustrating an example configuration of the information processing apparatus;
FIG. 3: is a flowchart illustrating an example of an operation procedure of the information processing apparatus;
FIG. 4: is a diagram illustrating an example of a change in volume of road noise when passing through a switching point;
FIG. 5: is a diagram illustrating an example of a change in volume of road noise when passing through a switching point;
FIG. 6: is a diagram illustrating an example of a change in volume of road noise when passing through a switching point; and
FIG. 7: is a diagram illustrating an example of a change in volume of road noise when passing through a switching point.

[0009] Hereinafter, an embodiment of the present disclosure will be described with reference to the drawings. In each drawing, the same reference numerals are assigned to parts having the same configuration or function. In the description of the present embodiment, redundant or repetitive explanations regarding the same parts may be omitted or simplified as appropriate.

[0010] FIG. 1 is a diagram illustrating an example of a vehicle 50 equipped with an information processing apparatus 10 according to an embodiment. The information processing apparatus 10 outputs a cancellation sound for canceling noise (noise) generated during traveling of the vehicle 50, thereby reducing noise inside the vehicle cabin.

[0011] The information processing apparatus 10 includes a camera 14, a microphone 15, a speaker 16, an accelerometer 17, and an arithmetic unit 19.

[0012] The camera 14 captures an image of the road surface G in the direction in which the vehicle 50 is traveling and acquires a captured image of the road surface G. The camera 14 is, for example, a stereo camera that acquires a stereoscopic image including depth information as a captured image, but may also be an imaging device that acquires a two-dimensional image. The camera 14 may include two or more imaging elements to acquire a stereoscopic image. In the example of FIG. 1, the camera 14 is provided at the front of the vehicle 50 so as to be able to capture the road surface G ahead of the vehicle 50, but it may also be provided at the rear of the vehicle 50.

[0013] The microphone 15 detects audio information of noise inside the cabin of the vehicle 50. The microphone 15 may, for example, be provided near a seat of the vehicle 50. The information processing apparatus 10 may generate a cancellation sound for canceling noise by inverting the phase of the audio information of noise detected by the microphone 15. In a state where the cancellation sound is being output, the information processing apparatus 10 may use the audio information in the cabin acquired by the microphone 15 to evaluate the effect of noise canceling.

[0014] The speaker 16 outputs the cancellation sound as a sound wave. The speaker 16 may be realized by an audio output device of an audio system originally provided in the vehicle 50. The speaker 16 may be installed at any location inside the vehicle. For example, the speaker 16 may be provided on or near the floor inside the vehicle.

[0015] The accelerometer 17 measures the acceleration of the vehicle 50. The measurement value of the accelerometer 17 is used for evaluation of NVH (Noise, Vibration, and Harshness). The accelerometer 17 may be realized by any type of sensor, such as a semiconductor gauge, capacitance type, or differential transformer type. The accelerometer 17 may, for example, be attached to an axle that transmits power generated by a drive unit such as an engine, motor, or a combination thereof, to the tires 51 and 52.

[0016] The arithmetic unit 19 is connected to the camera 14, microphone 15, speaker 16, and accelerometer 17, and controls the operation of these devices. As will be described later with reference to FIG. 2, the arithmetic unit 19 includes a controller 11, a storage 12, and a communication interface 13.

[0017] The vehicle 50 is, for example, an automobile such as a standard passenger car, but is not limited thereto and may be any vehicle. The automobile may be, for example, a gasoline vehicle, a hybrid vehicle, a plug-in hybrid vehicle, a fuel cell vehicle, or a battery electric vehicle, but is not limited thereto. The vehicle 50 includes tires 51 and 52.

[0018] The tire 51 is provided with a communication device 53. The tire 52 is provided with a communication device 54.

[0019] The communication devices 53 and 54 perform wireless communication. The communication devices 53 and 54 are, for example, RF (Radio Frequency) tags. An RF tag is also referred to as an RFID (Radio Frequency Identification) tag. The communication devices 53 and 54 include an IC (Integrated Circuit) chip constituting a controller and a storage, and one or more antennas connected to the IC chip. The IC chip may store any information regarding the tires 51 and 52, such as identification information, manufacturing date, circumference, and the number of pitches per revolution. The pitch is a groove in the width direction formed on the surface of the tires 51 and 52. For example, the communication devices 53 and 54 may be provided such that two antennas extending linearly, wavy-shaped, or helically extend from the IC chip in opposite directions, and the entire device may have a longitudinal shape.

[0020] The IC chip may operate by dielectric electromotive force generated by electromagnetic waves received by one or more antennas. That is, the communication devices 53 and 54 may be passive-type communication devices. Alternatively, the communication devices 53 and 54 may further include a battery and be capable of generating electromagnetic waves for communication by their own power. That is, the communication devices 53 and 54 may be active-type communication devices.

[0021] In the above configuration, the information processing apparatus 10 acquires audio information of noise generated during traveling of the vehicle 50 by the microphone 15, generates a cancellation sound for canceling road noise based on the audio information, and causes the speaker 16 to output the generated cancellation sound. The road noise is noise generated due to unevenness of the road surface G on which the vehicle 50 is traveling. The road noise is generated when the elastic motion of the tires 51 and 52, which are vibrated by the unevenness of the road surface G, is transmitted through the suspension, causing the ceiling and floor of the vehicle body to vibrate, resulting in sound inside the vehicle.

[0022] Here, the information processing apparatus 10 acquires road surface information indicating a condition of the road surface G in the direction in which the vehicle 50 is traveling. The information processing apparatus 10 detects a switching point at which a condition of unevenness of the road surface G switches, based on the acquired road surface information. For example, a boundary between a paved road and an unpaved rough road corresponds to such a switching point. In response to detecting the switching point, the information processing apparatus 10 causes the speaker 16 to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface G before or after the vehicle 50 passes the switching point during travel is smaller. For example, when the vehicle 50 moves from a good road with a small degree of unevenness to a bad road with a large degree of unevenness, in the transition section before the switching point, which is the boundary between the good road and the bad road, the information processing apparatus 10 causes the speaker 16 to output a noise sound simulating the road noise. Conversely, when the vehicle 50 moves from a bad road to a good road, in the transition section after passing the switching point, the information processing apparatus 10 causes the speaker 16 to output a noise sound simulating the road noise.

[0023] In this way, the information processing apparatus 10, by intentionally causing the speaker 16 to output a noise sound simulating the road noise in a prede-

termined transition section in which a degree of unevenness before or after passing the switching point is smaller, reduces the change in noise perceived by occupants inside the cabin before and after the switching point. Therefore, even when the vehicle 50 passes the switching point, the change in the volume of road noise due to the change in road surface becomes more gradual, and discomfort of occupants caused by noise can be more effectively reduced.

[0024] FIG. 2 is a block diagram illustrating an example configuration of the information processing apparatus 10. As described above, the information processing apparatus 10 includes the camera 14, microphone 15, speaker 16, accelerometer 17, and arithmetic unit 19. The arithmetic unit 19 includes the controller 11, storage 12, and communication interface 13. The arithmetic unit 19 is one or a plurality of computer devices capable of communicating with each other. The arithmetic unit 19 is not limited to these, and may be any general-purpose electronic device such as an FPGA (Field Programmable Gate Array), a single board computer (SBC: Single Board Computer), or a PC (Personal Computer), or may be another dedicated electronic device.

[0025] The controller 11 includes one or more processors. In one embodiment, the "processor" is a general-purpose processor or a dedicated processor specialized for specific processing, but is not limited thereto. The controller 11 is communicably connected to each component constituting the information processing apparatus 10 and controls the overall operation of the information processing apparatus 10.

[0026] The storage 12 includes, for example, any storage module such as an HDD (Hard Disk Drive), SSD (Solid State Drive), ROM (Read-Only Memory), and RAM (Random Access Memory). The storage 12 may function as, for example, a main storage device, auxiliary storage device, or cache memory. The storage 12 stores any information used for the operation of the information processing apparatus 10. For example, the storage 12 may store a system program, application program, and various information received by the communication interface 13. The storage 12 is not limited to being built into the information processing apparatus 10, and may be an external database or an external storage module.

[0027] The communication interface 13 includes any communication module capable of communication connection with other devices such as a scanner by any communication technology. The communication interface 13 may further include a communication control module for controlling communication with other devices, and a storage module for storing communication data such as identification information necessary for communication with other devices.

[0028] The functions of the information processing apparatus 10 may be realized by executing a computer program (program) according to the present embodiment by a processor included in the controller 11. That is, the functions of the information processing apparatus 10 may be realized by software. The computer program causes a computer to execute processing of steps included in the operation of the information processing apparatus 10, thereby realizing functions corresponding to the processing of each step in the computer. That is, the computer program is a program for causing the computer to function as the information processing apparatus 10 according to the present embodiment. The computer program may be recorded on a computer-readable recording medium. The program includes information to be used for processing by an electronic computer and equivalents to programs. For example, data that is not a direct instruction to the computer but has a property of defining processing by the computer corresponds to "equivalents to programs."

[0029] Some or all of the functions of the information processing apparatus 10 may be realized by a dedicated circuit included in the controller 11. That is, some or all of the functions of the information processing apparatus 10 may be realized by hardware. Further, the information processing apparatus 10 may be realized by a single computer or by cooperation of a plurality of computers.

[0030] FIG. 3 is a flowchart illustrating an example of an operation procedure of the information processing apparatus 10. The operation of the information processing apparatus 10 described with reference to FIG. 3 may correspond to one control method of the information processing apparatus 10. The operation of each step in FIG. 3 may be executed based on control by the controller 11 of the information processing apparatus 10. The following processing is executed in parallel with the traveling of the vehicle 50.

[0031] In step S1, the controller 11 acquires audio information of noise generated during traveling of the vehicle 50, detected by the microphone 15.

[0032] In step S2, the controller 11 analyzes the audio information acquired in step S1 and generates a cancellation sound for canceling road noise generated due to unevenness of the road surface G on which the vehicle 50 is traveling.

[0033] Specifically, the controller 11 may generate a cancellation sound for canceling road noise based on the audio information detected by the microphone 15 and the acceleration of the vehicle 50 detected by the accelerometer 17. Specifically, the controller 11 may predict a frequency band of the road noise based on the acceleration of the vehicle 50 detected by the accelerometer 17, and extract the road noise from the audio information detected by the microphone 15 based on the predicted frequency band or the like. The controller 11 may generate the cancellation sound for the road noise by inverting the phase of the extracted road noise.

[0034] In step S3, the controller 11 causes the speaker 16 to output the cancellation sound generated in

step S2.

[0035] In step S4, the controller 11 acquires road surface information indicating a condition of the road surface G in the direction in which the vehicle 50 is traveling. The road surface information is any information indicating a condition of the road surface G on which the vehicle 50 is traveling, which may affect noise reaching the cabin. For example, the road surface information may be a captured image of the road surface G in the direction in which the vehicle 50 is traveling acquired by the camera 14, audio information detected by the microphone 15, or a combination thereof, but is not limited thereto. For example, the road surface information may be information regarding the road surface G acquired by any sensor such as radar or LiDAR (Light Detection And Ranging). Alternatively, an external device such as a cloud or the storage 12 of the information processing apparatus 10 may store in advance road surface information indicating a condition of the road surface G in association with map information indicating a geographic location. The controller 11 may acquire road surface information corresponding to location information from an external device or the storage 12 or the like, using the location information of the vehicle 50 measured by a device such as a GPS (Global Positioning System) receiver as a query.

[0036] In step S5, the controller 11 determines, based on the road surface information acquired in step S4, whether there is a switching point at which a condition of unevenness of the road surface G switches. For example, the controller 11 may determine a degree of unevenness of the road surface G based on the road surface information, and determine a point where the amount of change in the degree of unevenness exceeds a certain threshold as a switching point. For example, the switching point may exist at a boundary portion between a good road with less or smaller unevenness of the road surface G and a bad road with more or larger unevenness. When using information acquired by the camera 14 as the road surface information, the controller 11 may determine whether there is a switching point at a location a predetermined distance away from the vehicle 50. Alternatively, the controller 11 may determine whether there is a switching point at a location that takes a predetermined time to reach from the current location, based on the speed and acceleration of the vehicle 50. The speed of the vehicle 50 can be acquired by any method. For example, the controller 11 may calculate the speed of the vehicle 50 based on the acceleration detected by the accelerometer 17. If a switching point exists (YES in step S5), the controller 11 proceeds to step S6; if not (NO in step S5), the controller 11 proceeds to step S7.

[0037] In step S6, in response to detecting the switching point, the controller 11 causes the speaker 16 to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface G before or after the vehicle 50 passes the switching point during travel is smaller.

[0038] The processing of step S5 and step S6 will be described with reference to FIGS. 4 to 7. FIGS. 4 to 7 are diagrams illustrating examples of changes in the volume of road noise when passing through a switching point. In FIGS. 4 to 7, the horizontal axis indicates time. The vertical axis indicates the volume of road noise reaching the cabin of the vehicle 50.

[0039] FIGS. 4 and 5 illustrate changes in the volume of road noise reaching the cabin when the vehicle 50 moves from a good road to a bad road. In FIGS. 4 and 5, at time t1, the vehicle 50 passes the switching point where the road surface G switches from a good road to a bad road. FIG. 4 illustrates the change in road noise when the processing of step S6 is not performed. The graph 61 in FIG. 4 indicates the change in road noise after outputting the cancellation sound in step S3. As indicated by the graph 61 in FIG. 4, when the processing of step S6 is not performed, the volume of road noise reaching the cabin suddenly increases from V1 to V2 at the switching point. Such a sudden change in the volume of noise is perceived as unpleasant noise by occupants. Therefore, in order to mitigate such a sudden change in the volume of noise, the controller 11 causes the speaker 16 to output a noise sound simulating the road noise in the transition section before the switching point.

[0040] FIG. 5 illustrates the change in road noise when the processing of step S6 is performed. In the example of FIG. 5, a noise sound simulating the road noise is output in the transition section from time t0 to time t1. The region 62 indicates the volume of such intentionally added noise sound. As a result, as indicated by the graph 63, the volume of road noise reaching the cabin gradually increases in the transition section, making it possible to reduce the discomfort of occupants.

[0041] Even when the vehicle 50 moves from a bad road to a good road, the controller 11 may perform similar processing. FIGS. 6 and 7 illustrate changes in the volume of road noise reaching the cabin when the vehicle 50 moves from a bad road to a good road. In FIGS. 6 and 7, at time t1, the vehicle 50 passes the switching point where the road surface G switches from a bad road to a good road. FIG. 6 illustrates the change in road noise when the processing of step S6 is not performed. The graph 64 in FIG. 6 indicates the change in road noise after outputting the cancellation sound in step S3. As indicated by the graph 64 in FIG. 6, when the processing of step S6 is not performed, the volume of road noise reaching the cabin suddenly decreases from V2 to V1 at the switching point. Even when the noise decreases, such a sudden change in the volume of noise is perceived as unpleasant by occupants. Therefore, in order to mitigate such a sudden change in the volume of noise, the controller 11 causes the speaker 16 to output a noise sound simulating the road

noise in the transition section after passing the switching point.

[0042] FIG. 7 illustrates the change in road noise when the processing of step S6 is performed. In the example of FIG. 7, a noise sound simulating the road noise is output in the transition section from time t1 to time t2. The region 65 indicates the volume of such intentionally added noise sound. As a result, as indicated by the graph 66, the volume of road noise reaching the cabin gradually decreases in the transition section, making it possible to reduce the discomfort of occupants.

[0043] In step S7, the controller 11 determines whether to terminate the processing of the flowchart. For example, the controller 11 may determine to terminate the processing when the engine of the vehicle 50 is turned off or when termination of processing is instructed by an occupant. If the controller 11 determines to terminate the processing (YES in step S7), the processing of the flowchart is terminated; if not (NO in step S7), the process returns to step S1 and continues.

[0044] As described above, the information processing apparatus 10, in a certain transition section where the degree of unevenness before or after the vehicle 50 passes the switching point is smaller, intentionally causes the speaker 16 to output a noise sound simulating road noise. Therefore, even when the vehicle passes the switching point, changes in noise due to changes in the road surface become more gradual, and it is possible to more effectively reduce discomfort of occupants caused by noise.

[0045] Note that, during travel in the transition section, the information processing apparatus 10 may, in step S3, either reduce the volume of the cancellation sound to be output by the speaker 16 or stop outputting the cancellation sound. According to such processing, even without outputting a noise sound simulating road noise from the speaker 16, it is possible to reduce discomfort of occupants caused by noise.

[0046] Further, as described with reference to FIG. 5 and FIG. 7, in the transition section, the information processing apparatus 10 may increase the volume of the noise sound simulating road noise when the vehicle is traveling at a location closer to the switching point.

[0047] For example, when it is detected that the vehicle 50 is traveling from a good road with a smaller degree of unevenness of the road surface G to a bad road with a greater degree of unevenness before and after the switching point, the information processing apparatus 10 may cause the speaker 16 to output the noise sound in the transition section before passing the switching point. With such a configuration, when the vehicle is traveling from a good road to a bad road, by intentionally outputting noise during travel in the transition section before the switching point, changes in noise before and after passing the switching point are reduced. Therefore, changes in noise before and after passing the switching point become more gradual, and it is possible to more effectively reduce discomfort of occupants caused by noise.

[0048] Specifically, when moving from a good road to a bad road, the information processing apparatus 10 may cause the speaker 16 to output a noise sound with a greater volume as the vehicle 50 approaches the switching point while traveling in the transition section. With such a configuration, by varying the volume of the noise sound output during travel in the transition section according to the distance from the switching point, it is possible to further reduce changes in noise perceived by the occupants, and to more effectively reduce discomfort of the occupants.

[0049] Further, when it is detected that the vehicle 50 is traveling from a bad road to a good road before and after the switching point, the information processing apparatus 10 may cause the speaker 16 to output the noise sound in the transition section after passing the switching point. With such a configuration, when the vehicle is traveling from a bad road to a good road, by intentionally outputting noise during travel in the transition section after passing the switching point, changes in noise before and after passing the switching point are reduced. Therefore, changes in noise before and after passing the switching point become more gradual, and it is possible to more effectively reduce discomfort of occupants caused by noise.

[0050] Specifically, when moving from a bad road to a good road, the information processing apparatus 10 may cause the speaker 16 to output a noise sound with a smaller volume as the vehicle 50 moves away from the switching point while traveling in the transition section. With such a configuration, by varying the volume of the noise sound output during travel in the transition section according to the distance from the switching point, it is possible to further reduce changes in noise perceived by the occupants, and to more effectively reduce discomfort of the occupants.

[0051] As described above, by varying the volume of the noise sound output during travel in the transition section according to the distance from the switching point, the information processing apparatus 10 can further reduce changes in noise perceived by the occupants, and more effectively reduce discomfort of the occupants. However, the information processing apparatus 10 may simplify the processing and not continuously vary the volume of the noise sound. For example, in the transition section, the information processing apparatus 10 may cause the speaker 16 to output a noise sound at a constant volume. Alternatively, the information processing apparatus 10 may select one of a plurality of predetermined volume levels and appropriately switch the volume level during travel in the transition section to cause the speaker 16 to output the noise sound.

[0052] Further, as road surface information, the information processing apparatus 10 may acquire a captured image of the road surface G in the direction in

which the vehicle 50 is traveling, captured by the camera 14, and analyze the captured image to detect a switching point at which the condition of unevenness of the road surface G switches. In this way, since the condition of the road surface G is detected based on a captured image of the road surface G that the vehicle 50 is about to travel, it is possible to accurately determine the timing of passing the switching point and to effectively perform processing for reducing discomfort of the occupants with minimal time lag.

[0053] Further, as road surface information, the information processing apparatus 10 may acquire audio information detected by the microphone 15, analyze the audio information, and detect a switching point at which the condition of unevenness of the road surface G switches. For example, the information processing apparatus 10 may detect, based on the audio information, the passing of a switching point where the road surface switches from a bad road to a good road, and, in response to detecting the passing of the switching point, cause the speaker 16 to output the noise sound. In this way, since the switching point is detected based on audio information from the microphone 15 used for noise canceling, it is possible to perform processing for reducing discomfort of the occupants without providing additional equipment.

[0054] The present disclosure is not limited to the above-described embodiments. For example, a plurality of blocks described in the block diagram may be integrated, or one block may be divided. A plurality of steps described in the flowchart may be executed in parallel or in a different order according to the processing capability of the apparatus executing each step or as necessary, instead of being executed in chronological order as described. Other modifications may be made without departing from the spirit of the present disclosure.

[Contribution to the Sustainable Development Goals (SDGs) Led by the United Nations]

[0055] The SDGs have been proposed toward the realization of a sustainable society. An embodiment of the present disclosure is considered to be a technology that can contribute to, for example, "No. 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."

REFERENCE SIGNS LIST

[0056]

10	Information processing apparatus
11	Controller
12	Storage
13	Communication interface
14	Camera
15	Microphone
16	Speaker
17	Accelerometer
19	Arithmetic unit
50	Vehicle
51, 52	Tire
53, 54	Communication device
61-66	Graph
G	Road surface

Claims

1. An information processing apparatus comprising a controller configured to:

   acquire audio information on noise, detected by a microphone, generated during traveling of a vehicle;
   generate a cancellation sound for canceling road noise, the road noise occurring due to unevenness of a road surface on which the vehicle is traveling, based on the acquired audio information;
   cause a speaker to output the generated cancellation sound;
   acquire road surface information indicating a condition of the road surface in a direction in which the vehicle is traveling;
   detect a switching point at which a condition of unevenness of the road surface switches, based on the acquired road surface information; and
   in response to detecting the switching point, cause the speaker to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface before or after the vehicle passes the switching point during travel is smaller.

2. The information processing apparatus according to claim 1, wherein the controller is configured either to reduce a volume of the cancellation sound to be outputted by the speaker or to stop outputting the cancellation sound in the transition section.

3. The information processing apparatus according to claim 1, wherein when it is detected, based on the acquired road surface information, that the vehicle is traveling from a section with a smaller degree of unevenness of the road surface to a section with a greater degree of unevenness before and after the switching point, the controller is configured to cause the speaker to output the noise sound in the transition section before passing the switching point.

4. The information processing apparatus according to claim 3, wherein the controller is configured to

cause the speaker to output the noise sound with a greater volume as the vehicle approaches the switching point while traveling in the transition section.

5. The information processing apparatus according to claim 1, wherein when it is detected, based on the acquired road surface information, that the vehicle is traveling from a section with a greater degree of unevenness of the road surface to a section with a smaller degree of unevenness before and after the switching point, the controller is configured to cause the speaker to output the noise sound in the transition section after passing the switching point.

6. The information processing apparatus according to claim 5, wherein the controller is configured to cause the speaker to output the noise sound with a smaller volume as the vehicle moves away from the switching point while traveling in the transition section.

7. The information processing apparatus according to claim 1, wherein the controller is configured to:

acquire, as the road surface information, a captured image of the road surface in the direction in which the vehicle is traveling; and
detect the switching point at which the condition of the unevenness of the road surface switches by analyzing the captured image.

8. The information processing apparatus according to claim 1, wherein the controller is configured to:

acquire, as the road surface information, the audio information detected by the microphone; and
detect the switching point at which the condition of the unevenness of the road surface switches by analyzing the audio information.

9. A control method for an information processing apparatus comprising a controller, the control method comprising:

acquiring, by the controller, audio information on noise, detected by a microphone, generated during traveling of a vehicle;
generating, by the controller, a cancellation sound for canceling road noise, the road noise occurring due to unevenness of a road surface on which the vehicle is traveling, based on the acquired audio information; and
causing, by the controller, a speaker to output the generated cancellation sound,
wherein the controller is configured to:

acquire road surface information indicating a condition of the road surface in a direction in which the vehicle is traveling;
detect a switching point at which a condition of unevenness of the road surface switches, based on the acquired road surface information; and
in response to detecting the switching point, cause the speaker to output a noise sound simulating the road noise in a predetermined transition section in which a degree of unevenness of the road surface before or after the vehicle passes the switching point during travel is smaller.

10. A program configured to cause a computer to operate as the information processing apparatus according to any one of claims 1 to 8.

FIG. 1

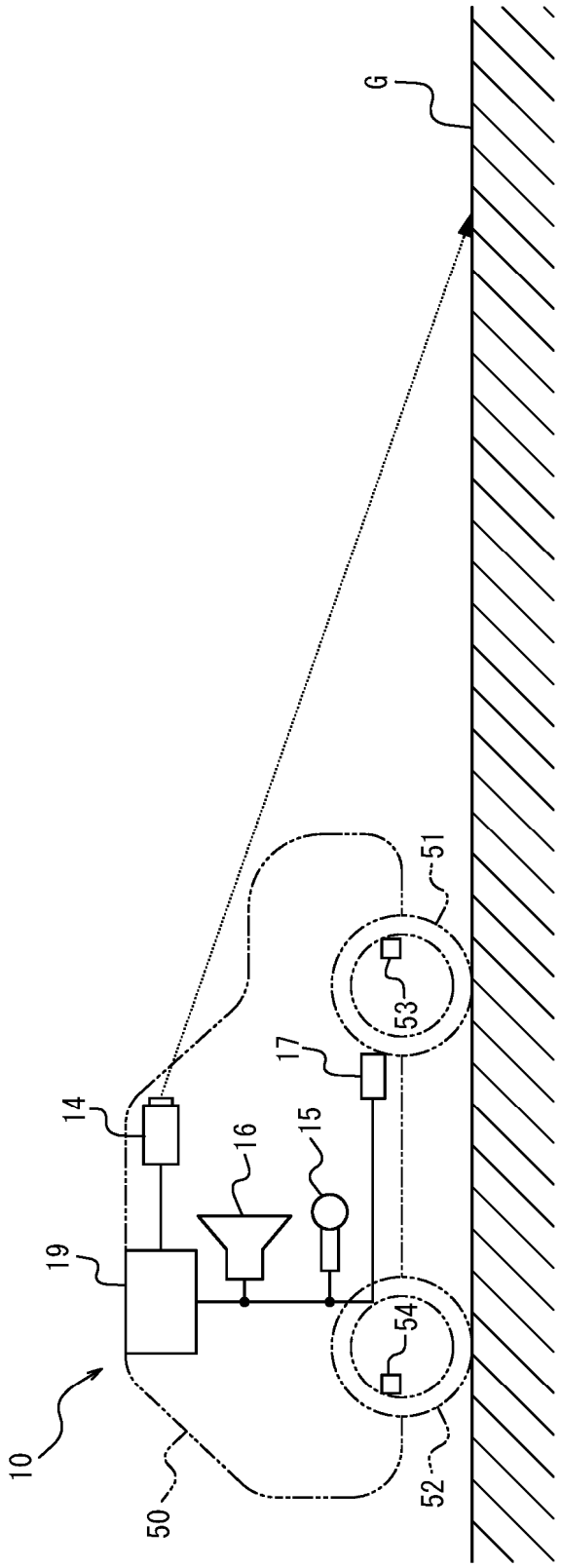


FIG. 2

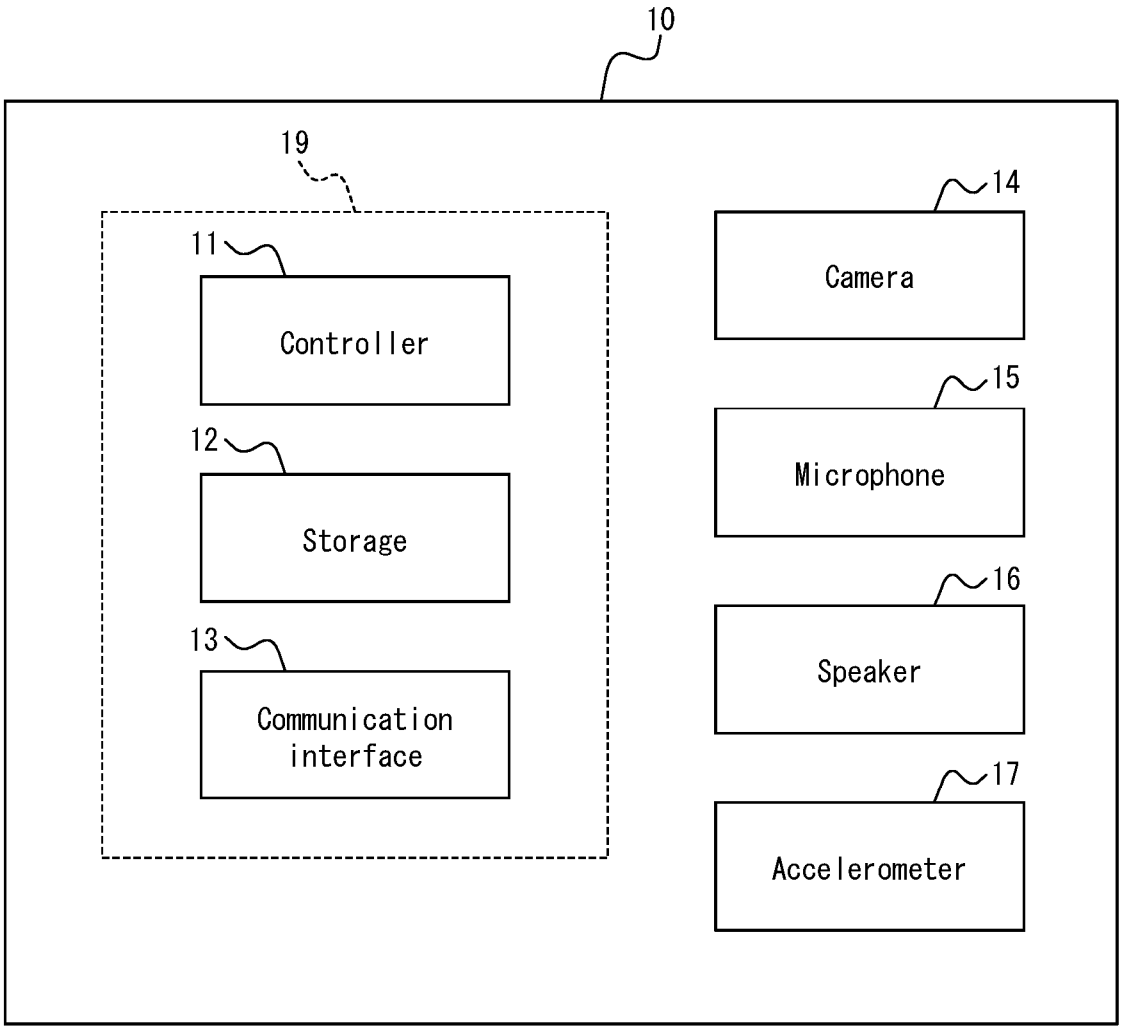

10
19
11
Controller
12
Storage
13
Communication interface
14
Camera
15
Microphone
16
Speaker
17
Accelerometer

FIG. 3

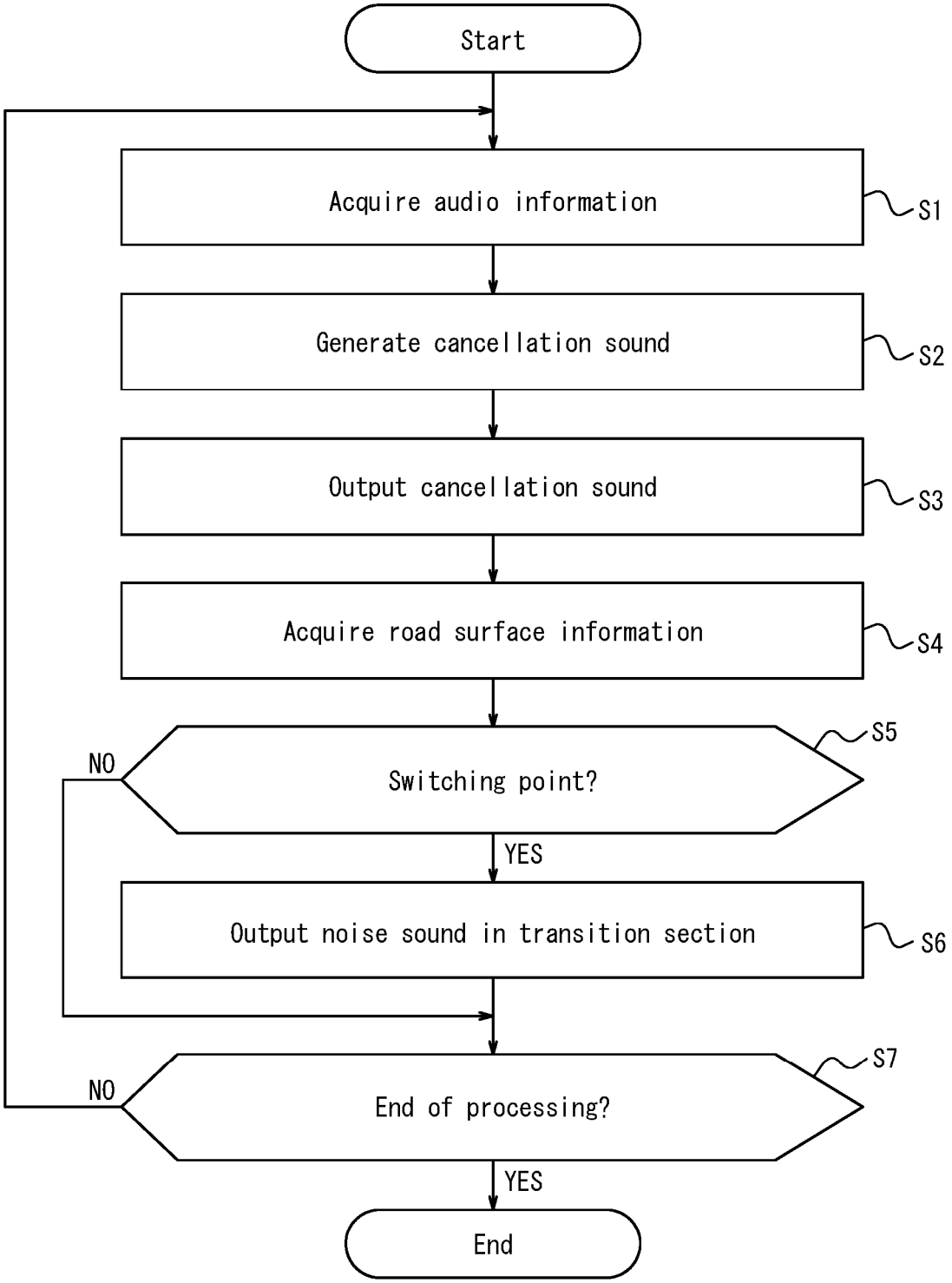

Start
Acquire audio information
S1
Generate cancellation sound
S2
Output cancellation sound
S3
Acquire road surface information
S4
S5
NO
Switching point?
YES
Output noise sound in transition section
S6
S7
NO
End of processing?
YES
End

FIG. 4

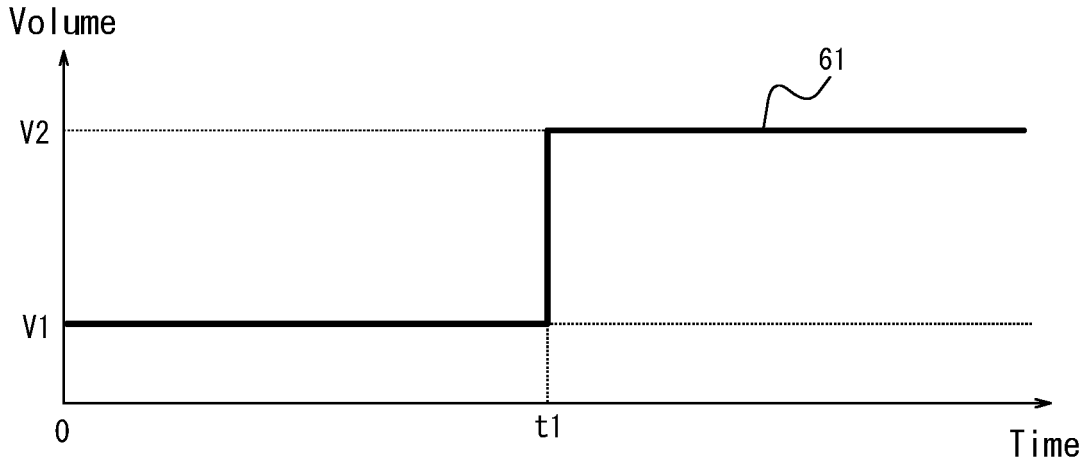


FIG. 5

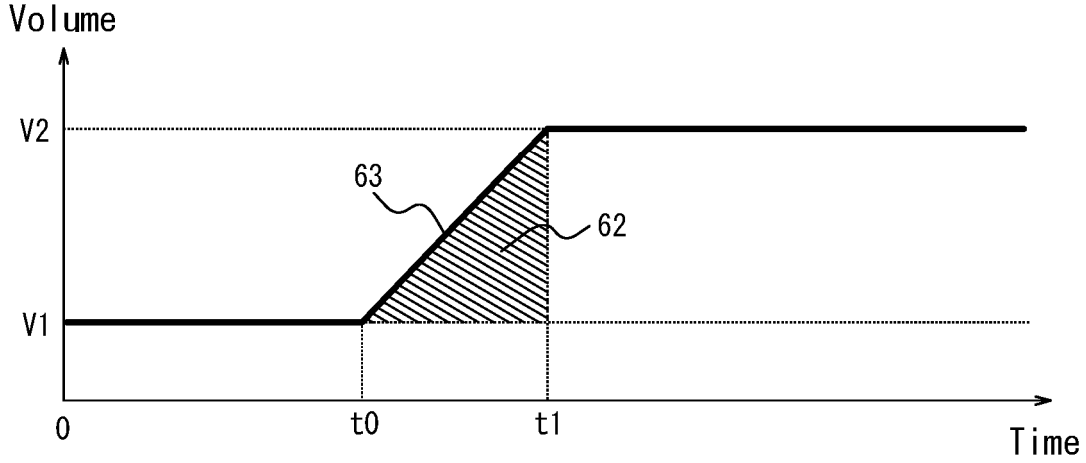


FIG. 6

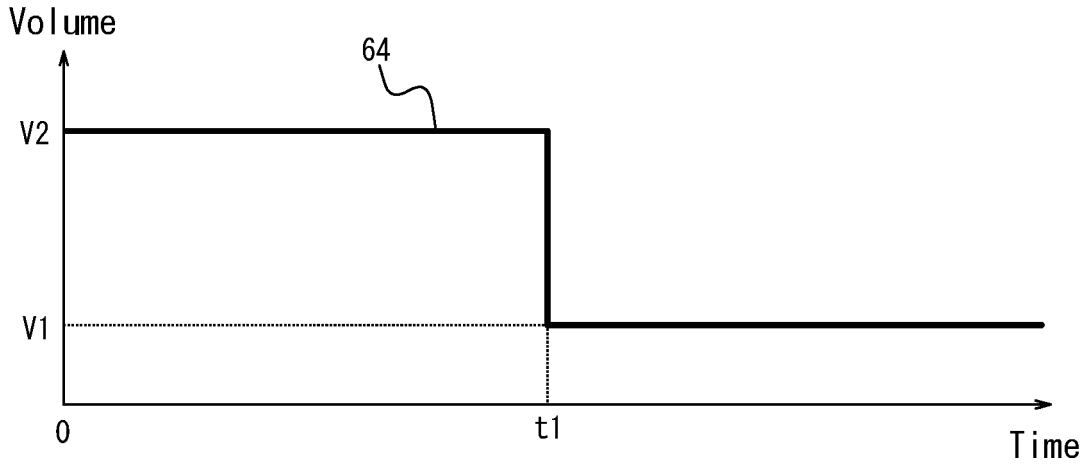
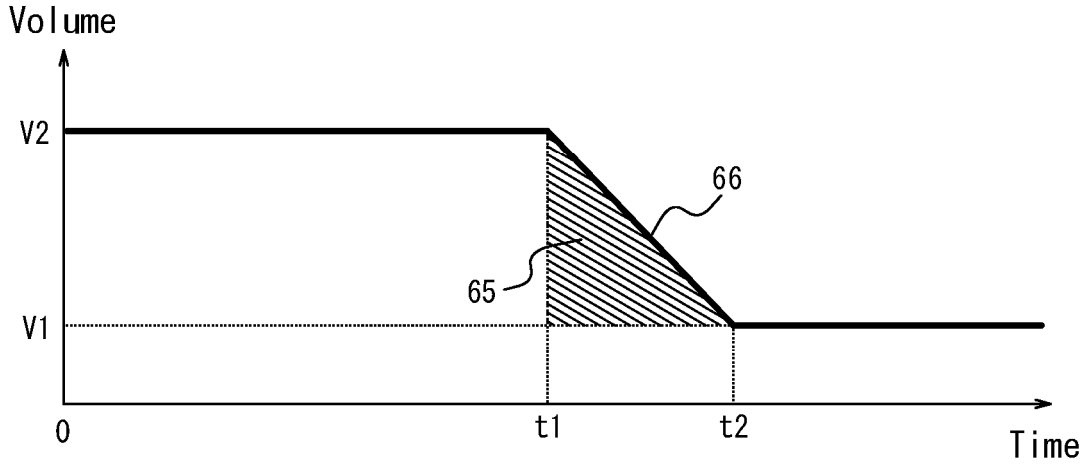


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/039716

A. CLASSIFICATION OF SUBJECT MATTER

G10K 11/178(2006.01)i; ***B60R 11/02***(2006.01)i; ***G10K 15/04***(2006.01)i
FI: G10K11/178 100; B60R11/02 S; G10K15/04 302G; G10K15/04 303E

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G10K11/178; B60R11/02; G10K15/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2025
Registered utility model specifications of Japan 1996-2025
Published registered utility model applications of Japan 1994-2025

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2022-46259 A (DENSO TEN LTD.) 23 March 2022 (2022-03-23) paragraphs [0015]-[0047], fig. 1-7	1-10
A	JP 2006-214465 A (NISSAN MOTOR CO., LTD.) 17 August 2006 (2006-08-17) paragraphs [0008]-[0120], fig. 1-16	1-10
A	JP 6-332469 A (HITACHI, LTD.) 02 December 1994 (1994-12-02) paragraphs [0013]-[0026], fig. 1-6	1-10
A	KR 10-2021-0045895 A (HYUNDAI MOBIS CO., LTD.) 27 April 2021 (2021-04-27) paragraphs [0018]-[0050], fig. 1-6	1-10

☐ Further documents are listed in the continuation of Box C.
☑ See patent family annex.

* Special categories of cited documents:
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 January 2025	**21 January 2025**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/039716

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2022-46259 A	23 March 2022	(Family: none)	
JP 2006-214465 A	17 August 2006	(Family: none)	
JP 6-332469 A	02 December 1994	(Family: none)	
KR 10-2021-0045895 A	27 April 2021	(Family: none)	

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2018169525 A **[0003]**