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(54) **AUDIBLE MODE-BASED ALERTING IN MULTI-MODE VEHICLE SYSTEMS**

(71) Applicant: **Rivian IP Holdings, LLC**, Irvine, CA (US)

(72) Inventors: **Kok Wei KOH**, Mountain View, CA (US); **Matthew Royce MILLER**, San Francisco, CA (US)

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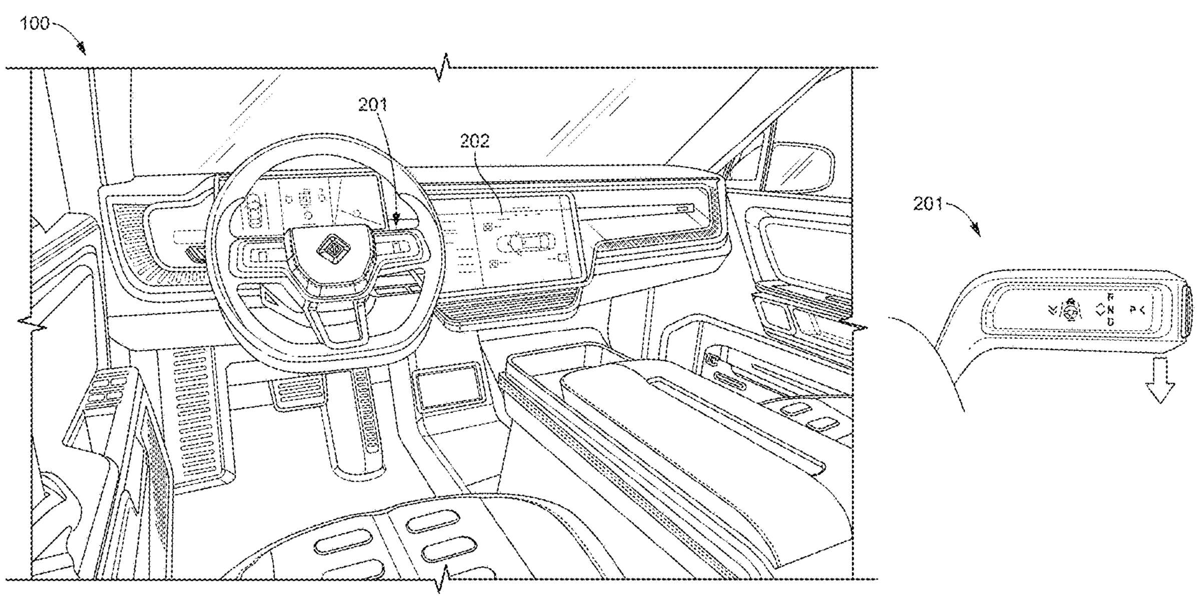
(57) **ABSTRACT**

In an embodiment, a method of audibly alerting a user of a vehicle includes receiving, in a vehicle control system, a first event associated with a first operational mode related to the vehicle and, responsive to the first event, triggering, by the vehicle control system, playback of first audio indicative of the first operational mode. The method also includes receiving, in the vehicle control system, a second event associated with a second operational mode related to the vehicle and, responsive to the second event, triggering, by the vehicle control system, playback of second audio in correspondence to a predefined time relationship between the first audio and the second audio, such that substantially continuous audio indicative of the second operational mode is played to the user. The substantially continuous audio includes at least a portion of the first audio and at least a portion of the second audio.



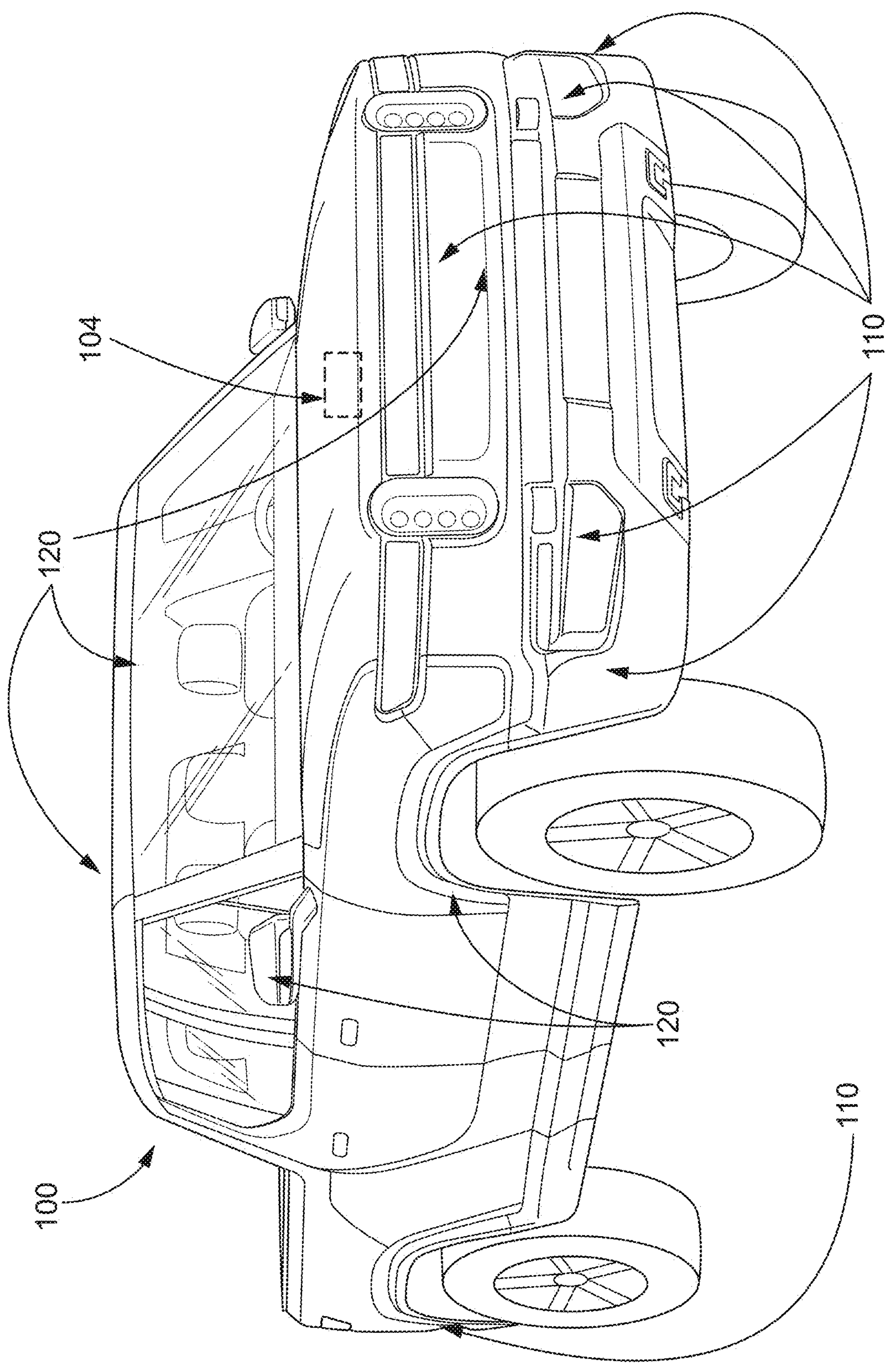


FIG. 1

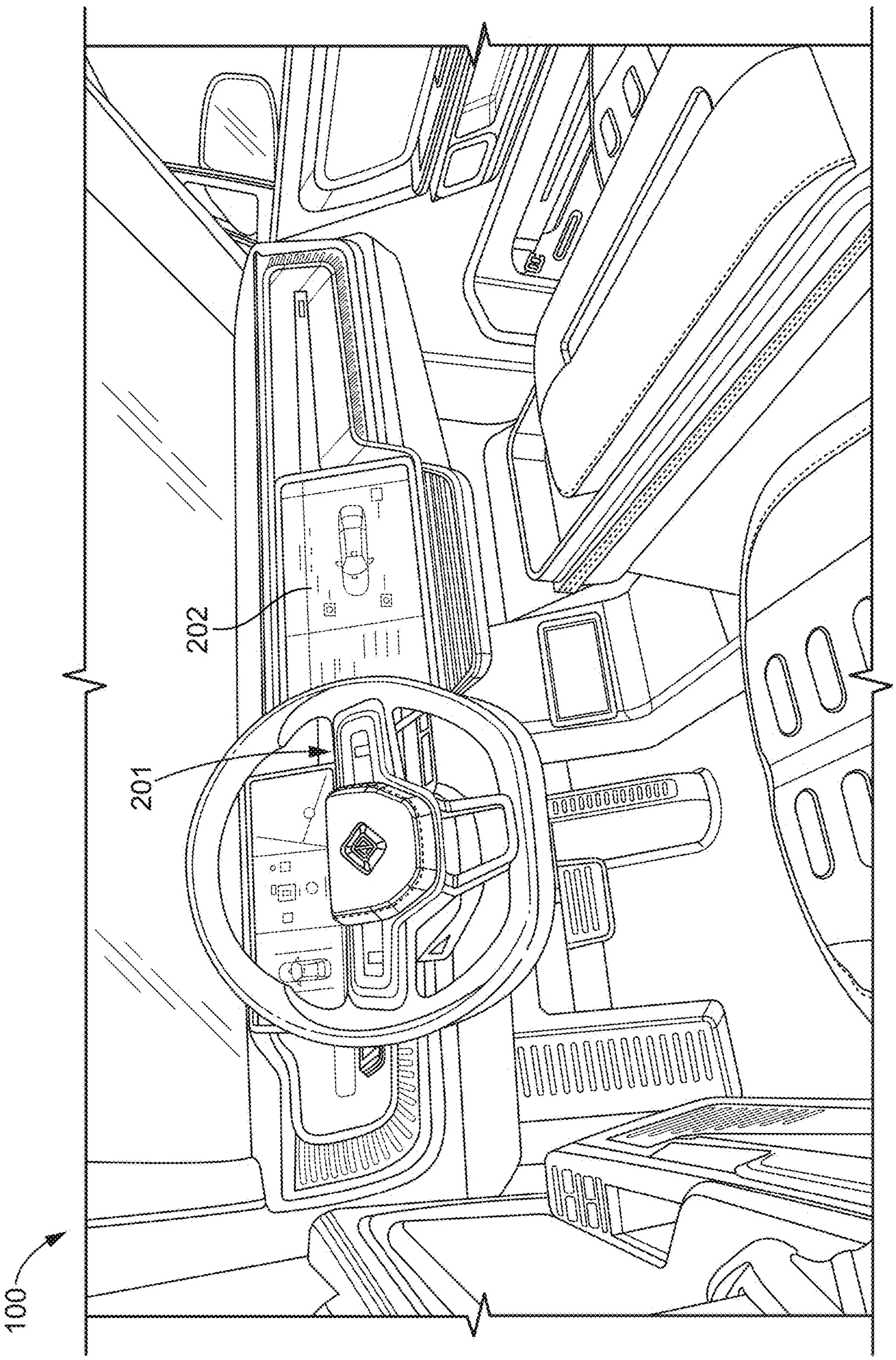


FIG. 2A

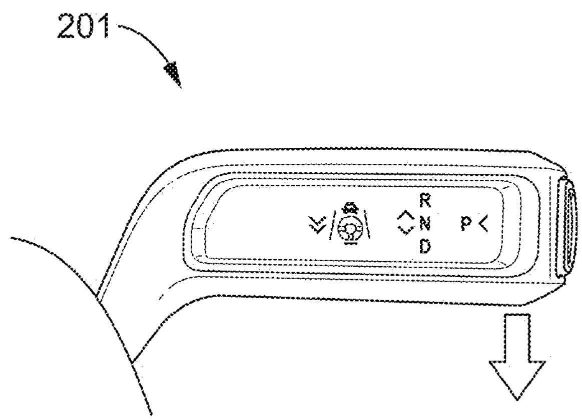


FIG. 2B

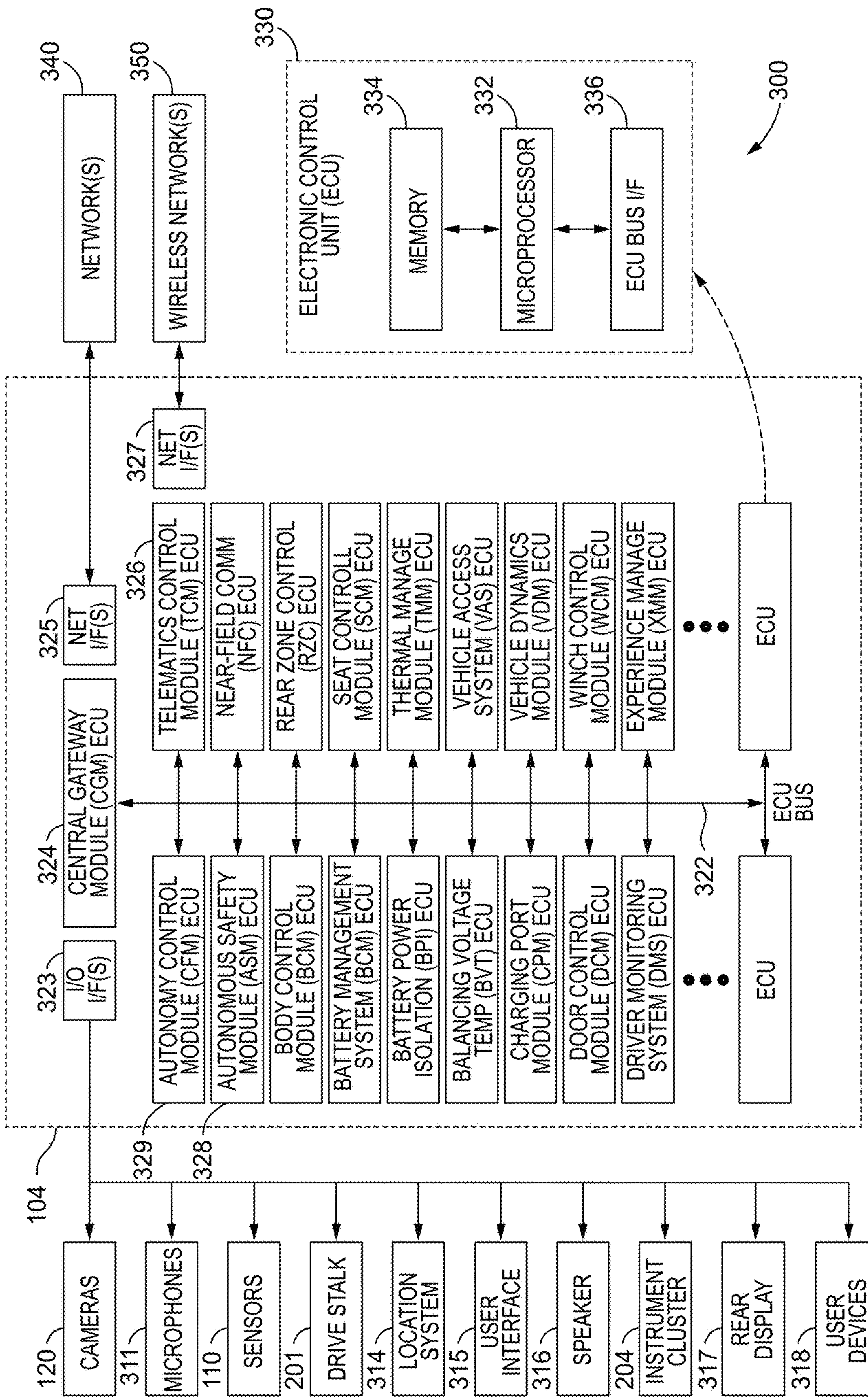

340
NETWORK(S)
350
WIRELESS NETWORK(S)
330
ELECTRONIC CONTROL UNIT (ECU)
334
MEMORY
332
MICROPROCESSOR
336
ECU BUS I/F
300
323
I/O I/F(S)
324
CENTRAL GATEWAY MODULE (CGM) ECU
325
NET I/F(S)
326
327
NET I/F(S)
AUTONOMY CONTROL MODULE (CFM) ECU
AUTONOMOUS SAFETY MODULE (ASM) ECU
BODY CONTROL MODULE (BCM) ECU
BATTERY MANAGEMENT SYSTEM (BCM) ECU
BATTERY POWER ISOLATION (BPI) ECU
BALANCING VOLTAGE TEMP (BVT) ECU
CHARGING PORT MODULE (CPM) ECU
DOOR CONTROL MODULE (DCM) ECU
DRIVER MONITORING SYSTEM (DMS) ECU
ECU
TELEMATICS CONTROL MODULE (TCM) ECU
NEAR-FIELD COMM (NFC) ECU
REAR ZONE CONTROL (RZC) ECU
SEAT CONTROLL MODULE (SCM) ECU
THERMAL MANAGE MODULE (TMM) ECU
VEHICLE ACCESS SYSTEM (VAS) ECU
VEHICLE DYNAMICS MODULE (VDM) ECU
WINCH CONTROL MODULE (WCM) ECU
EXPERIENCE MANAGE MODULE (XMM) ECU
ECU
322
ECU BUS
329
328
104
120
CAMERAS
311
MICROPHONES
110
SENSORS
201
DRIVE STALK
314
LOCATION SYSTEM
315
USER INTERFACE
316
SPEAKER
204
INSTRUMENT CLUSTER
317
REAR DISPLAY
318
USER DEVICES

FIG. 3

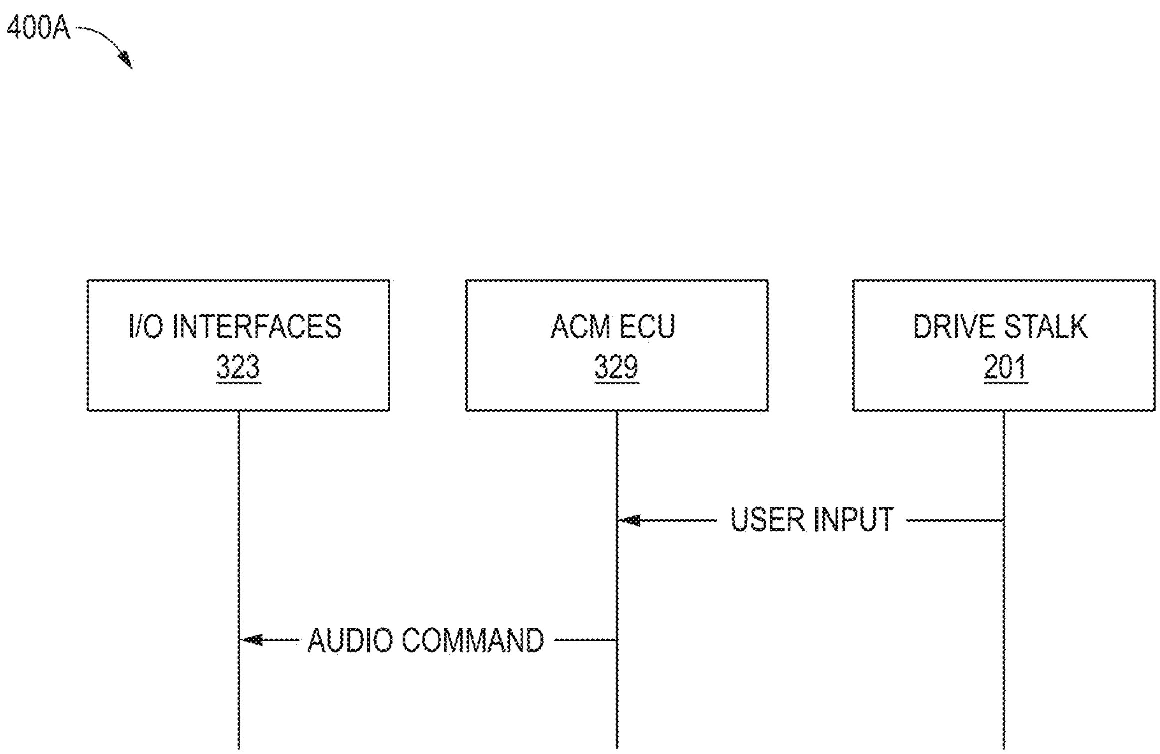

400A
I/O INTERFACES
323
ACM ECU
329
DRIVE STALK
201
USER INPUT
AUDIO COMMAND

FIG. 4A

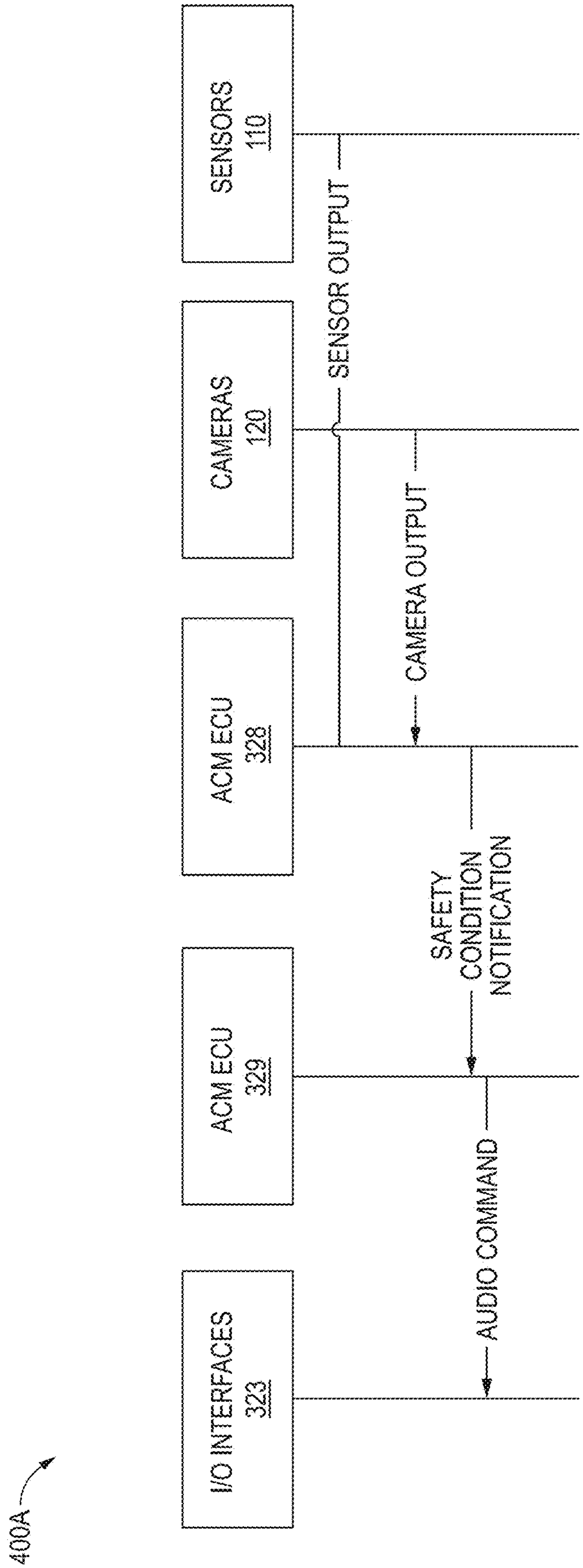

SENSORS
110
CAMERAS
120
ACM ECU
328
ACM ECU
329
I/O INTERFACES
323
SENSOR OUTPUT
CAMERA OUTPUT
SAFETY
CONDITION
NOTIFICATION
AUDIO COMMAND
400A

FIG. 4B

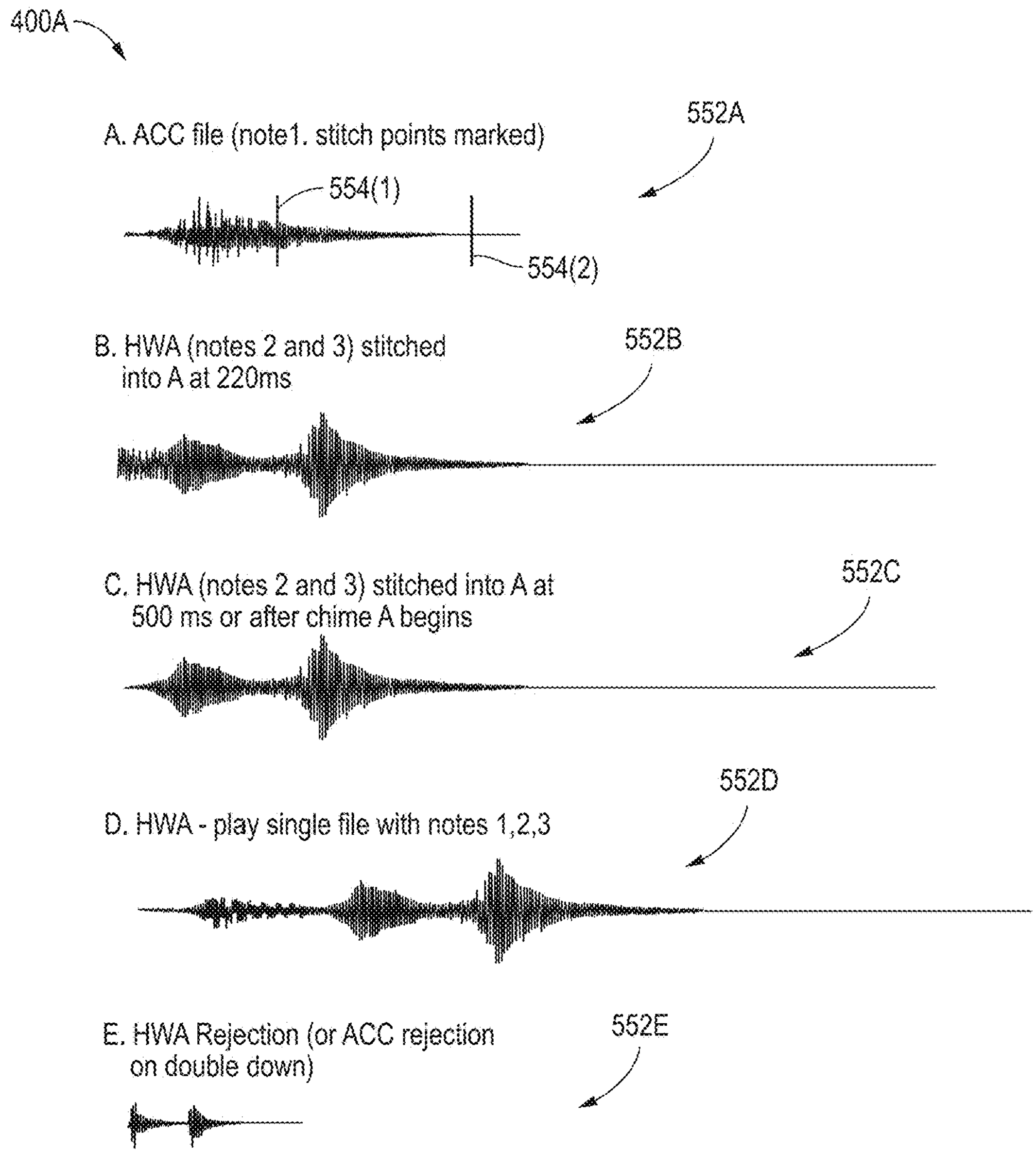

400A
A. ACC file (note1. stitch points marked)
552A
554(1)
554(2)
B. HWA (notes 2 and 3) stitched into A at 220ms
552B
C. HWA (notes 2 and 3) stitched into A at 500 ms or after chime A begins
552C
D. HWA - play single file with notes 1,2,3
552D
E. HWA Rejection (or ACC rejection on double down)
552E

FIG. 5

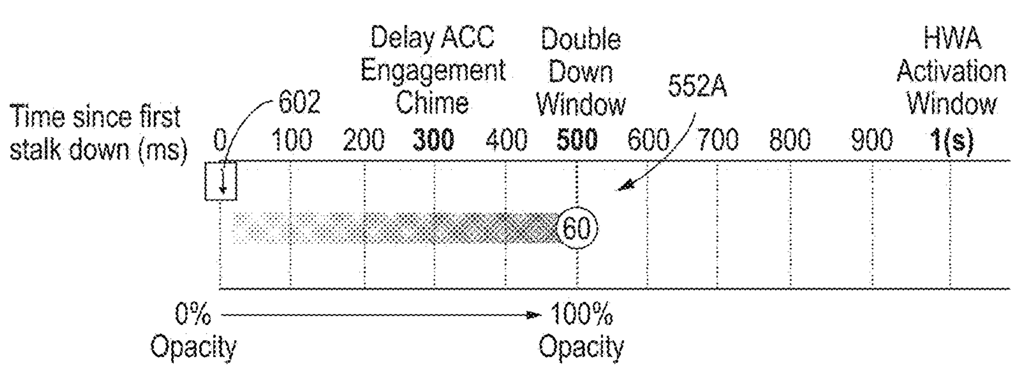

Delay ACC Engagement Chime
Double Down Window
HWA Activation Window
552A
602
Time since first stalk down (ms)
0
100
200
300
400
500
600
700
800
900
1(s)
60
0% Opacity
100% Opacity

FIG. 6

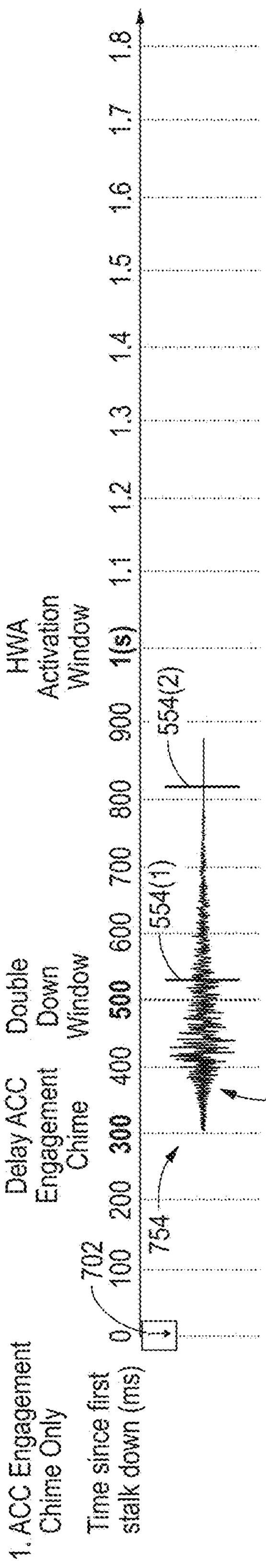


FIG. 7

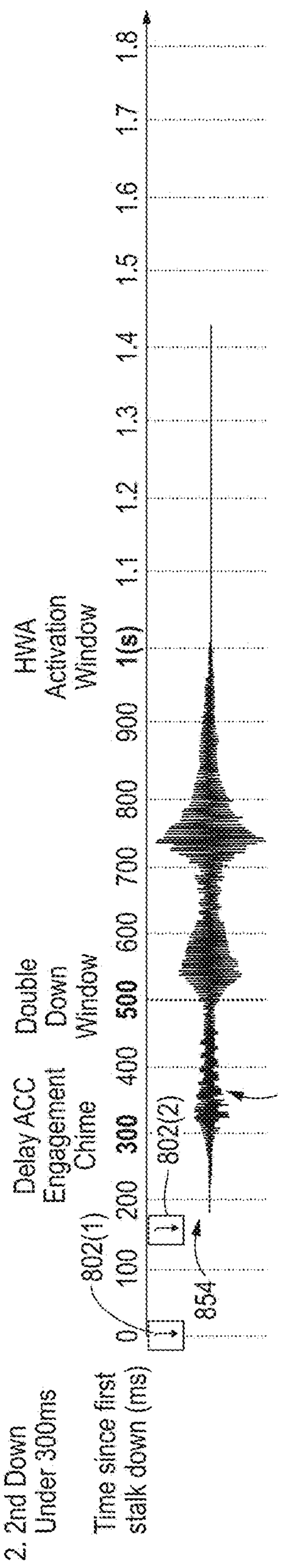


FIG. 8

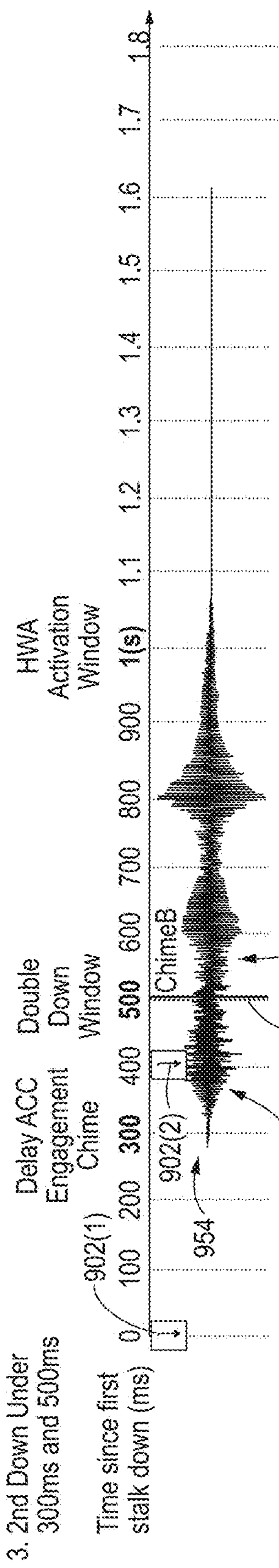


FIG. 9

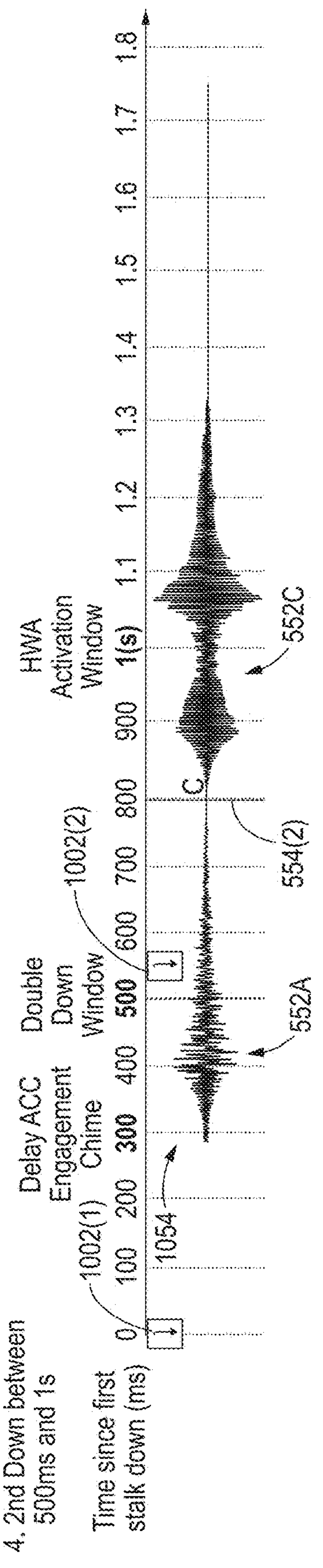

4. 2nd Down between 500ms and 1s
Time since first stalk down (ms)
0
100
200
300
400
500
600
700
800
900
1(s)
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Delay ACC Engagement Chime
Double Down Window
HWA Activation Window
1002(1)
1054
552A
1002(2)
554(2)
C
552C

FIG. 10

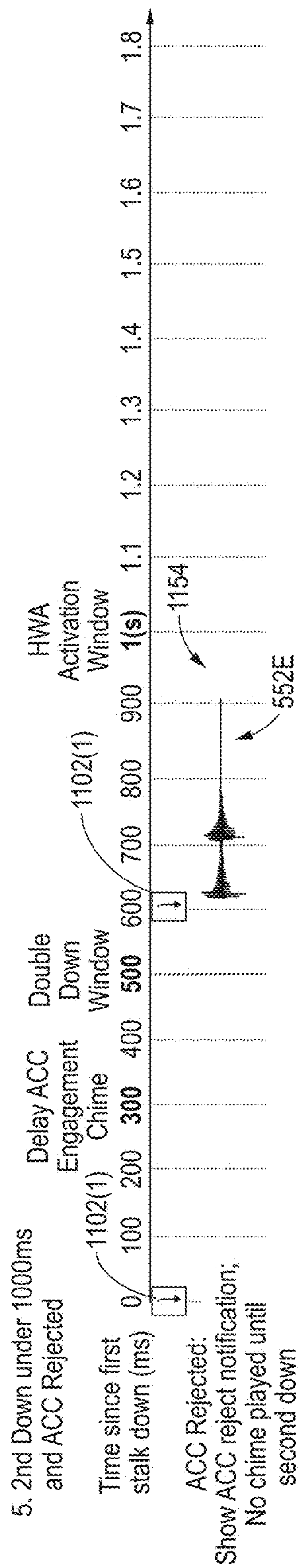

5. 2nd Down under 1000ms and ACC Rejected
Time since first stalk down (ms)
ACC Rejected: Show ACC reject notification; No chime played until second down
0
100
200
300
400
500
600
700
800
900
1(s)
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Delay ACC Engagement Chime
Double Down Window
HWA Activation Window
1102(1)
1102(1)
552E
1154

FIG. 11

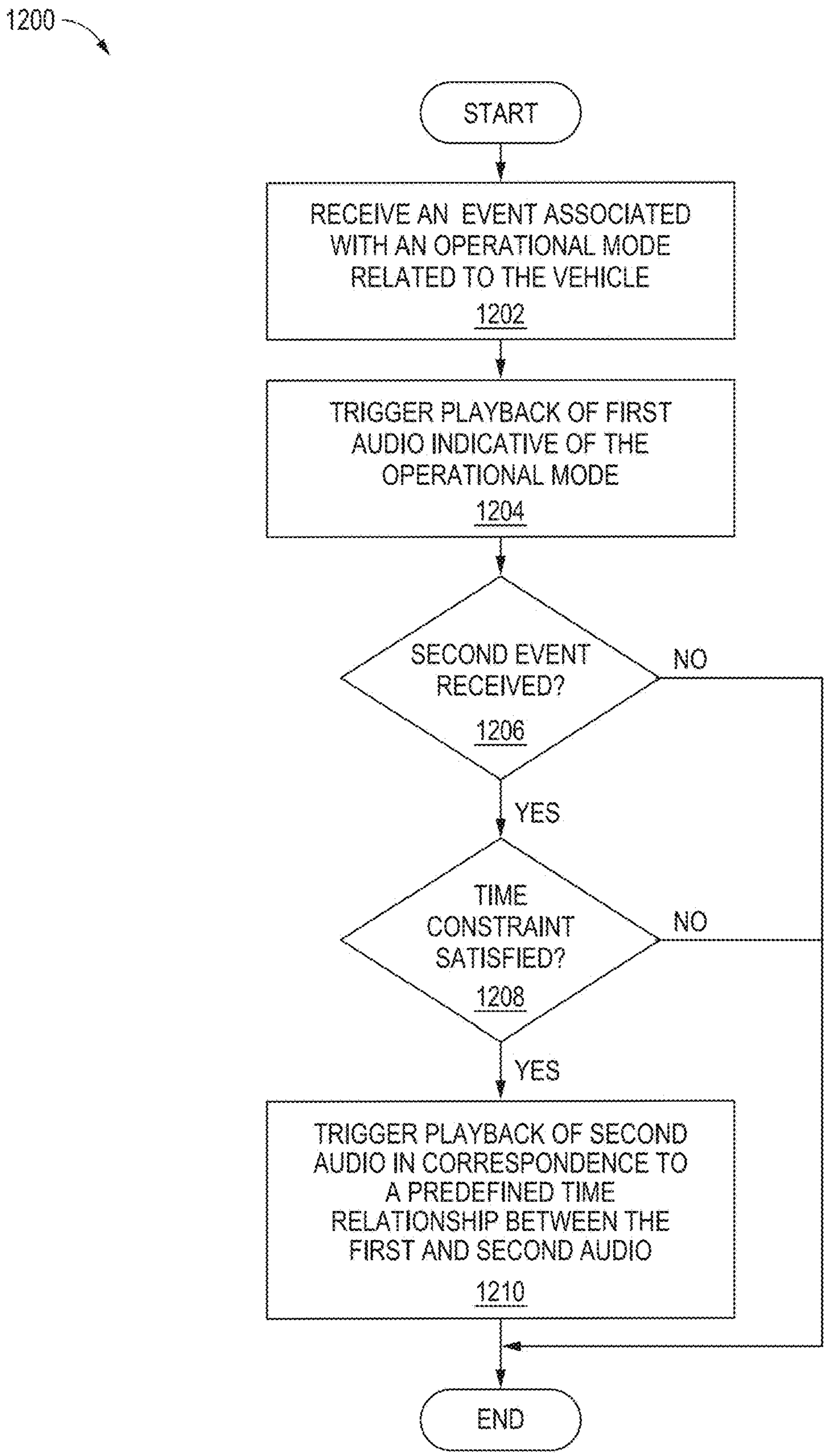

1200
START
RECEIVE AN EVENT ASSOCIATED WITH AN OPERATIONAL MODE RELATED TO THE VEHICLE
1202
TRIGGER PLAYBACK OF FIRST AUDIO INDICATIVE OF THE OPERATIONAL MODE
1204
SECOND EVENT RECEIVED?
1206
NO
YES
TIME CONSTRAINT SATISFIED?
1208
NO
YES
TRIGGER PLAYBACK OF SECOND AUDIO IN CORRESPONDENCE TO A PREDEFINED TIME RELATIONSHIP BETWEEN THE FIRST AND SECOND AUDIO
1210
END

FIG. 12

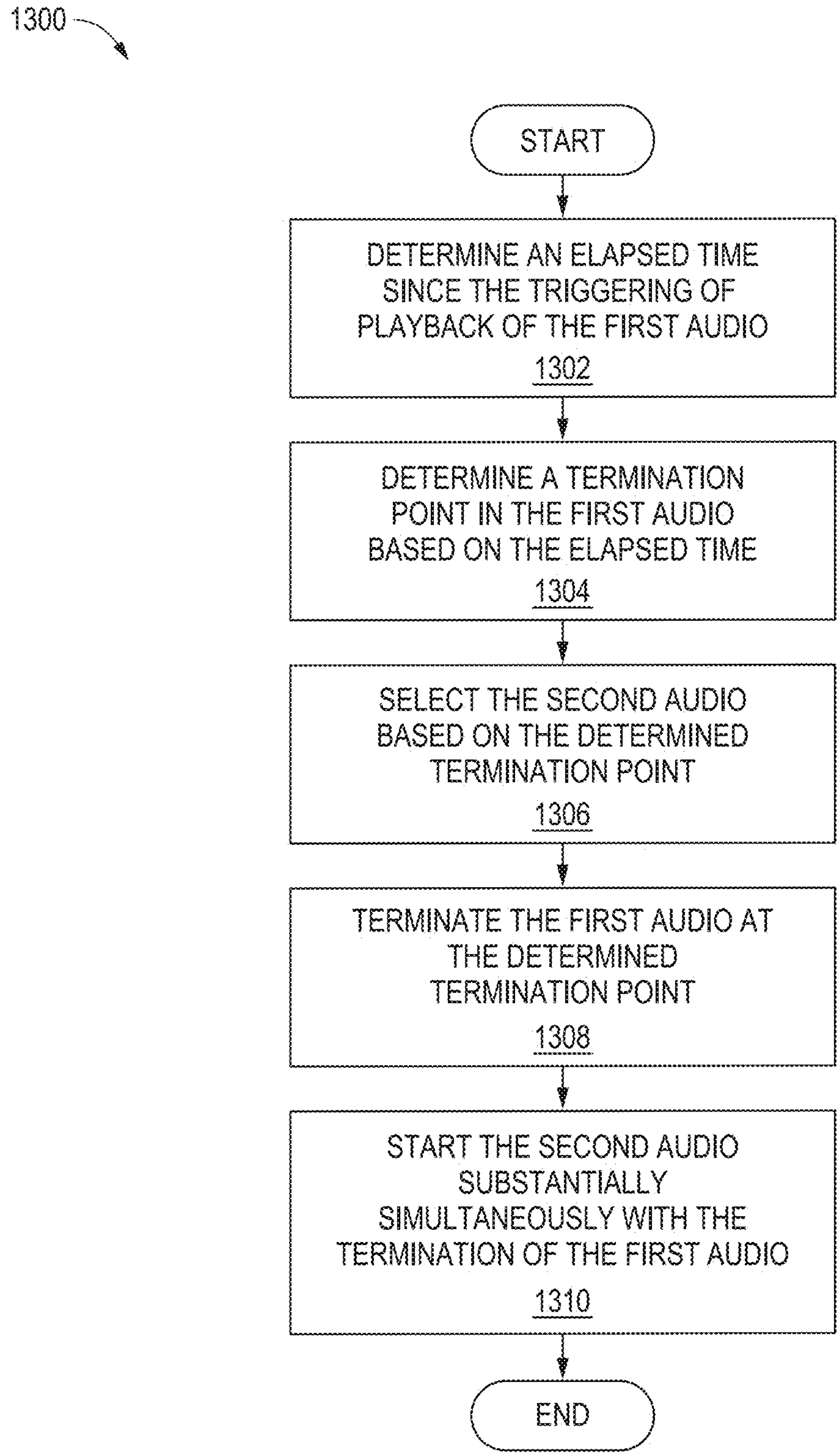

1300
START
DETERMINE AN ELAPSED TIME SINCE THE TRIGGERING OF PLAYBACK OF THE FIRST AUDIO
1302
DETERMINE A TERMINATION POINT IN THE FIRST AUDIO BASED ON THE ELAPSED TIME
1304
SELECT THE SECOND AUDIO BASED ON THE DETERMINED TERMINATION POINT
1306
TERMINATE THE FIRST AUDIO AT THE DETERMINED TERMINATION POINT
1308
START THE SECOND AUDIO SUBSTANTIALLY SIMULTANEOUSLY WITH THE TERMINATION OF THE FIRST AUDIO
1310
END

FIG. 13

AUDIBLE MODE-BASED ALERTING IN MULTI-MODE VEHICLE SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and benefit of U.S. Provisional Patent Application No. 63/555,393, filed Feb. 19, 2024, which is assigned to the assignee hereof and hereby expressly incorporated herein in its entirety as if fully set forth below and for all applicable purposes.

INTRODUCTION

[0002] The present disclosure relates to vehicle dynamics, and more particularly, but not by way of limitation, to audible mode-based alerting in multi-mode vehicle systems.

SUMMARY

[0003] In certain embodiments, one general aspect includes a method of audibly alerting a user of a vehicle. The method includes receiving, in a vehicle control system, a first event associated with a first operational mode related to the vehicle. The method also includes, responsive to the first event, triggering, by the vehicle control system, playback of first audio indicative of the first operational mode. The method also includes receiving, in the vehicle control system, a second event associated with a second operational mode related to the vehicle. The method also includes, responsive to the second event, triggering, by the vehicle control system, playback of second audio in correspondence to a predefined time relationship between the first audio and the second audio, such that substantially continuous audio indicative of the second operational mode is played to the user. The substantially continuous audio includes at least a portion of the first audio and at least a portion of the second audio.

[0004] In certain embodiments, another general aspect includes a system for audibly alerting a user of a vehicle. The system includes a vehicle speaker and a vehicle control system communicably coupled to the vehicle speaker. The vehicle control system is operable to receive a first event associated with a first operational mode related to the vehicle and, responsive to the first event, trigger playback, on the vehicle speaker, of first audio indicative of the first operational mode. The vehicle control system is further operable to receive a second event associated with a second operational mode related to the vehicle and, responsive to the second event, trigger playback, on the vehicle speaker, of second audio in correspondence to a predefined time relationship between the first audio and the second audio, such that substantially continuous audio indicative of the second operational mode is played to the user. The substantially continuous audio includes at least a portion of the first audio and at least a portion of the second audio.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates an example of a vehicle, in accordance with certain embodiments of the present disclosure.

[0006] FIG. **2**A illustrates an example vehicle interior, in accordance with certain embodiments of the present disclosure.

[0007] FIG. **2**B illustrates an example of an input device proximate a driver, in accordance with certain embodiments of the present disclosure.

[0008] FIG. **3** illustrates a block diagram of example components of a vehicle, in accordance with certain embodiments of the present disclosure.

[0009] FIG. **4**A illustrates an example of a sequence diagram for audibly alerting a user of a vehicle in response to user engagement of an operational mode, in accordance with certain embodiments of the present disclosure.

[0010] FIG. **4**B illustrates an example of a sequence diagram for audibly alerting a user of a vehicle in response to automated notifications of safety conditions, in accordance with certain embodiments of the present disclosure.

[0011] FIG. **5** illustrates an example of audio files that can be utilized for audibly alerting the user of vehicle, in accordance with certain embodiments of the present disclosure.

[0012] FIG. **6** illustrates an example of faded-in playback of an audio file, in accordance with certain embodiments of the present disclosure.

[0013] FIG. **7** illustrates an example of audibly alerting for ACC engagement, in accordance with to certain embodiments of the present disclosure.

[0014] FIG. **8** illustrates an example of audibly alerting for HWA engagement, in accordance with certain embodiments of the present disclosure.

[0015] FIG. **9** illustrates another example of audibly alerting for HWA engagement, in accordance with certain embodiments of the present disclosure.

[0016] FIG. **10** illustrates another example of audibly alerting for HWA engagement, in accordance with certain embodiments of the present disclosure.

[0017] FIG. **11** illustrates an example of audibly alerting for rejection of ACC and/or HWA, in accordance with certain embodiments of the present disclosure.

[0018] FIG. **12** illustrates an example of a process for audibly alerting a user, in accordance with certain embodiments of the present disclosure.

[0019] FIG. **13** illustrates an example of a process for triggering playback of second audio after first audio has already been triggered, in accordance with certain embodiments of the present disclosure.

DETAILED DESCRIPTION

[0020] In certain vehicles, different operational modes can be engaged based on the timing of particular types of events that occur during vehicle operation. For example, a single event can correspond to engagement of one operational mode, while two events in rapid succession can correspond to engagement of a different operational mode. The operational modes can relate, for example, to an advanced driver-assistance system (ADAS) of the vehicle. In various embodiments, the events can be user inputs (e.g., a button press, a pull-down of a drive stalk, etc.), automated indicators of safety conditions (e.g., a notification from a blind spot monitoring system), and/or the like.

[0021] In some such vehicles, different audible alerts can be provided to a user (e.g., driver) based on the operational mode. Audible alerts can include sounds, such as chimes, notes, chirps, alarms, beeps, short phrases, and/or the like, that serve a notification or reporting function for the user. Audible alerts can be advantageous since they notify the user in a manner that is not visually distracting. However, from the perspective of a vehicle system, it is not generally known at the time of a first event whether there will be a second event. Consequently, it is technically challenging to audibly alert the user, timely and accurately, based on a current operational mode of the vehicle.

[0022] For example, in certain vehicles, a user can engage different operational modes via the same input device (e.g., a drive stalk). User inputs via the input device can be treated as events, the timing of which impacts which mode is engaged. According to this example, the operational modes can correspond to automation levels, such as levels of automatic driver assistance provided by the ADAS, where the automation levels progressively increase in the amount of automatic driver assistance provided. Examples of levels of automatic driver assistance are adaptive cruise control (ACC) and highway assistance (HWA). For example, one user input may be interpreted as engaging one level of automatic driver assistance, such as ACC, while two user inputs in rapid succession may be interpreted as engaging a higher level of automatic driver assistance, such as HWA.

[0023] As mentioned above, from the perspective of a vehicle system, it is not generally known at the time of a first user input whether there will be a second user input. Therefore, if the vehicle system initiates an audible alert upon receipt of the first user input (e.g., an alert that ACC is engaged), such alert may be rendered erroneous upon subsequent receipt of the second user input (e.g., because the second user input is indicative of HWA being engaged). In that scenario, the erroneous alert could cause user confusion and potentially compromise vehicle safety. Furthermore, if HWA, for example, is unavailable for any reason (e.g., due to a state of the vehicle), the alert that ACC is engaged may be particularly misleading and confusing, since the user did not request ACC and, in fact, will not be able to engage HWA.

[0024] Similar problems arise relative to other types of vehicle operational modes. For example, in certain vehicles, a vehicle system can engage different operational modes based on automated notifications of safety conditions relative to the vehicle. The automated notifications can be treated as events, the timing of which impacts which mode is engaged. The automated notifications can be generated, for example, by a blind spot monitoring system or other safety system. According to this example, the operational modes can correspond to alerting levels provided by the ADAS, where the alerting levels progressively increase in severity and/or urgency. For example, one automated notification may be interpreted as engaging one alerting level, while two automated notifications in rapid succession may be interpreted as engaging a higher alerting level. Each alerting level can be associated with different audible alerting (e.g., different sounds, tempo, pitch, etc.), thus creating potential for user confusion similar to the discussion above relative to levels of automatic driver assistance.

[0025] Taking a vehicle system with two operational modes as an example, one way to approach the above problem is for the vehicle system to maintain two audio segments, one for each operational mode. Upon receipt of the first event, the audio segment for the first operational mode could be played. Upon receipt of the second event, the audio segment for the first operational mode could be terminated, if it is still playing, and the audio segment for the second operational mode could then be played in its entirety. From the perspective of the user, however, the playback and subsequent termination of the audio segment for the first operational mode might be noticeably abrupt, with the playback sounding "clipped." Further, the fact that both audio segments were at least partially played might cause user confusion about which operational mode is currently engaged.

[0026] The present disclosure describes examples of audibly alerting a user regarding a current operational mode of a vehicle, for example, to minimize user confusion and improve audio clarity. In various embodiments of the present disclosure, after receiving an event, a vehicle system can trigger first audio indicating engagement of a first operational mode (e.g., an audio file containing a chime). If a second event is received while the first audio is playing, the vehicle system can stop the first audio at a predefined termination point and, substantially simultaneously, trigger a second audio segment (e.g., an audio file containing one or more additional chimes to complete a multi-chime sequence). In various embodiments, the user can thereby hear substantially continuous audio feedback indicating engagement of the second operational mode.

[0027] For illustrative purposes, examples are periodically provided herein relative to levels of automatic driver assistance provided by an ADAS (e.g., ACC and HWA), sometimes referred to herein as "ADAS automation levels." It should be appreciated, however, that the principles described herein are also applicable to other types of operational modes, such as levels of alerting provided by an ADAS, sometimes referred to herein as "ADAS alerting levels." Other examples of operational modes to which the principles described herein may be applied will be apparent to one skilled in the art after a detailed review of the present disclosure.

[0028] FIG. **1** illustrates an example vehicle **100**, in accordance with certain embodiments of the present disclosure. Vehicle **100** may include multiple sensors **110**, multiple cameras **120**, and a control system **104**. As an example and not by way of limitation, the sensors **110** may be, or include, an accelerometer, a gyroscope, a magnetometer, a global positioning satellite (GPS) signal sensor, a vibration sensor (e.g., piezoelectric accelerometer), a light detection and ranging (LiDAR) sensor, a radio detection and ranging (RADAR) sensor, an ultrasonic sensor, a temperature sensor, a pressure sensor, a humidity sensor, a chemical sensor, an electromagnetic proximity sensor, an electric current sensor, a motion sensor, another suitable sensor, or a combination thereof. As an example and not by way of limitation, a camera **120** may be a still image camera, a video camera, a 3D scanning system (e.g., based on modulated light, laser triangulation, laser pulse, structured light, light detection and ranging (LiDAR)), an infrared camera, another suitable camera, or a combination thereof. Vehicle **100** may include various controllable components (e.g., doors, seats, windows, lights, HVAC, entertainment system, security system) and instrument and information displays and/or interactive interfaces.

[0029] While FIG. **1** depicts one or more of cameras **120** in particular locations, it should be appreciated that any suitable number of cameras may be employed (e.g., any number of cameras positioned at a front, rear and each side of vehicle **100**). Such cameras **120** may be mounted at any suitable respective positions or portions of vehicle **100** in order to facilitate the capturing of images of the entire region or environment around vehicle **100**, while vehicle **100** is stationary or in motion. A series of images may be captured by cameras **120**, including any suitable number of images. In some embodiments, images may be captured repeatedly, e.g., at a predetermined frequency, to capture the surrounding environment of vehicle **100**. In similar fashion, sensors **110** may be deployed in any suitable number and/or in any suitable location relative to vehicle **100**.

[0030] More particularly, in certain embodiments, cameras **120** are configured to capture images of blind spots relative to vehicle **100**, as all or part of their field of view. For example, in certain embodiments, at least one of the cameras **120** is configured to capture images of a blind spot on a driver side of vehicle **100**, and at least one of the cameras **120** is configured to capture images of a blind spot on a passenger side of vehicle **100**. In addition, or alternatively, sensors **110** are configured to produce outputs indicative of a presence of a vehicle or object in such a blind spot, for example, on the driver side or passenger side of vehicle **100**.

[0031] Control system **104** may enable control of various systems on-board the vehicle. Control system **104** may communicate with, and control operation of, cameras **120** and sensors **110**. In certain aspects, control system **104** can provide ADAS functionality for multiple operational modes, including functionality to audibly alert a user in a way that is indicative of a current operational mode. In some embodiments, the operational modes can correspond to ADAS automation levels, such as ACC and HWA, where the ADAS automation levels progressively increase in the amount of automatic driver assistance provided. In addition, or alternatively, the operational modes can correspond to ADAS alerting levels, where the ADAS alerting levels progressively increase in severity and/or urgency. Example operation of control system **104** will be described in greater detail relative to FIG. **3**.

[0032] FIG. **2**A illustrates an example interior of vehicle **100**, in accordance with certain embodiments of the present disclosure. FIG. **2**B illustrates an example input device in the example interior of FIG. **2**A, in accordance with certain embodiments of the present disclosure. FIGS. **2**A-B will be described collectively. In the example of FIGS. **2**A-B, a drive stalk **201** and an infotainment display **202** are shown.

[0033] In certain embodiments, an input device proximate a user (e.g., a driver), such as the drive stalk **201**, can be employed by the user to engage a desired ADAS automation level. For example, one user input via the drive stalk **201** (e.g., the user pulling down the drive stalk **201** one time) may be interpreted by the control system **104** as engaging one level of automatic driver assistance, such as ACC. Continuing the same example, two user inputs that satisfy a time constraint relative to each other (e.g., the user pulling down the drive stalk **201** two times within 300 ms, 500 ms, 1 s, etc.) may be interpreted by the control system **104** as engaging a higher level of automatic driver assistance, such as HWA. For simplicity of description, examples will be described herein with respect to the drive stalk **201**. It should be appreciated, however, that the principles described herein are similarly applicable to other input mechanisms that may be proximate the driver, including the infotainment display **202** in some cases.

[0034] FIG. **3** illustrates a block diagram **300** of example components of vehicle **100**, in accordance with certain embodiments of the present disclosure. As described relative to FIG. **1**, vehicle **100** includes control system **104**, where control system **104** is configured to perform the functions described relative to FIGS. **1** and **2**A-B, as well as other functions for operation of vehicle **100**. In many embodiments, control system **104** includes a number of electronic control units (ECUs) **330** coupled to ECU Bus **322**. Each ECU **330** performs a particular set of functions, and includes, inter alia, microprocessor **332** coupled to memory **334** and ECU Bus I/F **336**. In certain embodiments, control system **104** may include one or more system-on-chips (SOCs). Each SOC may include a number of multi-core processors coupled to a high-speed interconnect and on-chip memory, and may perform a much larger set of functions than a single ECU **330**.

[0035] Control system **104** is coupled to sensors, input/output (I/O) devices and actuators, as well as other components within a propulsion system, an energy storage system, and/or an accessory system. The sensors may include, for example, cameras **120**, microphones **311**, sensors **110**, location system **314**, etc. The I/O devices may include, for example, user interface **315**, infotainment display **202**, speaker **316**, rear display **317**, drive stalk **201**, user devices **318**, etc. The actuators may include, for example, actuators that adjust cameras **120** and/or actuators that implement automatic driver assistance according to an applicable operational mode. Additionally, control system **104** may be coupled to network(s) **340**, network(s) **350**, etc. In certain embodiments, one or more ECUs **330** may include the necessary interfaces to be coupled directly to particular sensors, I/O devices, actuators and other vehicle system components.

[0036] Speaker **316** may be located at any location within the cabin of vehicle **100**, e.g., at a dashboard of vehicle **100** and/or on an interior portion of a vehicle door. In some embodiments, speaker **316** may be configured to play audio described herein based on commands, for example, from control system **104**. Although speaker **316** is described singly, speaker **316** can be representative of multiple speakers.

[0037] In many embodiments, control system **104** includes Central Gateway Module (CGM) ECU **324** which provides a central communications hub for vehicle **100**. CGM ECU **324** includes (or is coupled to) I/O interfaces **323** to receive data, send commands, etc., to and from the sensors, I/O devices, actuators and other vehicle system components. CGM ECU **324** also includes (or is coupled to) network interface(s) **325** that provides network connectivity through Controller Area Network (CAN) ports, Local Interconnect Network (LIN) ports, Ethernet ports, etc.

[0038] For example, CGM ECU **324** may receive data from cameras **120**, microphones **311**, sensors **110**, drive stalk **201** and location system **314**, as well as user interface **315**, and then communicate the data over ECU Bus **322** to the appropriate ECU **330**. Similarly, CGM ECU **324** may receive commands and data from the ECUs **330** and send them to the appropriate I/O devices, actuators and vehicle components. For example, a GUI widget may be sent to user interface **315** (e.g., infotainment display **202**, rear display **317**, and/or user devices **318**), and video data from cameras **120** may be sent to infotainment display **202**, rear display **317**, user devices **318** etc.

[0039] In many embodiments, control system **104** includes Telematics Control Module (TCM) ECU **326** which provides a vehicle communication gateway for vehicle **100**. TCM ECU **326** includes (or is coupled to) network interface

(s) **327** that provides network connectivity to support functionality such as over-the-air (OTA) software updates, communication between the vehicle and the internet, communication between the vehicle and a computing device, in-vehicle navigation, vehicle-to-vehicle communication, communication between the vehicle and landscape features (e.g., automated toll road sensors, automated toll gates, power dispensers at charging stations), automated calling functionality, etc.

[0040] In many embodiments, control system **104** also includes, inter alia, Autonomy Control Module (ACM) ECU, Autonomous Safety Module (ASM) ECU, Body Control Module (BCM) ECU, Battery Management System (BMS) ECU, Battery Power Isolation (BPI) ECU, Balancing Voltage Temperature (BVT) ECU, Door Control Module (DCM) ECU, Driver Monitoring System (DMS) ECU, Near-Field Communication (NFC) ECU, Rear Zone Control (RZC) ECU, Seat Control Module (SCM) ECU, Thermal Management Module (TMM) ECU, Vehicle Access System (VAS) ECU, Vehicle Dynamics Module (VDM) ECU, Winch Control Module (WCM) ECU, an Experience Management Module (XMM) ECU, etc.

[0041] In some embodiments, ASM ECU **328** and/or another of the ECUs **330** may provide functions to support driving safety by monitoring sensors **110** and/or cameras **120**. In various embodiments, ASM ECU **328** may be configured to identify vehicles or other objects in the images captured by cameras **120** using any suitable image recognition technique. In some cases, object proximity to vehicle **100** may be estimated based on an object detection representation. In addition, or alternatively, ASM ECU **328** can identify a presence of a vehicle or other object in a blind spot based on an output from one of the sensors **110**, or based on a combination of such outputs.

[0042] In certain embodiments, ASM ECU **328** may be configured to generate a notification of a safety condition, such as a notification indicative of a presence of a vehicle or other object relative to a portion of vehicle **100**. The safety notification may indicate, for example, the portion of the vehicle **100**, such as the driver side, passenger side, front, rear, etc. In certain embodiments, the portion of the vehicle may correspond to a blind spot, for example, on the driver side or passenger side of vehicle **100**.

[0043] In some embodiments, the ACM ECU **329** and/or other of the ECUs may provide functions to cause the user to be audibly alerted, via speaker **316**, based on a current operational mode related to vehicle **100**. In certain embodiments, the memory **334** of the ACM ECU **329**, or other memory, can maintain audio files with predefined time relationships relative to each other. In various embodiments, the predefined time relationships enable the ACM ECU **329** to gracefully splice together two or more of the audio files to form substantially continuous audio feedback to the user.

[0044] For example, in response to receiving a first event associated with a first operational mode, the ACM ECU **239** can trigger playback of a first audio file indicative of that mode. If a second event is received that satisfies a time constraint relative to the first event (e.g., within 300 ms, 500 ms, 1 s, etc.), the ACM ECU **329** can dynamically cause playback to switch to a second audio file based on a predefined time relationship between the two files. According to this example, a played portion of the first audio file and a played portion of the second audio file can together form substantially continuous audio feedback indicative of the second operational mode. Examples will be described in greater detail relative to FIGS. **5-12**.

[0045] FIG. **4**A illustrates an example of a sequence diagram **400**A for audibly alerting the user of vehicle **100** in response to user engagement of an operational mode, in accordance with certain embodiments of the present disclosure. Generally, the sequence diagram **400**A depicts the I/O interfaces **323**, the ACM ECU **329**, and the drive stalk **201**.

[0046] In the example of FIG. **4**A, the drive stalk **201** produces a user input, for example, in response to a user action relative thereto (e.g., a pulldown as described relative to FIGS. **2**A-B). The user input may be associated with an operational mode related to vehicle **100**, such as an ADAS automation level. For example, if the user input satisfies a time constraint relative to a previously received user input (e.g., within 300 ms, 500 ms, 1 s, etc.), the associated operational mode may be HWA. Continuing the example, if the user input does not satisfy a time constraint relative to any previously received user input, the associated operational mode may be ACC.

[0047] The ACM ECU **329** may receive the user input and, based thereon, issue an audio command via the I/O interfaces **232**. The audio command may cause substantially continuous audio feedback indicative of the associated operational mode to be output to the speaker **316** discussed relative to FIG. **3**. As discussed above relative to FIG. **3**, such playback can involve playing one audio file and/or gracefully splicing together multiple audio files for playback. Examples of the substantially continuous audio feedback will be described in greater detail relative to FIGS. **5-12**.

[0048] FIG. **4**B illustrates an example of a sequence diagram **400**B for audibly alerting the user of vehicle **100** in response to automated notifications of safety conditions, in accordance with certain embodiments of the present disclosure. Generally, the sequence diagram **400**B depicts the I/O interfaces **323**, the ACM ECU **329**, the ASM ECU **328**, the cameras **120**, and the sensors **110**.

[0049] The ASM ECU **328** may receive a sensor output from one or more of the sensors **110** and/or a camera output from one or more of the cameras **120**. As described relative to FIG. **3**, the ASM ECU **328** may generate, based on the sensor output and/or the camera output, an automated notification of a safety condition, such as a notification indicating a presence of a vehicle or other object relative to a portion of vehicle **100**.

[0050] The notification of the safety condition may be associated with an operational mode related to vehicle **100**, such as an ADAS alerting level. For example, if the notification satisfies a time constraint relative to a previously received safety condition notification (e.g., within 300 ms, 500 ms, 1 s, etc.), the associated operational mode may be a second or more severe alerting level. Continuing the example, if the notification does not satisfy a time constraint relative to any previously received safety condition notification, the associated operational mode may be a first or initial alerting level.

[0051] The ACM ECU **329** may receive the notification of the safety condition and, based thereon, issue an audio command via the I/O interfaces **323**. The audio command may cause substantially continuous audio feedback indicative of the associated operational mode to be output to the speaker **316** discussed relative to FIG. **3**. As discussed above relative to FIG. **3**, such playback can involve playing one audio file and/or gracefully splicing together multiple audio files for playback. Examples of the substantially continuous audio feedback will be described in greater detail relative to FIGS. **5-12**.

[0052] FIGS. **5-11** illustrate examples of audible alerting based on ADAS automation levels, in accordance with certain embodiments of the present disclosure. In general, the ADAS automation levels progressively increase in the amount of automatic driver assistance provided in vehicle **100**. Although the ADAS automation levels can include any number of levels and/or types of automation, for simplicity of description, in the example of FIGS. **5-11**, the automation levels are described as including ACC and HWA.

[0053] FIG. **5** illustrates an example of audio files **552** that can be utilized for audibly alerting the user of vehicle **100**, according to certain embodiments of the present disclosure. In various embodiments, the audio files **552** can be maintained in the memory **334** of the ACM ECU **329**, for example, as discussed relative to FIG. **3**.

[0054] In the example of FIG. **5**, the audio files **552** include five audio files, namely, audio files **552**A-E. It should be appreciated that the audio files **552** can include any suitable number of audio files for a given implementation. As described in greater detail below, some of the audio files **552** can have predefined time relationships with each other to facilitate graceful splicing thereof for substantially continuous audio feedback.

[0055] The audio file **552**A defines an audio segment indicative of ACC. The audio file **552**A can include, for example, one or more chimes, notes, chirps, alarms, beeps, short phrases, and/or other sounds. In certain embodiments, the audio file **552**A, if played to completion (e.g., via the speaker **316** of FIG. **3**), is substantially continuous audio that indicates to the user of vehicle **100** that ACC is engaged.

[0056] The audio file **552**A includes two predefined termination points, namely, a termination point **554**(**1**) and a termination point **554**(**2**). The termination points **554**(**1**) and **554**(**2**) can be maintained with the audio file **552**A, for example, in the memory **334** of the ACM ECU **529** or in other memory. In the example of FIG. **5**, the termination point **554**(**1**) corresponds to approximately 200 ms into the audio file **552**A, while the termination point **554**(**2**) corresponds to a range covering approximately 500 ms to an end of the audio file **552**A.

[0057] The audio files **552**B and **552**C are audio segments associated with HWA that have predefined time relationships with the audio file **552**A. In particular, the audio file **552**B has a predefined time relationship with the audio file **552**A based on the termination point **554**(**1**). According to the example of FIG. **5**, if playback of the audio file **552**A is stopped at the termination point **554**(**1**) and, substantially simultaneously, playback of the audio file **552**B is triggered, then substantially continuous audio feedback indicative of HWA (i.e., that HWA is engaged) is played to the user, for example, via the speaker **316** of FIG. **3**. In this way, the audio file **552**A and the audio file **552**B are configured to be gracefully spliced together based on the termination point **554**(**1**). For example, the substantially continuous audio indicative of HWA can be a sequence of sounds (e.g., chimes or notes), with the audio file **552**A to the termination point **554**(**1**) including a first portion (e.g., a first sound) of the sequence and the audio file **552**B including a second portion (e.g., second and third sounds) of the sequence.

[0058] In similar fashion, the audio file **552**C has a predefined time relationship with the audio file **552**A based on the termination point **554**(**2**). According to the example of FIG. **5**, if playback of the audio file **552**A is stopped at the termination point **554**(**2**) (e.g., 500 ms into playback or thereafter) and, substantially simultaneously, playback of the audio file **552**B is triggered, then substantially continuous audio feedback indicative of HWA is played to the user, for example, via the speaker **316** of FIG. **3**. In this way, the audio file **552**A and the audio file **552**C are configured to be gracefully spliced together based on the termination point **554**(**2**). For example, the substantially continuous audio indicative of HWA can be a sequence of sounds (e.g., chimes or notes), with the audio file **552**A to the termination point **554**(**2**) including a first portion (e.g., a first sound) of the sequence and the audio file **552**C including a second portion (e.g., second and third sounds) of the sequence.

[0059] The audio file **552**D defines an audio segment indicative of HWA. The audio file **552**D can include, for example, one or more chimes, notes, chirps, alarms, beeps, short phrases, and/or other sounds. In certain embodiments, the audio file **552**D, if played to completion (e.g., via the speaker **316**), is substantially continuous audio that indicates to the user of vehicle **100** that HWA is engaged.

[0060] The audio file **552**E defines an audio segment indicative of rejection of ACC and/or HWA. The audio file **552**E can include, for example, one or more chimes, notes, chirps, alarms, beeps, short phrases, and/or other sounds that indicate that ACC and/or HWA is not engaged following a user attempt to engage the same (e.g., via the drive stalk **210** of FIGS. **2**A-B).

[0061] FIG. **6** illustrates an example of faded-in playback of the audio file **552**A. As discussed previously, the audio file **552**A defines an audio segment indicative of ACC. In the example of FIG. **6**, playback of the audio file **552**A is triggered a predefined time duration after receipt of user input **602** (e.g., 0 ms, 300 ms, etc.). The user input **602** may be received, for example, via an input device proximate the user, such as the drive stalk **201** discussed above relative to FIGS. **2**A-B and **4**A. In the example of FIG. **6**, once playback has been triggered, the audio file **552**A can be gradually faded in over a period (e.g., over a period of 200 ms, 500 ms, etc.). In various embodiments, the fading in of the audio file **552**A facilitates other audio files to be gracefully spliced together with audio file **552**A, as needed.

[0062] FIGS. **7-11** illustrate operational examples utilizing the audio files **552** of FIG. **5**, in accordance with certain embodiments of the present disclosure. For purposes of FIGS. **7-11**, user inputs may be received via an input device proximate the user (e.g., driver) of vehicle **100**, such as via the drive stalk **201** described relative to FIGS. **2**A-B and **4**A. As applicable, playback of the audio files **552** (e.g., on the speaker **316**) can be started or terminated, for example, by issuing an audio command as discussed relative to FIG. **4**A.

[0063] Table 1 illustrates example parameters and values that are utilized in the operational examples of FIGS. **7-11**. In Table 1, a predefined time duration corresponds to a period of delay, following a first user input, before audio playback is triggered. The period of delay may be zero in some cases, although it is nonzero for purposes of the example of FIGS. **7-11**. Also in Table 1, a time constraint corresponds to a window, following the first user input, during which HWA may become engaged due to a second user input.

TABLE 1

EXAMPLE PARAMETER	EXAMPLE VALUE
PREDEFINED TIME DURATION	300 ms
TIME CONSTRAINT	1 s

[0064] FIG. **7** illustrates an example of audibly alerting for ACC engagement, according to certain embodiments of the present disclosure. In the example of FIG. **7**, a user input **702** is received. The user input **702** is the first user input and, accordingly, is associated with ACC. Since no additional user inputs are received within the predefined time duration after the user input **702** (e.g., within 300 ms following the user input **702**), playback of the audio file **552**A, for example, on the speaker **316**, is triggered at that time (e.g., at 300 ms). Furthermore, since no additional user inputs are received in satisfaction of the time constraint (e.g., within 1 s following the user input **702**), the audio file **552**A is played to completion without being terminated at the termination point **554**(**1**) or the termination point **554**(**2**). Therefore, in the example of FIG. **7**, substantially continuous audio feedback **754** indicative of ACC engagement is played to the user, for example, via the speaker **316** of FIG. **3**. As illustrated, the substantially continuous audio feedback **754** includes all or substantially all of the audio file **552**A.

[0065] FIG. **8** illustrates an example of audibly alerting for HWA engagement, according to certain embodiments of the present disclosure. In the example of FIG. **8**, a user input **802**(**1**) is received. The user input **802**(**1**) is the first user input and, accordingly, is associated with ACC. During the predetermined time duration after the user input **802**(**1**) (e.g., within 300 ms of the user input **802**(**1**)), a user input **802**(**2**) is received. The user input **802**(**2**) is the second user input and satisfies the time constraint relative to the user input **802**(**1**). In response, the user input **802**(**2**) is associated with HWA and playback of the audio file **552**D, for example, on the speaker **316** of FIG. **3**, is triggered.

[0066] Still with reference to FIG. **8**, the receipt of the user input **802**(**2**) resolves the question of whether a second user input will be received. As such, in various embodiments, the audible alerting can be optimized by not waiting the remainder of the predefined time duration. Instead, as illustrated, the playback of the audio file **552**D can be triggered substantially immediately after receipt of the user input **802**(**2**), with the audio file **552**D being played to completion. Therefore, in the example of FIG. **8**, substantially continuous audio feedback **854** indicative of HWA engagement is played to the user, for example, via the speaker **316** of FIG. **3**. As illustrated, the substantially continuous audio feedback **854** can include all or substantially all of the audio file **552**D.

[0067] FIG. **9** illustrates another example of audibly alerting for HWA engagement, according to certain embodiments of the present disclosure. In the example of FIG. **9**, a user input **902**(**1**) is received. The user input **902**(**1**) is the first user input and, accordingly, is associated with ACC. No additional user inputs are received within the predefined time duration after the user input **902**(**1**). Therefore, upon expiration of the predefined time duration, playback of the audio file **552**A is triggered (e.g., via the speaker **316** of FIG. **3**).

[0068] Still with reference to FIG. **9**, during the playback of the audio file **552**A, a user input **902**(**2**) is received. The user input **902**(**2**) is the second user input and satisfies the time constraint relative to the user input **902**(**1**). In response, the user input **902**(**2**) is associated with HWA and playback of the audio file **552**B is triggered (e.g., via the speaker **316** of FIG. **3**). In particular, the playback of the audio file **552**B is triggered approximately 220 ms into the playback of the audio file **552**A in correspondence to the termination point **554**(**1**). According to the example of FIG. **9**, the termination point **554**(**1**) represents the earliest available termination point at the time of receiving the user input **902**(**2**). The triggering can include, for example, terminating the audio file **552**A at the termination point **554**(**1**) and, substantially simultaneously, starting the audio file **552**B, with the audio file **552**B being played to completion. Therefore, in the example of FIG. **9**, substantially continuous audio feedback **954** indicative of HWA engagement is played to the user via, for example, the speaker **316** of FIG. **3**. As illustrated, the substantially continuous audio feedback **954** includes a portion of the audio file **552**A (e.g., from a beginning until the termination point **554**(**1**)) and all or substantially all of the audio file **552**B.

[0069] FIG. **10** illustrates another example of audibly alerting for HWA engagement, according to certain embodiments of the present disclosure. In the example of FIG. **10**, a user input **1002**(**1**) is received. The user input **1002**(**1**) is the first user input and, accordingly, is associated with ACC. No additional user inputs are received within the predefined time duration after the user input **1002**(**1**). Therefore, upon expiration of the predefined time duration, playback of the audio file **552**A is triggered (e.g., via the speaker **316** of FIG. **3**).

[0070] Still with reference to FIG. **10**, during the playback of the audio file **552**A, a user input **1002**(**2**) is received. The user input **1002**(**2**) is the second user input and satisfies the time constraint relative to the user input **1002**(**1**). In response, the user input **1002**(**2**) is associated with HWA and playback of the audio file **552**C is triggered (e.g., via the speaker **316** of FIG. **3**). In particular, the playback of the audio file **552**C is triggered 500 ms or more into the playback of the audio file **552**A in correspondence to the termination point **554**(**2**). According to the example of FIG. **10**, the termination point **554**(**2**) is the earliest available termination point at the time of receiving the user input **1002**(**2**). The triggering can include, for example, terminating the audio file **552**A at the termination point **554**(**1**) and, substantially simultaneously, starting the audio file **552**C, with the audio file **552**C being played to completion. Therefore, in the example of FIG. **10**, substantially continuous audio feedback **1054** indicative of HWA engagement is played to the user via, for example, the speaker **316** of FIG. **3**. As illustrated, the substantially continuous audio feedback **1054** includes a portion of the audio file **552**A (i.e., from a beginning until the termination point **554**(**2**)) and all or substantially all of the audio file **552**C.

[0071] FIG. **11** illustrates an example of audibly alerting for rejection of ACC and/or HWA, according to certain embodiments of the present disclosure. In the example of FIG. **11**, a user input **1102**(**1**) is received. The user input **1102**(**1**) is the first user input and, accordingly, is associated with ACC. However, in the example of FIG. **11**, ACC is rejected, for example, due to a state of the vehicle (e.g., vehicle **100** may be traveling below a threshold speed). According to this example, no playback is triggered in response to the user input **1102**(**1**).

[0072] Still with reference to FIG. **11**, a user input **1102**(**2**) is received at approximately 600 ms following the user input

1102(1). The user input **1002(2)** is the second user input and satisfies the time constraint relative to the user input **1102(1)**. However, HWA, like ACC, is rejected due to the state of the vehicle, in response to which playback of the audio file **552**E is triggered (e.g., via the speaker **316** of FIG. **3**). Therefore, in the example of FIG. **11**, substantially continuous audio feedback **1154** indicative of HWA rejection is played to the user via, for example, the speaker **316** of FIG. **3**. As illustrated, the substantially continuous audio feedback **1154** includes all or substantially all of the audio file **552**E.

[0073] FIG. **12** illustrates an example of a process **1200** for audibly alerting a user, in accordance with certain embodiments of the present disclosure. In certain embodiments, the process **1200** can be implemented by any vehicle system that can process data. Although any number of systems, in whole or in part, can implement the process **1200**, to simplify discussion, the process **1200** will be described in relation to the control system **104** of vehicle **100** as described relative to FIGS. **1-3**.

[0074] At block **1202**, the control system **104** receives a first event associated with an operational mode related to vehicle **100**. In various embodiments, the first event can be, for example, a user input, a notification of safety condition related to vehicle **100**, and/or the like. In some cases, as discussed previously, the first event can be associated with a first automation level in a progression of ADAS automation levels, such as ACC. In addition, or alternatively, in some cases, the first event can be associated with a first alerting level in a progression of alerting levels that increase in severity and/or urgency.

[0075] At block **1204**, the control system **104** triggers playback of first audio indicative of the operational mode associated with the first event. The triggering can include outputting the playback, for example, to the speaker **316** of FIG. **3** (e.g., via an audio command as discussed relative to FIG. **4**A). The first audio can be similar, for example, to the audio file **552**A of FIG. **5**. In some cases, the control system **104** can trigger the playback a predefined time duration after the receipt of the first event, as discussed previously, so as to allow time for a second event before any audio playback is triggered. In some cases, the predefined time duration can be zero, such that the playback of the first audio is triggered immediately upon the receipt of the first event. In certain embodiments, the block **1204** can include the control system **104** fading in the first audio as described relative to FIG. **6**.

[0076] At decision block **1206**, the control system **104** determines whether a second event has been received. If no second event has been received, the process **1200** ends. Otherwise, if it is determined, at the decision block **1206**, that a second event has been received, at decision block **1208**, the control system **104** determines whether the second event satisfies the time constraint relative to the first event (i.e., whether elapsed time since the first event is less than or equal to than the time constraint). If the second event does not satisfy the time constraint, the process **1200** ends. Otherwise, if it is determined, at the decision block **1208**, that the second event satisfies the time constraint relative to the first event, at block **1210**, the control system **104** triggers playback of second audio in correspondence to a predefined time relationship between the first audio and the second audio. As with the first audio, the playback of the second audio can be output, for example, to the speaker **316** of FIG. **3** (e.g., via an audio command as discussed relative to FIG. **4**A). An example of the triggering at the block **1210** will be described in greater detail relative to FIG. **13**. After block **1210**, the process **1200** ends.

[0077] FIG. **13** illustrates an example of a process **1300** for triggering playback of second audio after first audio has already been triggered, in accordance with certain embodiments of the present disclosure. In certain embodiments, the process **1300** can be performed as all or part of the block **1210** of FIG. **12**. In certain embodiments, the process **1300** can be implemented by any vehicle system that can process data. Although any number of systems, in whole or in part, can implement the process **1300**, to simplify discussion, the process **1300** will be described in relation to the control system **104** of vehicle **100** as described relative to FIGS. **1-3**.

[0078] At block **1302**, the control system **104** determines an elapsed time since the triggering of playback of first audio, for example, at the block **1204** of FIG. **12**. At block **1304**, the control system **104** determines a termination point in the first audio based on the elapsed time. As described relative to FIGS. **9-10**, in some cases, the determined termination point can be the earliest available termination point that has not already been passed in the playback of the first audio.

[0079] At block **1306**, the control system **104** selects the second audio from a plurality of audio options (e.g., from a plurality of audio files) based on the determined termination point, for example, as described relative to FIGS. **5-11**. In various embodiments, blocks **1308** and **1310** can execute substantially simultaneously in response to the block **1306**. At block **1308**, the control system **104** terminates the first audio at the determined termination point. At block **1310**, the control system **104** starts the second audio substantially simultaneously with the termination of the first audio. After block **1310**, the process **1300** ends.

[0080] The many features and advantages of the disclosure are apparent from the detailed specification, and, thus, it is intended by the appended claims to cover all such features and advantages of the disclosure which fall within the scope of the disclosure. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the disclosure to the exact construction and operation illustrated and described, and, accordingly, all suitable modifications and equivalents may be resorted to that fall within the scope of the disclosure.

What is claimed is:

1. A method of audibly alerting a user of a vehicle, the method comprising:

receiving, in a vehicle control system, a first event associated with a first operational mode related to the vehicle;

responsive to the first event, triggering, by the vehicle control system, playback of first audio indicative of the first operational mode;

receiving, in the vehicle control system, a second event associated with a second operational mode related to the vehicle; and

responsive to the second event, triggering, by the vehicle control system, playback of second audio in correspondence to a predefined time relationship between the first audio and the second audio, such that substantially continuous audio indicative of the second operational mode is played to the user, the substantially continuous audio comprising at least a portion of the first audio and at least a portion of the second audio.

2. The method of claim 1, wherein the second event is received during the triggered playback of the first audio.

3. The method of claim 2, wherein the triggering playback of the second audio comprises starting the second audio substantially simultaneously with a termination of the first audio.

4. The method of claim 3, wherein the triggering playback of the second audio further comprises terminating the first audio prior to completion and at a predefined termination point in the first audio.

5. The method of claim 2, wherein the triggering playback of the second audio comprises:

determining an elapsed time since the triggering of playback of the first audio;

determining a termination point in the first audio based on the elapsed time;

selecting the second audio from a plurality of audio options based on the determined termination point;

terminating the first audio at the termination point; and

starting the second audio substantially simultaneously with the terminating.

6. The method of claim 1, wherein the triggering playback of the first audio occurs a predefined time duration after the receiving the first event.

7. The method of claim 6, wherein the predefined time duration is nonzero.

8. The method of claim 1, further comprising, in response to determining that the second event satisfies a time constraint relative to the first event, the vehicle control system associating the second event with the second operational mode.

9. The method of claim 1, wherein the second operational mode represents a progression in a plurality of operational levels related to the vehicle.

10. The method of claim 9, wherein the plurality of operational levels correspond to levels of automatic driver assistance provided by the vehicle control system, the second operational mode representing an increased level of automatic driver assistance relative to the first operational mode.

11. The method of claim 10, wherein:

the first operational mode comprises adaptive cruise control; and

the second operational mode comprises highway assistance.

12. The method of claim 1, wherein the first event and the second event comprise user inputs received via the same input device.

13. The method of claim 1, wherein the first event and the second event comprise automated notifications of safety conditions relative to the vehicle.

14. The method of claim 1, wherein the substantially continuous audio comprises a sequence of sounds indicative of the second operational mode, the at least a portion of the first audio comprising at least one of the sequence of sounds.

15. A system for audibly alerting a user of a vehicle, the system comprising:

a vehicle speaker; and

a vehicle control system communicably coupled to the vehicle speaker, wherein the vehicle control system is operable to:

receive a first event associated with a first operational mode related to the vehicle;

responsive to the first event, trigger playback, on the vehicle speaker, of first audio indicative of the first operational mode;

receive a second event associated with a second operational mode related to the vehicle; and

responsive to the second event, trigger playback, on the vehicle speaker, of second audio in correspondence to a predefined time relationship between the first audio and the second audio, such that substantially continuous audio indicative of the second operational mode is played to the user, the substantially continuous audio comprising at least a portion of the first audio and at least a portion of the second audio.

16. The system of claim 15, wherein:

the second event is received during the triggered playback of the first audio;

the triggering playback of the second audio comprises:

terminating the first audio prior to completion and at a predefined termination point in the first audio; and

starting the second audio substantially simultaneously with the terminating.

17. The system of claim 15, wherein the triggering playback of the second audio comprises:

determining an elapsed time since the triggering of playback of the first audio;

determining a termination point in the first audio based on the elapsed time;

selecting the second audio from a plurality of audio options based on the determined termination point;

terminating the first audio at the termination point; and

starting the second audio substantially simultaneously with the terminating.

18. The system of claim 15, wherein the vehicle control system is further operable, in response to determining that the second event satisfies a time constraint relative to the first event, to associate the second event with the second operational mode.

19. The system of claim 15, wherein the second operational mode represents a progression in a plurality of operational levels related to the vehicle, the plurality of operational levels corresponding to levels of automatic driver assistance provided by the vehicle control system.

20. The system of claim 15, wherein the first event and the second event comprise user inputs received via the same input device.

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