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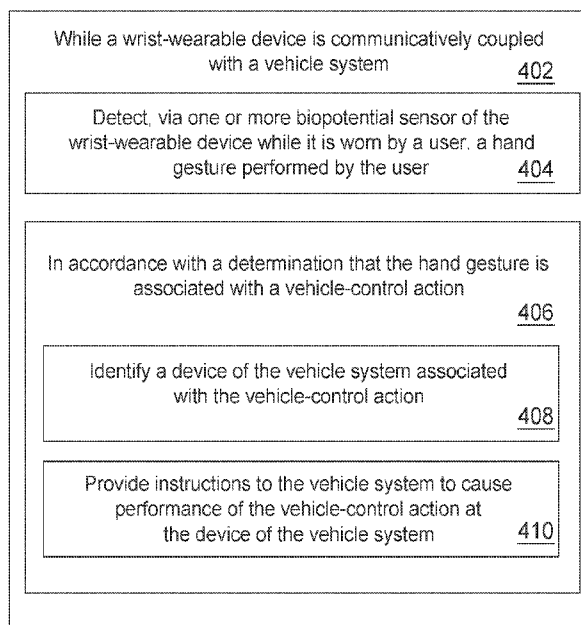
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FIG. 4

400



(57) Abstract: Systems and methods for controlling a vehicle system using a wearable device are disclosed. The method includes, while a wrist-wearable device is communicatively coupled with a vehicle system, detecting, via a wrist-wearable device worn by a user, a hand gesture performed by the user. In accordance with a determination that the hand gesture is associated with a vehicle-control action, the method further includes identifying a device of the vehicle system associated with the vehicle-control action, and providing instructions to the vehicle system to cause performance of the vehicle-control action at the device of the vehicle system. The hand gesture is an in-air hand gesture or a surface-contact gesture.

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EMG-BASED CONTROL FOR INTERACTING WITH VEHICLES, AND SYSTEMS
AND METHODS OF USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Prov. App. No. 63/491,041, filed on March 17, 2023, and entitled “EMG-Based Control for Interacting With Vehicles, And Systems And Methods Of Use Thereof,”.

TECHNICAL FIELD

[0002] This application relates generally to frictionless interactions with communicatively coupled devices using a wearable device, including but not limited to techniques for detecting hand gestured performed by a user wearing a wrist-wearable device that are associated with control actions for performing one or more operations at a vehicle system.

BACKGROUND

[0003] Vehicle drivers have limited control of the input means for controlling their vehicle. For example, drivers utilize voice commands and/or physical inputs to adjust one or more components of their vehicle, such as a media player, an air conditioner, etc. The limited number of inputs means cause distractions that can increase the probability of a driver being in an accident. Further, drivers have limited access to their vehicle's status while not in proximity to their vehicle. For example, the drivers can use a mobile application on their phones. However, using a phone can be distracting and may not be socially acceptable at all times.

[0004] The present disclosure seeks to address, at least in part, any or all of the drawbacks and disadvantages described above. A brief summary of solutions to the issues noted above are described below.

SUMMARY

[0005] The systems and methods disclosed herein allow a user to control a vehicle system (e.g., a vehicle and/or one or more components of the vehicle) using a worn wrist-wearable device communicatively coupled with the vehicle system. The wrist-wearable device can detect one or hand gestures (e.g., in-air hand gestures) associated with a vehicle-control action and provide instructions to the vehicle system for performing the vehicle-control action. The use of a wrist-wearable device to provide control inputs to a vehicle system allows a user to interact with their vehicle in an easy to use, frictionless, and socially accepted manner. Further, the systems and methods disclosed herein reduce driver distraction (e.g., manual, visual, and/or cognitive distractions) by increasing the input means

1 for controlling their vehicle that are intuitive and do not require the user to lose focus while
2 driving. Through use of the systems and methods disclosed herein, the user can have greater
3 control of their vehicle and improve their overall driving experience.

4 **[0006]** According to a first aspect of the present disclosure there is provided a non-
5 transitory, computer-readable storage medium including instructions that, when executed by
6 one or more processors of a wrist-wearable device, cause the wrist-wearable device to: while
7 a wrist-wearable device is communicatively coupled with a vehicle system: detect, via one or
8 more biopotential sensors of the wrist-wearable device while it is worn by a user, a hand
9 gesture performed by the user; and in accordance with a determination that the hand gesture
10 is associated with a vehicle-control action: identify a device of the vehicle system associated
11 with the vehicle-control action, and provide instructions to the vehicle system to cause
12 performance of the vehicle-control action at the device of the vehicle system.

13 **[0007]** In some embodiments, the hand gesture may be a first hand gesture and the
14 vehicle-control action may be a first vehicle-control action, and the instructions, when
15 executed by the one or more processors of the wrist-wearable device, may further cause the
16 wrist-wearable device to: detect, via the one or more biopotential sensors of the wrist-
17 wearable device while it is worn by the user, a second hand gesture; and in accordance with a
18 determination that the second hand gesture may be associated with a second vehicle-control
19 action, distinct from the first vehicle-control action: determine a different device of the
20 vehicle system associated with the second vehicle-control action, and provide instructions to
21 the vehicle system to cause performance of the second vehicle-control action at the different
22 device of the vehicle system.

23 **[0008]** In some embodiments, the instructions, when executed by the one or more
24 processors of the wrist-wearable device, may further cause the wrist-wearable device to:
25 detect, via the one or more biopotential sensors of the wrist-wearable device while it is worn
26 by the user, a third hand gesture; and in accordance with a determination that the third hand
27 gesture may be associated with a device-cycle control action that causes the vehicle system to
28 alternate between devices of the vehicle system, provide instructions to the vehicle system to
29 cause selection of another device of the vehicle system for receiving one or more vehicle-
30 control actions.

31 **[0009]** In some embodiments, the instructions, when executed by the one or more
32 processors of the wrist-wearable device, may further cause the wrist-wearable device to:
33 while a head-wearable device is communicatively coupled with the wrist-wearable device
34 and/or the vehicle system: detect, via the head-wearable device worn by the user, a field of

1 view of the user; and in accordance with a determination that another device of the vehicle
2 system may be within the field of view of the user, provide instructions to the vehicle system
3 to cause performance of the vehicle-control action at the other device of the vehicle system
4 within the user's field of view.

5 **[0010]** In some embodiments, the vehicle-control action may cause activation of a
6 vehicle self-driving action.

7 **[0011]** In some embodiments, the instructions, when executed by the one or more
8 processors of the wrist-wearable device, may further cause the wrist-wearable device to:
9 detect, via the one or more biopotential sensors of the wrist-wearable device while it is worn
10 by the user, a hand gesture performed by the user; and in accordance with a determination
11 that the hand gesture may be associated with a vehicle-monitoring action: receiving from, the
12 vehicle system, current vehicle information, and causing presentation of the current vehicle
13 information at the wrist-wearable device or at a device in communication with the wrist-
14 wearable device.

15 **[0012]** In some embodiments, the vehicle-monitoring action may include playback of
16 image data captured by an imaging device of the vehicle system.

17 **[0013]** In some embodiments, the vehicle-monitoring action may include playback of
18 audio data captured by a microphone device of the vehicle system, presentation of a vehicle
19 battery level, presentation of a vehicle-charging status, and/or presentation of a vehicle's
20 status.

21 **[0014]** In some embodiments, the vehicle-monitoring action may include presentation
22 of one or more of a vehicle battery level, a vehicle-charging status, and a vehicle's status.

23 **[0015]** In some embodiments, the vehicle-control action may be a media-player
24 control action.

25 **[0016]** In some embodiments, the vehicle-control action may be an engine-ignition
26 control action or an engine-shutoff control action.

27 **[0017]** In some embodiments, the vehicle-control action may be a vehicle-security
28 control action.

29 **[0018]** In some embodiments, the vehicle-control action may be a vehicle-thermal
30 control action.

31 **[0019]** In some embodiments, the vehicle-control action may be a vehicle-window
32 control action.

33 **[0020]** In some embodiments, respective hand gestures may be determined to be
34 directed to the wrist-wearable device when it is not in communication with the vehicle

1 system, and those same respective hand gesture may be determined to be directed to the
2 vehicle system when the wrist-wearable device is in communication with the vehicle system.

3 **[0021]** In some embodiments, the hand gesture may be one of an in-air hand gesture
4 or a surface-contact gesture, and the in-air hand gesture and the surface-contact gesture may
5 not include contact with a touchscreen of the wrist-wearable device.

6 **[0022]** According to a second aspect of the present disclosure there is provided a
7 method comprising, while a wrist-wearable device is communicatively coupled with a vehicle
8 system, detecting, via one or more biopotential sensors of the wrist-wearable device while it
9 is worn by a user, a hand gesture performed by the user; in accordance with a determination
10 that the hand gesture is associated with a vehicle-control action, the method includes
11 identifying a device of the vehicle system associated with the vehicle-control action, and
12 providing instructions to the vehicle system to cause performance of the vehicle-control
13 action at the device of the vehicle system.

14 **[0023]** In some embodiments, the hand gesture may be a first hand gesture and the
15 vehicle-control action is a first vehicle-control action, and the method may further comprise:
16 detecting, via the one or more biopotential sensors of the wrist-wearable device while it is
17 worn by the user, a second hand gesture; and in accordance with a determination that the
18 second hand gesture may be associated with a second vehicle-control action, distinct from the
19 first vehicle-control action: determining a different device of the vehicle system associated
20 with the second vehicle-control action, and providing instructions to the vehicle system to
21 cause performance of the second vehicle-control action at the different device of the vehicle
22 system.

23 **[0024]** In some embodiments, the method may further comprise: detecting, via the
24 one or more biopotential sensors of the wrist-wearable device while it is worn by the user, a
25 third hand gesture; and in accordance with a determination that the third hand gesture may be
26 associated with a device-cycle control action that causes the vehicle system to alternate
27 between devices of the vehicle system, providing instructions to the vehicle system to cause
28 selection of another device of the vehicle system for receiving one or more vehicle-control
29 actions.

30 **[0025]** In some embodiments, the method may further comprise: while a head-
31 wearable device is communicatively coupled with the wrist-wearable device and/or the
32 vehicle system: detecting, via the head-wearable device worn by the user, a field of view of
33 the user; and in accordance with a determination that another device of the vehicle system
34 may be within the field of view of the user, providing instructions to the vehicle system to

1 cause performance of the vehicle-control action at the other device of the vehicle system
2 within the user's field of view.

3 **[0026]** According to a third aspect of the present disclosure there is provided a wrist-
4 wearable device for controlling a vehicle system using one or more hand gestures, the wrist-
5 wearable device configured to perform or cause performance of: while a wrist-wearable
6 device is communicatively coupled with a vehicle system: detecting, via one or more
7 biopotential sensors of the wrist-wearable device while it is worn by a user, a hand gesture
8 performed by the user; and in accordance with a determination that the hand gesture is
9 associated with a vehicle-control action: identifying a device of the vehicle system associated
10 with the vehicle-control action, and providing instructions to the vehicle system to cause
11 performance of the vehicle-control action at the device of the vehicle system.

12 **[0027]** In some embodiments, the hand gesture may be a first hand gesture and the
13 vehicle-control action is a first vehicle-control action, and the wrist-wearable device may be
14 further configured to perform or cause performance of: detect, via the one or more
15 biopotential sensors of the wrist-wearable device while it is worn by the user, a second hand
16 gesture; and in accordance with a determination that the second hand gesture may be
17 associated with a second vehicle-control action, distinct from the first vehicle-control action:
18 determine a different device of the vehicle system associated with the second vehicle-control
19 action, and provide instructions to the vehicle system to cause performance of the second
20 vehicle-control action at the different device of the vehicle system.

21 **[0028]** In some embodiments, respective hand gestures may be determined to be
22 directed to the wrist-wearable device when it is not in communication with the vehicle
23 system, and those same respective hand gesture may be determined to be directed to the
24 vehicle system when the wrist-wearable device is in communication with the vehicle system.

25 **[0029]** In some embodiments, the hand gesture may be one of an in-air hand gesture
26 or a surface-contact gesture, and the in-air hand gesture and the surface-contact gesture may
27 not include contact with a touchscreen of the wrist-wearable device.

28 **[0030]** In some embodiments, the at least one of the respective hand gestures may
29 cause performance of a first action at the wrist-wearable device, and that same at least one
30 respective hand gesture may cause performance of a second action, distinct from the first
31 action, at the vehicle system.

32 **[0031]** In some embodiments, each respective action caused by each of the respective
33 hand gestures while the wrist-wearable device is in communication with the vehicle system
34 may be distinct from a different respective action caused by each of the respective hand

gestures while the wrist-wearable device is not in communication with the vehicle system.

[0032] In one example, a wrist-wearable device for controlling a vehicle system using one or more detected hand gestures is disclosed.

[0033] In another example, a head-wearable device for controlling a vehicle system using one or more detected hand gestures is disclosed.

[0034] In yet another example, a system for controlling a vehicle system using a wearable device, head-wearable device, and/or intermediary device is disclosed.

[0035] In an additional example, a non-transitory, computer-readable storage medium including instructions that, when executed by a head-wearable device, a wrist-wearable device, and/or an intermediary device in communication with a vehicle system, cause performance of one or more control actions at the vehicle system is disclosed.

[0036] In another additional example, a means on a wrist-wearable device, head-wearable device, and/or intermediary device for performing or causing performance of one or more control actions at the vehicle system is disclosed.

[0037] It will be appreciated that any features described herein as being suitable for incorporation into one or more aspects or embodiments of the present disclosure are intended to be generalizable across any and all aspects and embodiments of the present disclosure. Other aspects of the present disclosure can be understood by those skilled in the art in light of the description, the claims, and the drawings of the present disclosure. The foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the claims.

[0038] The features and advantages described in the specification are not necessarily all inclusive and, in particular, certain additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes.

[0039] Having summarized the above example aspects, a brief description of the drawings will now be presented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] For a better understanding of the various described embodiments, reference should be made to the Detailed Description below, in conjunction with the following drawings in which like reference numerals refer to corresponding parts throughout the figures.

[0041] Figures 1A-1H illustrate a system for controlling one or more components of a

1 vehicle system, in accordance with one or more embodiments of the present disclosure.

2 **[0042]** Figures 2A-2D illustrate remote monitoring of a vehicle using a worn
3 wearable device, in accordance with one or more embodiments of the present disclosure.

4 **[0043]** Figures 3A-3C illustrate remote control of a vehicle using a worn wearable
5 device, in accordance with one or more embodiments of the present disclosure.

6 **[0044]** Figure 4 illustrates a flow diagram of a method for controlling one or more
7 operations of a vehicle via a wearable device, in accordance with one or more embodiments
8 of the present disclosure.

9 **[0045]** Figures 5A-5C-2 illustrate example artificial-reality systems, in accordance
10 with one or more embodiments of the present disclosure.

11 **[0046]** Figures 6A and 6B illustrate an example wrist-wearable device 600, in
12 accordance with one or more embodiments of the present disclosure.

13 **[0047]** Figures 7A-7C illustrate example head-wearable devices, in accordance with
14 one or more embodiments of the present disclosure.

15 **[0048]** Figures 8A and 8B illustrate an example handheld intermediary processing
16 device, in accordance with one or more embodiments of the present disclosure.

17 **[0049]** In accordance with common practice, the various features illustrated in the
18 drawings may not be drawn to scale. Accordingly, the dimensions of the various features
19 may be arbitrarily expanded or reduced for clarity. In addition, some of the drawings may
20 not depict all of the components of a given system, method, or device. Finally, like reference
21 numerals may be used to denote like features throughout the specification and figures.

22 **DETAILED DESCRIPTION**

23 **[0050]** Numerous details are described herein to provide a thorough understanding of
24 the example embodiments illustrated in the accompanying drawings. However, some
25 embodiments may be practiced without many of the specific details, and the scope of the
26 claims is only limited by those features and aspects specifically recited in the claims.
27 Furthermore, well-known processes, components, and materials have not necessarily been
28 described in exhaustive detail so as to avoid obscuring pertinent aspects of the embodiments
29 described herein.

30 **[0051]** Embodiments of this disclosure can include or be implemented in conjunction
31 with various types or embodiments of artificial-reality systems. Artificial-reality, as
32 described herein, is any superimposed functionality and or sensory-detectable presentation
33 provided by an artificial-reality system within a user's physical surroundings. Such artificial-
34 realities (AR) can include and/or represent virtual reality (VR), augmented reality, mixed

1 artificial-reality (MAR), or some combination and/or variation one of these. For example, a
2 user can perform a swiping in-air hand gesture to cause a song to be skipped by a song-
3 providing API providing playback at, for example, a home speaker. In some embodiments of
4 an AR system, ambient light (e.g., a live feed of the surrounding environment that a user
5 would normally see) can be passed through a display element of a respective head-wearable
6 device presenting aspects of the AR system. In some embodiments, ambient light can be
7 passed through respective aspect of the AR system. For example, a visual user interface
8 element (e.g., a notification user interface element) can be presented at the head-wearable
9 device, and an amount of ambient light (e.g., 15-50% of the ambient light) can be passed
10 through the user interface element, such that the user can distinguish at least a portion of the
11 physical environment over which the user interface element is being displayed.

12 **[0052]** Artificial-reality content can include completely generated content or
13 generated content combined with captured (e.g., real-world) content. The artificial-reality
14 content can include video, audio, haptic events, or some combination thereof, any of which
15 can be presented in a single channel or in multiple channels (such as stereo video that
16 produces a three-dimensional effect to a viewer). Additionally, in some embodiments,
17 artificial reality can also be associated with applications, products, accessories, services, or
18 some combination thereof, which are used, for example, to create content in an artificial
19 reality and/or are otherwise used in (e.g., to perform activities in) an artificial reality.

20 **[0053]** A hand gesture, as described herein, can include an in-air gesture, a surface-
21 contact gesture, and or other gestures that can be detected and determined based on
22 movements of a single hand or a combination of the user's hands. In-air means, in some
23 embodiments, that the user hand does not contact a surface, object, or portion of an electronic
24 device (e.g., the head-wearable device 110 or other communicatively coupled device, such as
25 the wrist-wearable device 120), in other words the gesture is performed in open air in 3D
26 space and without contacting a surface, an object, or an electronic device. Surface-contact
27 gestures (contacts at a surface, object, body part of the user, or electronic device) more
28 generally are also contemplated in which a contact (or an intention to contact) is detected at a
29 surface (e.g., a single or double finger tap on a table, on a user's hand or another finger, on
30 the user's leg, a couch, a steering wheel, etc.). The different hand gestures disclosed herein
31 can be detected using image data and/or sensor data (e.g., neuromuscular signals sensed by
32 one or more biopotential sensors (e.g., EMG sensors) or other types of data from other
33 sensors, such as proximity sensors, time-of-flight sensors, sensors of an inertial measurement
34 unit, etc.) detected by a wearable device worn by the user and/or other electronic devices in

1 the user's possession (e.g., smartphones, laptops, imaging devices, intermediary devices,
2 and/or other devices described herein).

3 **[0054]** As described herein, a wrist-wearable device (or other wearable device) worn
4 by a user and communicatively coupled with a vehicle can detect a hand gesture associated
5 with a vehicle-control action performed by the user. The wrist-wearable device (or other
6 device communicatively coupled with the wrist-wearable device, such as a head-wearable
7 device, a handheld intermediary processing device, a vehicle system, etc.) can cause
8 performance of the vehicle-control action at the vehicle. In particular, the methods and
9 devices described herein include methods and systems for detecting hand gestures performed
10 by the user using one or more sensors (e.g., electromyography (EMG) sensors) of the wrist-
11 wearable device and performing one or more operations at a vehicle based on the detected
12 hand gestures. The use of hand gestures to perform one or more operations at a vehicle
13 improves a user's ability to control their vehicle without having to directly interact with a
14 user interface of the vehicle. Additionally, the use of hand gestures reduces user distractions
15 by reducing the number of times the user needs to interact with the user interface of the
16 vehicle and/or reducing the number of times the user needs to look away from the road to
17 make an adjustment to the vehicle. The systems and methods disclosed herein provide a user
18 with a frictionless and socially acceptable means of controlling and/or accessing their vehicle.

19 **[0055]** While the primary example herein is a hand gesture detected by one or more
20 biopotential sensors of the wrist-wearable device while it is worn by a user, the disclosure is
21 not limited to biopotential sensors for detecting hand gestures, as other sensors or devices for
22 detecting hand gestures are also contemplated, including the inertial measurement units
23 (IMU)s and imaging devices.

24 **[0056]** Figures 1A-1H illustrate a system for controlling one or more components of a
25 vehicle system, in accordance with some embodiments. The system 100 includes a wrist-
26 wearable device 120 communicatively coupled with a vehicle system 130. In some
27 embodiments, the system 100 includes a head-wearable device 110 and/or an intermediary
28 device (e.g., a handheld intermediary processing device (not shown), a smartphone, etc.)
29 communicatively coupled with the wrist-wearable device 120 and/or vehicle system 130.
30 The wrist-wearable device 120 and the head-wearable device 110 are worn by a user 115.

31 **[0057]** In some embodiments, the wrist-wearable device 120 includes one or more
32 displays 605 (e.g., Figure 6B, such as a touch screen), speakers, microphones, and sensors
33 621 (e.g., inertial measurement units (IMU)s, biometric sensors, position sensors,
34 electromyography (EMG) sensors, and/or any other sensors), and/or one or more processors

1 (e.g., processors 679). In some embodiments, the one or more components of the wrist-
2 wearable device 120 described above are coupled with a wrist-wearable structure (e.g., a
3 band portion) of the wrist-wearable device 120, housed within a capsule portion of the wrist-
4 wearable device 120, or a combination of the wrist-wearable structure and the capsule
5 portion. In some embodiments, the wrist-wearable device 120 is communicatively coupled
6 with the vehicle system 130 and/or other devices described above (e.g., by way of a
7 communication interface, such as a Bluetooth connection between the two devices). In some
8 embodiments, the wrist-wearable device 120, the vehicle system 130, and/or the head-
9 wearable device 110 are communicatively coupled via an intermediary device that is
10 configured to control the wrist-wearable and/or head-wearable devices 120 and 110.
11 Additional components of the wrist-wearable device 120 are described below with reference
12 to Figures 5A-8B.

13 **[0058]** The head-wearable device 110 includes, with reference to Figures 7A-7C, one
14 or more imaging devices (e.g., cameras 738), microphones 737, speakers 736, displays (e.g.,
15 displays 735 including a heads-up display, a built-in or integrated monitor or screen, a
16 projector, and/or similar device), sensors 723, and/or one or more processors 748. In some
17 embodiments, the one or more components of the head-wearable device 110 described above
18 are coupled with the housing and/or lenses of the head-wearable device 110. In some
19 embodiments, the head-wearable device 110 is a pair of smart glasses, smart contacts, and/or
20 any other ocularly coupled device (e.g., AR goggles (with or without a heads-up display), AR
21 glasses (with or without a heads-up display), other head-mounted displays). In some
22 embodiments, the display is coupled with one or both of the lenses of the head-wearable
23 device 110. In some embodiments, image data presented by the display is presented in
24 conjunction with the field of view of the user 115. Alternatively, or additionally, in some
25 embodiments, the image data is overlaid over a portion of the field of view of the user 115
26 (e.g., as an overlay over one or more real-world objects or the physical environment). The
27 head-wearable device 110 can communicatively couple with one or more of the wrist-
28 wearable device 120, the vehicle system 130, and/or an intermediary device (e.g., by way of a
29 respective communication interface 715). Additional components of the head-wearable
30 device are described below with reference to Figures 5A-8B.

31 **[0059]** In some embodiments, the vehicle system 130 includes one or more displays
32 (e.g., driver instrument displays 154 (e.g., speedometer, fuel gauge or battery level, odometer,
33 etc.), touch screens or information displays (e.g., 140, 150, and 158), etc.), speakers 142,
34 microphones (not shown), and sensors, and/or one or more processors (not shown). The

1 vehicle system 130 can include one or more controllable devices such as a media player, a
2 navigation or GPS system, a heating, ventilation, and air conditioning (HVAC) system (e.g.,
3 represented by vents 156), a window control system (e.g., window controls 170), a mirror
4 control system (e.g., side mirror or rearview mirror 135 control), a compartment (e.g., glove
5 box 172) control system, a security system, a heated and/or ventilated seat system
6 (represented by driver seat 132 and passenger seat 134), a phone system, and/or other user
7 controllable systems. As described above, the vehicle system 130 can be communicatively
8 couple with one or more of a wrist-wearable device 120, the vehicle system 130, and/or an
9 intermediary device.

10 **[0060]** While the wrist-wearable device 120 is communicatively coupled with the
11 vehicle system 130, the wrist-wearable device 120 can detect, via one or more biopotential
12 sensors of the wrist-wearable device while it is worn by the user 115, hand gestures
13 performed by the user 115. The hand gestures can include in-air hand gestures, surface
14 contact gestures, and/or gestures performed by the user's hand (e.g., wrist rotations, user hand
15 digits contacting different portions of the hand including other hand digits, the palm, the
16 opposite hand, etc.). For example, the wrist-wearable device 120 can detect hand gestures
17 using one or more EMG sensors and/or other sensors 621 of the wrist-wearable device.
18 Further, the wrist-wearable device 120 determines whether a detected hand gesture is
19 associated with a control action, such as a vehicle-control action.

20 **[0061]** In some embodiments, the hand gestures are detected and determined to be
21 associated with a particular control action (such as a vehicle-control action) based on the
22 sensor data captured by the wrist-wearable device 120 alone. Alternatively, in some
23 embodiments, the hand gestures are determined based on the sensor data captured by the
24 wrist-wearable device 120 and/or at least one other device (e.g., sensor data and/or image
25 data captured by the head-wearable device 110 and/or an intermediary device).

26 **[0062]** In accordance with a determination that the hand gesture is associated with a
27 vehicle-control action, the wrist-wearable device 120 identifies a device of the vehicle system
28 associated with the vehicle-control action and provides instructions to the vehicle system 130
29 to cause performance of the vehicle-control action at the device of the vehicle system 130. In
30 some embodiments, the wrist-wearable device 120 can provide instructions to the vehicle
31 system 130 to cause performance of the vehicle-control action and the vehicle system 130 can
32 identify a device to perform the vehicle-control action. In some embodiments, a device for
33 performing the vehicle-control action is determined by one or more communicatively coupled
34 devices, such as the wrist-wearable device 120, the vehicle system 130, the head-wearable

1 device 110, and/or an intermediary device.

2 **[0063]** For example, as shown in Figure 1B, the user 115 performs an in-air hand
3 gesture (e.g., a finger pinch gesture 125 or finger tap). The wrist-wearable device 120 detects
4 the in-air hand gesture and determines that the in-air hand gesture is associated with a
5 vehicle-control action for heating a seat. The wrist-wearable device 120 identifies a device of
6 the vehicle system 130 associated with the vehicle-control action, such as the passenger seat
7 134, and provides instructions to the vehicle system 130 to cause performance of the vehicle-
8 control action at the passenger seat 134 (e.g., activating the heated seat). In some
9 embodiments, when the vehicle-control action is performed, the vehicle system 130 provides
10 a notification to the user 115. For example, as further shown in Figure 1B, the vehicle system
11 130 presents via a touch display 140 that the passenger seat 134 heating is active. In some
12 embodiments, the user 115 is notified of a completed vehicle-control action via the wrist-
13 wearable device 120 and/or head-wearable device 110 (e.g., via haptic feedback, visual
14 indicators, and/or audio indicators).

15 **[0064]** The user 115 can perform additional hand gestures that, when detected by the
16 wrist-wearable device 120, causes performance of additional vehicle-control action at the
17 vehicle system 130 or components thereof. The additional hand gestures can cause
18 performance of an additional vehicle-control action at the same device or at a distinct device
19 (e.g., activating heating of the driver seat 132, adjusting a media player, etc.). For example,
20 after performing the in-air hand gesture to active a heater of the passenger seat 134, the user
21 115 can perform a subsequent hand gesture associated with a vehicle-control action for
22 adjusting a temperature of the passenger seat 134 (e.g., rotating their wrist clockwise or
23 counterclockwise), that when detected by the wrist-wearable device 120 causes the wrist-
24 wearable device 120 to identify a device of the vehicle system 130 associated with the
25 vehicle-control action (e.g., the passenger seat 134) and provide instructions to the vehicle
26 system 130 to cause performance of the vehicle-control action at the passenger seat 134 (e.g.,
27 reducing or increasing the heat generated by the passenger seat 134).

28 **[0065]** Turning to Figure 1C, in some embodiments, the user 115 can perform one or
29 more hand gestures that, when detected by the wrist-wearable device 120, allows the user 115
30 to switch or cycle between devices included in the vehicle system 130. For example, the user
31 115 can perform a hand gesture associated with a vehicle-control action for alternating or
32 selecting a device of the vehicle system 130 (e.g., moving their wrist side to side or up and
33 down), that when detected by the wrist-wearable device 120 causes the wrist-wearable device
34 120 to deselect the passenger seat and select the media player (as shown in reference to

Figure 1D). In this way, the user 115 can select the device to be controlled without requiring the wrist-wearable device 120, the vehicle system 130, and/or other communicatively coupled device to determine which device to control.

[0066] After a device has been selected by the user 115, the user can perform additional hand gestures to control the selected device. For example, as shown in Figure 1D, the wrist-wearable device 120 detects another in-air hand gesture (e.g., a pinch gesture 125), determines that the in-air hand gesture is associated with an vehicle-control action for the media player of the vehicle system 130, and provides instructions to the vehicle system 130 to cause performance of the vehicle-control action at the media player (e.g., activating the media player). Information regarding particular device of the vehicle system 130 can be presented to the user 115. For example, Figure 1D illustrates media content information (e.g., track information, artist, etc.) on a display 150.

[0067] In some embodiments, the head-wearable device 110 can be used in conjunction with the wrist-wearable device 120 to control operation of the vehicle system 130. In particular, one or more sensors and/or imaging devices of the head-wearable device 110 can be used to assist the user 115 in selecting a device of the vehicle system 130 to control. For example, as shown in Figure 1E, the user 115 focuses on the passenger seat window controls 170 (as shown by user's field of view). The head-wearable device 110 detects that the user 115 is focused on the passenger seat window controls 170 based on image data captured by the head-wearable device 110 and/or sensor data of the head-wearable device 110 detecting that the user 115's head and/or eyes have moved in the direction of the passenger seat window controls 170. In some embodiments, the user 115 performs a hand gesture that when detected by the wrist-wearable device 120, the head-wearable device 110, and/or a communicatively coupled intermediary device to select a device of the vehicle system 130 or to confirm a device identified by the head-wearable device 110. For example, as shown in Figure 1E, the user 115 performs a hand gesture (e.g., pointing gesture 145) that when detected by the wrist-wearable device 120, the head-wearable device 110, and/or a communicatively coupled intermediary device confirm user selection of the passenger seat window controls 170.

[0068] After a device has been selected by the user 115, the user can perform additional hand gestures to control the selected device. For example, as shown in Figure 1F, the wrist-wearable device 120 detects an additional in-air hand gesture (e.g., a wrist rotation 155), determines that the in-air hand gesture is associated with an vehicle-control action for adjusting the passenger seat window controls 170, and provides instructions to the vehicle

1 system 130 to cause performance of the vehicle-control action at the passenger seat window
2 controls 170 (e.g., rolling down window 176).

3 **[0069]** Figures 1G and 1H illustrate performance of a surface-contact gesture
4 performed by the user 115, in accordance with some embodiments. For example, the user
5 115 can perform a surface-contact gesture (e.g., a tap on the steering wheel 180), and the
6 wrist-wearable device 120 can detect and determine that the surface-contact gesture is
7 associated with a vehicle-control action for activating the HVAC system of the vehicle
8 system 130. The wrist-wearable device 120 identifies a device of the vehicle system 130
9 associated with the vehicle-control action, such as the HVAC system, and provides
10 instructions to the vehicle system 130 to cause performance of the vehicle-control action at
11 the HVAC system (e.g., activating an air conditioner). In some embodiments, the user 115
12 can provide additional hand gesture to adjust operation of the HVAC system (e.g., control the
13 temperature, control the active vents 156, etc.) In some embodiments, when the vehicle-
14 control action is performed, the vehicle system 130 provides a notification to the user 115.
15 For example, as further shown in Figure 1H, the vehicle system 130 presents via the touch
16 display 140 that the air conditioner (AC) is active.

17 **[0070]** As described above, the user 115 can perform hand gestures, that when
18 detected by the wrist-wearable device 120, can be used to control operations of different
19 devices of the vehicle system 130. Non-limiting examples of the vehicle-control actions
20 include a media-player control action (e.g., turn the volume up or down, change tracks,
21 change play list, etc.), an engine-ignition control action (e.g., turn the vehicle on), an engine-
22 shutoff control action (e.g., turn the vehicle off), a mirror adjustment control action (e.g.,
23 adjustment to side mirrors and/or the rearview mirror 135), a vehicle-security control action
24 (e.g., unlock or lock the vehicle, activate or deactivate the alarm, open a vehicle trunk, etc.), a
25 vehicle-window control action (e.g., raise or lower a window 176), charging control (e.g.,
26 initiating charging, pausing, ceasing charging, etc.), and/or a vehicle-thermal control action
27 (e.g., control of the HVAC system (or other cooling and/or heating system) of the vehicle).

28 **[0071]** In some embodiments, the wrist-wearable device 120 is configured to detect
29 universal hand gestures that can be used to control a selected and/or particular device of the
30 vehicle system 130. For example, the wrist-wearable device 120 can detect a universal hand
31 gesture for increasing a magnitude of a selected device (e.g., increasing a volume of the
32 media player) or a universal hand gesture for turning on and off a vehicle. Alternatively, or
33 additionally, in some embodiments, the user 115 can define device specific hand gestures that
34 can be detected by the wrist-wearable device 120.

1 [0072] Other users associated with the vehicle system 130 can also perform hand
2 gestures using a wearable device to control one or more operations of the vehicle control
3 system. For example, a passenger can lower their window or adjust the HVAC system by
4 performing a respective hand gesture detected by the wrist-wearable device 120. Each
5 passenger wearing a wearable device that is associated with the vehicle system can be
6 associated with distinct privileges and access rights. For example, the driver can have
7 universal control of the vehicle and its components whereas a rear seat passenger may only
8 have control of rear seat components. In this way, the driver has full control of the vehicle
9 and can reduce distractions as needed. Further, ensures that a passenger is not able to
10 interfere with the driver of the vehicle.

11 [0073] Figures 2A-2D illustrate remote monitoring of a vehicle using a worn
12 wearable device, in accordance with some embodiments. In Figures 2A-2D, a user 215 is
13 shown wearing a wrist-wearable device 120 and a head-wearable device 110. The wrist-
14 wearable device 120 and the head-wearable device 110 are communicatively coupled with a
15 vehicle system 130 as described above in reference to Figures 1A-1H. In some embodiments,
16 an intermediary device (e.g., a handheld intermediary processing device, a smartphone,
17 computer, etc.) is communicatively coupled with the wrist-wearable device 120, the head-
18 wearable device 110, and/or the vehicle system 130.

19 [0074] Figure 2A shows the user 215's field of view 260 while seated at a desk 210.
20 While seated at the desk 210, the user 215 performs a hand gesture associated with a vehicle-
21 control action. For example, as shown in Figure 2B, the user 215 performs a surface-contact
22 gesture 230 (e.g., a tap on the desk 210), which the wrist-wearable device 120 detects and
23 determines to be associated with a vehicle-control action for monitoring the vehicle of the
24 vehicle system 130 (also referred to as a vehicle-monitoring action). As described above, the
25 hand gesture can be detected via data captured by one or more biopotential sensors of the
26 wrist-wearable device 120 while it is worn by the user 215. In some embodiments, the hand
27 gesture is detected using sensor data of the wrist-wearable device 120 along with sensor data
28 and/or image data captured by the head-wearable device 110.

29 [0075] In Figure 2B, the wrist-wearable device 110 determines that the hand gesture
30 is associated with a vehicle-monitoring action and sends instructions to the vehicle system
31 130 for providing information on the vehicle. For example, the wrist-wearable device 120
32 can determine that the vehicle-monitoring action is a request to view image data captured by
33 image sensors of a vehicle and request from the vehicle system 130 image data associated
34 with the request. The wrist-wearable device 120 can receive the image data and/or other

1 vehicle information from the vehicle system 130 and cause presentation of the image data
2 and/or vehicle information at a display communicatively coupled device with wrist-wearable
3 device 130. For example, as shown in Figure 2B, the wrist-wearable device 120 causes
4 presentation of the image data received from the vehicle system 130 at a display of the head-
5 wearable device 110 (e.g., via image data user interface 270). While the image data is
6 presented to the user 215, the user can perform one or more hand gestures for controlling the
7 imaging devices or adjusting the image data presented to the user 215. For example, the user
8 215 can pan, rotate, zoom in, zoom out, etc. of the displayed image data, and, if the imaging
9 device is controllable, adjust a view angle of the imaging device and/or cycle to another
10 imaging device. In some embodiments, the image data is presented in conjunction with the
11 user 215's field of view (e.g., as an overlay, such as image data user interface (UI) 270). In
12 some embodiments, the image data is presented such that the user's field of view is not
13 obstructed (e.g., at a portion of a lens, semi-transparent, etc.). In some embodiments, the user
14 215 can perform a gesture to initiate an audio connection with the vehicle to allow the user
15 215 to receive and/or send audio data for interacting with others adjacent to the vehicle.

16 **[0076]** Turning to Figure 2C, the user 215 performs another hand gesture (e.g., a
17 double tap 235 on the desk 210). The wrist-wearable device 120 detects the other hand
18 gesture and determines that the other hand gesture is associated with a vehicle-control action
19 for controlling the internal temperature of the vehicle. The wrist-wearable device 120
20 identifies a device of the vehicle system 130 associated with the vehicle-control action, such
21 as an HVAC system, and provides instructions to the vehicle system 130 to cause
22 performance of the vehicle-control action at the HVAC system (e.g., activating a pet mode of
23 the HVAC system). As described above, the vehicle system 130 can provide a notification
24 that is presented to the user 215 (e.g., via the wrist-wearable device 120 and/or head-wearable
25 device 110) that the vehicle-control action was performed (e.g., UI indicating "Pet Mode
26 Activated Temp Set to X").

27 **[0077]** In Figure 2D, the user 215 performs yet another hand gesture (e.g., a snap
28 gesture 245). The wrist-wearable device 120 detects the snap gesture 245 and determines
29 that the snap gesture 245 is associated with a vehicle-control action for monitoring a status of
30 the vehicle. The wrist-wearable device 120 identifies a device of the vehicle system 130
31 associated with the vehicle-control action (e.g., the overall vehicle system 130), and provides
32 instructions to the vehicle system 130 to cause performance of the vehicle-control action
33 (e.g., provide vehicle system status). The vehicle system 130 provides the vehicle system
34 status to the wrist-wearable device 120, which is received by the wrist-wearable device 120

1 and presented via a display communicatively coupled with the wrist-wearable device 120.
2 For example, as shown in Figure 2D, the wrist-wearable device 120 presents via its display
3 605 the vehicle system status. The vehicle system status can include battery information, fuel
4 information, alarm information (e.g., active or triggered), lock information, charging status,
5 temperature, location, etc.

6 **[0078]** Figures 3A-3C illustrate remote control of a vehicle using a worn wearable
7 device, in accordance with some embodiments. In Figures 3A-3C, a user 115 is shown
8 wearing a wrist-wearable device 120 and a head-wearable device 110. The wrist-wearable
9 device 120 and the head-wearable device 110 are communicatively coupled with a vehicle
10 system 330 (similar to vehicle system 130 described above in reference to Figures 1A-1H) of
11 a vehicle 310. As described above, in some embodiments, an intermediary device (e.g., a
12 handheld intermediary processing device) is communicatively coupled with the wrist-
13 wearable device 120, the head-wearable device 110, and/or the vehicle system 330.

14 **[0079]** In Figure 3A, the user 115's vehicle 310 is parked in a parking lot and the user
15 115 is at an entrance of the parking lot. The user 115 performs an in-air hand gesture (e.g., a
16 finger pinch gesture 325), which the wrist-wearable device 120 detects (e.g., via one or more
17 biopotential sensors) and determines to be associated with a vehicle-control action for
18 summoning or activating a valet mode of the vehicle 310. The wrist-wearable device 120
19 determines one or more device of the vehicle system 330 associated with the vehicle-control
20 action and provides instructions to the vehicle system 130 (or the one or more devices of the
21 vehicle system 330) to cause performance of the vehicle-control action. For example, the
22 wrist-wearable device 120 can provide instructions to the vehicle system 330 to cause the
23 vehicle 310 to turn on and transition from a park mode to a valet or self-driving mode. When
24 in valet mode, the vehicle 310 moves from its parked position to the user 115's current
25 position as shown in Figure 3B.

26 **[0080]** The instructions provided by the wrist-wearable device 120 to the vehicle
27 system 330 (or the one or more devices of the vehicle system 330) can include sensor data or
28 other device data captured by the wrist-wearable device 120, head-wearable device 110,
29 and/or other device communicatively coupled to the wrist-wearable device 120 to assist in
30 completion of the vehicle-control action. For example, the instructions can include the wrist-
31 wearable device's location and/or positional data to assist the vehicle in locating the user 115
32 and/or avoid hitting or harming the user 115. Similarly, image data captured by the head-
33 wearable device 110 can be provided to the vehicle system 330, via the instructions provided
34 by the wrist-wearable device 120, to assist the vehicle system 330 in identifying one or more

1 objects and/or pedestrians along its path and/or for determining a navigation path that avoid
2 collisions with the identified objects and/or pedestrians. For example, as shown Figure 3B,
3 the vehicle system 330 determines a navigation path 320 for avoiding a shopping cart 325
4 near the vehicle 310 and moving the vehicle 310 adjacent to the user 115.

5 **[0081]** In Figure 3C, the vehicle 310 reaches the user 115's position and parks near
6 the user 115. The user 115 can perform additional hand gestures that, when detected by the
7 wrist-wearable device 120, causes performance of additional vehicle-control actions at the
8 vehicle system 330 or components thereof. For example, after the vehicle 310 parks adjacent
9 to the user 115, the user 115 can perform a subsequent hand gesture associated with a
10 vehicle-control action for unlocking the vehicle 310 (e.g., double tap gesture 345), that when
11 detected by the wrist-wearable device 120 causes the wrist-wearable device 120 to provide
12 instructions to the vehicle system 330 for unlocking the vehicle 310. In some embodiments,
13 the wrist-wearable device 120 automatically provides instructions the vehicle system 330 for
14 unlocking the vehicle 310 when the wrist-wearable device 120 is in proximity (e.g., within 3
15 to 5 meters) of the vehicle 310.

16 **[0082]** In some embodiments, the wrist-wearable device 120 includes authentication
17 keys that are included in the instructions provided to the vehicle system 330 for unlocking
18 and/or locking the vehicle 310. Alternatively, or in addition, in some embodiments,
19 instructions for unlocking and/or locking the vehicle 310 are provided to the vehicle system
20 330 after a user specific gesture is detected by the wrist-wearable device 120. For example,
21 the specific gesture can be user-defined hand digit positions (e.g., fingers crossed), a user-
22 defined sequence of gestures (e.g., tapping a thumb to an index finger and then tapping the
23 thumb to the middle finger), a user-defined hand gesture (e.g., holding a thumb to a palm of
24 the hand), etc.

25 **[0083]** While the primary examples of in-air hand gestures and/or surface-contact
26 gestures described herein are finger taps, the disclosure is not limited to finger tap hand
27 gestures. The wrist-wearable device 120 is configured to detect, via one or more sensors,
28 different hand gestures performed by the user 115. Non-limiting examples of detectable hand
29 gestures include contact of a hand digit with another digit or another portion of the hand (e.g.,
30 a finger pinch), contact by two or more hand digits at a particular point in time (e.g., a thumb
31 contacting a middle finger and index finger at the same time), maintaining contact between a
32 digit and a portion of the hand (e.g., maintaining a pinch), forming a fist, squeezing and/or
33 holding a fist, wrist rotations, wrist movements (e.g., movement of the wrist up, down, left,
34 right, and/or at a diagonal), hand digit movement (e.g., thumb movement imitating a

directional pad), handwriting (e.g., writing out one or more letters with a digit or hand), etc.
As described above, a hand gesture can be determined by a wrist-wearable device 120, a head-wearable device 110, and/or by both devices working in conjunction.

[0084] Figure 4 illustrates a flow diagram of a method for controlling one or more operations of a vehicle via a wearable device, in accordance with some embodiments. Operations (e.g., steps) of the method 400 can be performed by one or more processors (e.g., central processing unit and/or MCUs, e.g., processors 649 and 679 (Figures 6A-8B)) of a wrist-wearable device 120. In some embodiments, the wrist-wearable device 120 is coupled with one or more sensors (e.g., various sensors discussed in reference to Figures 5A-8B, such as a heart rate sensor, IMU, an EMG sensor, SpO2 sensor, altimeter, thermal sensor or thermal couple, ambient light sensor, ambient noise sensor), a display, a speaker, an image device (e.g., a camera), and a microphone to perform the one or more operations. At least some of the operations shown in Figure 4 correspond to instructions stored in a computer memory or computer-readable storage medium (e.g., storage, RAM, and/or memory, described below in reference to Figures 6A-8B). Operations of the method 400 can be performed by the wrist-wearable device 120 alone or in conjunction with one or more processors and/or hardware components of another device communicatively coupled to the wrist-wearable device 120 (e.g., a head-wearable device 110, handheld intermediary processing device 800, a smartphone 191, a laptop, a tablet, etc.) and/or instructions stored in memory or computer-readable medium of the other device communicatively coupled to the wrist-wearable device 120.

[0085] The method 400 is performed while (402) while a wrist-wearable device is communicatively coupled with a vehicle system. The 400 method includes detecting (404), via one or more biopotential sensors of the wrist-wearable device while it is worn by a user, a hand gesture performed by the user. In accordance with a determination (406) that the hand gesture is associated with a vehicle-control action, the method 400 includes identifying (408) a device of the vehicle system associated with the vehicle-control action, and providing (410) instructions to the vehicle system to cause performance of the vehicle-control action at the device of the vehicle system. For example, as described above in reference to Figures 1A-1H, a user 115 can perform different in-air hand gestures and/or surface-contact gestures that, when detected by the wrist-wearable device 120, can cause one or more operations to be performed at the vehicle.

[0086] Non-limiting examples of the vehicle-control actions include a media-player control action (e.g., turn the volume up or down, change tracks, change play list, etc.), an

1 engine-ignition control action (e.g., turn the vehicle on), an engine-shutoff control action
2 (e.g., turn the vehicle off), a mirror adjustment control action (e.g., adjustment to side mirrors
3 and/or the rearview mirror 135), a vehicle compartment control action (e.g., open a glove
4 box 172), a vehicle-security control action (e.g., unlock or lock the vehicle, activate or
5 deactivate the vehicle alarm, open the vehicle trunk or frunk (e.g., front trunk), etc.), a
6 vehicle-window control action (e.g., lower or raising a window), a vehicle-thermal control
7 action (e.g., control an HVAC system of the vehicle).

8 **[0087]** In some embodiments, the hand gesture is a first hand gesture and the vehicle-
9 control action is a first vehicle-control action, and the method 400 further includes detecting,
10 via the via one or more biopotential sensors of the wrist-wearable device while it is worn by
11 the user, a second hand gesture. In accordance with a determination that the second hand
12 gesture is associated with a second vehicle-control action, distinct from the first vehicle-
13 control action, the method 400 further includes identifying a different device of the vehicle
14 system associated with the second vehicle-control action, and providing instructions to the
15 vehicle system to cause performance of the second vehicle-control action at the different
16 device of the vehicle system. For example, as described above in reference to Figures 1A-
17 1H, the user 115 can perform a subsequent hand gesture (e.g., after activating the heated seat
18 of the passenger seat 134) that is associated with a vehicle-control action for adjusting a
19 temperature of the heated seat of the passenger seat 134 such that, when the subsequent hand
20 gesture is detected by the wrist-wearable device 120, the wrist-wearable device 120 provides
21 instructions to the vehicle system 130 to cause an adjustment to the temperature of the heated
22 seat of the passenger seat 134. Alternatively, the subsequent hand gesture can be associated
23 with a vehicle-control action for opening the glove box 172 such that, when the subsequent
24 hand gesture is detected by the wrist-wearable device 120, the wrist-wearable device 120
25 provides instructions to the vehicle system 130 to cause the glove box 172 to open.

26 **[0088]** In some embodiments, the hand gesture is a first hand gesture and the vehicle-
27 control action is a first vehicle-control action, and the method 400 further includes detecting,
28 via the one or more biopotential sensors of the wrist-wearable device while it is worn by the
29 user, a third hand gesture. In accordance with a determination that the third hand gesture is
30 associated with a device-cycle control action that causes the vehicle system to alternate
31 between devices of the vehicle system, the method 400 includes providing instructions to the
32 vehicle system to cause selection of another device of the vehicle system for receiving one or
33 more vehicle-control actions. For example, as described above in reference to Figures 1A-
34 1H, the user 115 can perform one or more additional hand gestures to cycle through and

1 select a particular device to control. For example, the user can deselect the passenger seat
2 134 of the vehicle and select the frunk to control such that subsequent detected hand gestures
3 associated with a vehicle-control action cause performance of an action at the frunk (e.g.,
4 opening the frunk).

5 **[0089]** In some embodiments, while a head-wearable device is communicatively
6 coupled with the wrist-wearable device and/or the vehicle system, the method 400 includes
7 detecting, via the head-wearable device worn by the user, a field of view of the user. In
8 accordance with a determination that a device is within the field of view of the user, the
9 method 400 includes providing instructions to the vehicle system to cause performance of the
10 vehicle-control action at the device of the vehicle system within the user's field of view. For
11 example, as described above in reference to Figure 1A-1H, the user 115 focuses their field of
12 view on the window controls 170 of the passenger side of the vehicle such that subsequent
13 detected hand gestures associated with a vehicle-control action cause performance of an
14 action at the window controls 170 (e.g., casing the window 176 to lower).

15 **[0090]** In some embodiments, method 400 includes detecting, via the wrist-wearable
16 device worn by the user, a hand gesture performed by the user and, in accordance with a
17 determination that the hand gesture is associated with a vehicle-monitoring action, receiving
18 from the vehicle system a vehicle status and/or other vehicle information, and causing
19 presentation of the vehicle status (e.g., vehicle's battery life or fuel, location, internal
20 temperature, security status (e.g., locked or unlocked, entry attempts, etc.), active components
21 (e.g., media player is on, lights are on, etc.), and/or other vehicle information at the wrist-
22 wearable device. For example, as shown in Figures 2A-2D, the user 215 requests
23 information regarding a vehicle communicatively coupled with the wrist-wearable device
24 120, and the vehicle, responsive to the request, provides vehicle information to the wrist-
25 wearable device 120 for display at a communicatively coupled display.

26 **[0091]** In some embodiments, the vehicle-monitoring action includes playback of
27 image data captured by an imaging device of the vehicle system, playback of audio data
28 captured by a microphone device of the vehicle system, presentation of a vehicle battery
29 level, presentation of a vehicle-charging status, presentation of the vehicle's status (e.g.,
30 locked, unlocked, alarm active, etc.), and/or other examples provided above in reference to
31 Figures 2A-2D.

32 **[0092]** In some embodiments, the vehicle-control action is activation of a vehicle self-
33 driving action or a valet mode. For example, as described above in reference to Figures 3A-
34 3C, the user 115 can perform a hand gesture associated with a vehicle-control action for

1 activating a valet mode of the vehicle system 330, such that, when the hand gesture is
2 detected by the wrist-wearable device 120, the wrist-wearable device 120 provides
3 instructions to the vehicle system 330 to summon the vehicle 310 (e.g., cause the vehicle 310
4 to move towards the user 115).

5 **[0093]** In some embodiments, hand gestured detected by the wrist-wearable device
6 perform one or more distinct operations when not communicatively coupled to a vehicle. For
7 example, respective hand gestures can be determined to be directed to the wrist-wearable
8 device when it is not in communication with the vehicle system, and those same respective
9 hand gesture are determined to be directed to the vehicle system when the wrist-wearable
10 device is in communication with the vehicle system. In some embodiments, at least one of
11 the respective hand gestures causes performance of a first action at the wrist-wearable device,
12 and that same at least one respective hand gesture causes performance of a second action,
13 distinct from the first action, at the vehicle system. In some embodiments, each respective
14 action caused by each of the respective hand gestures while the wrist-wearable device is in
15 communication with the vehicle system is distinct from a different respective action caused
16 by each of the respective hand gestures while the wrist-wearable device is not in
17 communication with the vehicle system.

18 **[0094]** The devices described above are further detailed below, including systems,
19 wrist-wearable devices, headset devices, and smart textile-based garments. Specific
20 operations described above may occur as a result of specific hardware, such hardware is
21 described in further detail below. The devices described below are not limiting and features
22 on these devices can be removed or additional features can be added to these devices. The
23 different devices can include one or more analogous hardware components. For brevity,
24 analogous devices and components are described below. Any differences in the devices and
25 components are described below in their respective sections.

26 **[0095]** As described herein, a processor (e.g., a central processing unit (CPU) or
27 microcontroller unit (MCU)), is an electronic component that is responsible for executing
28 instructions and controlling the operation of an electronic device (e.g., a wrist-wearable
29 device 600, a head-wearable device, an HIPD 800, a smart textile-based garment, or other
30 computer system). There are various types of processors that may be used interchangeably or
31 specifically required by embodiments described herein. For example, a processor may be (i)
32 a general processor designed to perform a wide range of tasks, such as running software
33 applications, managing operating systems, and performing arithmetic and logical operations;
34 (ii) a microcontroller designed for specific tasks such as controlling electronic devices,

1 sensors, and motors; (iii) a graphics processing unit (GPU) designed to accelerate the creation
2 and rendering of images, videos, and animations (e.g., virtual-reality animations, such as
3 three-dimensional modeling); (iv) a field-programmable gate array (FPGA) that can be
4 programmed and reconfigured after manufacturing and/or customized to perform specific
5 tasks, such as signal processing, cryptography, and machine learning; (v) a digital signal
6 processor (DSP) designed to perform mathematical operations on signals such as audio,
7 video, and radio waves. One of skill in the art will understand that one or more processors of
8 one or more electronic devices may be used in various embodiments described herein.

9 **[0096]** As described herein, controllers are electronic components that manage and
10 coordinate the operation of other components within an electronic device (e.g., controlling
11 inputs, processing data, and/or generating outputs). Examples of controllers can include
12 (i) microcontrollers, including small, low-power controllers that are commonly used in
13 embedded systems and Internet of Things (IoT) devices; (ii) programmable logic controllers
14 (PLCs) that may be configured to be used in industrial automation systems to control and
15 monitor manufacturing processes; (iii) system-on-a-chip (SoC) controllers that integrate
16 multiple components such as processors, memory, I/O interfaces, and other peripherals into a
17 single chip; and/or DSPs. As described herein, a graphics module is a component or software
18 module that is designed to handle graphical operations and/or processes, and can include a
19 hardware module and/or a software module.

20 **[0097]** As described herein, memory refers to electronic components in a computer or
21 electronic device that store data and instructions for the processor to access and manipulate.
22 The devices described herein can include volatile and non-volatile memory. Examples of
23 memory can include (i) random access memory (RAM), such as DRAM, SRAM, DDR RAM
24 or other random access solid state memory devices, configured to store data and instructions
25 temporarily; (ii) read-only memory (ROM) configured to store data and instructions
26 permanently (e.g., one or more portions of system firmware and/or boot loaders); (iii) flash
27 memory, magnetic disk storage devices, optical disk storage devices, other non-volatile solid
28 state storage devices, which can be configured to store data in electronic devices (e.g.,
29 universal serial bus (USB) drives, memory cards, and/or solid-state drives (SSDs)); and (iv)
30 cache memory configured to temporarily store frequently accessed data and instructions.
31 Memory, as described herein, can include structured data (e.g., SQL databases, MongoDB
32 databases, GraphQL data, or JSON data). Other examples of memory can include: (i) profile
33 data, including user account data, user settings, and/or other user data stored by the user; (ii)
34 sensor data detected and/or otherwise obtained by one or more sensors; (iii) media content

1 data including stored image data, audio data, documents, and the like; (iv) application data,
2 which can include data collected and/or otherwise obtained and stored during use of an
3 application; and/or any other types of data described herein.

4 **[0098]** As described herein, a power system of an electronic device is configured to
5 convert incoming electrical power into a form that can be used to operate the device. A power
6 system can include various components, including (i) a power source, which can be an
7 alternating current (AC) adapter or a direct current (DC) adapter power supply; (ii) a charger
8 input that can be configured to use a wired and/or wireless connection (which may be part of
9 a peripheral interface, such as a USB, micro-USB interface, near-field magnetic coupling,
10 magnetic inductive and magnetic resonance charging, and/or radio frequency (RF) charging);
11 (iii) a power-management integrated circuit, configured to distribute power to various
12 components of the device and ensure that the device operates within safe limits (e.g.,
13 regulating voltage, controlling current flow, and/or managing heat dissipation); and/or (iv) a
14 battery configured to store power to provide usable power to components of one or more
15 electronic devices.

16 **[0099]** As described herein, peripheral interfaces are electronic components (e.g., of
17 electronic devices) that allow electronic devices to communicate with other devices or
18 peripherals and can provide a means for input and output of data and signals. Examples of
19 peripheral interfaces can include (i) USB and/or micro-USB interfaces configured for
20 connecting devices to an electronic device; (ii) Bluetooth interfaces configured to allow
21 devices to communicate with each other, including Bluetooth low energy (BLE); (iii) near-
22 field communication (NFC) interfaces configured to be short-range wireless interfaces for
23 operations such as access control; (iv) POGO pins, which may be small, spring-loaded pins
24 configured to provide a charging interface; (v) wireless charging interfaces; (vi) global-
25 position system (GPS) interfaces; (vii) Wi-Fi interfaces for providing a connection between a
26 device and a wireless network; and (viii) sensor interfaces.

27 **[0100]** As described herein, sensors are electronic components (e.g., in and/or
28 otherwise in electronic communication with electronic devices, such as wearable devices)
29 configured to detect physical and environmental changes and generate electrical signals.
30 Examples of sensors can include (i) imaging sensors for collecting imaging data (e.g.,
31 including one or more cameras disposed on a respective electronic device); (ii) biopotential-
32 signal sensors; (iii) inertial measurement unit (e.g., IMUs) for detecting, for example, angular
33 rate, force, magnetic field, and/or changes in acceleration; (iv) heart rate sensors for
34 measuring a user's heart rate; (v) SpO2 sensors for measuring blood oxygen saturation and/or

1 other biometric data of a user; (vi) capacitive sensors for detecting changes in potential at a
2 portion of a user's body (e.g., a sensor-skin interface) and/or the proximity of other devices or
3 objects; and (vii) light sensors (e.g., ToF sensors, infrared light sensors, or visible light
4 sensors), and/or sensors for sensing data from the user or the user's environment. As
5 described herein biopotential-signal-sensing components are devices used to measure
6 electrical activity within the body (e.g., biopotential-signal sensors). Some types of
7 biopotential-signal sensors include: (i) electroencephalography (EEG) sensors configured to
8 measure electrical activity in the brain to diagnose neurological disorders; (ii)
9 electrocardiography (ECG or EKG) sensors configured to measure electrical activity of the
10 heart to diagnose heart problems; (iii) electromyography (EMG) sensors configured to
11 measure the electrical activity of muscles and diagnose neuromuscular disorders; (iv)
12 electrooculography (EOG) sensors configured to measure the electrical activity of eye
13 muscles to detect eye movement and diagnose eye disorders.

14 **[0101]** As described herein, an application stored in memory of an electronic device
15 (e.g., software) includes instructions stored in the memory. Examples of such applications
16 include (i) games; (ii) word processors; (iii) messaging applications; (iv) media-streaming
17 applications; (v) financial applications; (vi) calendars; (vii) clocks; (viii) web browsers; (ix)
18 social media applications, (x) camera applications, (xi) web-based applications; (xii) health
19 applications; (xiii) artificial-reality (AR) applications, and/or any other applications that can
20 be stored in memory. The applications can operate in conjunction with data and/or one or
21 more components of a device or communicatively coupled devices to perform one or more
22 operations and/or functions.

23 **[0102]** As described herein, communication interface modules can include hardware
24 and/or software capable of data communications using any of a variety of custom or standard
25 wireless protocols (e.g., IEEE 802.15.4, Wi-Fi, ZigBee, 6LoWPAN, Thread, Z-Wave,
26 Bluetooth Smart, ISA100.11a, WirelessHART, or MiWi), custom or standard wired protocols
27 (e.g., Ethernet or HomePlug), and/or any other suitable communication protocol, including
28 communication protocols not yet developed as of the filing date of this document. A
29 communication interface is a mechanism that enables different systems or devices to
30 exchange information and data with each other, including hardware, software, or a
31 combination of both hardware and software. For example, a communication interface can
32 refer to a physical connector and/or port on a device that enables communication with other
33 devices (e.g., USB, Ethernet, HDMI, or Bluetooth). In some embodiments, a communication
34 interface can refer to a software layer that enables different software programs to

1 communicate with each other (e.g., application programming interfaces (APIs) and protocols
2 such as HTTP and TCP/IP).

3 **[0103]** As described herein, a graphics module is a component or software module
4 that is designed to handle graphical operations and/or processes, and can include a hardware
5 module and/or a software module.

6 **[0104]** As described herein, non-transitory computer-readable storage media are
7 physical devices or storage medium that can be used to store electronic data in a non-
8 transitory form (e.g., such that the data is stored permanently until it is intentionally deleted
9 or modified).

10 ***Example AR Systems***

11 **[0105]** Figures 5A-5C-2 illustrate example artificial-reality systems, in accordance
12 with some embodiments. Figure 5A shows a first AR system 500a and first example user
13 interactions using a wrist-wearable device 600, a head-wearable device (e.g., AR device 700),
14 and/or a handheld intermediary processing device (HIPD) 800. Figure 5B shows a second
15 AR system 500b and second example user interactions using a wrist-wearable device 600,
16 AR device 700, and/or an HIPD 800. Figures 5C-1 and 5C-2 show a third AR system 500c
17 and third example user interactions using a wrist-wearable device 600, a head-wearable
18 device (e.g., virtual-reality (VR) device 710), and/or an HIPD 800. As the skilled artisan will
19 appreciate upon reading the descriptions provided herein, the above-example AR systems
20 (described in detail below) can perform various functions and/or operations described above
21 with reference to Figures 1A-4.

22 **[0106]** The wrist-wearable device 600 and its constituent components are described
23 below in reference to Figures 6A-6B, the head-wearable devices and their constituent
24 components are described below in reference to Figures 7A-7D, and the HIPD 800 and its
25 constituent components are described below in reference to Figures 8A-8B. The wrist-
26 wearable device 600, the head-wearable devices, and/or the HIPD 800 can communicatively
27 couple via a network 525 (e.g., cellular, near field, Wi-Fi, personal area network, wireless
28 LAN, etc.). Additionally, the wrist-wearable device 600, the head-wearable devices, and/or
29 the HIPD 800 can also communicatively couple with one or more servers 530, computers 540
30 (e.g., laptops, computers, etc.), mobile devices 550 (e.g., smartphones, tablets, etc.), and/or
31 other electronic devices via the network 525 (e.g., cellular, near field, Wi-Fi, personal area
32 network, wireless LAN, etc.)

33 **[0107]** Turning to Figure 5A, a user 502 is shown wearing the wrist-wearable device
34 600 and the AR device 700, and having the HIPD 800 on their desk. The wrist-wearable

1 device 600, the AR device 700, and the HIPD 800 facilitate user interaction with an AR
2 environment. In particular, as shown by the first AR system 500a, the wrist-wearable device
3 600, the AR device 700, and/or the HIPD 800 cause presentation of one or more avatars 504,
4 digital representations of contacts 506, and virtual objects 508. As discussed below, the user
5 502 can interact with the one or more avatars 504, digital representations of the contacts 506,
6 and virtual objects 508 via the wrist-wearable device 600, the AR device 700, and/or the
7 HIPD 800.

8 **[0108]** The user 502 can use any of the wrist-wearable device 600, the AR device
9 700, and/or the HIPD 800 to provide user inputs. For example, the user 502 can perform one
10 or more hand gestures that are detected by the wrist-wearable device 600 (e.g., using one or
11 more EMG sensors and/or IMUs, described below in reference to Figures 6A-6B) and/or AR
12 device 700 (e.g., using one or more image sensors or cameras, described below in reference
13 to Figures 7A-7B) to provide a user input. Alternatively, or additionally, the user 502 can
14 provide a user input via one or more touch surfaces of the wrist-wearable device 600, the AR
15 device 700, and/or the HIPD 800, and/or voice commands captured by a microphone of the
16 wrist-wearable device 600, the AR device 700, and/or the HIPD 800. In some embodiments,
17 the wrist-wearable device 600, the AR device 700, and/or the HIPD 800 include a digital
18 assistant to help the user in providing a user input (e.g., completing a sequence of operations,
19 suggesting different operations or commands, providing reminders, confirming a command).
20 In some embodiments, the user 502 can provide a user input via one or more facial gestures
21 and/or facial expressions. For example, cameras of the wrist-wearable device 600, the AR
22 device 700, and/or the HIPD 800 can track the user 502's eyes for navigating a user interface.

23 **[0109]** The wrist-wearable device 600, the AR device 700, and/or the HIPD 800 can
24 operate alone or in conjunction to allow the user 502 to interact with the AR environment. In
25 some embodiments, the HIPD 800 is configured to operate as a central hub or control center
26 for the wrist-wearable device 600, the AR device 700, and/or another communicatively
27 coupled device. For example, the user 502 can provide an input to interact with the AR
28 environment at any of the wrist-wearable device 600, the AR device 700, and/or the HIPD
29 800, and the HIPD 800 can identify one or more back-end and front-end tasks to cause the
30 performance of the requested interaction and distribute instructions to cause the performance
31 of the one or more back-end and front-end tasks at the wrist-wearable device 600, the AR
32 device 700, and/or the HIPD 800. In some embodiments, a back-end task is a background-
33 processing task that is not perceptible by the user (e.g., rendering content, decompression,
34 compression, etc.), and a front-end task is a user-facing task that is perceptible to the user

(e.g., presenting information to the user, providing feedback to the user, etc.)). As described below in reference to Figures 8A-8B, the HIPD 800 can perform the back-end tasks and provide the wrist-wearable device 600 and/or the AR device 700 operational data corresponding to the performed back-end tasks such that the wrist-wearable device 600 and/or the AR device 700 can perform the front-end tasks. In this way, the HIPD 800, which has more computational resources and greater thermal headroom than the wrist-wearable device 600 and/or the AR device 700, performs computationally intensive tasks and reduces the computer resource utilization and/or power usage of the wrist-wearable device 600 and/or the AR device 700.

[0110] In the example shown by the first AR system 500a, the HIPD 800 identifies one or more back-end tasks and front-end tasks associated with a user request to initiate an AR video call with one or more other users (represented by the avatar 504 and the digital representation of the contact 506) and distributes instructions to cause the performance of the one or more back-end tasks and front-end tasks. In particular, the HIPD 800 performs back-end tasks for processing and/or rendering image data (and other data) associated with the AR video call and provides operational data associated with the performed back-end tasks to the AR device 700 such that the AR device 700 performs front-end tasks for presenting the AR video call (e.g., presenting the avatar 504 and the digital representation of the contact 506).

[0111] In some embodiments, the HIPD 800 can operate as a focal or anchor point for causing the presentation of information. This allows the user 502 to be generally aware of where information is presented. For example, as shown in the first AR system 500a, the avatar 504 and the digital representation of the contact 506 are presented above the HIPD 800. In particular, the HIPD 800 and the AR device 700 operate in conjunction to determine a location for presenting the avatar 504 and the digital representation of the contact 506. In some embodiments, information can be presented within a predetermined distance from the HIPD 800 (e.g., within five meters). For example, as shown in the first AR system 500a, virtual object 508 is presented on the desk some distance from the HIPD 800. Similar to the above example, the HIPD 800 and the AR device 700 can operate in conjunction to determine a location for presenting the virtual object 508. Alternatively, in some embodiments, presentation of information is not bound by the HIPD 800. More specifically, the avatar 504, the digital representation of the contact 506, and the virtual object 508 do not have to be presented within a predetermined distance of the HIPD 800.

[0112] User inputs provided at the wrist-wearable device 600, the AR device 700, and/or the HIPD 800 are coordinated such that the user can use any device to initiate,

1 continue, and/or complete an operation. For example, the user 502 can provide a user input
2 to the AR device 700 to cause the AR device 700 to present the virtual object 508 and, while
3 the virtual object 508 is presented by the AR device 700, the user 502 can provide one or
4 more hand gestures via the wrist-wearable device 600 to interact and/or manipulate the
5 virtual object 508.

6 **[0113]** Figure 5B shows the user 502 wearing the wrist-wearable device 600 and the
7 AR device 700, and holding the HIPD 800. In the second AR system 500b, the wrist-
8 wearable device 600, the AR device 700, and/or the HIPD 800 are used to receive and/or
9 provide one or more messages to a contact of the user 502. In particular, the wrist-wearable
10 device 600, the AR device 700, and/or the HIPD 800 detect and coordinate one or more user
11 inputs to initiate a messaging application and prepare a response to a received message via
12 the messaging application.

13 **[0114]** In some embodiments, the user 502 initiates, via a user input, an application
14 on the wrist-wearable device 600, the AR device 700, and/or the HIPD 800 that causes the
15 application to initiate on at least one device. For example, in the second AR system 500b the
16 user 502 performs a hand gesture associated with a command for initiating a messaging
17 application (represented by messaging user interface 512); the wrist-wearable device 600
18 detects the hand gesture; and, based on a determination that the user 502 is wearing AR
19 device 700, causes the AR device 700 to present a messaging user interface 512 of the
20 messaging application. The AR device 700 can present the messaging user interface 512 to
21 the user 502 via its display (e.g., as shown by user 502's field of view 510). In some
22 embodiments, the application is initiated and can be run on the device (e.g., the wrist-
23 wearable device 600, the AR device 700, and/or the HIPD 800) that detects the user input to
24 initiate the application, and the device provides another device operational data to cause the
25 presentation of the messaging application. For example, the wrist-wearable device 600 can
26 detect the user input to initiate a messaging application, initiate and run the messaging
27 application, and provide operational data to the AR device 700 and/or the HIPD 800 to cause
28 presentation of the messaging application. Alternatively, the application can be initiated and
29 run at a device other than the device that detected the user input. For example, the wrist-
30 wearable device 600 can detect the hand gesture associated with initiating the messaging
31 application and cause the HIPD 800 to run the messaging application and coordinate the
32 presentation of the messaging application.

33 **[0115]** Further, the user 502 can provide a user input provided at the wrist-wearable
34 device 600, the AR device 700, and/or the HIPD 800 to continue and/or complete an

operation initiated at another device. For example, after initiating the messaging application via the wrist-wearable device 600 and while the AR device 700 presents the messaging user interface 512, the user 502 can provide an input at the HIPD 800 to prepare a response (e.g., shown by the swipe gesture performed on the HIPD 800). The user 502's gestures performed on the HIPD 800 can be provided and/or displayed on another device. For example, the user 502's swipe gestures performed on the HIPD 800 are displayed on a virtual keyboard of the messaging user interface 512 displayed by the AR device 700.

[0116] In some embodiments, the wrist-wearable device 600, the AR device 700, the HIPD 800, and/or other communicatively coupled devices can present one or more notifications to the user 502. The notification can be an indication of a new message, an incoming call, an application update, a status update, etc. The user 502 can select the notification via the wrist-wearable device 600, the AR device 700, or the HIPD 800 and cause presentation of an application or operation associated with the notification on at least one device. For example, the user 502 can receive a notification that a message was received at the wrist-wearable device 600, the AR device 700, the HIPD 800, and/or other communicatively coupled device and provide a user input at the wrist-wearable device 600, the AR device 700, and/or the HIPD 800 to review the notification, and the device detecting the user input can cause an application associated with the notification to be initiated and/or presented at the wrist-wearable device 600, the AR device 700, and/or the HIPD 800.

[0117] While the above example describes coordinated inputs used to interact with a messaging application, the skilled artisan will appreciate upon reading the descriptions that user inputs can be coordinated to interact with any number of applications including, but not limited to, gaming applications, social media applications, camera applications, web-based applications, financial applications, etc. For example, the AR device 700 can present to the user 502 game application data and the HIPD 800 can use a controller to provide inputs to the game. Similarly, the user 502 can use the wrist-wearable device 600 to initiate a camera of the AR device 700, and the user can use the wrist-wearable device 600, the AR device 700, and/or the HIPD 800 to manipulate the image capture (e.g., zoom in or out, apply filters, etc.) and capture image data.

[0118] Turning to Figures 5C-1 and 5C-2, the user 502 is shown wearing the wrist-wearable device 600 and a VR device 710, and holding the HIPD 800. In the third AR system 500c, the wrist-wearable device 600, the VR device 710, and/or the HIPD 800 are used to interact within an AR environment, such as a VR game or other AR application. While the VR device 710 present a representation of a VR game (e.g., first AR game

environment 520) to the user 502, the wrist-wearable device 600, the VR device 710, and/or the HIPD 800 detect and coordinate one or more user inputs to allow the user 502 to interact with the VR game.

[0119] In some embodiments, the user 502 can provide a user input via the wrist-wearable device 600, the VR device 710, and/or the HIPD 800 that causes an action in a corresponding AR environment. For example, the user 502 in the third AR system 500c (shown in Figure 5C-1) raises the HIPD 800 to prepare for a swing in the first AR game environment 520. The VR device 710, responsive to the user 502 raising the HIPD 800, causes the AR representation of the user 522 to perform a similar action (e.g., raise a virtual object, such as a virtual sword 524). In some embodiments, each device uses respective sensor data and/or image data to detect the user input and provide an accurate representation of the user 502's motion. For example, image sensors 858 (e.g., SLAM cameras or other cameras discussed below in Figures 8A and 8B) of the HIPD 800 can be used to detect a position of the 800 relative to the user 502's body such that the virtual object can be positioned appropriately within the first AR game environment 520; sensor data from the wrist-wearable device 600 can be used to detect a velocity at which the user 502 raises the HIPD 800 such that the AR representation of the user 522 and the virtual sword 524 are synchronized with the user 502's movements; and image sensors 726 (Figures 7A-7C) of the VR device 710 can be used to represent the user 502's body, boundary conditions, or real-world objects within the first AR game environment 520.

[0120] In Figure 5C-2, the user 502 performs a downward swing while holding the HIPD 800. The user 502's downward swing is detected by the wrist-wearable device 600, the VR device 710, and/or the HIPD 800 and a corresponding action is performed in the first AR game environment 520. In some embodiments, the data captured by each device is used to improve the user's experience within the AR environment. For example, sensor data of the wrist-wearable device 600 can be used to determine a speed and/or force at which the downward swing is performed and image sensors of the HIPD 800 and/or the VR device 710 can be used to determine a location of the swing and how it should be represented in the first AR game environment 520, which, in turn, can be used as inputs for the AR environment (e.g., game mechanics, which can use detected speed, force, locations, and/or aspects of the user 502's actions to classify a user's inputs (e.g., user performs a light strike, hard strike, critical strike, glancing strike, miss) or calculate an output (e.g., amount of damage)).

[0121] While the wrist-wearable device 600, the VR device 710, and/or the HIPD 800 are described as detecting user inputs, in some embodiments, user inputs are detected at a

1 single device (with the single device being responsible for distributing signals to the other
2 devices for performing the user input). For example, the HIPD 800 can operate an
3 application for generating the first AR game environment 520 and provide the VR device 710
4 with corresponding data for causing the presentation of the first AR game environment 520,
5 as well as detect the 502's movements (while holding the HIPD 800) to cause the
6 performance of corresponding actions within the first AR game environment 520.
7 Additionally or alternatively, in some embodiments, operational data (e.g., sensor data, image
8 data, application data, device data, and/or other data) of one or more devices is provide to a
9 single device (e.g., the HIPD 800) to process the operational data and cause respective
10 devices to perform an action associated with processed operational data.

11 **[0122]** Having discussed example AR systems, devices for interacting with such AR
12 systems, and other computing systems more generally, will now be discussed in greater detail
13 below. Some definitions of devices and components that can be included in some or all of
14 the example devices discussed below are defined here for ease of reference. A skilled artisan
15 will appreciate that certain types of the components described below may be more suitable
16 for a particular set of devices, and less suitable for a different set of devices. But subsequent
17 reference to the components defined here should be considered to be encompassed by the
18 definitions provided.

19 **[0123]** In some embodiments discussed below example devices and systems,
20 including electronic devices and systems, will be discussed. Such example devices and
21 systems are not intended to be limiting, and one of skill in the art will understand that
22 alternative devices and systems to the example devices and systems described herein may be
23 used to perform the operations and construct the systems and device that are described herein.

24 **[0124]** As described herein, an electronic device is a device that uses electrical energy
25 to perform a specific function. It can be any physical object that contains electronic
26 components such as transistors, resistors, capacitors, diodes, and integrated circuits.
27 Examples of electronic devices include smartphones, laptops, digital cameras, televisions,
28 gaming consoles, and music players, as well as the example electronic devices discussed
29 herein. As described herein, an intermediary electronic device is a device that sits between
30 two other electronic devices, and/or a subset of components of one or more electronic devices
31 and facilitates communication, and/or data processing and/or data transfer between the
32 respective electronic devices and/or electronic components.

33 ***Example Wrist-Wearable Devices***

34 **[0125]** Figures 6A and 6B illustrate an example wrist-wearable device 600, in

1 accordance with some embodiments. The wrist-wearable device 600 is an instance of the
2 wearable device 120 described in reference to Figures 1A-4 herein, such that the wrist-
3 wearable devices 120 should be understood to have the features of the wrist-wearable device
4 600 and vice versa. Figure 6A illustrates components of the wrist-wearable device 600,
5 which can be used individually or in combination, including combinations that include other
6 electronic devices and/or electronic components.

7 **[0126]** Figure 6A shows a wearable band 610 and a watch body 620 (or capsule)
8 being coupled, as discussed below, to form the wrist-wearable device 600. The wrist-
9 wearable device 600 can perform various functions and/or operations associated with
10 navigating through user interfaces and selectively opening applications, as well as the
11 functions and/or operations described above with reference to Figures 1A-4.

12 **[0127]** As will be described in more detail below, operations executed by the wrist-
13 wearable device 600 can include (i) presenting content to a user (e.g., displaying visual
14 content via a display 605); (ii) detecting (e.g., sensing) user input (e.g., sensing a touch on
15 peripheral button 623 and/or at a touch screen of the display 605, a hand gesture detected by
16 sensors (e.g., biopotential sensors)); (iii) sensing biometric data via one or more sensors 613
17 (e.g., neuromuscular signals, heart rate, temperature, sleep, etc.); messaging (e.g., text,
18 speech, video, etc.); image capture via one or more imaging devices or cameras 625; wireless
19 communications (e.g., cellular, near field, Wi-Fi, personal area network, etc.); location
20 determination; financial transactions; providing haptic feedback; alarms; notifications;
21 biometric authentication; health monitoring; sleep monitoring.

22 **[0128]** The above-example functions can be executed independently in the watch
23 body 620, independently in the wearable band 610, and/or via an electronic communication
24 between the watch body 620 and the wearable band 610. In some embodiments, functions
25 can be executed on the wrist-wearable device 600 while an AR environment is being
26 presented (e.g., via one of the AR systems 500a to 500c). As the skilled artisan will
27 appreciate upon reading the descriptions provided herein, the novel wearable devices
28 described herein can be used with other types of AR environments.

29 **[0129]** The wearable band 610 can be configured to be worn by a user such that an
30 inner (or inside) surface of the wearable structure 611 of the wearable band 610 is in contact
31 with the user's skin. When worn by a user, sensors 613 contact the user's skin. The sensors
32 613 can sense biometric data such as a user's heart rate, saturated oxygen level, temperature,
33 sweat level, neuromuscular signal sensors, or a combination thereof. The sensors 613 can
34 also sense data about a user's environment, including a user's motion, altitude, location,

1 orientation, gait, acceleration, position, or a combination thereof. In some embodiments, the
2 sensors 613 are configured to track a position and/or motion of the wearable band 610. The
3 one or more sensors 613 can include any of the sensors defined above and/or discussed below
4 with respect to Figure 6B.

5 **[0130]** The one or more sensors 613 can be distributed on an inside and/or an outside
6 surface of the wearable band 610. In some embodiments, the one or more sensors 613 are
7 uniformly spaced along the wearable band 610. Alternatively, in some embodiments, the one
8 or more sensors 613 are positioned at distinct points along the wearable band 610. As shown
9 in Figure 6A, the one or more sensors 613 can be the same or distinct. For example, in some
10 embodiments, the one or more sensors 613 can be shaped as a pill (e.g., sensor 613a), an
11 oval, a circle a square, an oblong (e.g., sensor 613c) and/or any other shape that maintains
12 contact with the user's skin (e.g., such that neuromuscular signal and/or other biometric data
13 can be accurately measured at the user's skin). In some embodiments, the one or more
14 sensors 613 are aligned to form pairs of sensors (e.g., for sensing neuromuscular signals
15 based on differential sensing within each respective sensor). For example, sensor 613b is
16 aligned with an adjacent sensor to form sensor pair 614a and sensor 613d is aligned with an
17 adjacent sensor to form sensor pair 614b. In some embodiments, the wearable band 610 does
18 not have a sensor pair. Alternatively, in some embodiments, the wearable band 610 has a
19 predetermined number of sensor pairs (one pair of sensors, three pairs of sensors, four pairs
20 of sensors, six pairs of sensors, sixteen pairs of sensors, etc.).

21 **[0131]** The wearable band 610 can include any suitable number of sensors 613. In
22 some embodiments, the number and arrangements of sensors 613 depend on the particular
23 application for which the wearable band 610 is used. For instance, a wearable band 610
24 configured as an armband, wristband, or chest-band may include a plurality of sensors 613
25 with different number of sensors 613 and different arrangement for each use case, such as
26 medical use cases, compared to gaming or general day-to-day use cases.

27 **[0132]** In accordance with some embodiments, the wearable band 610 further
28 includes an electrical ground electrode and a shielding electrode. The electrical ground and
29 shielding electrodes, like the sensors 613, can be distributed on the inside surface of the
30 wearable band 610 such that they contact a portion of the user's skin. For example, the
31 electrical ground and shielding electrodes can be at an inside surface of coupling mechanism
32 616 or an inside surface of a wearable structure 611. The electrical ground and shielding
33 electrodes can be formed and/or use the same components as the sensors 613. In some
34 embodiments, the wearable band 610 includes more than one electrical ground electrode and

1 more than one shielding electrode.

2 **[0133]** The sensors 613 can be formed as part of the wearable structure 611 of the
3 wearable band 610. In some embodiments, the sensors 613 are flush or substantially flush
4 with the wearable structure 611 such that they do not extend beyond the surface of the
5 wearable structure 611. While flush with the wearable structure 611, the sensors 613 are still
6 configured to contact the user's skin (e.g., via a skin-contacting surface). Alternatively, in
7 some embodiments, the sensors 613 extend beyond the wearable structure 611 a
8 predetermined distance (e.g., 0.1 mm to 2 mm) to make contact and depress into the user's
9 skin. In some embodiments, the sensors 613 are coupled to an actuator (not shown)
10 configured to adjust an extension height (e.g., a distance from the surface of the wearable
11 structure 611) of the sensors 613 such that the sensors 613 make contact and depress into the
12 user's skin. In some embodiments, the actuators adjust the extension height between 0.01
13 mm to 1.2 mm. This allows the user to customize the positioning of the sensors 613 to
14 improve the overall comfort of the wearable band 610 when worn while still allowing the
15 sensors 613 to contact the user's skin. In some embodiments, the sensors 613 are
16 indistinguishable from the wearable structure 611 when worn by the user.

17 **[0134]** The wearable structure 611 can be formed of an elastic material, elastomers,
18 etc., configured to be stretched and fitted to be worn by the user. In some embodiments, the
19 wearable structure 611 is a textile or woven fabric. As described above, the sensors 613 can
20 be formed as part of a wearable structure 611. For example, the sensors 613 can be molded
21 into the wearable structure 611 or be integrated into a woven fabric (e.g., the sensors 613 can
22 be sewn into the fabric and mimic the pliability of fabric (e.g., the sensors 613 can be
23 constructed from a series of woven strands of fabric)).

24 **[0135]** The wearable structure 611 can include flexible electronic connectors that
25 interconnect the sensors 613, the electronic circuitry, and/or other electronic components
26 (described below in reference to Figure 6B) that are enclosed in the wearable band 610. In
27 some embodiments, the flexible electronic connectors are configured to interconnect the
28 sensors 613, the electronic circuitry, and/or other electronic components of the wearable band
29 610 with respective sensors and/or other electronic components of another electronic device
30 (e.g., watch body 620). The flexible electronic connectors are configured to move with the
31 wearable structure 611 such that the user adjustment to the wearable structure 611 (e.g.,
32 resizing, pulling, folding, etc.) does not stress or strain the electrical coupling of components
33 of the wearable band 610.

34 **[0136]** As described above, the wearable band 610 is configured to be worn by a user.

1 In particular, the wearable band 610 can be shaped or otherwise manipulated to be worn by a
2 user. For example, the wearable band 610 can be shaped to have a substantially circular
3 shape such that it can be configured to be worn on the user's lower arm or wrist.

4 Alternatively, the wearable band 610 can be shaped to be worn on another body part of the
5 user, such as the user's upper arm (e.g., around a bicep), forearm, chest, legs, etc. The
6 wearable band 610 can include a retaining mechanism 612 (e.g., a buckle, a hook and loop
7 fastener, etc.) for securing the wearable band 610 to the user's wrist or other body part.

8 While the wearable band 610 is worn by the user, the sensors 613 sense data (referred to as
9 sensor data) from the user's skin. In particular, the sensors 613 of the wearable band 610
10 obtain (e.g., sense and record) neuromuscular signals.

11 **[0137]** The sensed data (e.g., sensed neuromuscular signals) can be used to detect
12 and/or determine the user's intention to perform certain motor actions. In particular, the
13 sensors 613 sense and record neuromuscular signals from the user as the user performs
14 muscular activations (e.g., movements, gestures, etc.). The detected and/or determined motor
15 actions (e.g., phalange (or digits) movements, wrist movements, hand movements, and/or
16 other muscle intentions) can be used to determine control commands or control information
17 (instructions to perform certain commands after the data is sensed) for causing a computing
18 device to perform one or more input commands. For example, the sensed neuromuscular
19 signals can be used to control certain user interfaces displayed on the display 605 of the
20 wrist-wearable device 600 and/or can be transmitted to a device responsible for rendering an
21 artificial-reality environment (e.g., a head-mounted display) to perform an action in an
22 associated artificial-reality environment, such as to control the motion of a virtual device
23 displayed to the user. The muscular activations performed by the user can include static
24 gestures, such as placing the user's hand palm down on a table; dynamic gestures, such as
25 grasping a physical or virtual object; and covert gestures that are imperceptible to another
26 person, such as slightly tensing a joint by co-contracting opposing muscles or using sub-
27 muscular activations. The muscular activations performed by the user can include symbolic
28 gestures (e.g., gestures mapped to other gestures, interactions, or commands, for example,
29 based on a gesture vocabulary that specifies the mapping of gestures to commands).

30 **[0138]** The sensor data sensed by the sensors 613 can be used to provide a user with
31 an enhanced interaction with a physical object (e.g., devices communicatively coupled with
32 the wearable band 610) and/or a virtual object in an artificial-reality application generated by
33 an artificial-reality system (e.g., user interface objects presented on the display 605 or another
34 computing device (e.g., a smartphone)).

1 **[0139]** In some embodiments, the wearable band 610 includes one or more haptic
2 devices 646 (Figure 6B; e.g., a vibratory haptic actuator) that are configured to provide haptic
3 feedback (e.g., a cutaneous and/or kinesthetic sensation, etc.) to the user's skin. The sensors
4 613, and/or the haptic devices 646 can be configured to operate in conjunction with multiple
5 applications including, without limitation, health monitoring, social media, games, and
6 artificial reality (e.g., the applications associated with artificial reality).

7 **[0140]** The wearable band 610 can also include coupling mechanism 616 (e.g., a
8 cradle or a shape of the coupling mechanism can correspond to shape of the watch body 620
9 of the wrist-wearable device 600) for detachably coupling a capsule (e.g., a computing unit)
10 or watch body 620 (via a coupling surface of the watch body 620) to the wearable band 610.
11 In particular, the coupling mechanism 616 can be configured to receive a coupling surface
12 proximate to the bottom side of the watch body 620 (e.g., a side opposite to a front side of the
13 watch body 620 where the display 605 is located), such that a user can push the watch body
14 620 downward into the coupling mechanism 616 to attach the watch body 620 to the coupling
15 mechanism 616. In some embodiments, the coupling mechanism 616 can be configured to
16 receive a top side of the watch body 620 (e.g., a side proximate to the front side of the watch
17 body 620 where the display 605 is located) that is pushed upward into the cradle, as opposed
18 to being pushed downward into the coupling mechanism 616. In some embodiments, the
19 coupling mechanism 616 is an integrated component of the wearable band 610 such that the
20 wearable band 610 and the coupling mechanism 616 are a single unitary structure. In some
21 embodiments, the coupling mechanism 616 is a type of frame or shell that allows the watch
22 body 620 coupling surface to be retained within or on the wearable band 610 coupling
23 mechanism 616 (e.g., a cradle, a tracker band, a support base, a clasp, etc.).

24 **[0141]** The coupling mechanism 616 can allow for the watch body 620 to be
25 detachably coupled to the wearable band 610 through a friction fit, magnetic coupling, a
26 rotation-based connector, a shear-pin coupler, a retention spring, one or more magnets, a clip,
27 a pin shaft, a hook and loop fastener, or a combination thereof. A user can perform any type
28 of motion to couple the watch body 620 to the wearable band 610 and to decouple the watch
29 body 620 from the wearable band 610. For example, a user can twist, slide, turn, push, pull,
30 or rotate the watch body 620 relative to the wearable band 610, or a combination thereof, to
31 attach the watch body 620 to the wearable band 610 and to detach the watch body 620 from
32 the wearable band 610. Alternatively, as discussed below, in some embodiments, the watch
33 body 620 can be decoupled from the wearable band 610 by actuation of the release
34 mechanism 629.

1 **[0142]** The wearable band 610 can be coupled with a watch body 620 to increase the
2 functionality of the wearable band 610 (e.g., converting the wearable band 610 into a wrist-
3 wearable device 600, adding an additional computing unit and/or battery to increase
4 computational resources and/or a battery life of the wearable band 610, adding additional
5 sensors to improve sensed data, etc.). As described above, the wearable band 610 (and the
6 coupling mechanism 616) is configured to operate independently (e.g., execute functions
7 independently) from watch body 620. For example, the coupling mechanism 616 can include
8 one or more sensors 613 that contact a user's skin when the wearable band 610 is worn by the
9 user and provide sensor data for determining control commands.

10 **[0143]** A user can detach the watch body 620 (or capsule) from the wearable band
11 610 in order to reduce the encumbrance of the wrist-wearable device 600 to the user. For
12 embodiments in which the watch body 620 is removable, the watch body 620 can be referred
13 to as a removable structure, such that in these embodiments the wrist-wearable device 600
14 includes a wearable portion (e.g., the wearable band 610) and a removable structure (the
15 watch body 620).

16 **[0144]** Turning to the watch body 620, the watch body 620 can have a substantially
17 rectangular or circular shape. The watch body 620 is configured to be worn by the user on
18 their wrist or on another body part. More specifically, the watch body 620 is sized to be
19 easily carried by the user, attached on a portion of the user's clothing, and/or coupled to the
20 wearable band 610 (forming the wrist-wearable device 600). As described above, the watch
21 body 620 can have a shape corresponding to the coupling mechanism 616 of the wearable
22 band 610. In some embodiments, the watch body 620 includes a single release mechanism
23 629 or multiple release mechanisms (e.g., two release mechanisms 629 positioned on
24 opposing sides of the watch body 620, such as spring-loaded buttons) for decoupling the
25 watch body 620 and the wearable band 610. The release mechanism 629 can include,
26 without limitation, a button, a knob, a plunger, a handle, a lever, a fastener, a clasp, a dial, a
27 latch, or a combination thereof.

28 **[0145]** A user can actuate the release mechanism 629 by pushing, turning, lifting,
29 depressing, shifting, or performing other actions on the release mechanism 629. Actuation of
30 the release mechanism 629 can release (e.g., decouple) the watch body 620 from the coupling
31 mechanism 616 of the wearable band 610, allowing the user to use the watch body 620
32 independently from wearable band 610, and vice versa. For example, decoupling the watch
33 body 620 from the wearable band 610 can allow the user to capture images using rear-facing
34 camera 625B. Although the coupling mechanism 616 is shown positioned at a corner of

1 watch body 620, the release mechanism 629 can be positioned anywhere on watch body 620
2 that is convenient for the user to actuate. In addition, in some embodiments, the wearable
3 band 610 can also include a respective release mechanism for decoupling the watch body 620
4 from the coupling mechanism 616. In some embodiments, the release mechanism 629 is
5 optional and the watch body 620 can be decoupled from the coupling mechanism 616 as
6 described above (e.g., via twisting, rotating, etc.).

7 **[0146]** The watch body 620 can include one or more peripheral buttons 623 and 627
8 for performing various operations at the watch body 620. For example, the peripheral buttons
9 623 and 627 can be used to turn on or wake (e.g., transition from a sleep state to an active
10 state) the display 605, unlock the watch body 620, increase or decrease a volume, increase or
11 decrease brightness, interact with one or more applications, interact with one or more user
12 interfaces, etc. Additionally, or alternatively, in some embodiments, the display 605 operates
13 as a touch screen and allows the user to provide one or more inputs for interacting with the
14 watch body 620.

15 **[0147]** In some embodiments, the watch body 620 includes one or more sensors 621.
16 The sensors 621 of the watch body 620 can be the same or distinct from the sensors 613 of
17 the wearable band 610. The sensors 621 of the watch body 620 can be distributed on an
18 inside and/or an outside surface of the watch body 620. In some embodiments, the sensors
19 621 are configured to contact a user's skin when the watch body 620 is worn by the user. For
20 example, the sensors 621 can be placed on the bottom side of the watch body 620 and the
21 coupling mechanism 616 can be a cradle with an opening that allows the bottom side of the
22 watch body 620 to directly contact the user's skin. Alternatively, in some embodiments, the
23 watch body 620 does not include sensors that are configured to contact the user's skin
24 (e.g., including sensors internal and/or external to the watch body 620 that configured to
25 sense data of the watch body 620 and the watch body 620's surrounding environment). In
26 some embodiments, the sensors 613 are configured to track a position and/or motion of the
27 watch body 620.

28 **[0148]** The watch body 620 and the wearable band 610 can share data using a wired
29 communication method (e.g., a Universal Asynchronous Receiver/Transmitter (UART), a
30 USB transceiver, etc.) and/or a wireless communication method (e.g., near field
31 communication, Bluetooth, etc.). For example, the watch body 620 and the wearable band
32 610 can share data sensed by the sensors 613 and 621, as well as application- and device-
33 specific information (e.g., active and/or available applications), output devices (e.g., display,
34 speakers, etc.), input devices (e.g., touch screen, microphone, imaging sensors, etc.).

1 **[0149]** In some embodiments, the watch body 620 can include, without limitation, a
2 front-facing camera 625A and/or a rear-facing camera 625B, sensors 621 (e.g., a biometric
3 sensor, an IMU sensor, a heart rate sensor, a saturated oxygen sensor, a neuromuscular signal
4 sensor, an altimeter sensor, a temperature sensor, a bioimpedance sensor, a pedometer sensor,
5 an optical sensor (e.g., imaging sensor 663; Figure 6B), a touch sensor, a sweat sensor, etc.).
6 In some embodiments, the watch body 620 can include one or more haptic devices 676
7 (Figure 6B; a vibratory haptic actuator) that is configured to provide haptic feedback (e.g., a
8 cutaneous and/or kinesthetic sensation, etc.) to the user. The sensors 621 and/or the haptic
9 device 676 can also be configured to operate in conjunction with multiple applications
10 including, without limitation, health-monitoring applications, social media applications, game
11 applications, and artificial-reality applications (e.g., the applications associated with artificial
12 reality).

13 **[0150]** As described above, the watch body 620 and the wearable band 610, when
14 coupled, can form the wrist-wearable device 600. When coupled, the watch body 620 and
15 wearable band 610 operate as a single device to execute functions (operations, detections,
16 communications, etc.) described herein. In some embodiments, each device is provided with
17 particular instructions for performing the one or more operations of the wrist-wearable device
18 600. For example, in accordance with a determination that the watch body 620 does not
19 include neuromuscular signal sensors, the wearable band 610 can include alternative
20 instructions for performing associated instructions (e.g., providing sensed neuromuscular
21 signal data to the watch body 620 via a different electronic device). Operations of the wrist-
22 wearable device 600 can be performed by the watch body 620 alone or in conjunction with
23 the wearable band 610 (e.g., via respective processors and/or hardware components) and vice
24 versa. In some embodiments, operations of the wrist-wearable device 600, the watch body
25 620, and/or the wearable band 610 can be performed in conjunction with one or more
26 processors and/or hardware components of another communicatively coupled device (e.g.,
27 the HIPD 800; Figures 8A-8B).

28 **[0151]** As described below with reference to the block diagram of Figure 6B, the
29 wearable band 610 and/or the watch body 620 can each include independent resources
30 required to independently execute functions. For example, the wearable band 610 and/or the
31 watch body 620 can each include a power source (e.g., a battery), a memory, data storage, a
32 processor (e.g., a central processing unit (CPU)), communications, a light source, and/or
33 input/output devices.

34 **[0152]** Figure 6B shows block diagrams of a computing system 630 corresponding to

1 the wearable band 610, and a computing system 660 corresponding to the watch body 620,
2 according to some embodiments. A computing system of the wrist-wearable device 600
3 includes a combination of components of the wearable band computing system 630 and the
4 watch body computing system 660, in accordance with some embodiments.

5 **[0153]** The watch body 620 and/or the wearable band 610 can include one or more
6 components shown in watch body computing system 660. In some embodiments, a single
7 integrated circuit includes all or a substantial portion of the components of the watch body
8 computing system 660 are included in a single integrated circuit. Alternatively, in some
9 embodiments, components of the watch body computing system 660 are included in a
10 plurality of integrated circuits that are communicatively coupled. In some embodiments, the
11 watch body computing system 660 is configured to couple (e.g., via a wired or wireless
12 connection) with the wearable band computing system 630, which allows the computing
13 systems to share components, distribute tasks, and/or perform other operations described
14 herein (individually or as a single device).

15 **[0154]** The watch body computing system 660 can include one or more processors
16 679, a controller 677, a peripherals interface 661, a power system 695, and memory (e.g., a
17 memory 680), each of which are defined above and described in more detail below.

18 **[0155]** The power system 695 can include a charger input 696, a power-management
19 integrated circuit (PMIC) 697, and a battery 698, each are which are defined above. In some
20 embodiments, a watch body 620 and a wearable band 610 can have respective charger inputs
21 (e.g., charger input 696 and 657), respective batteries (e.g., battery 698 and 659), and can
22 share power with each other (e.g., the watch body 620 can power and/or charge the wearable
23 band 610, and vice versa). Although watch body 620 and/or the wearable band 610 can
24 include respective charger inputs, a single charger input can charge both devices when
25 coupled. The watch body 620 and the wearable band 610 can receive a charge using a variety
26 of techniques. In some embodiments, the watch body 620 and the wearable band 610 can use
27 a wired charging assembly (e.g., power cords) to receive the charge. Alternatively, or in
28 addition, the watch body 620 and/or the wearable band 610 can be configured for wireless
29 charging. For example, a portable charging device can be designed to mate with a portion of
30 watch body 620 and/or wearable band 610 and wirelessly deliver usable power to a battery of
31 watch body 620 and/or wearable band 610. The watch body 620 and the wearable band 610
32 can have independent power systems (e.g., power system 695 and 656) to enable each to
33 operate independently. The watch body 620 and wearable band 610 can also share power
34 (e.g., one can charge the other) via respective PMICs (e.g., PMICs 697 and 658) that can

1 share power over power and ground conductors and/or over wireless charging antennas.

2 **[0156]** In some embodiments, the peripherals interface 661 can include one or more
3 sensors 621, many of which listed below are defined above. The sensors 621 can include one
4 or more coupling sensors 662 for detecting when the watch body 620 is coupled with another
5 electronic device (e.g., a wearable band 610). The sensors 621 can include imaging sensors
6 663 (one or more of the cameras 625 and/or separate imaging sensors 663 (e.g., thermal-
7 imaging sensors)). In some embodiments, the sensors 621 include one or more SpO2 sensors
8 664. In some embodiments, the sensors 621 include one or more biopotential-signal sensors
9 (e.g., EMG sensors 665, which may be disposed on a user-facing portion of the watch body
10 620 and/or the wearable band 610). In some embodiments, the sensors 621 include one or
11 more capacitive sensors 666. In some embodiments, the sensors 621 include one or more
12 heart rate sensors 667. In some embodiments, the sensors 621 include one or more IMUs
13 668. In some embodiments, one or more IMUs 668 can be configured to detect movement of
14 a user's hand or other location that the watch body 620 is placed or held.

15 **[0157]** In some embodiments, the peripherals interface 661 includes an NFC
16 component 669, a global-position system (GPS) component 670, a long-term evolution (LTE)
17 component 671, and/or a Wi-Fi and/or Bluetooth communication component 672. In some
18 embodiments, the peripherals interface 661 includes one or more buttons 673 (e.g., the
19 peripheral buttons 623 and 627 in Figure 6A), which, when selected by a user, cause
20 operations to be performed at the watch body 620. In some embodiments, the peripherals
21 interface 661 includes one or more indicators, such as a light emitting diode (LED), to
22 provide a user with visual indicators (e.g., message received, low battery, an active
23 microphone, and/or a camera, etc.).

24 **[0158]** The watch body 620 can include at least one display 605 for displaying visual
25 representations of information or data to the user, including user-interface elements and/or
26 three-dimensional (3D) virtual objects. The display can also include a touch screen for
27 inputting user inputs, such as touch gestures, swipe gestures, and the like. The watch body
28 620 can include at least one speaker 674 and at least one microphone 675 for providing audio
29 signals to the user and receiving audio input from the user. The user can provide user inputs
30 through the microphone 675 and can also receive audio output from the speaker 674 as part
31 of a haptic event provided by the haptic controller 678. The watch body 620 can include at
32 least one camera 625, including a front-facing camera 625A and a rear-facing camera 625B.
33 The cameras 625 can include ultra-wide-angle cameras, wide-angle cameras, fish-eye
34 cameras, spherical cameras, telephoto cameras, a depth-sensing cameras, or other types of

1 cameras.

2 **[0159]** The watch body computing system 660 can include one or more haptic
3 controllers 678 and associated componentry (e.g., haptic devices 676) for providing haptic
4 events at the watch body 620 (e.g., a vibrating sensation or audio output in response to an
5 event at the watch body 620). The haptic controllers 678 can communicate with one or more
6 haptic devices 676, such as electroacoustic devices, including a speaker of the one or more
7 speakers 674 and/or other audio components and/or electromechanical devices that convert
8 energy into linear motion such as a motor, solenoid, electroactive polymer, piezoelectric
9 actuator, electrostatic actuator, or other tactile output generating component (e.g., a
10 component that converts electrical signals into tactile outputs on the device). The haptic
11 controller 678 can provide haptic events to respective haptic actuators that are capable of
12 being sensed by a user of the watch body 620. In some embodiments, the one or more haptic
13 controllers 678 can receive input signals from an application of the applications 682.

14 **[0160]** In some embodiments, the computer system 630 and/or the computer system
15 660 can include memory 680, which can be controlled by a memory controller of the one or
16 more controllers 677 and/or one or more processors 679. In some embodiments, software
17 components stored in the memory 680 include one or more applications 682 configured to
18 perform operations at the watch body 620. In some embodiments, the one or more
19 applications 682 include games, word processors, messaging applications, calling
20 applications, web browsers, social media applications, media streaming applications,
21 financial applications, calendars, clocks, etc. In some embodiments, software components
22 stored in the memory 680 include one or more communication interface modules 683 as
23 defined above. In some embodiments, software components stored in the memory 680
24 include one or more graphics modules 684 for rendering, encoding, and/or decoding audio
25 and/or visual data; and one or more data management modules 685 for collecting, organizing,
26 and/or providing access to the data 687 stored in memory 680. In some embodiments,
27 software components stored in the memory 680 include a device control module 686A, which
28 is configured to perform the features described above in reference to Figures 1A-4. In some
29 embodiments, one or more of applications 682 and/or one or more modules can work in
30 conjunction with one another to perform various tasks at the watch body 620.

31 **[0161]** In some embodiments, software components stored in the memory 680 can
32 include one or more operating systems 681 (e.g., a Linux-based operating system, an Android
33 operating system, etc.). The memory 680 can also include data 687. The data 687 can
34 include profile data 688A, sensor data 689A, media content data 690, application data 691,

1 and device control data 692A, which stores data related to the performance of the features
2 described above in reference to Figures 1A-4.

3 **[0162]** It should be appreciated that the watch body computing system 660 is an
4 example of a computing system within the watch body 620, and that the watch body 620 can
5 have more or fewer components than shown in the watch body computing system 660,
6 combine two or more components, and/or have a different configuration and/or arrangement
7 of the components. The various components shown in watch body computing system 660 are
8 implemented in hardware, software, firmware, or a combination thereof, including one or
9 more signal processing and/or application-specific integrated circuits.

10 **[0163]** Turning to the wearable band computing system 630, one or more components
11 that can be included in the wearable band 610 are shown. The wearable band computing
12 system 630 can include more or fewer components than shown in the watch body computing
13 system 660, combine two or more components, and/or have a different configuration and/or
14 arrangement of some or all of the components. In some embodiments, all, or a substantial
15 portion of the components of the wearable band computing system 630 are included in a
16 single integrated circuit. Alternatively, in some embodiments, components of the wearable
17 band computing system 630 are included in a plurality of integrated circuits that are
18 communicatively coupled. As described above, in some embodiments, the wearable band
19 computing system 630 is configured to couple (e.g., via a wired or wireless connection) with
20 the watch body computing system 660, which allows the computing systems to share
21 components, distribute tasks, and/or perform other operations described herein (individually
22 or as a single device).

23 **[0164]** The wearable band computing system 630, similar to the watch body
24 computing system 660, can include one or more processors 649, one or more controllers 647
25 (including one or more haptics controller 648), a peripherals interface 631 that can include
26 one or more sensors 613 and other peripheral devices, power source (e.g., a power system
27 656), and memory (e.g., a memory 650) that includes an operating system (e.g., an operating
28 system 651), data (e.g., data 654 including profile data 688B, sensor data 689B, device
29 control data 692B, etc.), and one or more modules (e.g., a communications interface module
30 652, a data management module 653, a device control module 686B, etc.).

31 **[0165]** The one or more sensors 613 can be analogous to sensors 621 of the computer
32 system 660 in light of the definitions above. For example, sensors 613 can include one or
33 more coupling sensors 632, one or more SpO2 sensors 634, one or more EMG sensors 635,
34 one or more capacitive sensors 636, one or more heart rate sensors 637, and one or more IMU

1 sensors 638.

2 **[0166]** The peripherals interface 631 can also include other components analogous to
3 those included in the peripheral interface 661 of the computer system 660, including an NFC
4 component 639, a GPS component 640, an LTE component 641, a Wi-Fi and/or Bluetooth
5 communication component 642, and/or one or more haptic devices 676 as described above in
6 reference to peripherals interface 661. In some embodiments, the peripherals interface 631
7 includes one or more buttons 643, a display 633, a speaker 644, a microphone 645, and a
8 camera 655. In some embodiments, the peripherals interface 631 includes one or more
9 indicators, such as an LED.

10 **[0167]** It should be appreciated that the wearable band computing system 630 is an
11 example of a computing system within the wearable band 610, and that the wearable band
12 610 can have more or fewer components than shown in the wearable band computing system
13 630, combine two or more components, and/or have a different configuration and/or
14 arrangement of the components. The various components shown in wearable band
15 computing system 630 can be implemented in one or a combination of hardware, software,
16 and firmware, including one or more signal processing and/or application-specific integrated
17 circuits.

18 **[0168]** The wrist-wearable device 600 with respect to Figures 6A is an example of the
19 wearable band 610 and the watch body 620 coupled, so the wrist-wearable device 600 will be
20 understood to include the components shown and described for the wearable band computing
21 system 630 and the watch body computing system 660. In some embodiments, wrist-
22 wearable device 600 has a split architecture (e.g., a split mechanical architecture or a split
23 electrical architecture) between the watch body 620 and the wearable band 610. In other
24 words, all of the components shown in the wearable band computing system 630 and the
25 watch body computing system 660 can be housed or otherwise disposed in a combined watch
26 device 600, or within individual components of the watch body 620, wearable band 610,
27 and/or portions thereof (e.g., a coupling mechanism 616 of the wearable band 610).

28 **[0169]** The techniques described above can be used with any device for sensing
29 neuromuscular signals, including the arm-wearable devices of Figure 6A-6B, but could also
30 be used with other types of wearable devices for sensing neuromuscular signals (such as
31 body-wearable or head-wearable devices that might have neuromuscular sensors closer to the
32 brain or spinal column).

33 **[0170]** In some embodiments, a wrist-wearable device 600 can be used in conjunction
34 with a head-wearable device described below (e.g., AR device 700 and VR device 710)

1 and/or an HIPD 800, and the wrist-wearable device 600 can also be configured to be used to
2 allow a user to control aspect of the artificial reality (e.g., by using EMG-based gestures to
3 control user interface objects in the artificial reality and/or by allowing a user to interact with
4 the touchscreen on the wrist-wearable device to also control aspects of the artificial reality).
5 Having thus described example wrist-wearable device, attention will now be turned to
6 example head-wearable devices, such AR device 700 and VR device 710.

7 ***Example Head-Wearable Devices***

8 [0171] Figures 7A-7C show example head-wearable devices, in accordance with
9 some embodiments. Head-wearable devices can include, but are not limited to, AR devices
10 710 (e.g., AR or smart eyewear devices, such as smart glasses, smart monocles, smart
11 contacts, etc.), VR devices 710 (e.g., VR headsets, head-mounted displays (HMD)s, etc.), or
12 other ocularly coupled devices. The AR devices 700 and the VR devices 710 are instances of
13 the head-wearable devices 110 described in reference to Figures 1A-4 herein, such that the
14 head-wearable device 110 should be understood to have the features of the AR devices 700
15 and/or the VR devices 710, and vice versa. The AR devices 700 and the VR devices 710 can
16 perform various functions and/or operations associated with navigating through user
17 interfaces and selectively opening applications, as well as the functions and/or operations
18 described above with reference to Figures 1A-4.

19 [0172] In some embodiments, an AR system (e.g., AR systems 500a-500c; Figures
20 5A-5C-2) includes an AR device 700 (as shown in Figure 7A) and/or VR device 710 (as
21 shown in Figures 7B-1-B-2). In some embodiments, the AR device 700 and the VR device
22 710 can include one or more analogous components (e.g., components for presenting
23 interactive artificial-reality environments, such as processors, memory, and/or presentation
24 devices, including one or more displays and/or one or more waveguides), some of which are
25 described in more detail with respect to Figure 7C. The head-wearable devices can use
26 display projectors (e.g., display projector assemblies 707A and 707B) and/or waveguides for
27 projecting representations of data to a user. Some embodiments of head-wearable devices do
28 not include displays.

29 [0173] Figure 7A shows an example visual depiction of the AR device 700 (e.g.,
30 which may also be described herein as augmented-reality glasses and/or smart glasses). The
31 AR device 700 can work in conjunction with additional electronic components that are not
32 shown in Figures 7A, such as a wearable accessory device and/or an intermediary processing
33 device, in electronic communication or otherwise configured to be used in conjunction with
34 the AR device 700. In some embodiments, the wearable accessory device and/or the

intermediary processing device may be configured to couple with the AR device 700 via a coupling mechanism in electronic communication with a coupling sensor 724, where the coupling sensor 724 can detect when an electronic device becomes physically or electronically coupled with the AR device 700. In some embodiments, the AR device 700 can be configured to couple to a housing (e.g., a portion of frame 704 or temple arms 705), which may include one or more additional coupling mechanisms configured to couple with additional accessory devices. The components shown in Figure 7A can be implemented in hardware, software, firmware, or a combination thereof, including one or more signal-processing components and/or application-specific integrated circuits (ASICs).

[0174] The AR device 700 includes mechanical glasses components, including a frame 704 configured to hold one or more lenses (e.g., one or both lenses 706-1 and 706-2). One of ordinary skill in the art will appreciate that the AR device 700 can include additional mechanical components, such as hinges configured to allow portions of the frame 704 of the AR device 700 to be folded and unfolded, a bridge configured to span the gap between the lenses 706-1 and 706-2 and rest on the user's nose, nose pads configured to rest on the bridge of the nose and provide support for the AR device 700, earpieces configured to rest on the user's ears and provide additional support for the AR device 700, temple arms 705 configured to extend from the hinges to the earpieces of the AR device 700, and the like. One of ordinary skill in the art will further appreciate that some examples of the AR device 700 can include none of the mechanical components described herein. For example, smart contact lenses configured to present artificial-reality to users may not include any components of the AR device 700.

[0175] The lenses 706-1 and 706-2 can be individual displays or display devices (e.g., a waveguide for projected representations). The lenses 706-1 and 706-2 may act together or independently to present an image or series of images to a user. In some embodiments, the lenses 706-1 and 706-2 can operate in conjunction with one or more display projector assemblies 707A and 707B to present image data to a user. While the AR device 700 includes two displays, embodiments of this disclosure may be implemented in AR devices with a single near-eye display (NED) or more than two NEDs.

[0176] The AR device 700 includes electronic components, many of which will be described in more detail below with respect to Figure 7C. Some example electronic components are illustrated in Figure 7A, including sensors 723-1, 723-2, 723-3, 723-4, 723-5, and 723-6, which can be distributed along a substantial portion of the frame 704 of the AR device 700. The different types of sensors are described below in reference to Figure 7C.

1 The AR device 700 also includes a left camera 739A and a right camera 739B, which are
2 located on different sides of the frame 704. And the eyewear device includes one or more
3 processors 748A and 748B (e.g., an integral microprocessor, such as an ASIC) that is
4 embedded into a portion of the frame 704.

5 **[0177]** Figures 7B-1 and 7B-2 show an example visual depiction of the VR device
6 710 (e.g., a head-mounted display (HMD) 712, also referred to herein as an artificial-reality
7 headset, a head-wearable device, a VR headset, etc.). The HMD 712 includes a front body
8 714 and a frame 716 (e.g., a strap or band) shaped to fit around a user's head. In some
9 embodiments, the front body 714 and/or the frame 716 includes one or more electronic
10 elements for facilitating presentation of and/or interactions with an AR and/or VR system
11 (e.g., displays, processors (e.g., processor 748A-1), IMUs, tracking emitter or detectors,
12 sensors, etc.). In some embodiments, the HMD 712 includes output audio transducers (e.g.,
13 an audio transducer 718-1), as shown in Figure 7B-2. In some embodiments, one or more
14 components, such as the output audio transducer(s) 718-1 and the frame 716, can be
15 configured to attach and detach (e.g., are detachably attachable) to the HMD 712 (e.g., a
16 portion or all of the frame 716, and/or the output audio transducer 718-1), as shown in Figure
17 7B-2. In some embodiments, coupling a detachable component to the HMD 712 causes the
18 detachable component to come into electronic communication with the HMD 712. The VR
19 device 710 includes electronic components, many of which will be described in more detail
20 below with respect to Figure 7C

21 **[0178]** Figure 7B-1 to 7B-2 also show that the VR device 710 one or more cameras,
22 such as the left camera 739A and the right camera 739B, which can be analogous to the left
23 and right cameras on the frame 704 of the AR device 700. In some embodiments, the VR
24 device 710 includes one or more additional cameras (e.g., cameras 739C and 739D), which
25 can be configured to augment image data obtained by the cameras 739A and 739B by
26 providing more information. For example, the camera 739C can be used to supply color
27 information that is not discerned by cameras 739A and 739B. In some embodiments, one or
28 more of the cameras 739A to 739D can include an optional IR cut filter configured to remove
29 IR light from being received at the respective camera sensors.

30 **[0179]** The VR device 710 can include a housing 790 storing one or more
31 components of the VR device 710 and/or additional components of the VR device 710. The
32 housing 790 can be a modular electronic device configured to couple with the VR device 710
33 (or an AR device 700) and supplement and/or extend the capabilities of the VR device 710
34 (or an AR device 700). For example, the housing 790 can include additional sensors,

1 cameras, power sources, processors (e.g., processor 748A-2), etc. to improve and/or increase
2 the functionality of the VR device 710. Examples of the different components included in the
3 housing 790 are described below in reference to Figure 7C.

4 **[0180]** Alternatively or in addition, in some embodiments, the head-wearable device,
5 such as the VR device 710 and/or the AR device 700), includes, or is communicatively
6 coupled to, another external device (e.g., a paired device), such as an HIPD 8 (discussed
7 below in reference to Figures 8A-8B) and/or an optional neckband. The optional neckband
8 can couple to the head-wearable device via one or more connectors (e.g., wired or wireless
9 connectors). The head-wearable device and the neckband can operate independently without
10 any wired or wireless connection between them. In some embodiments, the components of
11 the head-wearable device and the neckband are located on one or more additional peripheral
12 devices paired with the head-wearable device, the neckband, or some combination thereof.
13 Furthermore, the neckband is intended to represent any suitable type or form of paired device.
14 Thus, the following discussion of neckband may also apply to various other paired devices,
15 such as smart watches, smart phones, wrist bands, other wearable devices, hand-held
16 controllers, tablet computers, or laptop computers.

17 **[0181]** In some situations, pairing external devices, such as an intermediary
18 processing device (e.g., an HIPD device 800, an optional neckband, and/or wearable
19 accessory device) with the head-wearable devices (e.g., an AR device 700 and/or VR device
20 710) enables the head-wearable devices to achieve a similar form factor of a pair of glasses
21 while still providing sufficient battery and computation power for expanded capabilities.
22 Some, or all, of the battery power, computational resources, and/or additional features of the
23 head-wearable devices can be provided by a paired device or shared between a paired device
24 and the head-wearable devices, thus reducing the weight, heat profile, and form factor of the
25 head-wearable devices overall while allowing the head-wearable devices to retain its desired
26 functionality. For example, the intermediary processing device (e.g., the HIPD 800) can
27 allow components that would otherwise be included in a head-wearable device to be included
28 in the intermediary processing device (and/or a wearable device or accessory device), thereby
29 shifting a weight load from the user's head and neck to one or more other portions of the
30 user's body. In some embodiments, the intermediary processing device has a larger surface
31 area over which to diffuse and disperse heat to the ambient environment. Thus, the
32 intermediary processing device can allow for greater battery and computation capacity than
33 might otherwise have been possible on the head-wearable devices, standing alone. Because
34 weight carried in the intermediary processing device can be less invasive to a user than

1 weight carried in the head-wearable devices, a user may tolerate wearing a lighter eyewear
2 device and carrying or wearing the paired device for greater lengths of time than the user
3 would tolerate wearing a heavier eyewear device standing alone, thereby enabling an
4 artificial-reality environment to be incorporated more fully into a user's day-to-day activities.

5 **[0182]** In some embodiments, the intermediary processing device is communicatively
6 coupled with the head-wearable device and/or to other devices. The other devices may
7 provide certain functions (e.g., tracking, localizing, depth mapping, processing, storage, etc.)
8 to the head-wearable device. In some embodiments, the intermediary processing device
9 includes a controller and a power source. In some embodiments, sensors of the intermediary
10 processing device are configured to sense additional data that can be shared with the head-
11 wearable devices in an electronic format (analog or digital).

12 **[0183]** The controller of the intermediary processing device processes information
13 generated by the sensors on the intermediary processing device and/or the head-wearable
14 devices. The intermediary processing device, like an HIPD 800, can process information
15 generated by one or more sensors of its sensors and/or information provided by other
16 communicatively coupled devices. For example, a head-wearable device can include an
17 IMU, and the intermediary processing device (neckband and/or an HIPD 800) can compute
18 all inertial and spatial calculations from the IMUs located on the head-wearable device.
19 Additional examples of processing performed by a communicatively coupled device, such as
20 the HIPD 800, are provided below in reference to Figures 8A and 8B.

21 **[0184]** Artificial-reality systems may include a variety of types of visual feedback
22 mechanisms. For example, display devices in the AR devices 700 and/or the VR devices 710
23 may include one or more liquid-crystal displays (LCDs), light emitting diode (LED) displays,
24 organic LED (OLED) displays, and/or any other suitable type of display screen. Artificial-
25 reality systems may include a single display screen for both eyes or may provide a display
26 screen for each eye, which may allow for additional flexibility for varifocal adjustments or
27 for correcting a refractive error associated with the user's vision. Some artificial-reality
28 systems also include optical subsystems having one or more lenses (e.g., conventional
29 concave or convex lenses, Fresnel lenses, or adjustable liquid lenses) through which a user
30 may view a display screen. In addition to or instead of using display screens, some artificial-
31 reality systems include one or more projection systems. For example, display devices in the
32 AR device 700 and/or the VR device 710 may include micro-LED projectors that project
33 light (e.g., using a waveguide) into display devices, such as clear combiner lenses that allow
34 ambient light to pass through. The display devices may refract the projected light toward a

1 user's pupil and may enable a user to simultaneously view both artificial-reality content and
2 the real world. Artificial-reality systems may also be configured with any other suitable type
3 or form of image projection system. As noted, some AR systems may, instead of blending an
4 artificial reality with actual reality, substantially replace one or more of a user's sensory
5 perceptions of the real world with a virtual experience.

6 **[0185]** While the example head-wearable devices are respectively described herein as
7 the AR device 700 and the VR device 710, either or both of the example head-wearable
8 devices described herein can be configured to present fully-immersive VR scenes presented
9 in substantially all of a user's field of view, additionally or alternatively to, subtler
10 augmented-reality scenes that are presented within a portion, less than all, of the user's field
11 of view.

12 **[0186]** In some embodiments, the AR device 700 and/or the VR device 710 can
13 include haptic feedback systems. The haptic feedback systems may provide various types of
14 cutaneous feedback, including vibration, force, traction, shear, texture, and/or temperature.
15 The haptic feedback systems may also provide various types of kinesthetic feedback, such as
16 motion and compliance. The haptic feedback can be implemented using motors, piezoelectric
17 actuators, fluidic systems, and/or a variety of other types of feedback mechanisms. The
18 haptic feedback systems may be implemented independently of other artificial-reality
19 devices, within other artificial-reality devices, and/or in conjunction with other artificial-
20 reality devices (e.g., wrist-wearable devices which may be incorporated into headwear,
21 gloves, body suits, handheld controllers, environmental devices (e.g., chairs or floor mats),
22 and/or any other type of device or system, such as a wrist-wearable device 600, an HIPD 800,
23 etc.), and/or other devices described herein.

24 **[0187]** Figure 7C illustrates a computing system 720 and an optional housing 790,
25 each of which show components that can be included in a head-wearable device (e.g., the AR
26 device 700 and/or the VR device 710). In some embodiments, more or less components can
27 be included in the optional housing 790 depending on practical restraints of the respective
28 head-wearable device being described. Additionally, or alternatively, the optional housing
29 790 can include additional components to expand and/or augment the functionality of a head-
30 wearable device.

31 **[0188]** In some embodiments, the computing system 720 and/or the optional housing
32 790 can include one or more peripheral interfaces 722A and 722B, one or more power
33 systems 742A and 742B (including charger input 743, PMIC 744, and battery 745), one or
34 more controllers 746A and 746B (including one or more haptic controllers 747), one or more

1 processors 748A and 748B (as defined above, including any of the examples provided), and
2 memory 750A and 750B, which can all be in electronic communication with each other. For
3 example, the one or more processors 748A and/or 748B can be configured to execute
4 instructions stored in the memory 750A and/or 750B, which can cause a controller of the one
5 or more controllers 746A and/or 746B to cause operations to be performed at one or more
6 peripheral devices of the peripherals interfaces 722A and/or 722B. In some embodiments,
7 each operation described can occur based on electrical power provided by the power system
8 742A and/or 742B.

9 **[0189]** In some embodiments, the peripherals interface 722A can include one or more
10 devices configured to be part of the computing system 720, many of which have been defined
11 above and/or described with respect to wrist-wearable devices shown in Figures 6A and 6B.
12 For example, the peripherals interface can include one or more sensors 723A. Some example
13 sensors include: one or more coupling sensors 724, one or more acoustic sensors 725, one or
14 more imaging sensors 726, one or more EMG sensors 727, one or more capacitive sensors
15 728, and/or one or more IMUs 729. In some embodiments, the sensors 723A further include
16 depth sensors 767, light sensors 768 and/or any other types of sensors defined above or
17 described with respect to any other embodiments discussed herein.

18 **[0190]** In some embodiments, the peripherals interface can include one or more
19 additional peripheral devices, including one or more NFC devices 730, one or more GPS
20 devices 731, one or more LTE devices 732, one or more WiFi and/or Bluetooth devices 733,
21 one or more buttons 734 (e.g., including buttons that are slidable or otherwise adjustable),
22 one or more displays 735A, one or more speakers 736A, one or more microphones 737A, one
23 or more cameras 738A (e.g., including the a first camera 739-1 through nth camera 739-n,
24 which are analogous to the left camera 739A and/or the right camera 739B), one or more
25 haptic devices 740; and/or any other types of peripheral devices defined above or described
26 with respect to any other embodiments discussed herein.

27 **[0191]** The head-wearable devices can include a variety of types of visual feedback
28 mechanisms (e.g., presentation devices). For example, display devices in the AR device 700
29 and/or the VR device 710 can include one or more liquid-crystal displays (LCDs), light
30 emitting diode (LED) displays, organic LED (OLED) displays, micro-LEDs, and/or any other
31 suitable types of display screens. The head-wearable devices can include a single display
32 screen (e.g., configured to be seen by both eyes), and/or can provide separate display screens
33 for each eye, which can allow for additional flexibility for varifocal adjustments and/or for
34 correcting a refractive error associated with the user's vision. Some embodiments of the

1 head-wearable devices also include optical subsystems having one or more lenses (e.g.,
2 conventional concave or convex lenses, Fresnel lenses, or adjustable liquid lenses) through
3 which a user can view a display screen. For example, respective displays 735A can be
4 coupled to each of the lenses 706-1 and 706-2 of the AR device 700. The displays 735A
5 coupled to each of the lenses 706-1 and 706-2 can act together or independently to present an
6 image or series of images to a user. In some embodiments, the AR device 700 and/or the VR
7 device 710 includes a single display 735A (e.g., a near-eye display) or more than two
8 displays 735A.

9 **[0192]** In some embodiments, a first set of one or more displays 735A can be used to
10 present an augmented-reality environment, and a second set of one or more display devices
11 735A can be used to present a virtual-reality environment. In some embodiments, one or
12 more waveguides are used in conjunction with presenting artificial-reality content to the user
13 of the AR device 700 and/or the VR device 710 (e.g., as a means of delivering light from a
14 display projector assembly and/or one or more displays 735A to the user's eyes). In some
15 embodiments, one or more waveguides are fully or partially integrated into the AR device
16 700 and/or the VR device 710. Additionally, or alternatively to display screens, some
17 artificial-reality systems include one or more projection systems. For example, display
18 devices in the AR device 700 and/or the VR device 710 can include micro-LED projectors
19 that project light (e.g., using a waveguide) into display devices, such as clear combiner lenses
20 that allow ambient light to pass through. The display devices can refract the projected light
21 toward a user's pupil and can enable a user to simultaneously view both artificial-reality
22 content and the real world. The head-wearable devices can also be configured with any other
23 suitable type or form of image projection system. In some embodiments, one or more
24 waveguides are provided additionally or alternatively to the one or more display(s) 735A.

25 **[0193]** In some embodiments of the head-wearable devices, ambient light and/or a
26 real-world live view (e.g., a live feed of the surrounding environment that a user would
27 normally see) can be passed through a display element of a respective head-wearable device
28 presenting aspects of the AR system. In some embodiments, ambient light and/or the real-
29 world live view can be passed through a portion less than all, of an AR environment
30 presented within a user's field of view (e.g., a portion of the AR environment co-located with
31 a physical object in the user's real-world environment that is within a designated boundary
32 (e.g., a guardian boundary) configured to be used by the user while they are interacting with
33 the AR environment). For example, a visual user interface element (e.g., a notification user
34 interface element) can be presented at the head-wearable devices, and an amount of ambient

1 light and/or the real-world live view (e.g., 15-50% of the ambient light and/or the real-world
2 live view) can be passed through the user interface element, such that the user can distinguish
3 at least a portion of the physical environment over which the user interface element is being
4 displayed.

5 **[0194]** The head-wearable devices can include one or more external displays 735A
6 for presenting information to users. For example, an external display 735A can be used to
7 show a current battery level, network activity (e.g., connected, disconnected, etc.), current
8 activity (e.g., playing a game, in a call, in a meeting, watching a movie, etc.), and/or other
9 relevant information. In some embodiments, the external displays 735A can be used to
10 communicate with others. For example, a user of the head-wearable device can cause the
11 external displays 735A to present a do not disturb notification. The external displays 735A
12 can also be used by the user to share any information captured by the one or more
13 components of the peripherals interface 722A and/or generated by head-wearable device
14 (e.g., during operation and/or performance of one or more applications).

15 **[0195]** The memory 750A can include instructions and/or data executable by one or
16 more processors 748A (and/or processors 748B of the housing 790) and/or a memory
17 controller of the one or more controllers 746A (and/or controller 746B of the housing 790).
18 The memory 750A can include one or more operating systems 751; one or more applications
19 752; one or more communication interface modules 753A; one or more graphics modules
20 754A; one or more AR processing modules 755A; a device control module 756 (analogous to
21 the device control data 686; Figure 6B); and/or any other types of modules or components
22 defined above or described with respect to any other embodiments discussed herein.

23 **[0196]** The data 760 stored in memory 750A can be used in conjunction with one or
24 more of the applications and/or programs discussed above. The data 760 can include profile
25 data 761; sensor data 762; media content data 763; AR application data 764; device control
26 data 765 (analogous to the device control data 692A; Figure 6B); and/or any other types of
27 data defined above or described with respect to any other embodiments discussed herein.

28 **[0197]** In some embodiments, the controller 746A of the head-wearable devices
29 processes information generated by the sensors 723A on the head-wearable devices and/or
30 another component of the head-wearable devices and/or communicatively coupled with the
31 head-wearable devices (e.g., components of the housing 790, such as components of
32 peripherals interface 722B). For example, the controller 746A can process information from
33 the acoustic sensors 725 and/or image sensors 726. For each detected sound, the controller
34 746A can perform a direction of arrival (DOA) estimation to estimate a direction from which

1 the detected sound arrived at a head-wearable device. As one or more of the acoustic sensors
2 725 detects sounds, the controller 746A can populate an audio data set with the information
3 (e.g., represented by sensor data 762).

4 **[0198]** In some embodiments, a physical electronic connector can convey information
5 between the head-wearable devices and another electronic device, and/or between one or
6 more processors 748A of the head-wearable devices and the controller 746A. The
7 information can be in the form of optical data, electrical data, wireless data, or any other
8 transmittable data form. Moving the processing of information generated by the head-
9 wearable devices to an intermediary processing device can reduce weight and heat in the
10 eyewear device, making it more comfortable and safer for a user. In some embodiments, an
11 optional accessory device (e.g., an electronic neckband or an HIPD 800) is coupled to the
12 head-wearable devices via one or more connectors. The connectors can be wired or wireless
13 connectors and can include electrical and/or non-electrical (e.g., structural) components. In
14 some embodiments, the head-wearable devices and the accessory device can operate
15 independently without any wired or wireless connection between them.

16 **[0199]** The head-wearable devices can include various types of computer vision
17 components and subsystems. For example, the AR device 700 and/or the VR device 710 can
18 include one or more optical sensors such as two-dimensional (2D) or three-dimensional (3D)
19 cameras, time-of-flight depth sensors, single-beam or sweeping laser rangefinders, 3D
20 LiDAR sensors, and/or any other suitable type or form of optical sensor. A head-wearable
21 device can process data from one or more of these sensors to identify a location of a user
22 and/or aspects of the use's real-world physical surroundings, including the locations of real-
23 world objects within the real-world physical surroundings. In some embodiments, the
24 methods described herein are used to map the real world, to provide a user with context about
25 real-world surroundings, and/or to generate interactable virtual objects (which can be replicas
26 or digital twins of real-world objects that can be interacted with in AR environment), among
27 a variety of other functions. For example, Figures 7B-1 and 7B-2 show the VR device 710
28 having cameras 739A-739D, which can be used to provide depth information for creating a
29 voxel field and a two-dimensional mesh to provide object information to the user to avoid
30 collisions.

31 **[0200]** The optional housing 790 can include analogous components to those describe
32 above with respect to the computing system 720. For example, the optional housing 790 can
33 include a respective peripherals interface 722B including more or less components to those
34 described above with respect to the peripherals interface 722A. As described above, the

1 components of the optional housing 790 can be used augment and/or expand on the
2 functionality of the head-wearable devices. For example, the optional housing 790 can
3 include respective sensors 723B, speakers 736B, displays 735B, microphones 737B, cameras
4 738B, and/or other components to capture and/or present data. Similarly, the optional
5 housing 790 can include one or more processors 748B, controllers 746B, and/or memory
6 750B (including respective communication interface modules 753B; one or more graphics
7 modules 754B; one or more AR processing modules 755B, etc.) that can be used individually
8 and/or in conjunction with the components of the computing system 720.

9 **[0201]** The techniques described above in Figures 7A-7C can be used with different
10 head-wearable devices. In some embodiments, the head-wearable devices (e.g., the AR
11 device 700 and/or the VR device 710) can be used in conjunction with one or more wearable
12 device such as a wrist-wearable device 600 (or components thereof), and/or an HIPD 800.
13 Having thus described example the head-wearable devices, attention will now be turned to
14 example handheld intermediary processing devices, such as HIPD 800.

15 ***Example Handheld Intermediary Processing Devices***

16 **[0202]** Figures 8A and 8B illustrate an example handheld intermediary processing
17 device (HIPD) 800, in accordance with some embodiments. The HIPD 800 is an instance of
18 the intermediary device described in reference to Figures 1A-4 herein, such that the HIPD
19 800 should be understood to have the features described with respect to any intermediary
20 device defined above or otherwise described herein, and vice versa. The HIPD 800 can
21 perform various functions and/or operations associated with navigating through user
22 interfaces and selectively opening applications, as well as the functions and/or operations
23 described above with reference to Figures 1A-4.

24 **[0203]** Figure 8A shows a top view 805 and a side view 825 of the HIPD 800. The
25 HIPD 800 is configured to communicatively couple with one or more wearable devices (or
26 other electronic devices) associated with a user. For example, the HIPD 800 is configured to
27 communicatively couple with a user's wrist-wearable device 600 (or components thereof,
28 such as the watch body 620 and the wearable band 610), AR device 700, and/or VR device
29 710. The HIPD 800 can be configured to be held by a user (e.g., as a handheld controller),
30 carried on the user's person (e.g., in their pocket, in their bag, etc.), placed in proximity of the
31 user (e.g., placed on their desk while seated at their desk, on a charging dock, etc.), and/or
32 placed at or within a predetermined distance from a wearable device or other electronic
33 device (e.g., where, in some embodiments, the predetermined distance is the maximum
34 distance (e.g., 10 meters) at which the HIPD 800 can successfully be communicatively

1 coupled with an electronic device, such as a wearable device).

2 **[0204]** The HIPD 800 can perform various functions independently and/or in
3 conjunction with one or more wearable devices (e.g., wrist-wearable device 600, AR device
4 700, VR device 710, etc.). The HIPD 800 is configured to increase and/or improve the
5 functionality of communicatively coupled devices, such as the wearable devices. The HIPD
6 800 is configured to perform one or more functions or operations associated with interacting
7 with user interfaces and applications of communicatively coupled devices, interacting with an
8 AR environment, interacting with VR environment, and/or operating as a human-machine
9 interface controller, as well as functions and/or operations described above with reference to
10 Figures 1A-4. Additionally, as will be described in more detail below, functionality and/or
11 operations of the HIPD 800 can include, without limitation, task offloading and/or handoffs;
12 thermals offloading and/or handoffs; 6 degrees of freedom (6DoF) ray casting and/or gaming
13 (e.g., using imaging devices or cameras 814A and 814B, which can be used for simultaneous
14 localization and mapping (SLAM) and/or with other image processing techniques); portable
15 charging; messaging; image capturing via one or more imaging devices or cameras (e.g.,
16 cameras 822A and 822B); sensing user input (e.g., sensing a touch on a multi-touch input
17 surface 802); wireless communications and/or interlining (e.g., cellular, near field, Wi-Fi,
18 personal area network, etc.); location determination; financial transactions; providing haptic
19 feedback; alarms; notifications; biometric authentication; health monitoring; sleep
20 monitoring; etc. The above-example functions can be executed independently in the HIPD
21 800 and/or in communication between the HIPD 800 and another wearable device described
22 herein. In some embodiments, functions can be executed on the HIPD 800 in conjunction
23 with an AR environment. As the skilled artisan will appreciate upon reading the descriptions
24 provided herein, the novel the HIPD 800 described herein can be used with any type of
25 suitable AR environment.

26 **[0205]** While the HIPD 800 is communicatively coupled with a wearable device
27 and/or other electronic device, the HIPD 800 is configured to perform one or more operations
28 initiated at the wearable device and/or the other electronic device. In particular, one or more
29 operations of the wearable device and/or the other electronic device can be offloaded to the
30 HIPD 800 to be performed. The HIPD 800 performs the one or more operations of the
31 wearable device and/or the other electronic device and provides to data corresponded to the
32 completed operations to the wearable device and/or the other electronic device. For example,
33 a user can initiate a video stream using AR device 700 and back-end tasks associated with
34 performing the video stream (e.g., video rendering) can be offloaded to the HIPD 800, which

1 the HIPD 800 performs and provides corresponding data to the AR device 700 to perform
2 remaining front-end tasks associated with the video stream (e.g., presenting the rendered
3 video data via a display of the AR device 700). In this way, the HIPD 800, which has more
4 computational resources and greater thermal headroom than a wearable device, can perform
5 computationally intensive tasks for the wearable device improving performance of an
6 operation performed by the wearable device.

7 **[0206]** The HIPD 800 includes a multi-touch input surface 802 on a first side (e.g., a
8 front surface) that is configured to detect one or more user inputs. In particular, the multi-
9 touch input surface 802 can detect single tap inputs, multi-tap inputs, swipe gestures and/or
10 inputs, force-based and/or pressure-based touch inputs, held taps, and the like. The multi-
11 touch input surface 802 is configured to detect capacitive touch inputs and/or force (and/or
12 pressure) touch inputs. The multi-touch input surface 802 includes a first touch-input surface
13 804 defined by a surface depression, and a second touch-input surface 806 defined by a
14 substantially planar portion. The first touch-input surface 804 can be disposed adjacent to the
15 second touch-input surface 806. In some embodiments, the first touch-input surface 804 and
16 the second touch-input surface 806 can be different dimensions, shapes, and/or cover
17 different portions of the multi-touch input surface 802. For example, the first touch-input
18 surface 804 can be substantially circular and the second touch-input surface 806 is
19 substantially rectangular. In some embodiments, the surface depression of the multi-touch
20 input surface 802 is configured to guide user handling of the HIPD 800. In particular, the
21 surface depression is configured such that the user holds the HIPD 800 upright when held in a
22 single hand (e.g., such that the using imaging devices or cameras 814A and 814B are pointed
23 toward a ceiling or the sky). Additionally, the surface depression is configured such that the
24 user's thumb rests within the first touch-input surface 804.

25 **[0207]** In some embodiments, the different touch-input surfaces include a plurality of
26 touch-input zones. For example, the second touch-input surface 806 includes at least a first
27 touch-input zone 808 within a second touch-input zone 806 and a third touch-input zone 810
28 within the first touch-input zone 808. In some embodiments, one or more of the touch-input
29 zones are optional and/or user defined (e.g., a user can specific a touch-input zone based on
30 their preferences). In some embodiments, each touch-input surface and/or touch-input zone
31 is associated with a predetermined set of commands. For example, a user input detected
32 within the first touch-input zone 808 causes the HIPD 800 to perform a first command and a
33 user input detected within the second touch-input zone 806 causes the HIPD 800 to perform a
34 second command, distinct from the first. In some embodiments, different touch-input

1 surfaces and/or touch-input zones are configured to detect one or more types of user inputs.
2 The different touch-input surfaces and/or touch-input zones can be configured to detect the
3 same or distinct types of user inputs. For example, the first touch-input zone 808 can be
4 configured to detect force touch inputs (e.g., a magnitude at which the user presses down) and
5 capacitive touch inputs, and the second touch-input zone 806 can be configured to detect
6 capacitive touch inputs.

7 **[0208]** The HIPD 800 includes one or more sensors 851 for sensing data used in the
8 performance of one or more operations and/or functions. For example, the HIPD 800 can
9 include an IMU that is used in conjunction with cameras 814 for 3-dimensional object
10 manipulation (e.g., enlarging, moving, destroying, etc. an object) in an AR or VR
11 environment. Non-limiting examples of the sensors 851 included in the HIPD 800 include a
12 light sensor, a magnetometer, a depth sensor, a pressure sensor, and a force sensor.
13 Additional examples of the sensors 851 are provided below in reference to Figure 8B.

14 **[0209]** The HIPD 800 can include one or more light indicators 812 to provide one or
15 more notifications to the user. In some embodiments, the light indicators are LEDs or other
16 types of illumination devices. The light indicators 812 can operate as a privacy light to notify
17 the user and/or others near the user that an imaging device and/or microphone are active. In
18 some embodiments, a light indicator is positioned adjacent to one or more touch-input
19 surfaces. For example, a light indicator can be positioned around the first touch-input
20 surface 804. The light indicators can be illuminated in different colors and/or patterns to
21 provide the user with one or more notifications and/or information about the device. For
22 example, a light indicator positioned around the first touch-input surface 804 can flash when
23 the user receives a notification (e.g., a message), change red when the HIPD 800 is out of
24 power, operate as a progress bar (e.g., a light ring that is closed when a task is completed
25 (e.g., 0% to 100%)), operates as a volume indicator, etc.).

26 **[0210]** In some embodiments, the HIPD 800 includes one or more additional sensors
27 on another surface. For example, as shown Figure 8A, HIPD 800 includes a set of one or
28 more sensors (e.g., sensor set 820) on an edge of the HIPD 800. The sensor set 820, when
29 positioned on an edge of the of the HIPD 800, can be positioned at a predetermined tilt
30 angle (e.g., 26 degrees), which allows the sensor set 820 to be angled toward the user when
31 placed on a desk or other flat surface. Alternatively, in some embodiments, the sensor set
32 820 is positioned on a surface opposite the multi-touch input surface 802 (e.g., a back
33 surface). The one or more sensors of the sensor set 820 are discussed in detail below.

34 **[0211]** The side view 825 of the of the HIPD 800 shows the sensor set 820 and

1 camera 814B. The sensor set 820 includes one or more cameras 822A and 822B, a depth
2 projector 824, an ambient light sensor 828, and a depth receiver 830. In some embodiments,
3 the sensor set 820 includes a light indicator 826. The light indicator 826 can operate as a
4 privacy indicator to let the user and/or those around them know that a camera and/or
5 microphone is active. The sensor set 820 is configured to capture a user's facial expression
6 such that the user can puppet a custom avatar (e.g., showing emotions, such as smiles,
7 laughter, etc., on the avatar or a digital representation of the user). The sensor set 820 can be
8 configured as a side stereo RGB system, a rear indirect Time-of-Flight (iToF) system, or a
9 rear stereo RGB system. As the skilled artisan will appreciate upon reading the descriptions
10 provided herein, the novel HIPD 800 described herein can use different sensor set 820
11 configurations and/or sensor set 820 placement.

12 **[0212]** In some embodiments, the HIPD 800 includes one or more haptic devices 871
13 (Figure 8B; e.g., a vibratory haptic actuator) that are configured to provide haptic feedback
14 (e.g., kinesthetic sensation). The sensors 851, and/or the haptic devices 871 can be
15 configured to operate in conjunction with multiple applications and/or communicatively
16 coupled devices including, without limitation, wearable devices, health monitoring
17 applications, social media applications, game applications, and artificial reality applications
18 (e.g., the applications associated with artificial reality).

19 **[0213]** The HIPD 800 is configured to operate without a display. However, in
20 optional embodiments, the HIPD 800 can include a display 868 (Figure 8B). The HIPD 800
21 can also include one or more optional peripheral buttons 867 (Figure 8B). For example, the
22 peripheral buttons 867 can be used to turn on or turn off the HIPD 800. Further, the HIPD
23 800 housing can be formed of polymers and/or elastomer elastomers. The HIPD 800 can be
24 configured to have a non-slip surface to allow the HIPD 800 to be placed on a surface
25 without requiring a user to watch over the HIPD 800. In other words, the HIPD 800 is
26 designed such that it would not easily slide off surfaces. In some embodiments, the HIPD
27 800 include one or magnets to couple the HIPD 800 to another surface. This allows the user
28 to mount the HIPD 800 to different surfaces and provide the user with greater flexibility in
29 use of the HIPD 800.

30 **[0214]** As described above, the HIPD 800 can distribute and/or provide instructions
31 for performing the one or more tasks at the HIPD 800 and/or a communicatively coupled
32 device. For example, the HIPD 800 can identify one or more back-end tasks to be performed
33 by the HIPD 800 and one or more front-end tasks to be performed by a communicatively
34 coupled device. While the HIPD 800 is configured to offload and/or handoff tasks of a

communicatively coupled device, the HIPD 800 can perform both back-end and front-end tasks (e.g., via one or more processors, such as CPU 877; Figure 8B). The HIPD 800 can, without limitation, can be used to perform augmenting calling (e.g., receiving and/or sending 3D or 2.5D live volumetric calls, live digital human representation calls, and/or avatar calls), discreet messaging, 6DoF portrait/landscape gaming, AR/VR object manipulation, AR/VR content display (e.g., presenting content via a virtual display), and/or other AR/VR interactions. The HIPD 800 can perform the above operations alone or in conjunction with a wearable device (or other communicatively coupled electronic device).

[0215] Figure 8B shows block diagrams of a computing system 840 of the HIPD 800, in accordance with some embodiments. The HIPD 800, described in detail above, can include one or more components shown in HIPD computing system 840. The HIPD 800 will be understood to include the components shown and described below for the HIPD computing system 840. In some embodiments, all, or a substantial portion of the components of the HIPD computing system 840 are included in a single integrated circuit. Alternatively, in some embodiments, components of the HIPD computing system 840 are included in a plurality of integrated circuits that are communicatively coupled.

[0216] The HIPD computing system 840 can include a processor (e.g., a CPU 877, a GPU, and/or a CPU with integrated graphics), a controller 875, a peripherals interface 850 that includes one or more sensors 851 and other peripheral devices, a power source (e.g., a power system 895), and memory (e.g., a memory 878) that includes an operating system (e.g., an operating system 879), data (e.g., data 888), one or more applications (e.g., applications 880), and one or more modules (e.g., a communications interface module 881, a graphics module 882, a task and processing management module 883, an interoperability module 884, an AR processing module 885, a data management module 886, a device control module 887, etc.). The HIPD computing system 840 further includes a power system 895 that includes a charger input and output 896, a PMIC 897, and a battery 898, all of which are defined above.

[0217] In some embodiments, the peripherals interface 850 can include one or more sensors 851. The sensors 851 can include analogous sensors to those described above in reference to Figures 6B. For example, the sensors 851 can include imaging sensors 854, (optional) EMG sensors 856, IMUs 858, and capacitive sensors 860. In some embodiments, the sensors 851 can include one or more pressure sensor 852 for sensing pressure data, an altimeter 853 for sensing an altitude of the HIPD 800, a magnetometer 855 for sensing a magnetic field, a depth sensor 857 (or a time-of flight sensor) for determining a difference

1 between the camera and the subject of an image, a position sensor 859 (e.g., a flexible
2 position sensor) for sensing a relative displacement or position change of a portion of the
3 HIPD 800, a force sensor 861 for sensing a force applied to a portion of the HIPD 800, and a
4 light sensor 862 (e.g., an ambient light sensor) for detecting an amount of lighting. The
5 sensors 851 can include one or more sensors not shown in Figure 8B.

6 **[0218]** Analogous to the peripherals described above in reference to Figures 6B, the
7 peripherals interface 850 can also include an NFC component 863, a GPS component 864, an
8 LTE component 865, a Wi-Fi and/or Bluetooth communication component 866, a speaker
9 869, a haptic device 871, and a microphone 873. As described above in reference to Figure
10 8A, the HIPD 800 can optionally include a display 868 and/or one or more buttons 867. The
11 peripherals interface 850 can further include one or more cameras 870, touch surfaces 872,
12 and/or one or more light emitters 874. The multi-touch input surface 802 described above in
13 reference to Figure 8A is an example of touch surface 872. The light emitters 874 can be one
14 or more LEDs, lasers, etc. and can be used to project or present information to a user. For
15 example, the light emitters 874 can include light indicators 812 and 826 described above in
16 reference to Figure 8A. The cameras 870 (e.g., cameras 814A, 814B, and 822 described
17 above in Figure 8A) can include one or more wide angle cameras, fish-eye cameras, spherical
18 cameras, compound eye cameras (e.g., stereo and multi cameras), depth cameras, RGB
19 cameras, ToF cameras, RGB-D cameras (depth and ToF cameras), and/or other available
20 cameras. Cameras 870 can be used for SLAM; 6DoF ray casting, gaming, object
21 manipulation, and/or other rendering; facial recognition and facial expression recognition,
22 etc.

23 **[0219]** Similar to the watch body computing system 660 and the watch band
24 computing system 630 described above in reference to Figure 6B, the HIPD computing
25 system 840 can include one or more haptic controllers 876 and associated componentry (e.g.,
26 haptic devices 871) for providing haptic events at the HIPD 800.

27 **[0220]** Memory 878 can include high-speed random-access memory and/or non-
28 volatile memory, such as one or more magnetic disk storage devices, flash memory devices,
29 or other non-volatile solid-state memory devices. Access to the memory 878 by other
30 components of the HIPD 800, such as the one or more processors and the peripherals
31 interface 850, can be controlled by a memory controller of the controllers 875.

32 **[0221]** In some embodiments, software components stored in the memory 878 include
33 one or more operating systems 879, one or more applications 880, one or more
34 communication interface modules 881, one or more graphics modules 882, one or more data

1 management modules 885, which are analogous to the software components described above
2 in reference to Figure 6B. The software components stored in the memory 878 can also
3 include a device control module 887 (analogous to the device control data 686; Figure 6B).

4 **[0222]** In some embodiments, software components stored in the memory 878 include
5 a task and processing management module 883 for identifying one or more front-end and
6 back-end tasks associated with an operation performed by the user, performing one or more
7 front-end and/or back-end tasks, and/or providing instructions to one or more
8 communicatively coupled devices that cause performance of the one or more front-end and/or
9 back-end tasks. In some embodiments, the task and processing management module 883
10 uses data 888 (e.g., device data 890) to distribute the one or more front-end and/or back-end
11 tasks based on communicatively coupled devices' computing resources, available power,
12 thermal headroom, ongoing operations, and/or other factors. For example, the task and
13 processing management module 883 can cause the performance of one or more back-end
14 tasks (of an operation performed at communicatively coupled AR device 700) at the HIPD
15 800 in accordance with a determination that the operation is utilizing a predetermined amount
16 (e.g., at least 70%) of computing resources available at the AR device 700.

17 **[0223]** In some embodiments, software components stored in the memory 878 include
18 an interoperability module 884 for exchanging and utilizing information received and/or
19 provided to distinct communicatively coupled devices. The interoperability module 884
20 allows for different systems, devices, and/or applications to connect and communicate in a
21 coordinated way without user input. In some embodiments, software components stored in
22 the memory 878 include an AR module 885 that is configured to process signals based at
23 least on sensor data for use in an AR and/or VR environment. For example, the AR
24 processing module 885 can be used for 3D object manipulation, gesture recognition, facial
25 and facial expression, recognition, etc.

26 **[0224]** The memory 878 can also include data 887, including structured data. In
27 some embodiments, the data 887 can include profile data 889, device data 889 (including
28 device data of one or more devices communicatively coupled with the HIPD 800, such as
29 device type, hardware, software, configurations, etc.), sensor data 891, media content data
30 892, application data 893, and device control data 894 (analogous to the device control data
31 692; Figure 6B).

32 **[0225]** It should be appreciated that the HIPD computing system 840 is an example of
33 a computing system within the HIPD 800, and that the HIPD 800 can have more or fewer
34 components than shown in the HIPD computing system 840, combine two or more

1 components, and/or have a different configuration and/or arrangement of the components.
2 The various components shown in HIPD computing system 840 are implemented in
3 hardware, software, firmware, or a combination thereof, including one or more signal
4 processing and/or application-specific integrated circuits.

5 **[0226]** The techniques described above in Figure 8A-8B can be used with any device
6 used as a human-machine interface controller. In some embodiments, an HIPD 800 can be
7 used in conjunction with one or more wearable device such as a head-wearable device (e.g.,
8 AR device 700 and VR device 710) and/or a wrist-wearable device 600 (or components
9 thereof).

10 **[0227]** Any data collection performed by the devices described herein and/or any
11 devices configured to perform or cause the performance of the different embodiments
12 described above in reference to any of the Figures, hereinafter the “devices,” is done with
13 user consent and in a manner that is consistent with all applicable privacy laws. Users are
14 given options to allow the devices to collect data, as well as the option to limit or deny
15 collection of data by the devices. A user is able to opt-in or opt-out of any data collection at
16 any time. Further, users are given the option to request the removal of any collected data.

17 **[0228]** It will be understood that, although the terms “first,” “second,” etc. may be
18 used herein to describe various elements, these elements should not be limited by these terms.
19 These terms are only used to distinguish one element from another.

20 **[0229]** The terminology used herein is for the purpose of describing particular
21 embodiments only and is not intended to be limiting of the claims. As used in the description
22 of the embodiments and the appended claims, the singular forms “a,” “an” and “the” are
23 intended to include the plural forms as well, unless the context clearly indicates otherwise. It
24 will also be understood that the term “and/or” as used herein refers to and encompasses any
25 and all possible combinations of one or more of the associated listed items. It will be further
26 understood that the terms “comprises” and/or “comprising,” when used in this specification,
27 specify the presence of stated features, integers, steps, operations, elements, and/or
28 components, but do not preclude the presence or addition of one or more other features,
29 integers, steps, operations, elements, components, and/or groups thereof.

30 **[0230]** As used herein, the term “if” can be construed to mean “when” or “upon” or
31 “in response to determining” or “in accordance with a determination” or “in response to
32 detecting,” that a stated condition precedent is true, depending on the context. Similarly, the
33 phrase “if it is determined [that a stated condition precedent is true]” or “if [a stated condition
34 precedent is true]” or “when [a stated condition precedent is true]” can be construed to mean

1 “upon determining” or “in response to determining” or “in accordance with a determination”
2 or “upon detecting” or “in response to detecting” that the stated condition precedent is true,
3 depending on the context.

4 **[0231]** The foregoing description, for purpose of explanation, has been described with
5 reference to specific embodiments. However, the illustrative discussions above are not
6 intended to be exhaustive or to limit the claims to the precise forms disclosed. Many
7 modifications and variations are possible in view of the above teachings. The embodiments
8 were chosen and described in order to best explain principles of operation and practical
9 applications, to thereby enable others skilled in the art.

1 What is claimed is:

2 1. A non-transitory, computer-readable storage medium including instructions that,
3 when executed by one or more processors of a wrist-wearable device, cause the wrist-
4 wearable device to:

5 while a wrist-wearable device is communicatively coupled with a vehicle system:

6 detect, via one or more biopotential sensors of the wrist-wearable device while
7 it is worn by a user, a hand gesture performed by the user; and

8 in accordance with a determination that the hand gesture is associated with a
9 vehicle-control action:

10 identify a device of the vehicle system associated with the vehicle-
11 control action, and

12 provide instructions to the vehicle system to cause performance of the
13 vehicle-control action at the device of the vehicle system.

14 2. The non-transitory, computer-readable storage medium of claim 1, wherein the hand
15 gesture is a first hand gesture and the vehicle-control action is a first vehicle-control action,
16 and the instructions, when executed by the one or more processors of the wrist-wearable
17 device, further cause the wrist-wearable device to:

18 detect, via the one or more biopotential sensors of the wrist-wearable device while it
19 is worn by the user, a second hand gesture; and

20 in accordance with a determination that the second hand gesture is associated with a
21 second vehicle-control action, distinct from the first vehicle-control action:

22 determine a different device of the vehicle system associated with the second
23 vehicle-control action, and

24 provide instructions to the vehicle system to cause performance of the second
25 vehicle-control action at the different device of the vehicle system.

26 3. The non-transitory, computer-readable storage medium of claim 2, wherein the
27 instructions, when executed by the one or more processors of the wrist-wearable device,
28 further cause the wrist-wearable device to:

29 detect, via the one or more biopotential sensors of the wrist-wearable device while it
30 is worn by the user, a third hand gesture; and

31 in accordance with a determination that the third hand gesture is associated with a
32 device-cycle control action that causes the vehicle system to alternate between devices of the
33 vehicle system, provide instructions to the vehicle system to cause selection of another device
34 of the vehicle system for receiving one or more vehicle-control actions.

1 4. The non-transitory, computer-readable storage medium of any one of the preceding
2 claims, wherein the instructions, when executed by the one or more processors of the wrist-
3 wearable device, further cause the wrist-wearable device to:

4 while a head-wearable device is communicatively coupled with the wrist-wearable
5 device and/or the vehicle system:

6 detect, via the head-wearable device worn by the user, a field of view of the
7 user; and

8 in accordance with a determination that another device of the vehicle system is
9 within the field of view of the user, provide instructions to the vehicle system to cause
10 performance of the vehicle-control action at the other device of the vehicle system within the
11 user's field of view.

12 5. The non-transitory, computer-readable storage medium of any one of the preceding
13 claims, wherein the vehicle-control action causes activation of a vehicle self-driving action.

14 6. The non-transitory, computer-readable storage medium of any one of the preceding
15 claims, wherein the instructions, when executed by the one or more processors of the wrist-
16 wearable device, further cause the wrist-wearable device to:

17 detecting, via the one or more biopotential sensors of the wrist-wearable device while
18 it is worn by the user, a hand gesture performed by the user; and

19 in accordance with a determination that the hand gesture is associated with a vehicle-
20 monitoring action:

21 receiving from, the vehicle system, current vehicle information, and

22 causing presentation of the current vehicle information at the wrist-wearable

23 device or at a device in communication with the wrist-wearable device.

24 7. The non-transitory, computer-readable storage medium of claim 6, wherein the
25 vehicle-monitoring action includes one or more of playback of image data captured by an
26 imaging device of the vehicle system, playback of audio data captured by a microphone
27 device of the vehicle system, presentation of a vehicle battery level, presentation of a vehicle-
28 charging status, and presentation of a vehicle's status.

29 8. The non-transitory, computer-readable storage medium of any one of the preceding
30 claims, wherein the vehicle-control action includes one or more of a media-player control
31 action, an engine-ignition control action, an engine-shutoff control action, a vehicle-security
32 control action, a vehicle-thermal control action, and a vehicle-window control action.

33 9. A method comprising:

34 while a wrist-wearable device is communicatively coupled with a vehicle system:

1 detecting, via one or more biopotential sensors of the wrist-wearable device
2 while it is worn by a user, a hand gesture performed by the user; and
3 in accordance with a determination that the hand gesture is associated with a
4 vehicle-control action:
5 identifying a device of the vehicle system associated with the vehicle-
6 control action, and
7 providing instructions to the vehicle system to cause performance of
8 the vehicle-control action at the device of the vehicle system.

9 10. The method of claim 9, wherein the hand gesture is a first hand gesture and the
10 vehicle-control action is a first vehicle-control action, and the method further comprises:
11 detecting, via the one or more biopotential sensors of the wrist-wearable device while
12 it is worn by the user, a second hand gesture; and
13 in accordance with a determination that the second hand gesture is associated with a
14 second vehicle-control action, distinct from the first vehicle-control action:
15 determining a different device of the vehicle system associated with the
16 second vehicle-control action, and
17 providing instructions to the vehicle system to cause performance of the
18 second vehicle-control action at the different device of the vehicle system.

19 11. The method of claim 10, further comprising:
20 detecting, via the one or more biopotential sensors of the wrist-wearable device while
21 it is worn by the user, a third hand gesture; and
22 in accordance with a determination that the third hand gesture is associated with a
23 device-cycle control action that causes the vehicle system to alternate between devices of the
24 vehicle system, providing instructions to the vehicle system to cause selection of another
25 device of the vehicle system for receiving one or more vehicle-control actions.

26 12. The method of any one of claims 9 to 11, further comprising:
27 while a head-wearable device is communicatively coupled with the wrist-wearable
28 device and/or the vehicle system:
29 detecting, via the head-wearable device worn by the user, a field of view of the
30 user; and
31 in accordance with a determination that another device of the vehicle system is
32 within the field of view of the user, providing instructions to the vehicle system to cause
33 performance of the vehicle-control action at the other device of the vehicle system within the
34 user's field of view.

- 1 13. A wrist-wearable device for controlling a vehicle system using one or more hand
2 gestures, the wrist-wearable device configured to perform or cause performance of:
3 while a wrist-wearable device is communicatively coupled with a vehicle system:
4 detecting, via one or more biopotential sensors of the wrist-wearable device
5 while it is worn by a user, a hand gesture performed by the user; and
6 in accordance with a determination that the hand gesture is associated with a
7 vehicle-control action:
8 identifying a device of the vehicle system associated with the vehicle-
9 control action, and
10 providing instructions to the vehicle system to cause performance of
11 the vehicle-control action at the device of the vehicle system.
- 12 14. The wrist-wearable device of claim 13, wherein the hand gesture is a first hand
13 gesture and the vehicle-control action is a first vehicle-control action, and the wrist-wearable
14 device is further configured to perform or cause performance of:
15 detect, via the one or more biopotential sensors of the wrist-wearable device while it
16 is worn by the user, a second hand gesture; and
17 in accordance with a determination that the second hand gesture is associated with a
18 second vehicle-control action, distinct from the first vehicle-control action:
19 determine a different device of the vehicle system associated with the second
20 vehicle-control action, and
21 provide instructions to the vehicle system to cause performance of the second
22 vehicle-control action at the different device of the vehicle system.

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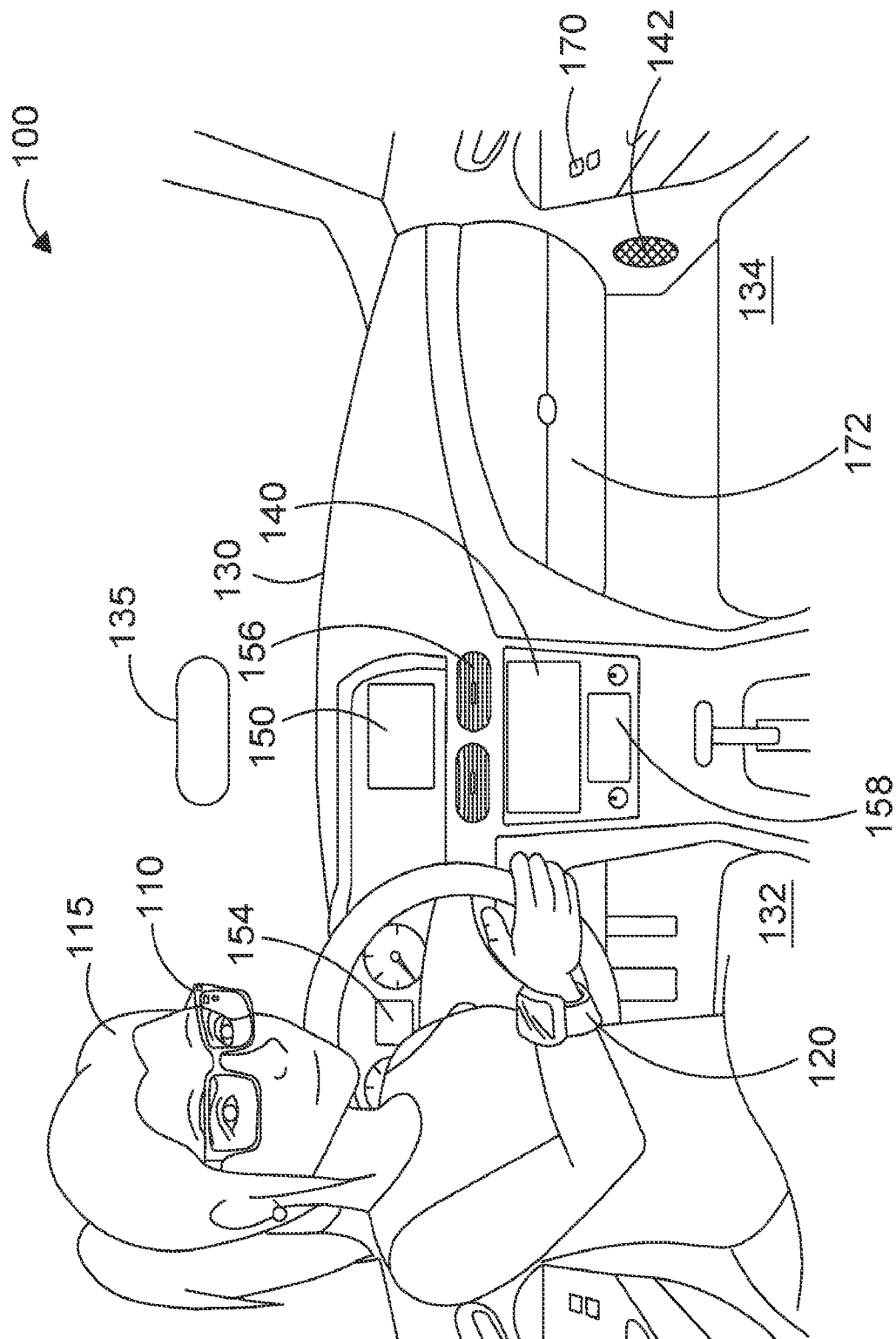


FIG. 1A

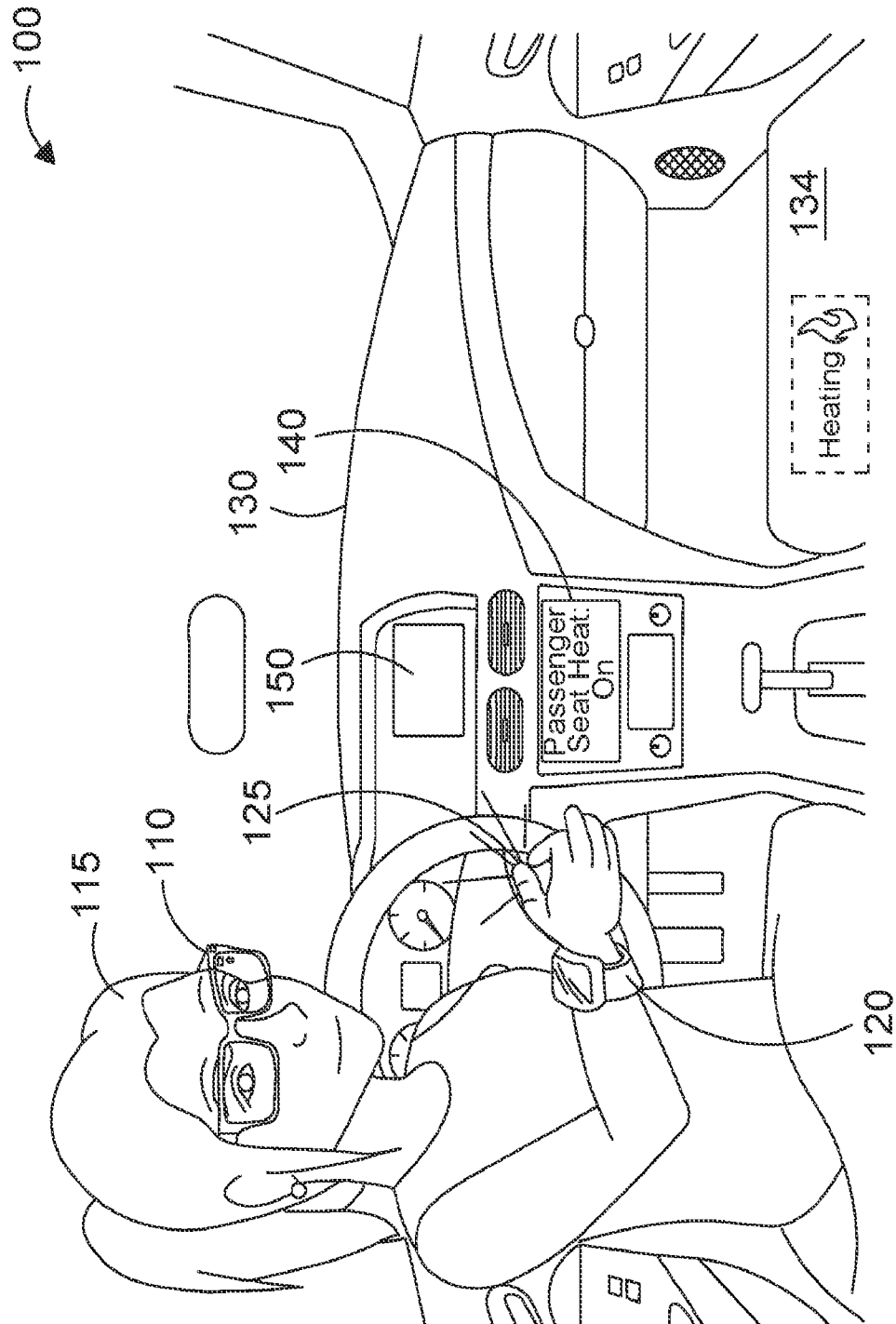


FIG. 1B

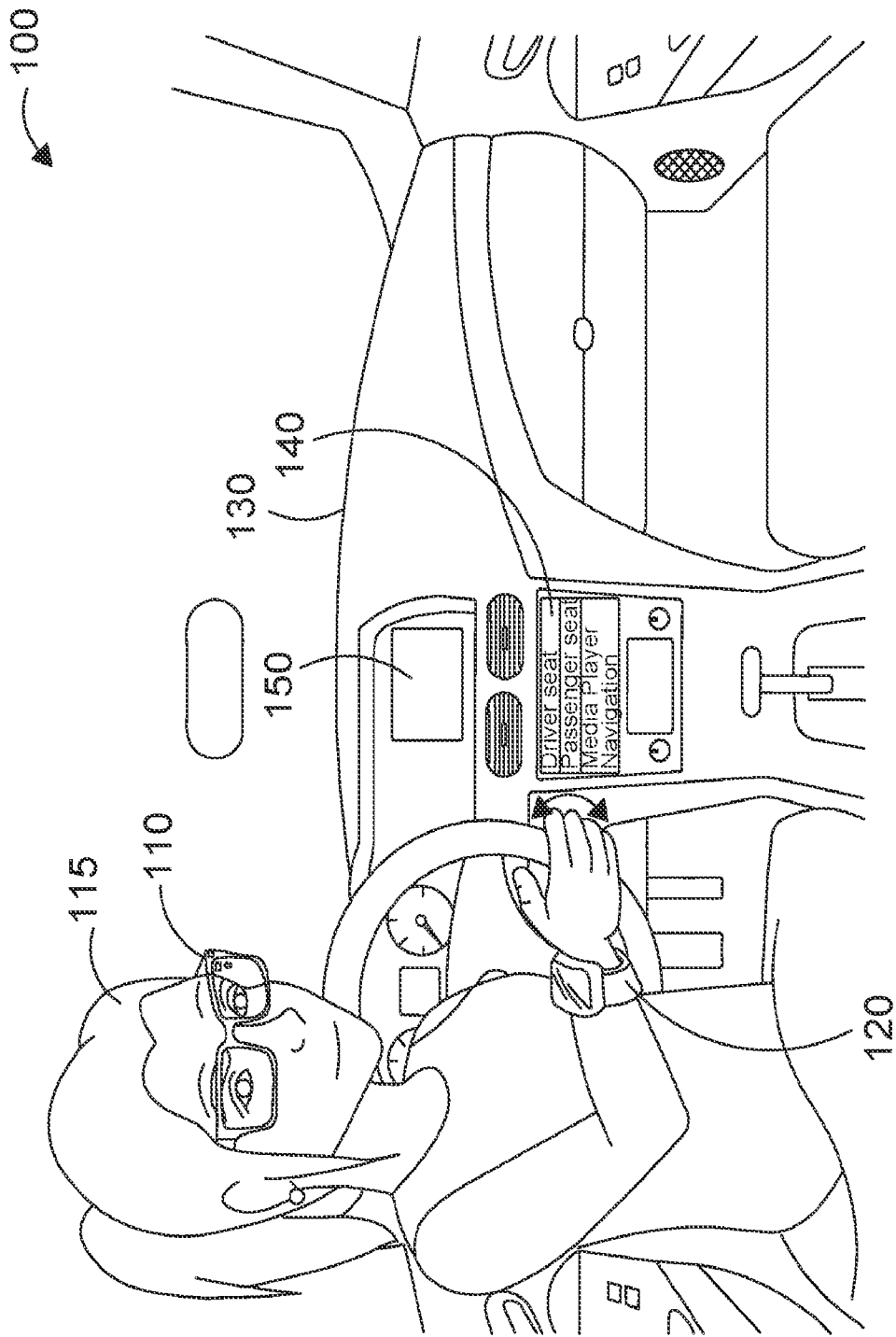


FIG. 1C

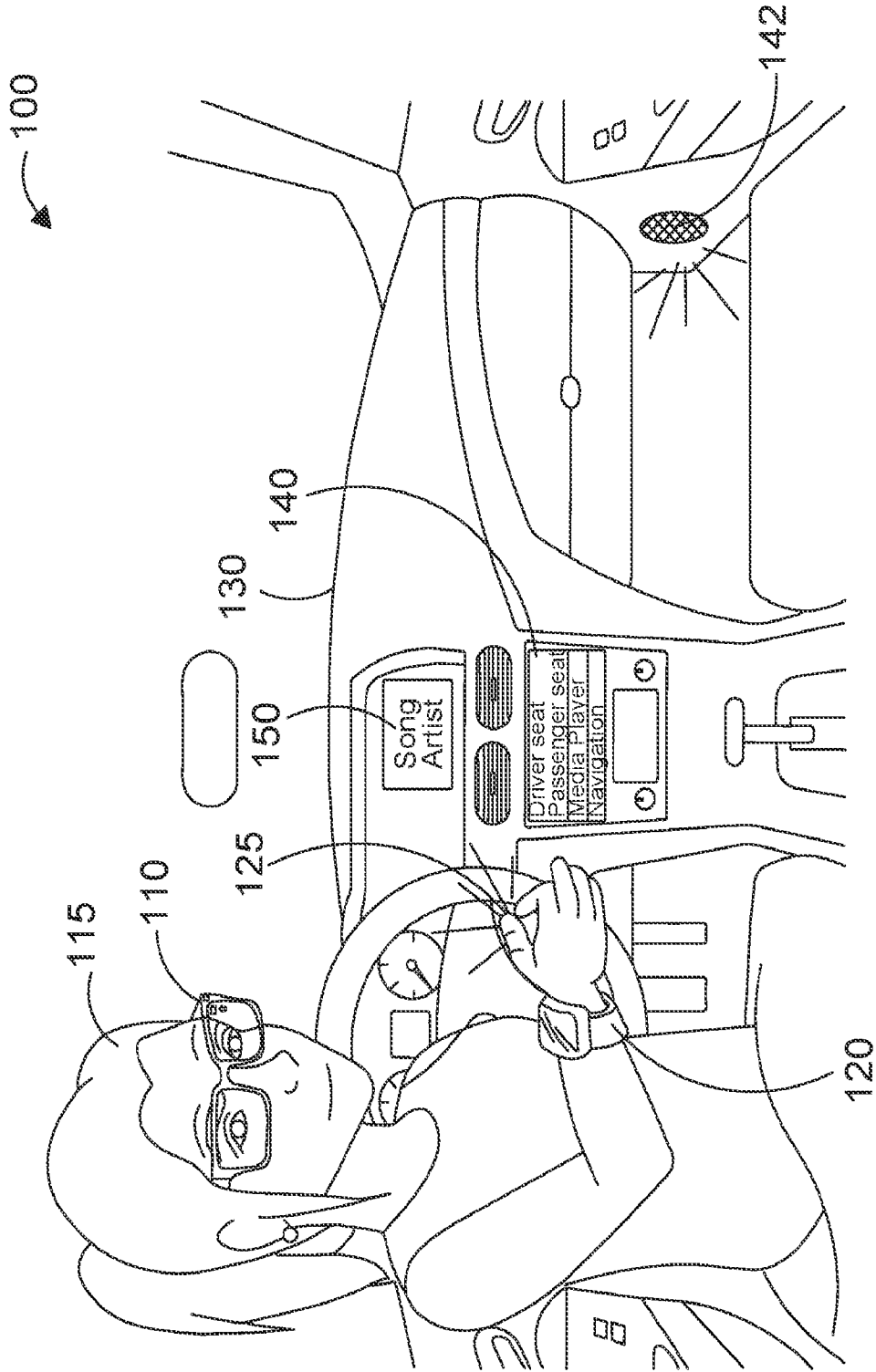


FIG. 1D

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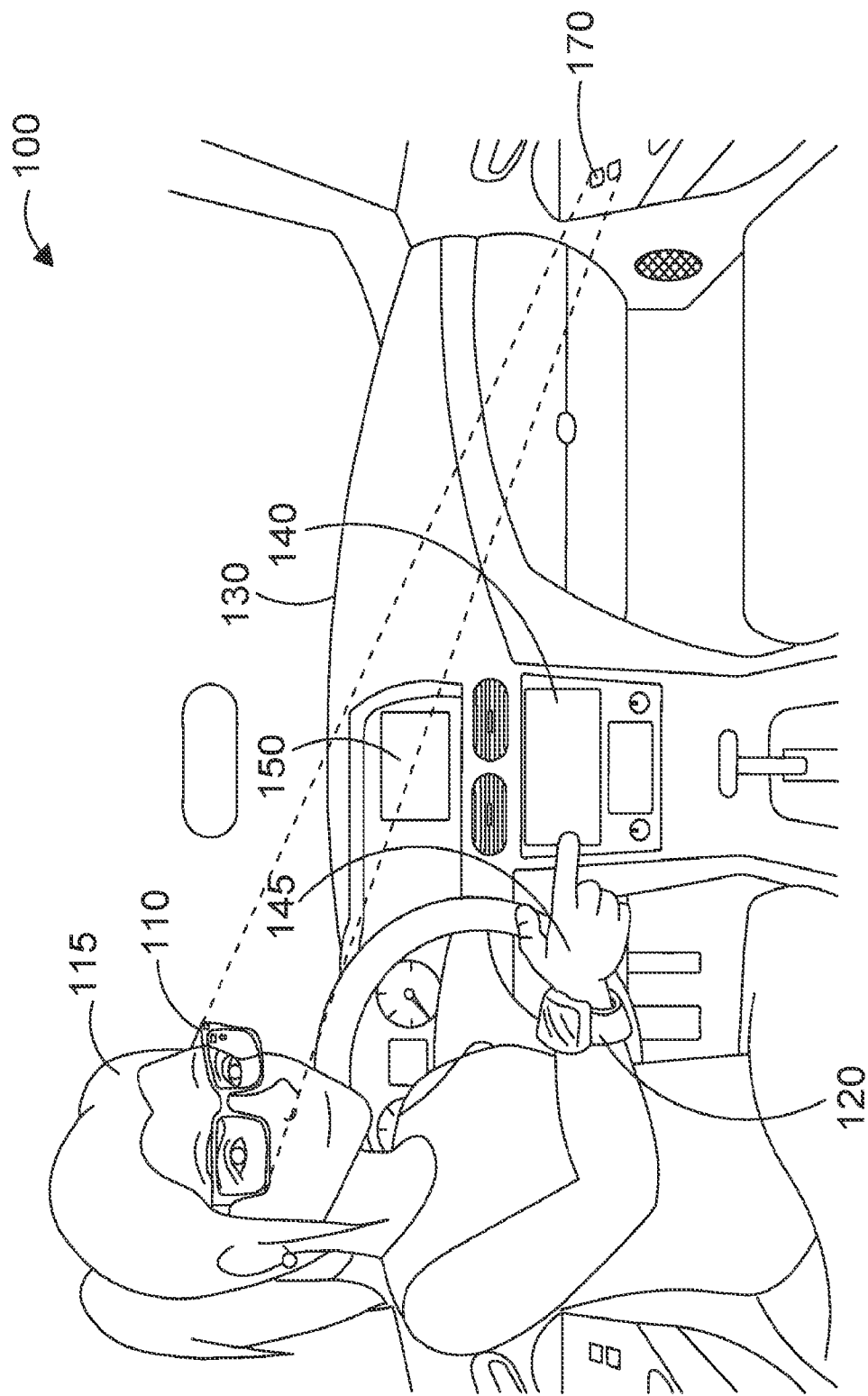


FIG. 1E

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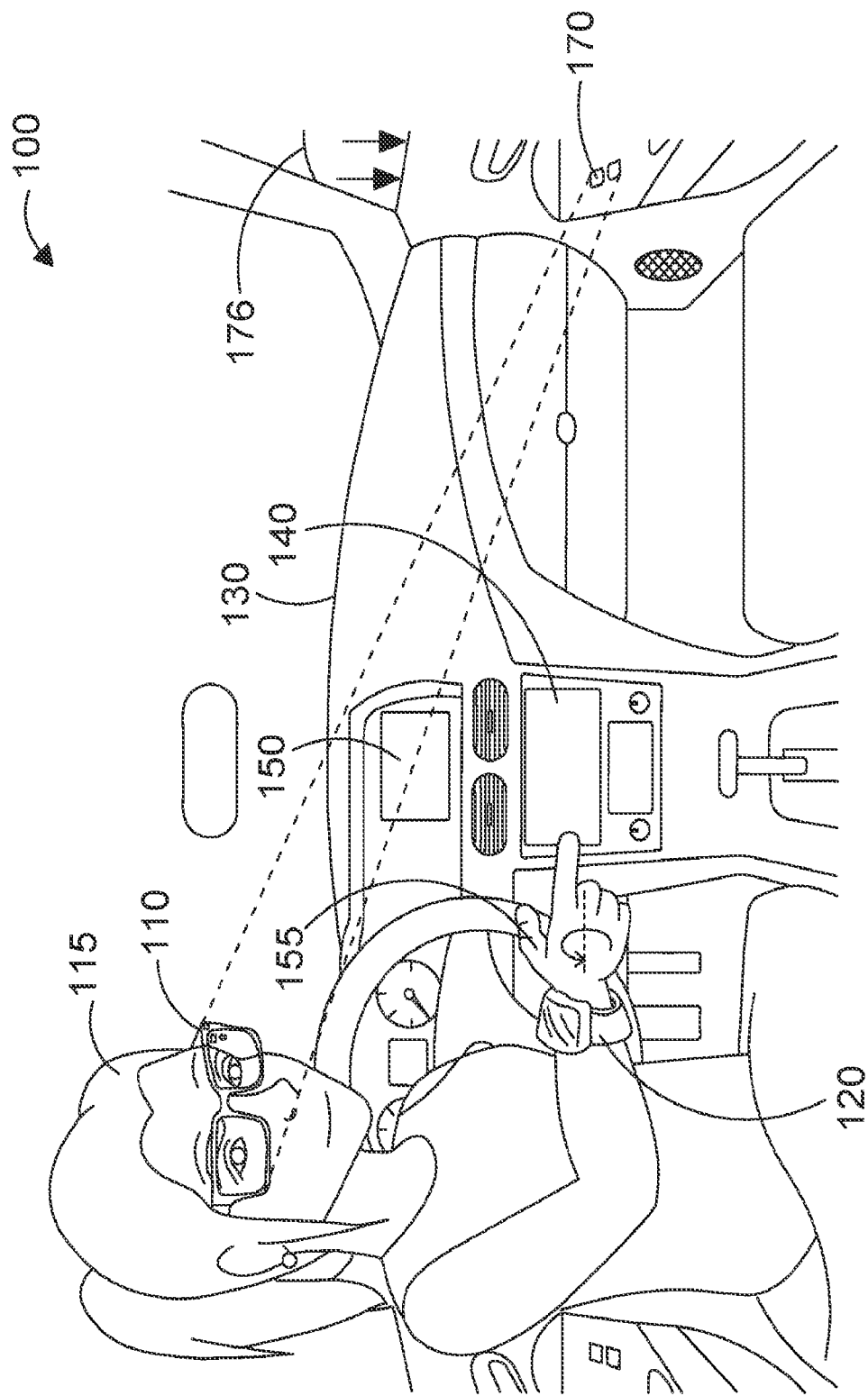


FIG. 1F

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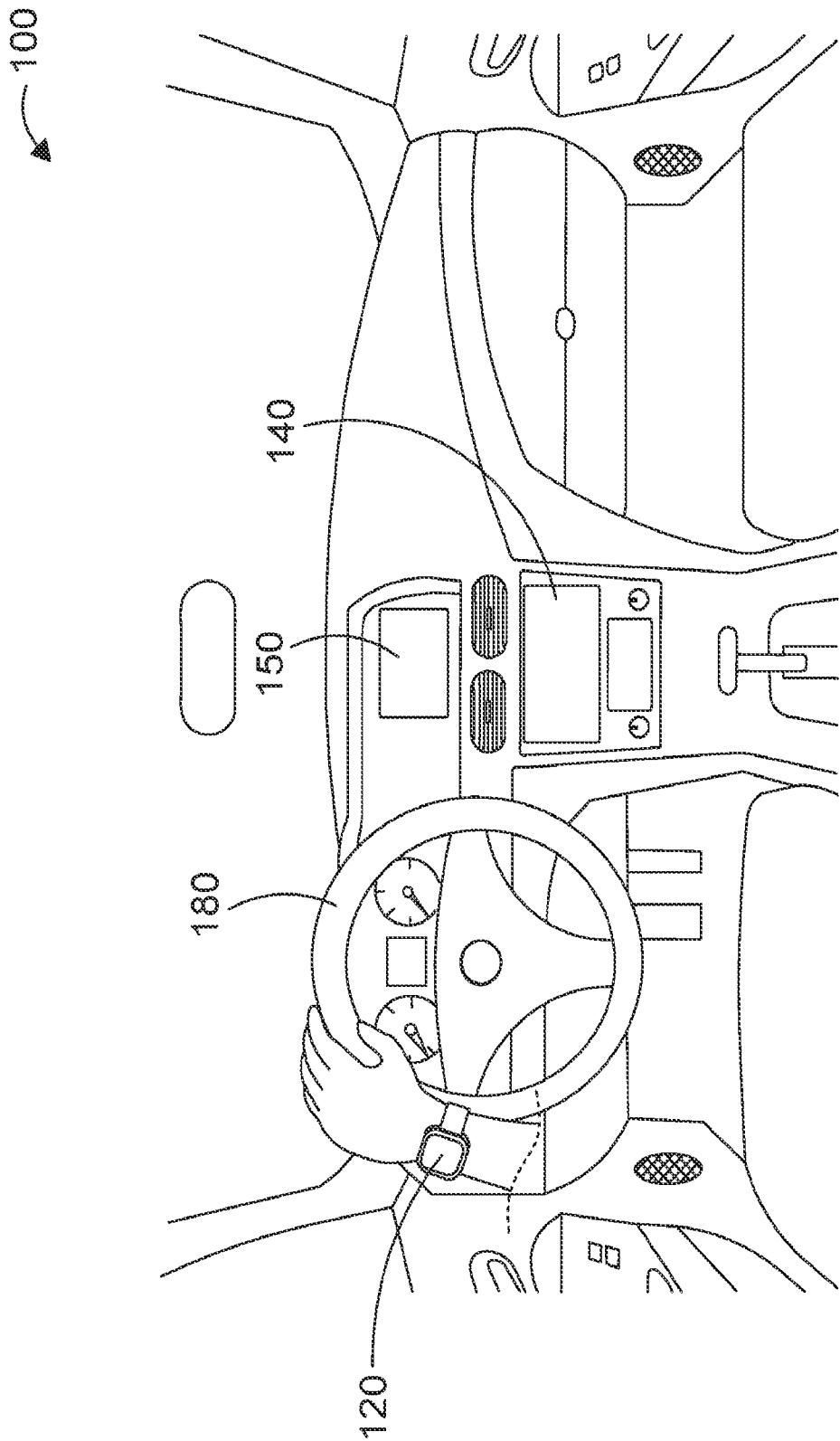


FIG. 1G

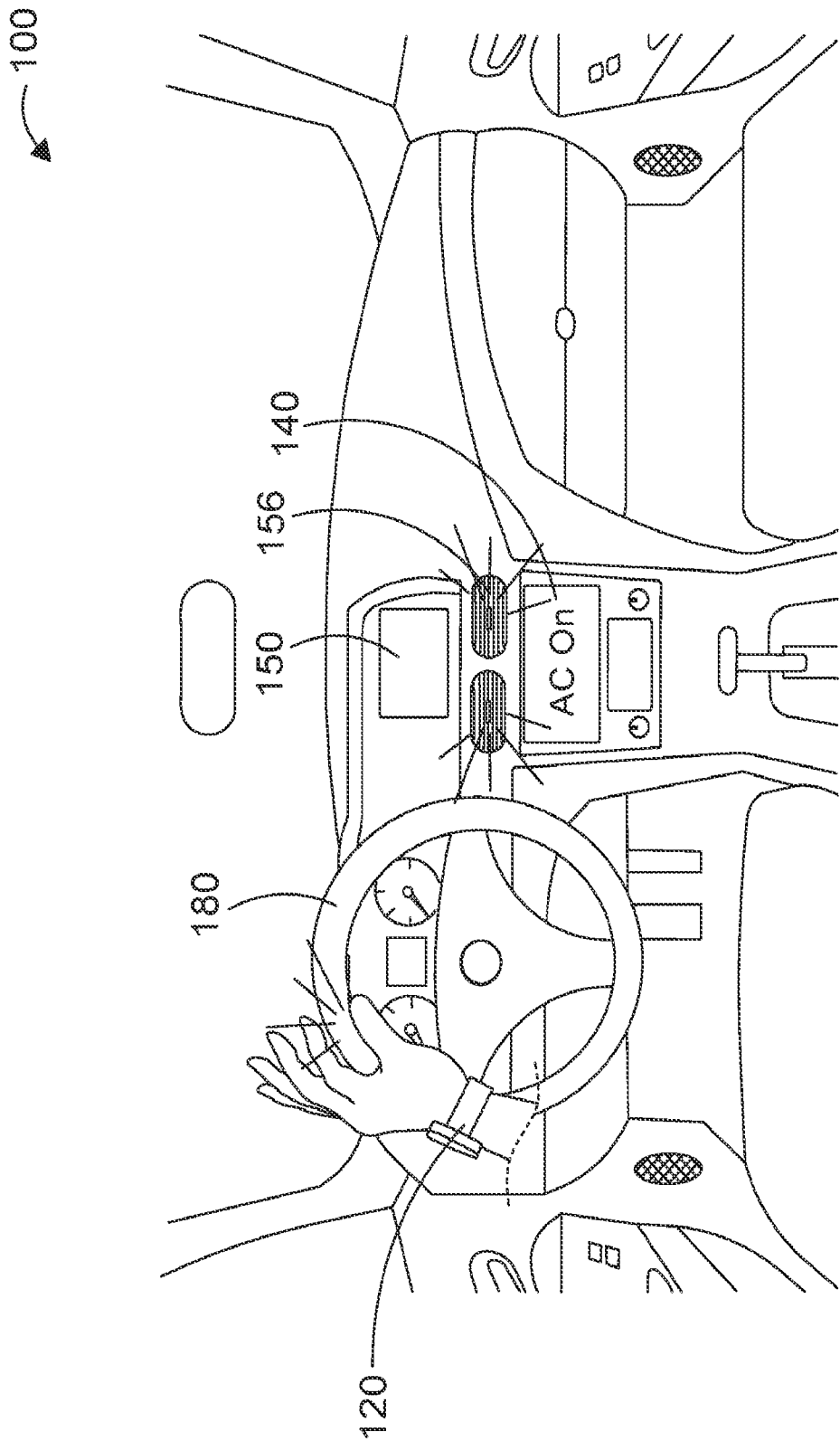


FIG. 1H

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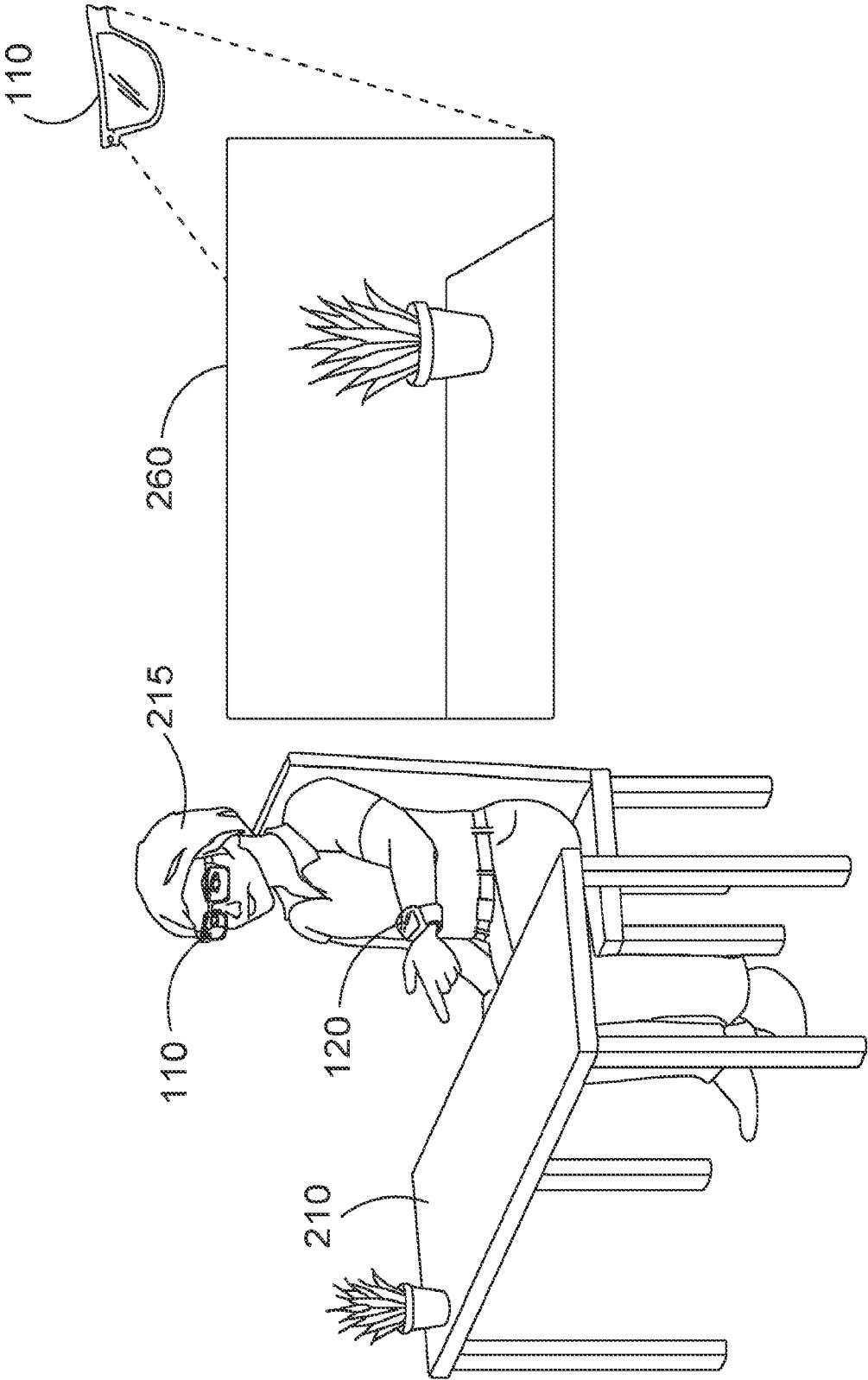


FIG. 2A

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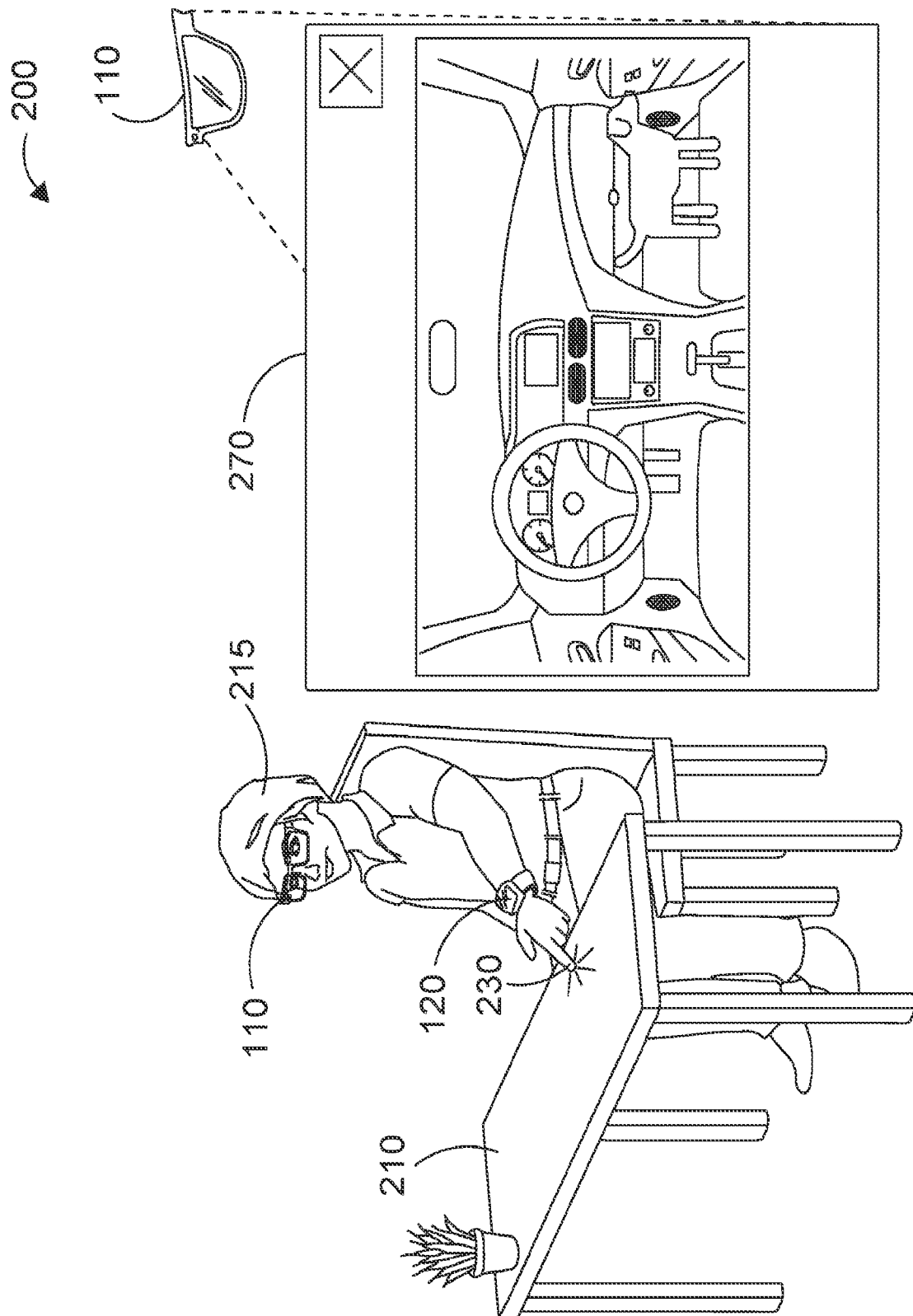


FIG. 2B

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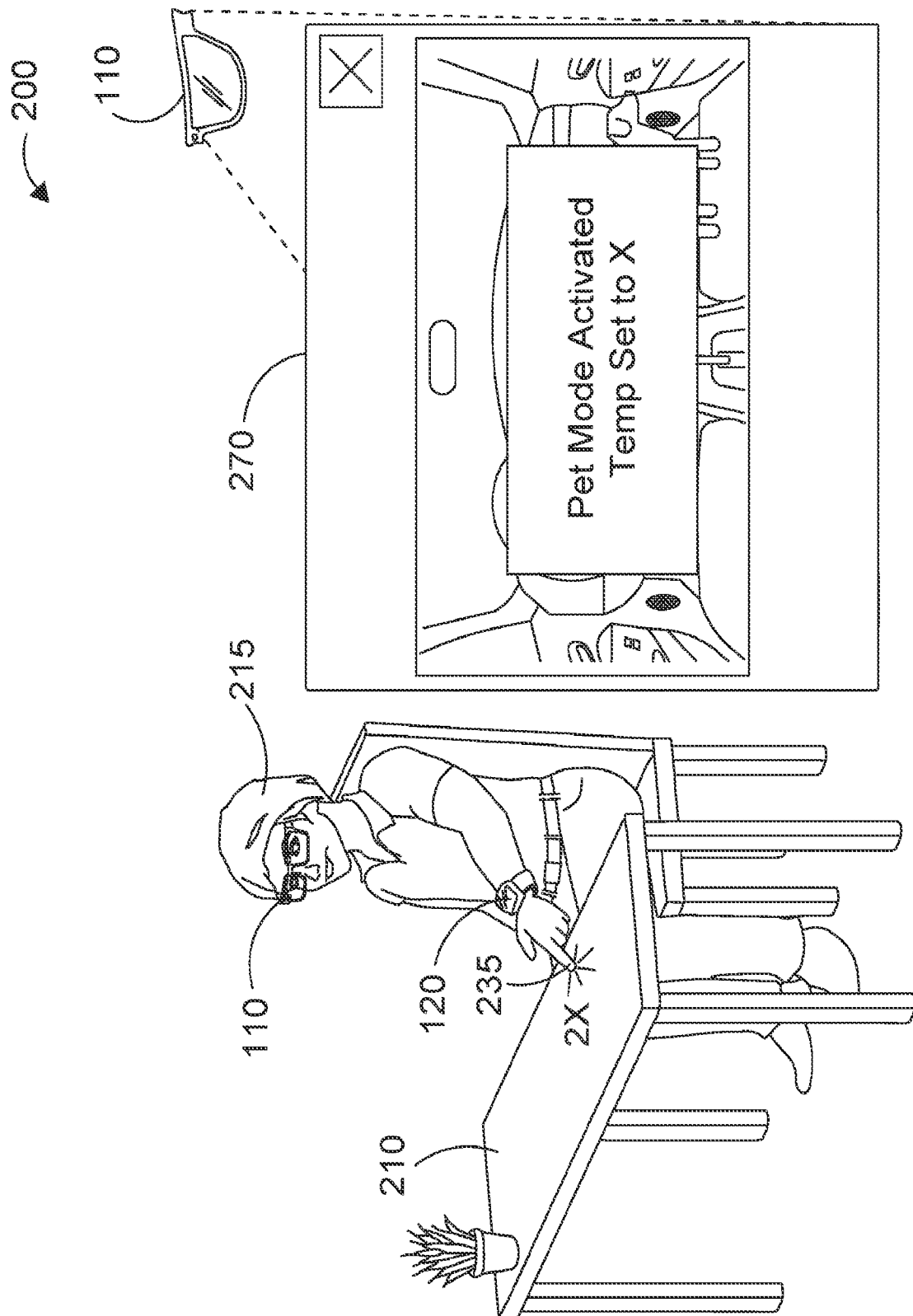


FIG. 2C

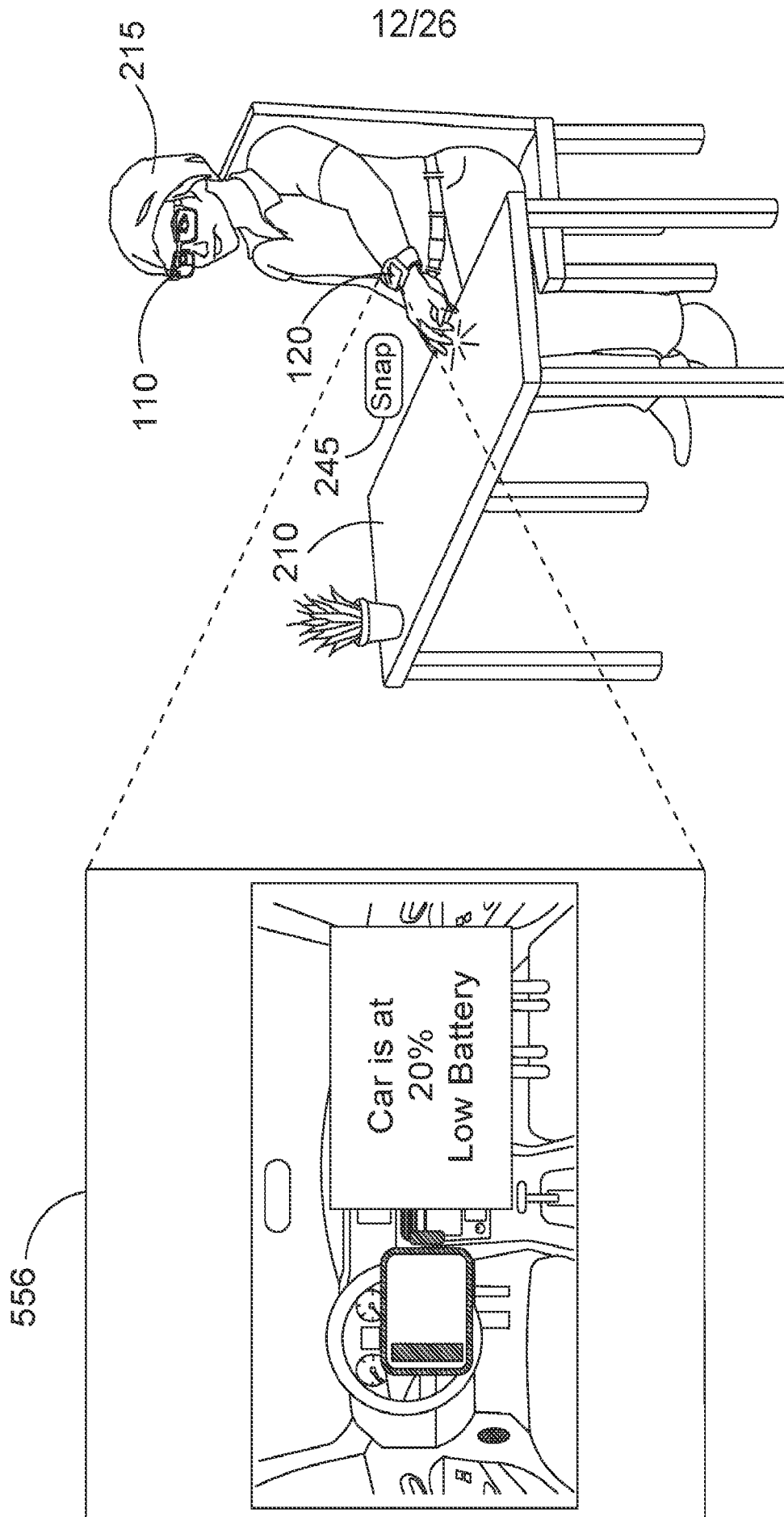


FIG. 2D

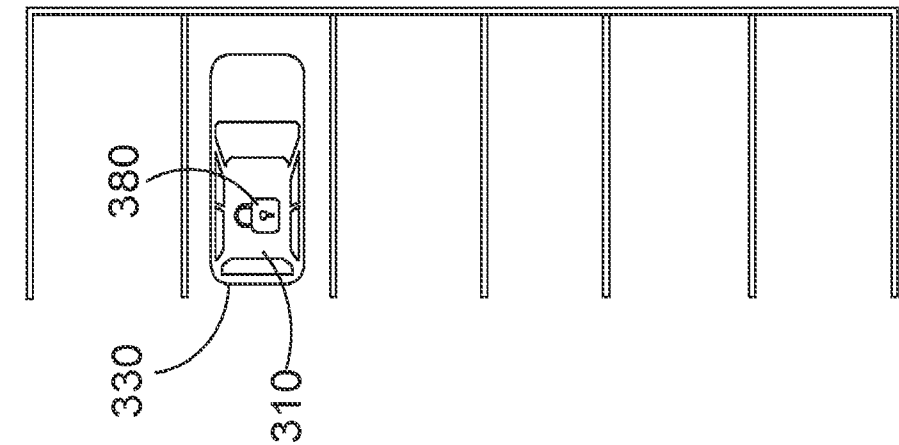
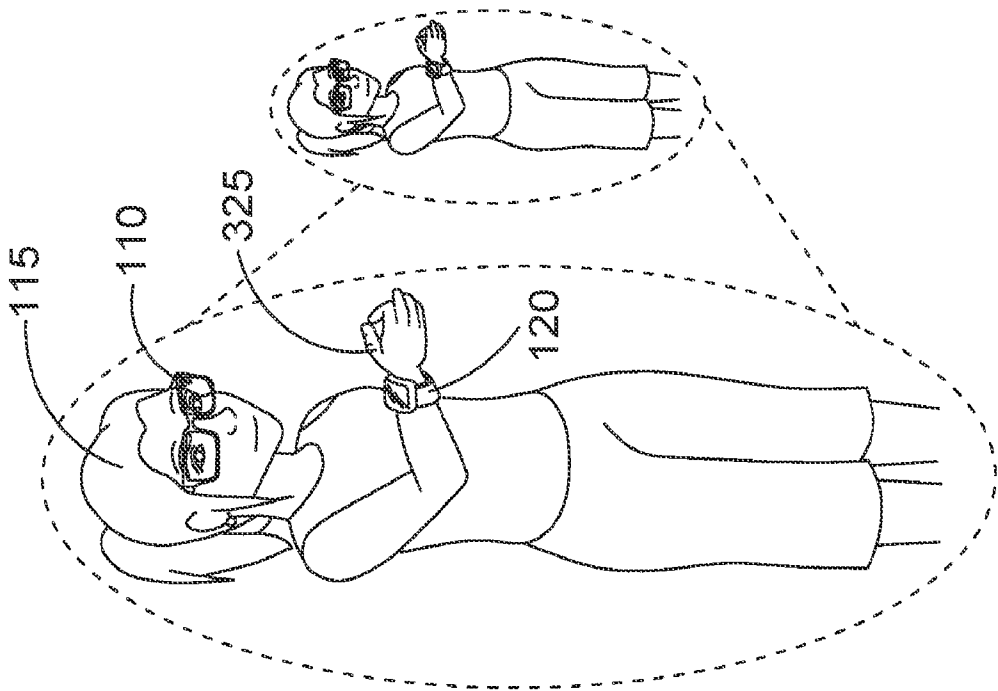


FIG. 3A



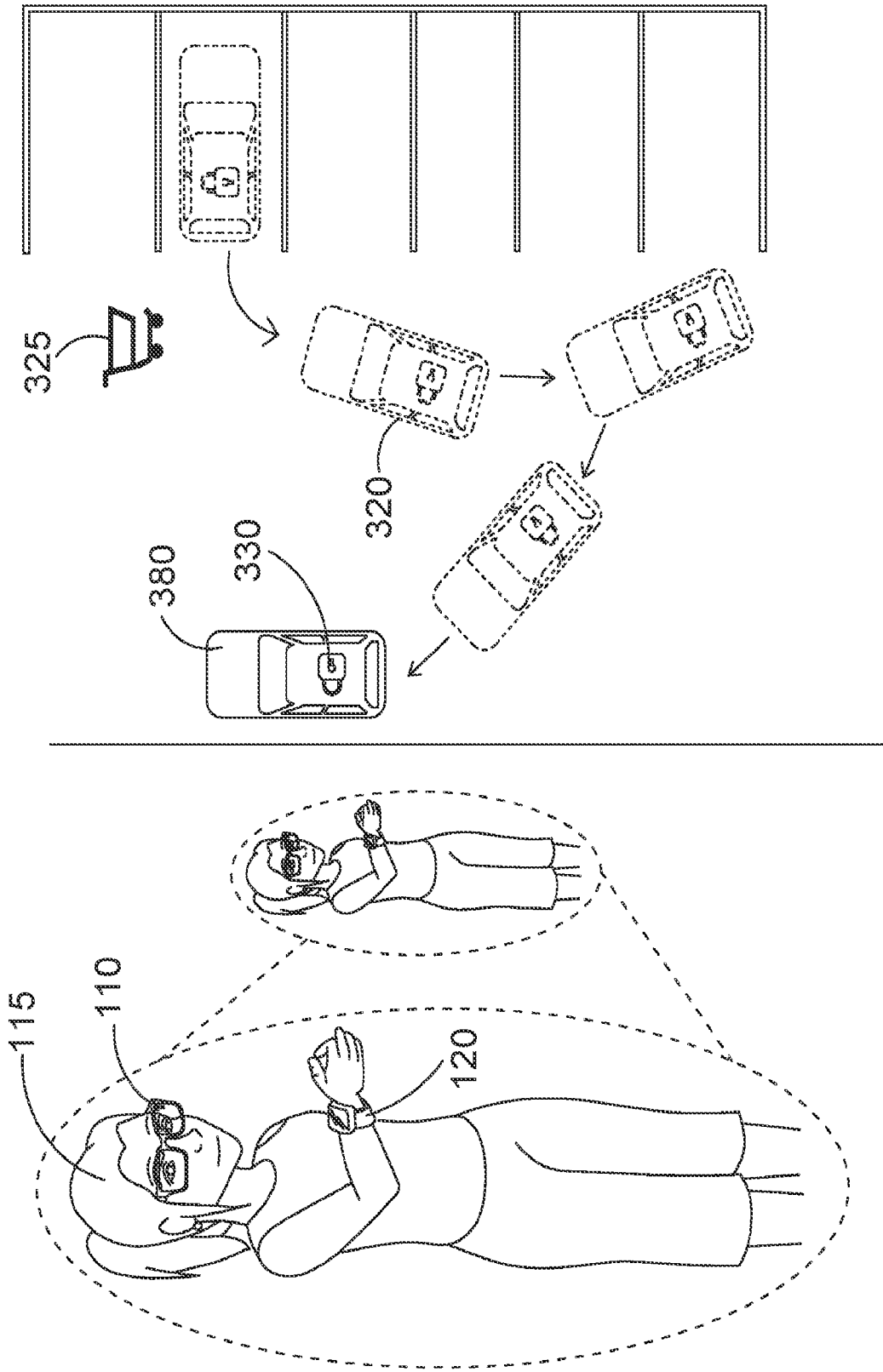


FIG. 3B

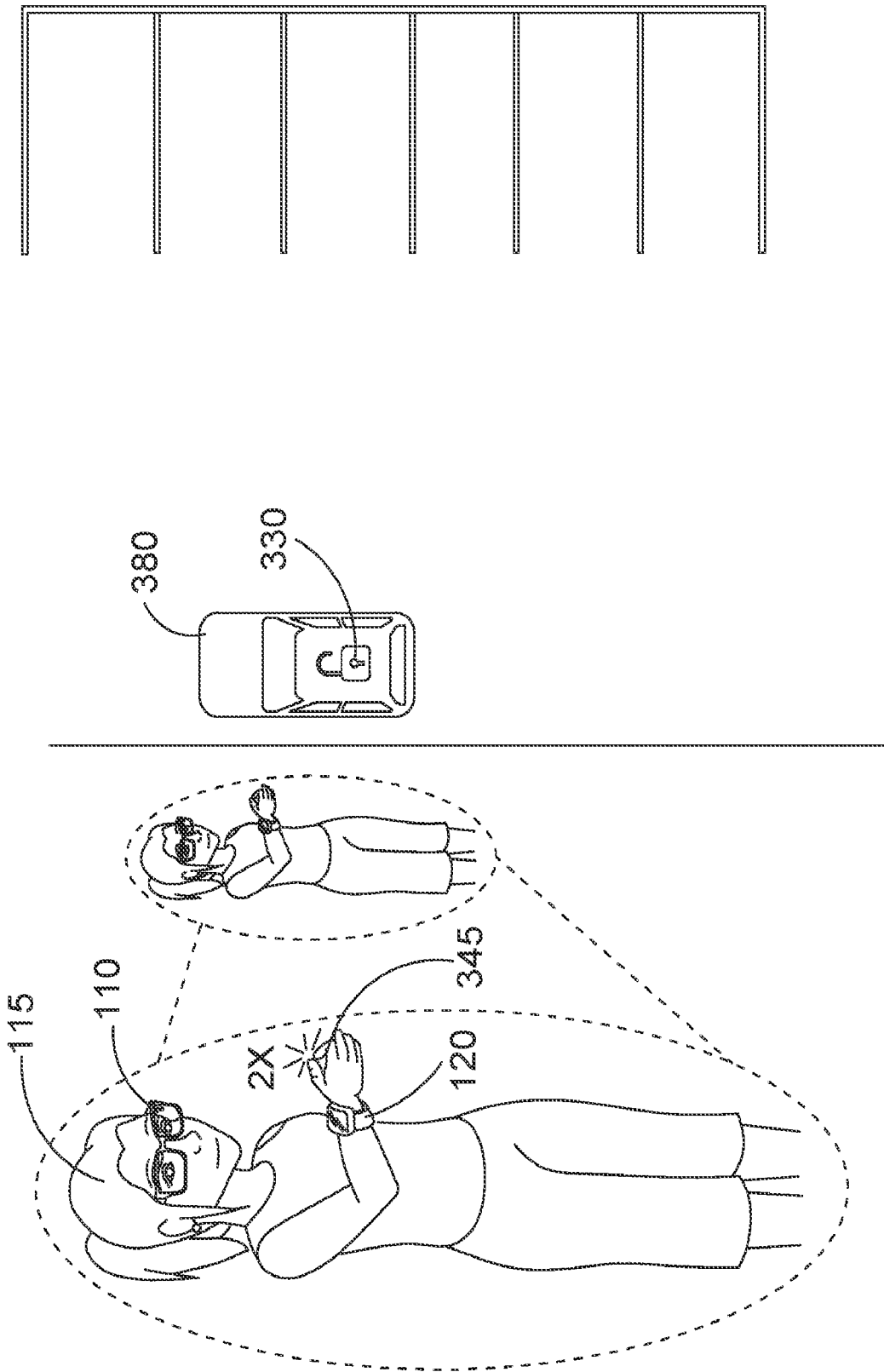


FIG. 3C

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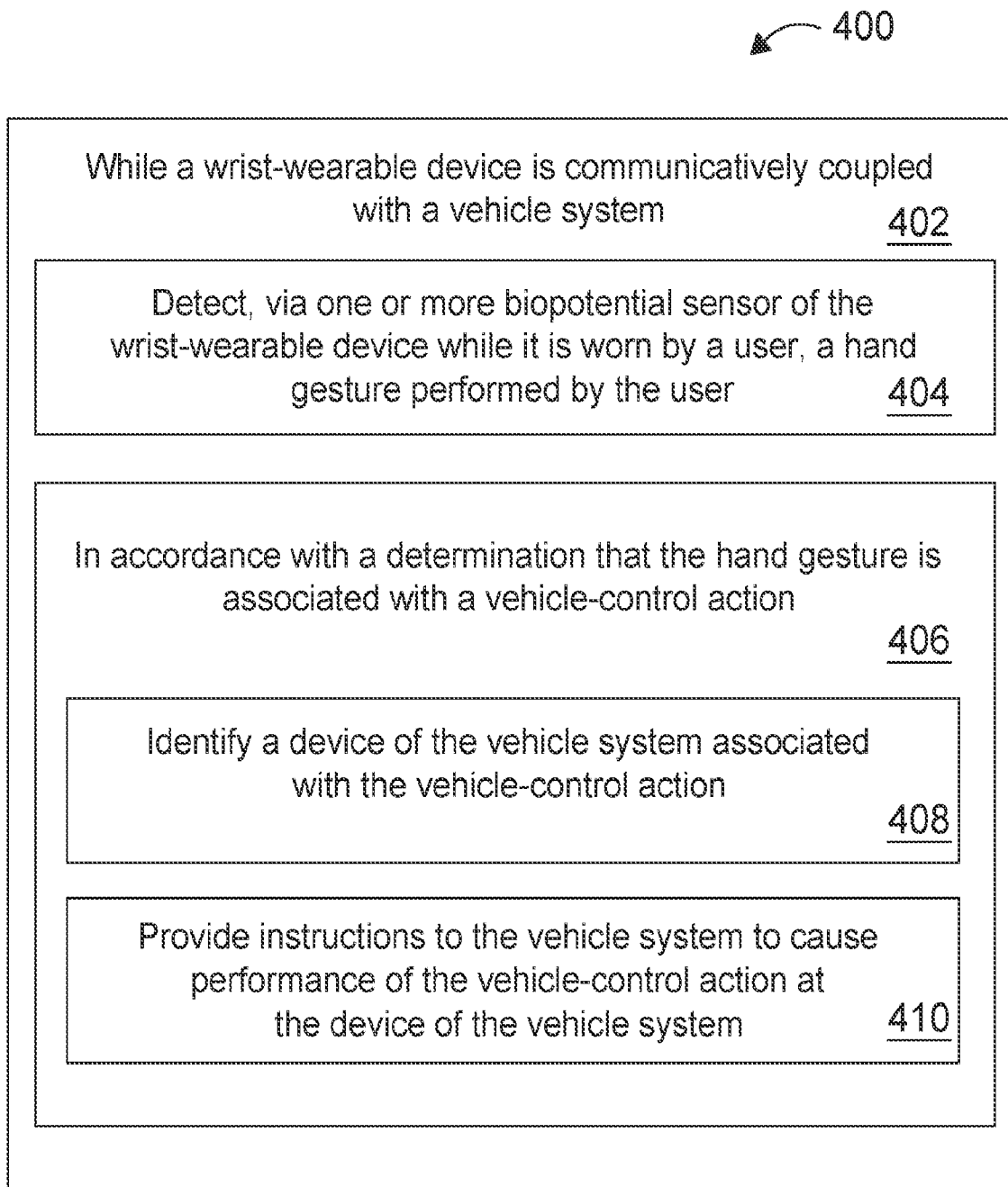


FIG. 4

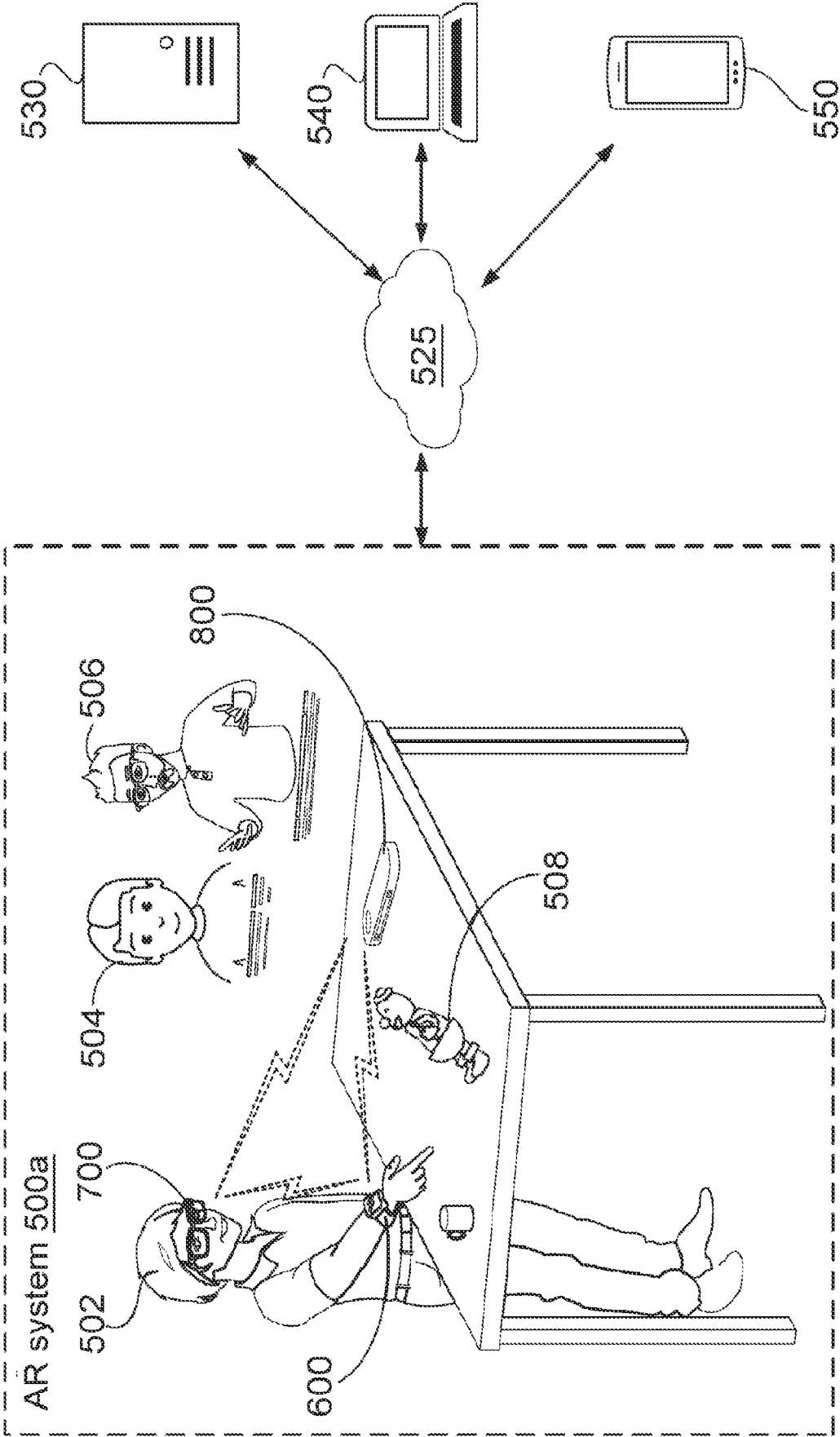


FIG. 5A

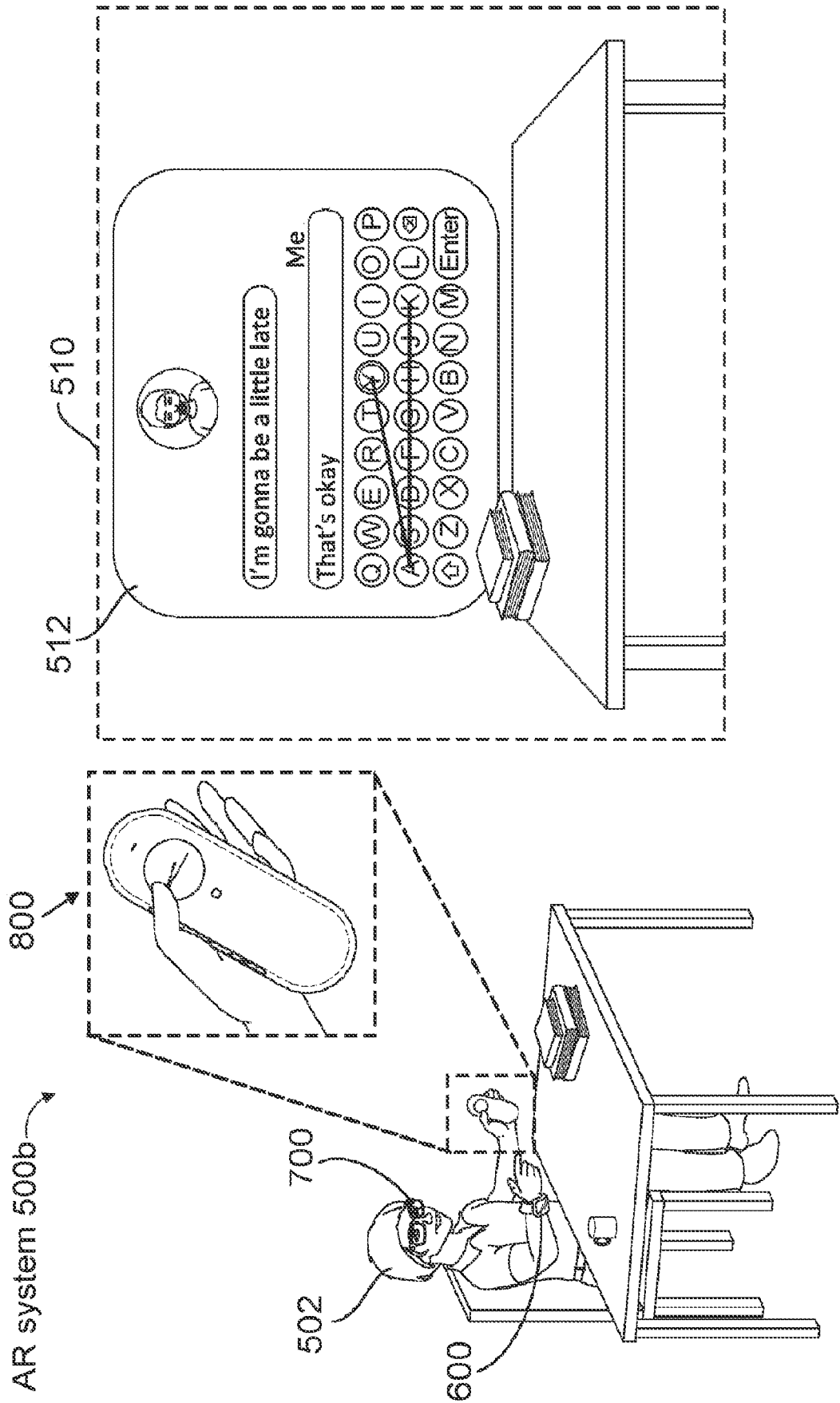


FIG. 5B

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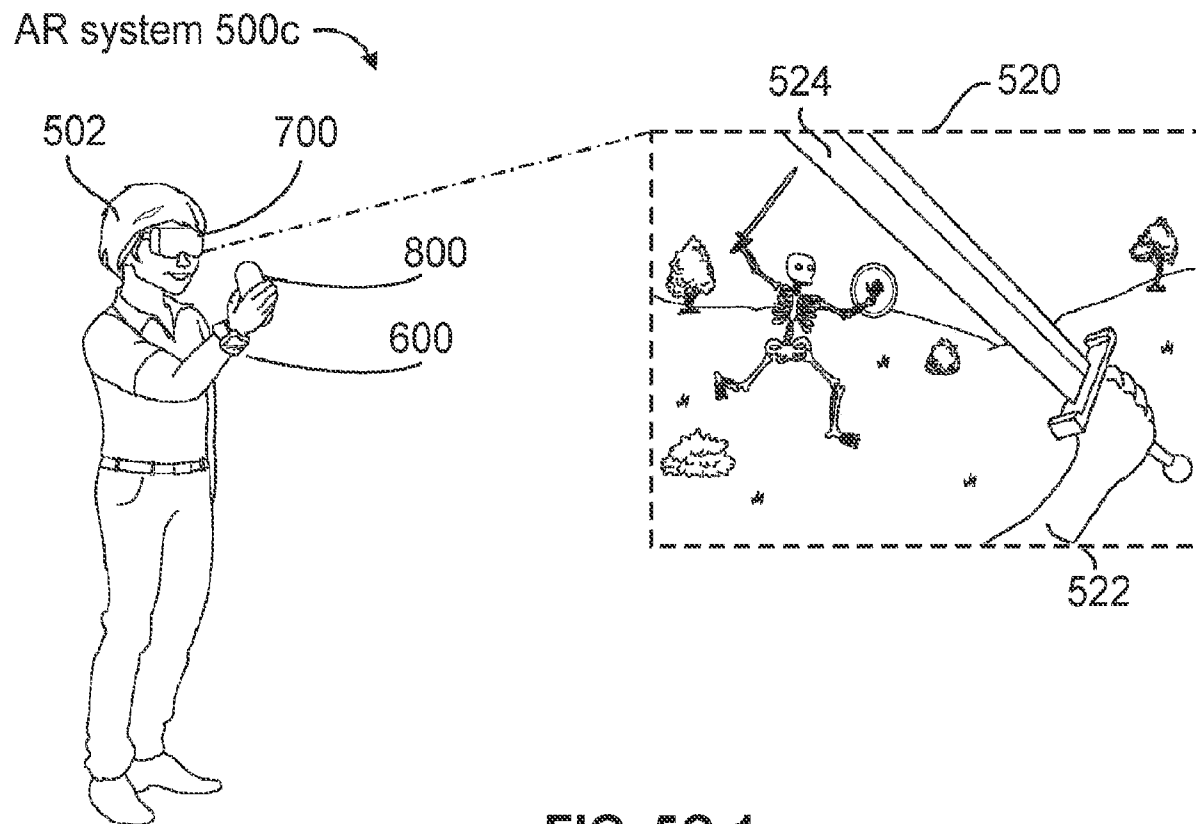


FIG. 5C-1

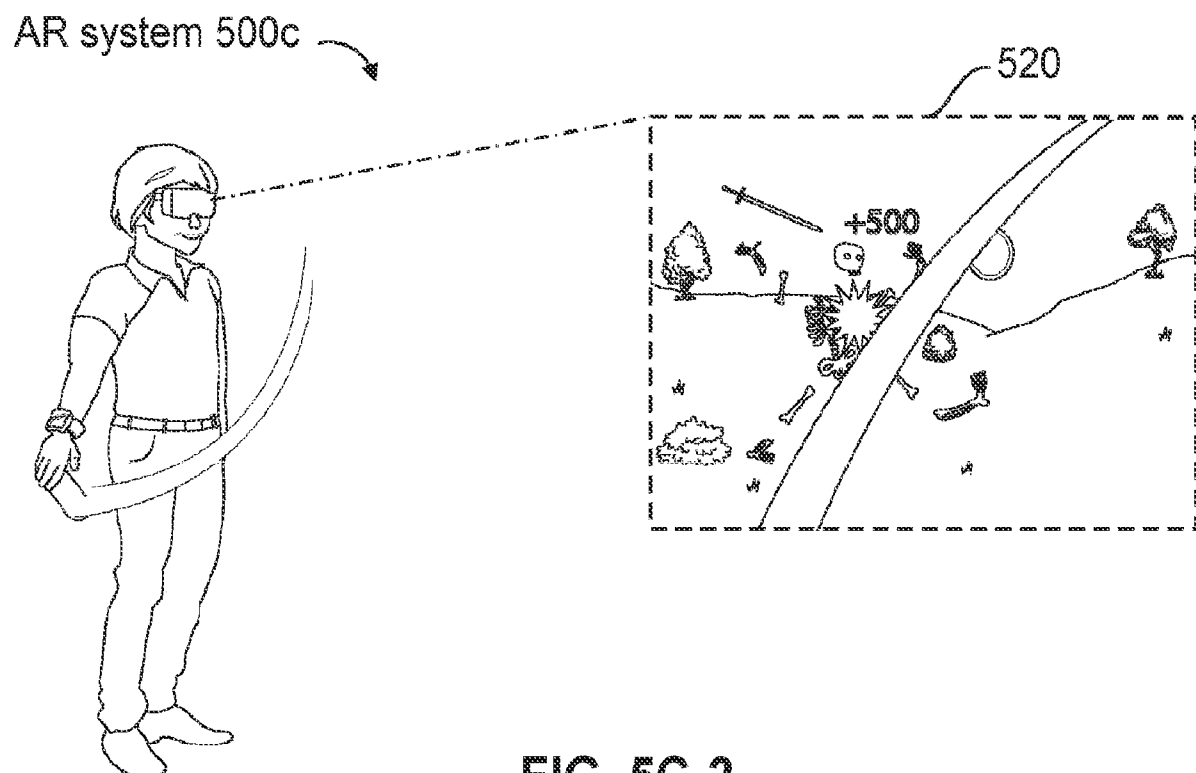


FIG. 5C-2

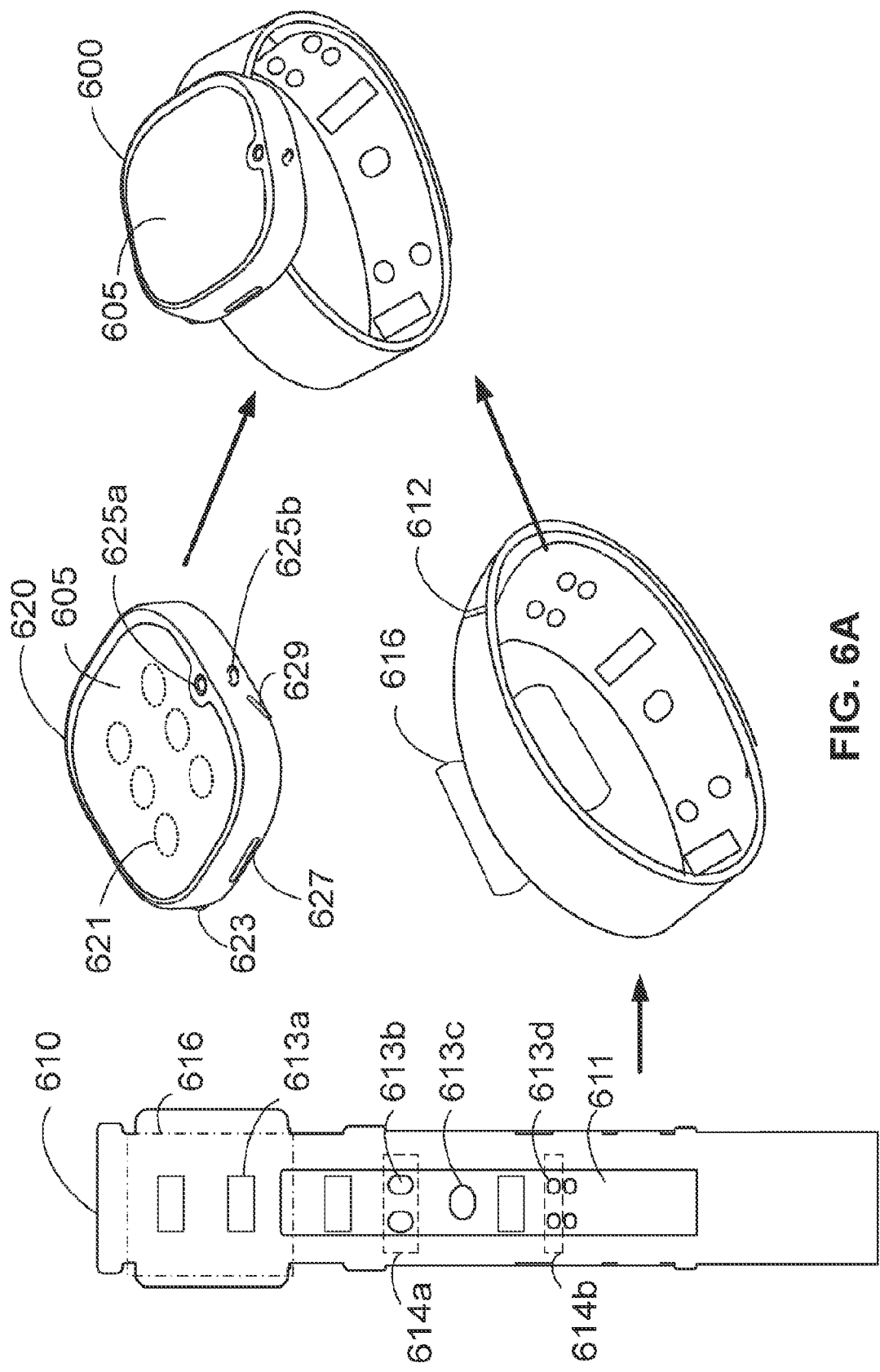


FIG. 6A

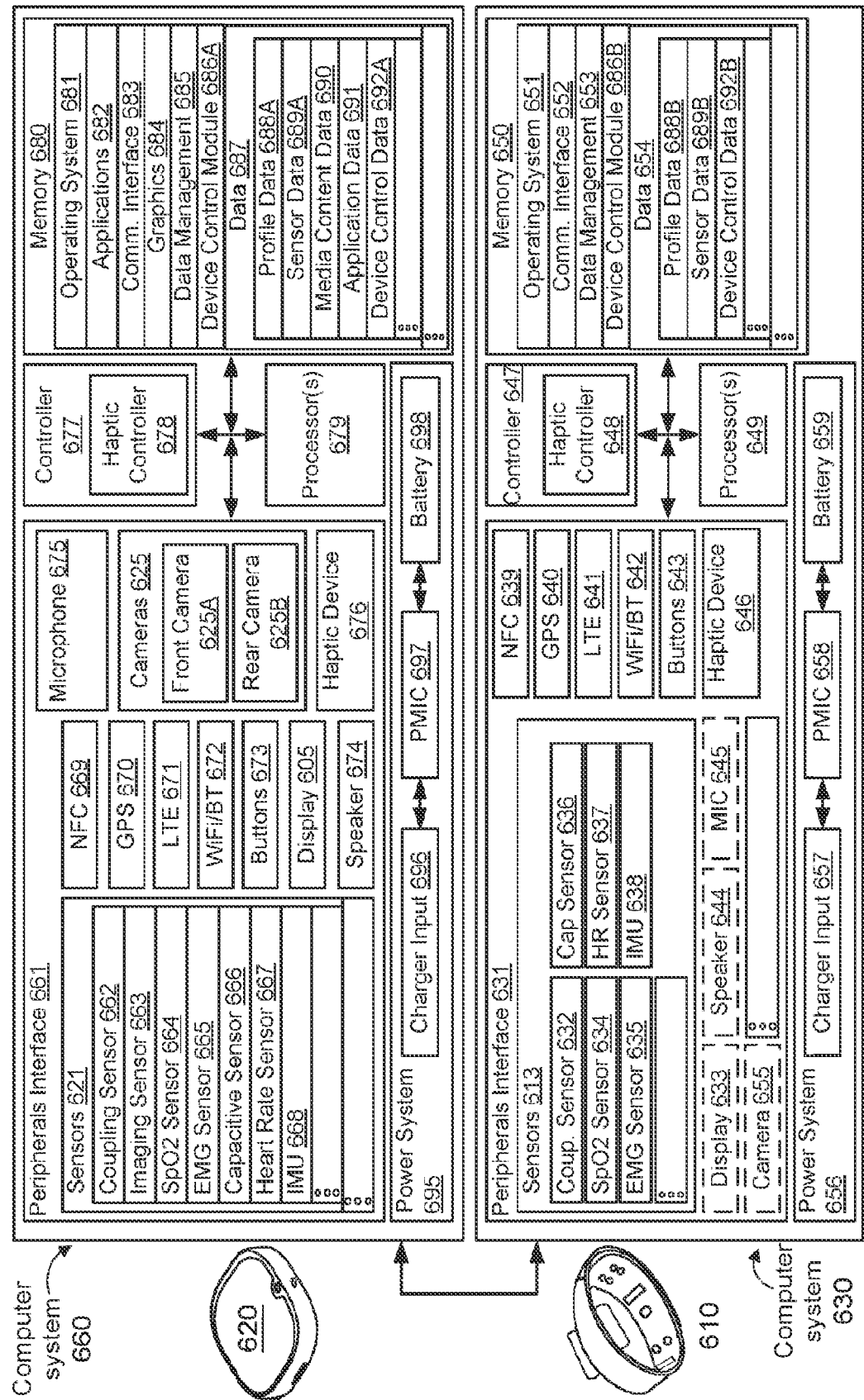


FIG. 6B

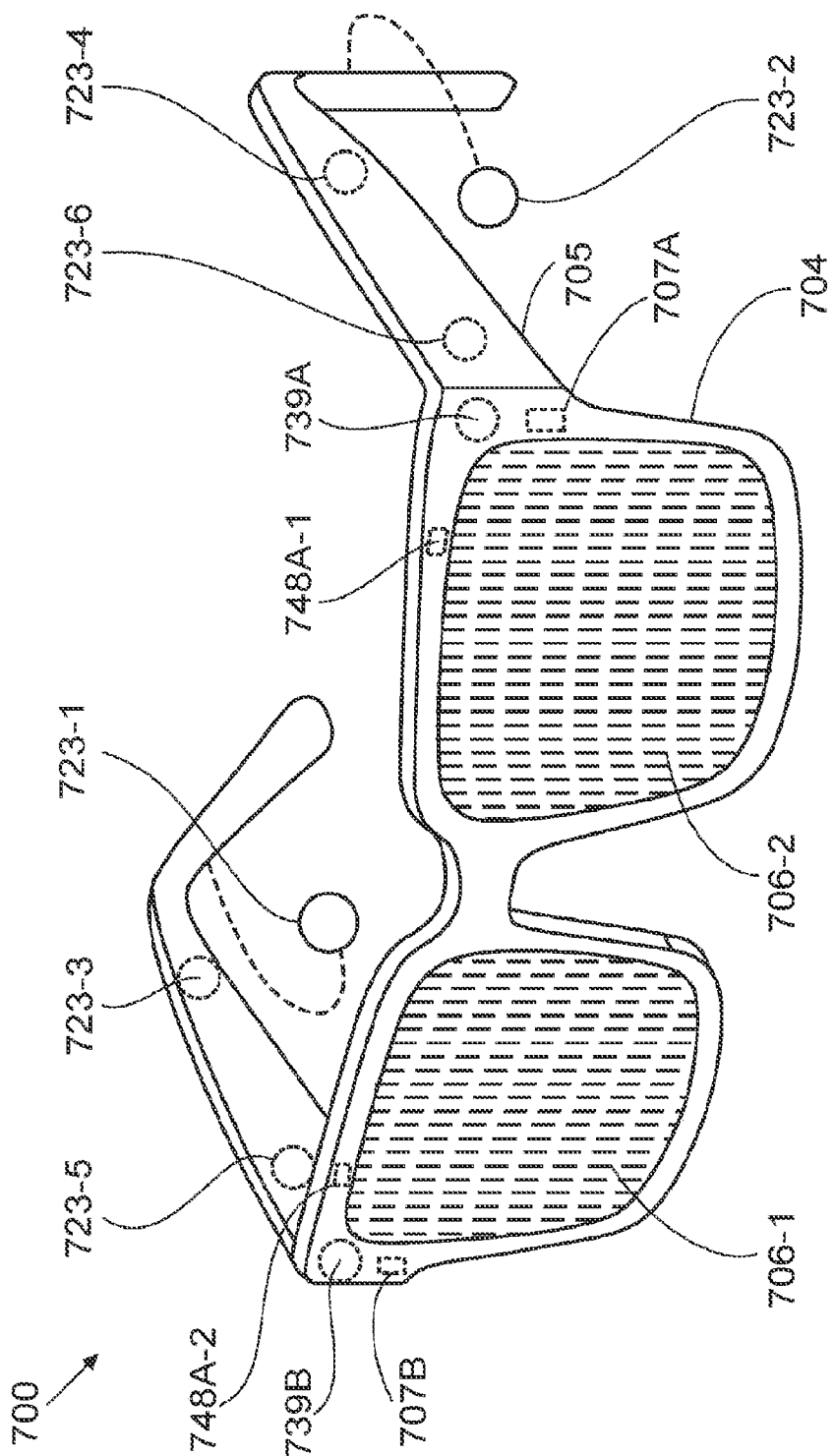


FIG. 7A

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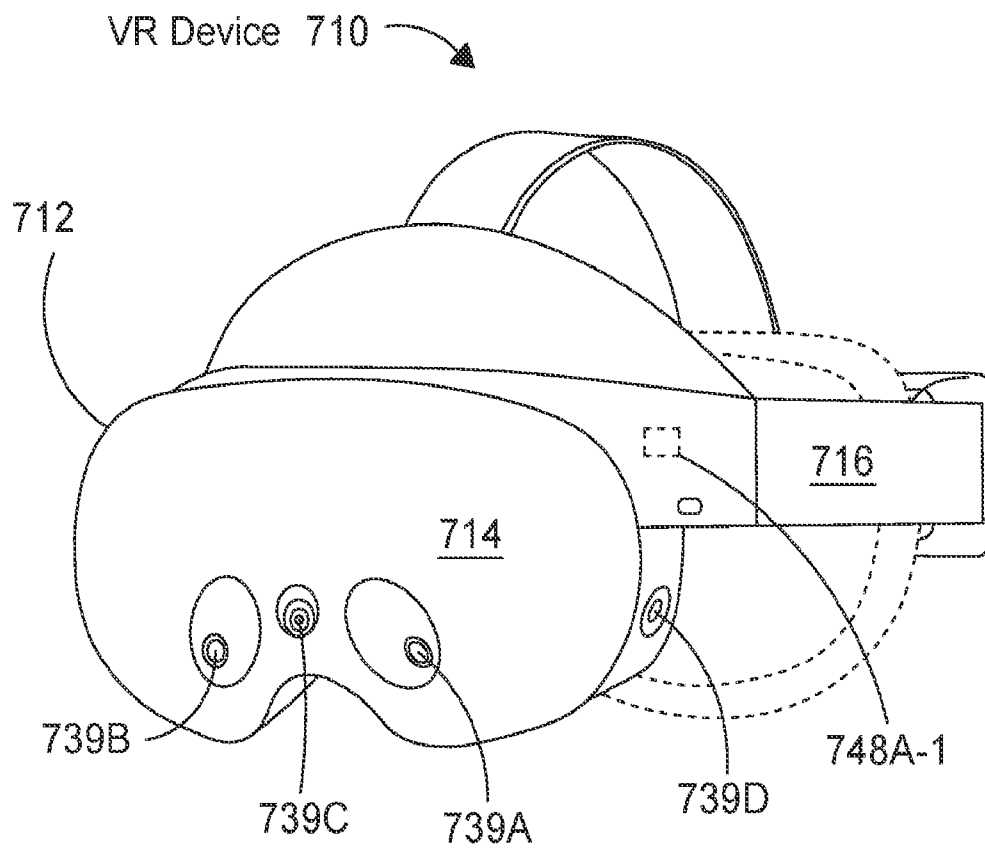


FIG. 7B-1

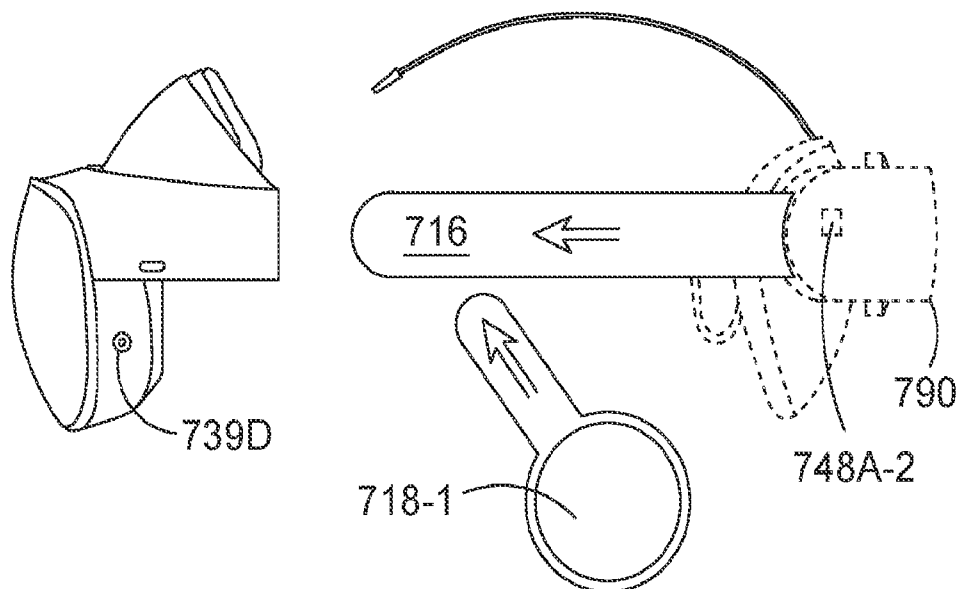
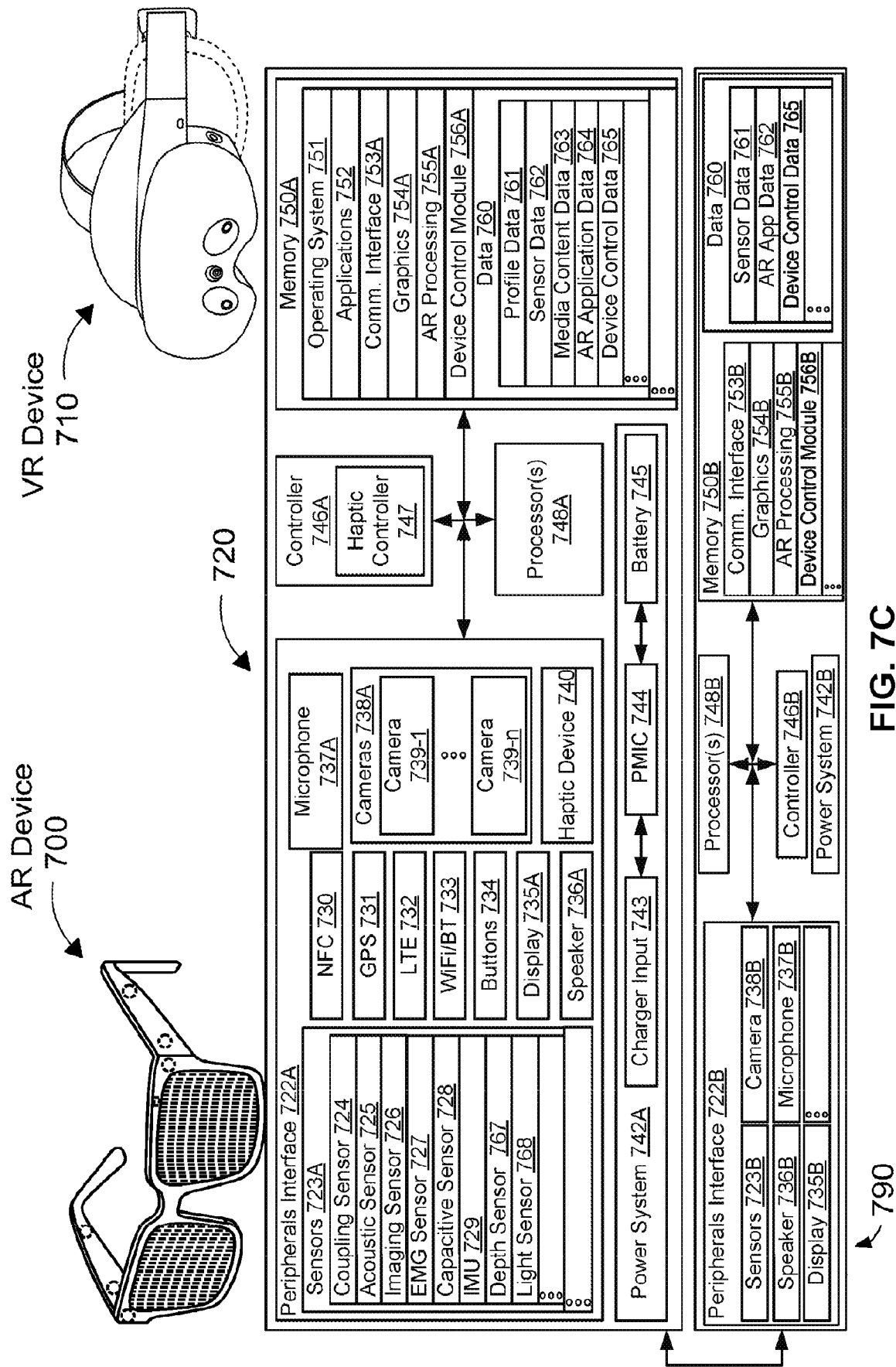


FIG. 7B-2



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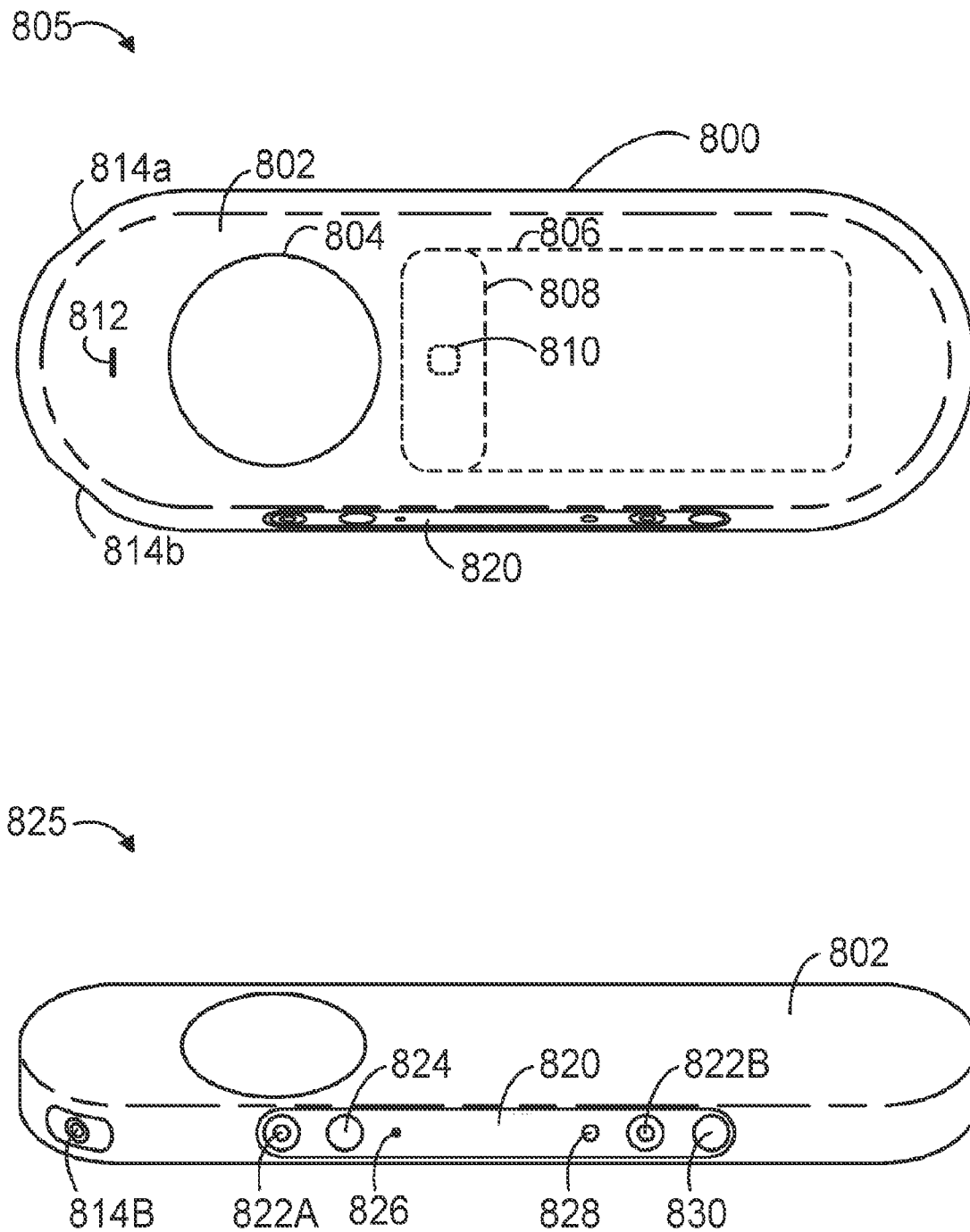


FIG. 8A

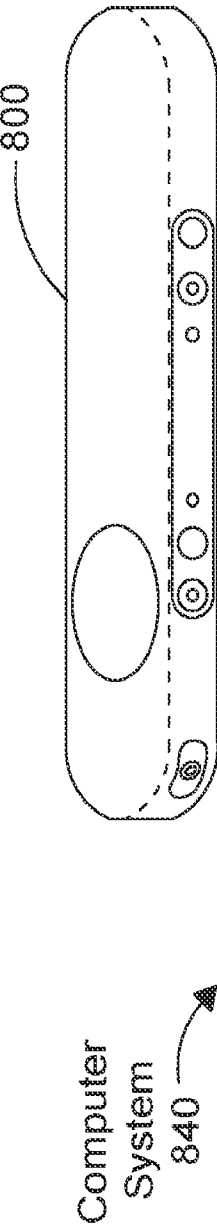
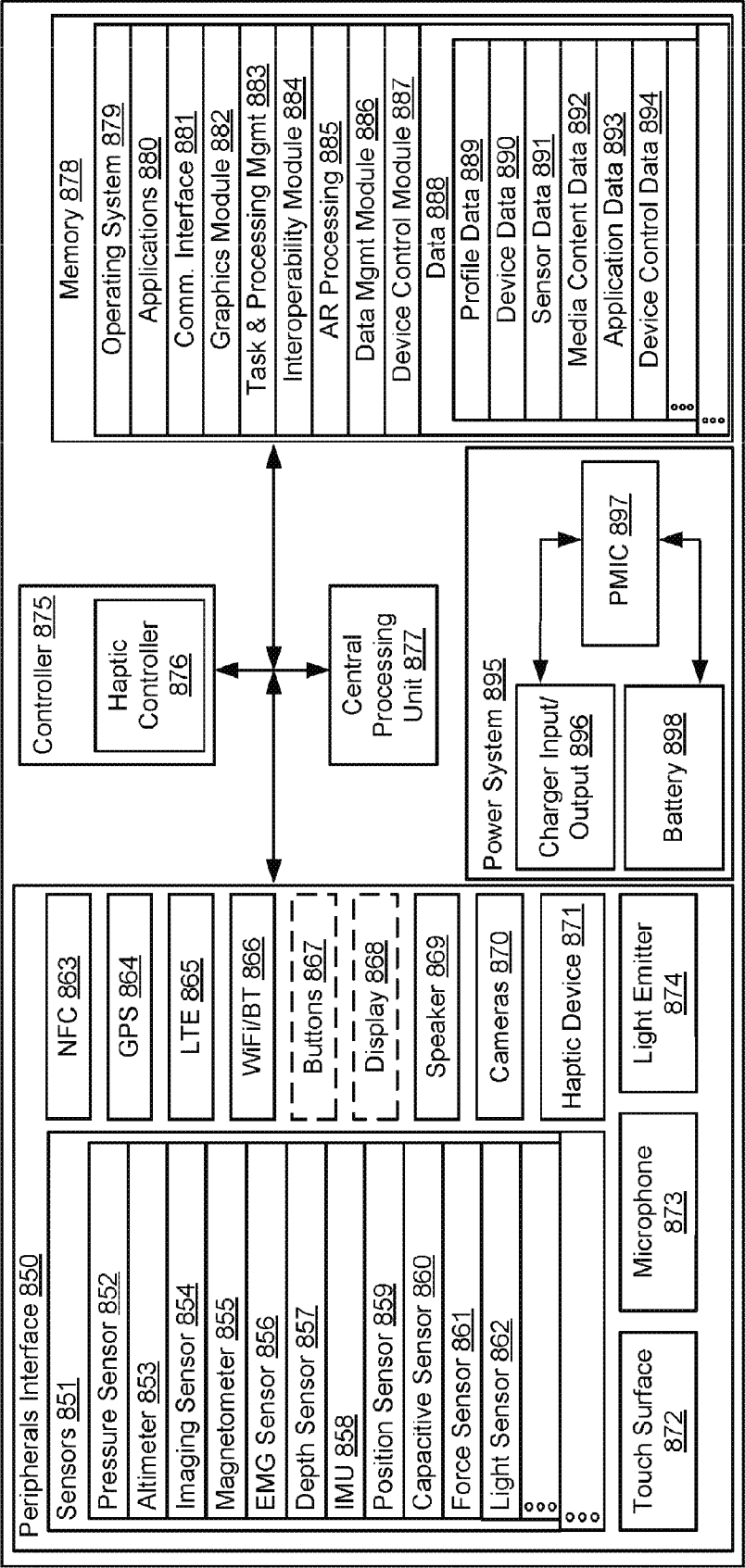


FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/020372

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06F3/01 B60K35/00 G06F3/0346
ADD.

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)
G06F B60K

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/102697 A1 (HASSAN ELNAJJAR [US] ET AL) 13 April 2017 (2017-04-13)	1-5,8-14
Y	abstract; figures 1-3 paragraphs [0024], [0034] claim 1	6,7

X	US 2021/158630 A1 (MUHAMMAD FAIZAN [US] ET AL) 27 May 2021 (2021-05-27)	1-5,8-14
Y	abstract; figure 7 paragraphs [0050], [0089], [0199]	6,7

X	US 2017/129335 A1 (LU PENG [US] ET AL) 11 May 2017 (2017-05-11)	1,5,9,13
A	abstract; figure 1 paragraphs [0103], [0110] - [0114] claim 9	2-4,6-8, 10-12,14

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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

10 June 2024

Date of mailing of the international search report

19/06/2024

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Fax: (+31-70) 340-3016

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Pfaffelhuber, Thomas

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/020372

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/183171 A1 (SHIUE YU-CHI [TW] ET AL) 17 June 2021 (2021-06-17)	6, 7
A	abstract; figures 1,4 paragraphs [0026] - [0028] claims 1,2 -----	1-5, 8-14
A	DE FREITAS RAFAELA C ET AL: "Electromyography-controlled car: A proof of concept based on surface electromyography, Extreme Learning Machines and low-cost open hardware", COMPUTERS & ELECTRICAL ENGINEERING, vol. 73, 31 December 2019 (2019-12-31), pages 167-179, XP085588519, ISSN: 0045-7906, DOI: 10.1016/J.COMPELECENG.2018.11.012 the whole document -----	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/020372

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