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(54) **DRIVER DISTRACTION DETECTION SYSTEM**

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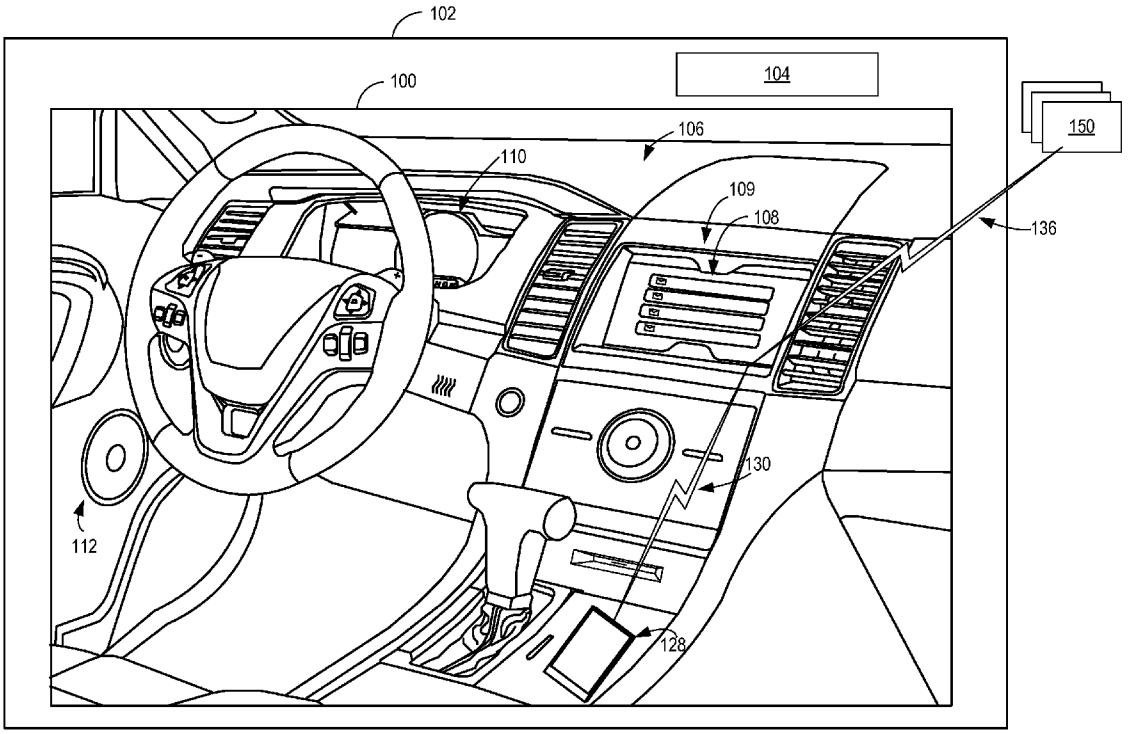
(57) **ABSTRACT**

Embodiments are described for determining and responding to driver distractions. An example in-vehicle computing system of a vehicle includes an external device interface communicatively connecting the in-vehicle computing system to a mobile device, an inter-vehicle system communication module communicatively connecting the in-vehicle computing system to one or more vehicle systems of the vehicle, a processor, and a storage device storing instructions executable by the processor to receive image data from the mobile device, and determine a driver state based on the received image data. The instructions are further executable to receive vehicle data from one or more of the vehicle systems, determine a vehicle state based on the vehicle data, determine a distraction severity level based on the driver state and the vehicle state, and control one or more devices of the vehicle to perform a selected action based on the distraction severity level.



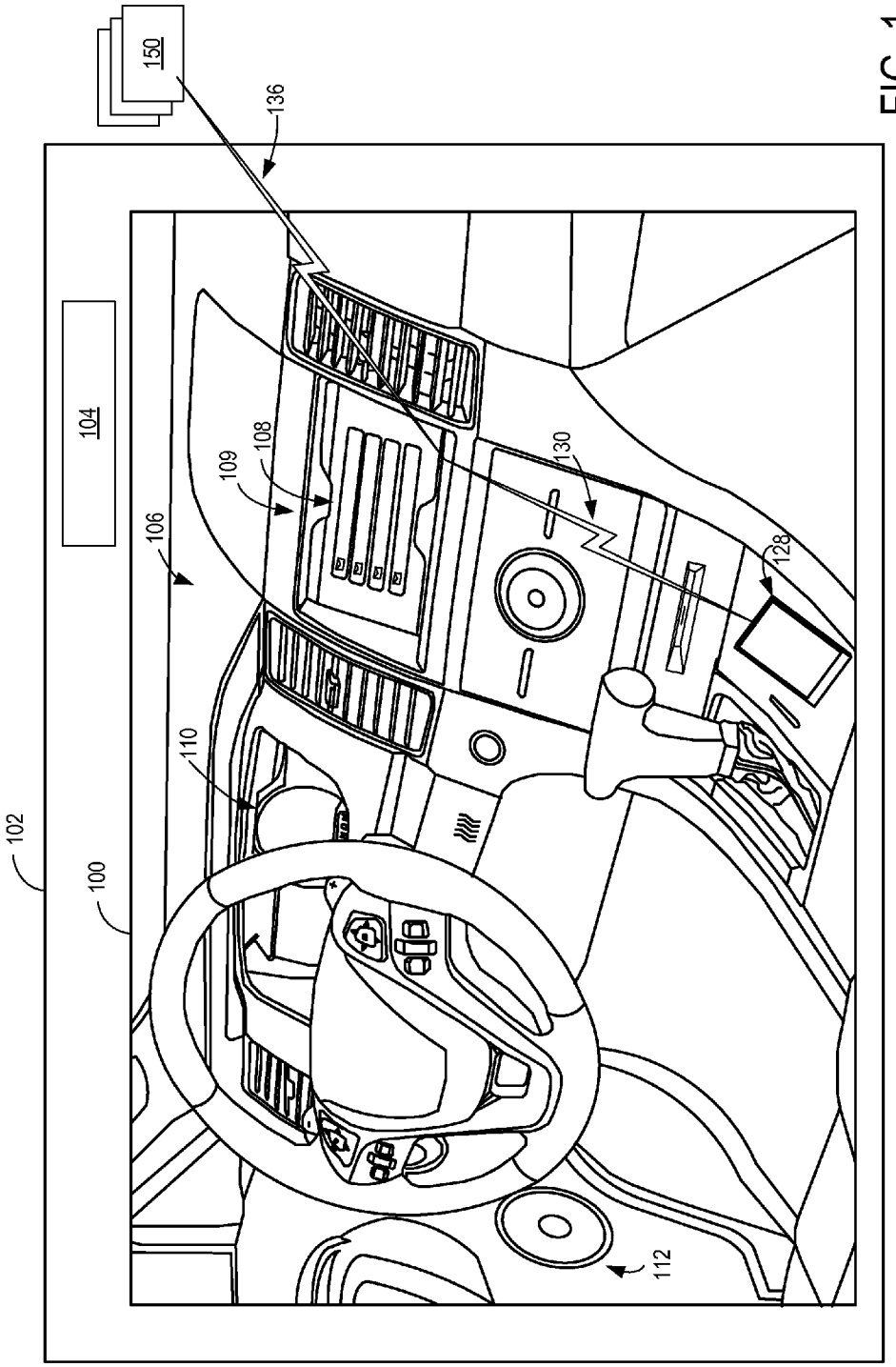


FIG. 1

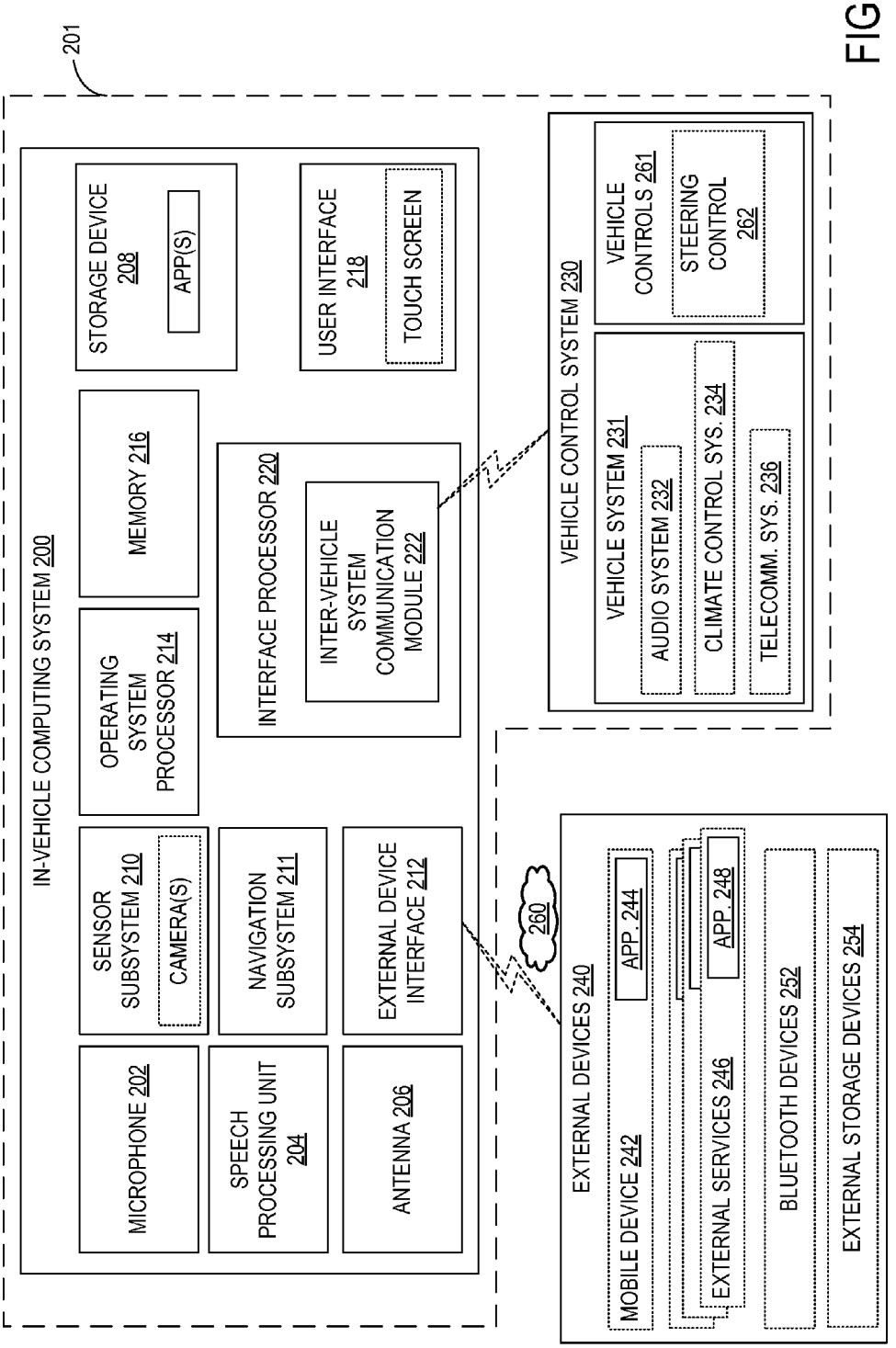

201
IN-VEHICLE COMPUTING SYSTEM 200
MICROPHONE 202
SENSOR SUBSYSTEM 210
CAMERA(S)
OPERATING SYSTEM PROCESSOR 214
STORAGE DEVICE 208
APP(S)
SPEECH PROCESSING UNIT 204
NAVIGATION SUBSYSTEM 211
MEMORY 216
ANTENNA 206
EXTERNAL DEVICE INTERFACE 212
INTERFACE PROCESSOR 220
INTER-VEHICLE SYSTEM COMMUNICATION MODULE 222
USER INTERFACE 218
TOUCH SCREEN
VEHICLE CONTROL SYSTEM 230
VEHICLE SYSTEM 231
AUDIO SYSTEM 232
CLIMATE CONTROL SYS. 234
TELECOMM. SYS. 236
VEHICLE CONTROLS 261
STEERING CONTROL 262
260
EXTERNAL DEVICES 240
MOBILE DEVICE 242
APP. 244
EXTERNAL SERVICES 246
APP. 248
BLUETOOTH DEVICES 252
EXTERNAL STORAGE DEVICES 254

FIG. 2

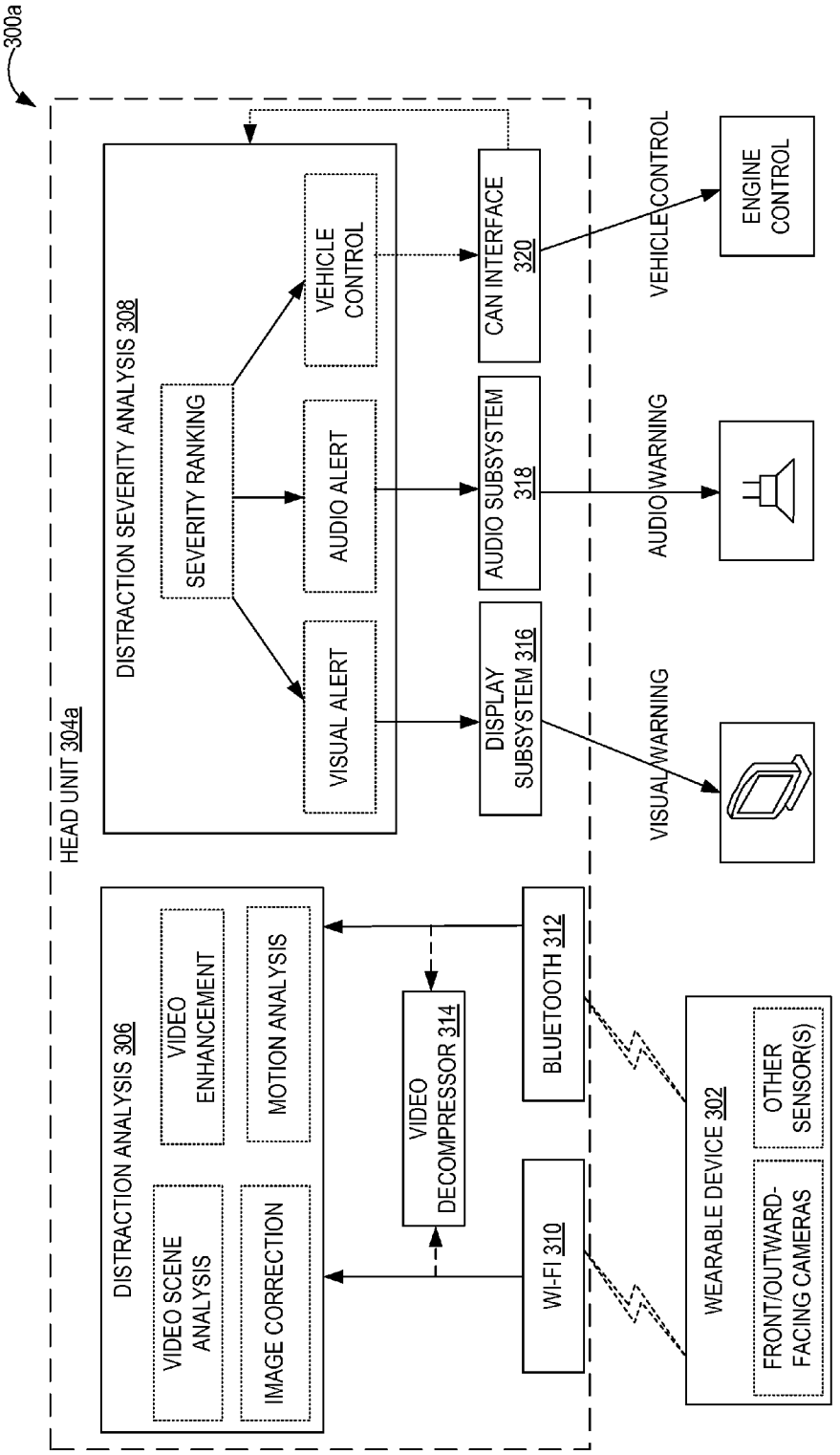

300a
HEAD UNIT 304a
DISTRACTION SEVERITY ANALYSIS 308
SEVERITY RANKING
VISUAL ALERT
AUDIO ALERT
VEHICLE CONTROL
DISPLAY SUBSYSTEM 316
AUDIO SUBSYSTEM 318
CAN INTERFACE 320
VISUAL WARNING
AUDIO WARNING
VEHICLE CONTROL
ENGINE CONTROL
DISTRACTION ANALYSIS 306
VIDEO SCENE ANALYSIS
IMAGE CORRECTION
VIDEO ENHANCEMENT
MOTION ANALYSIS
VIDEO DECOMPRESSOR 314
WI-FI 310
BLUETOOTH 312
WEARABLE DEVICE 302
FRONT/OUTWARD-FACING CAMERAS
OTHER SENSOR(S)

FIG. 3A

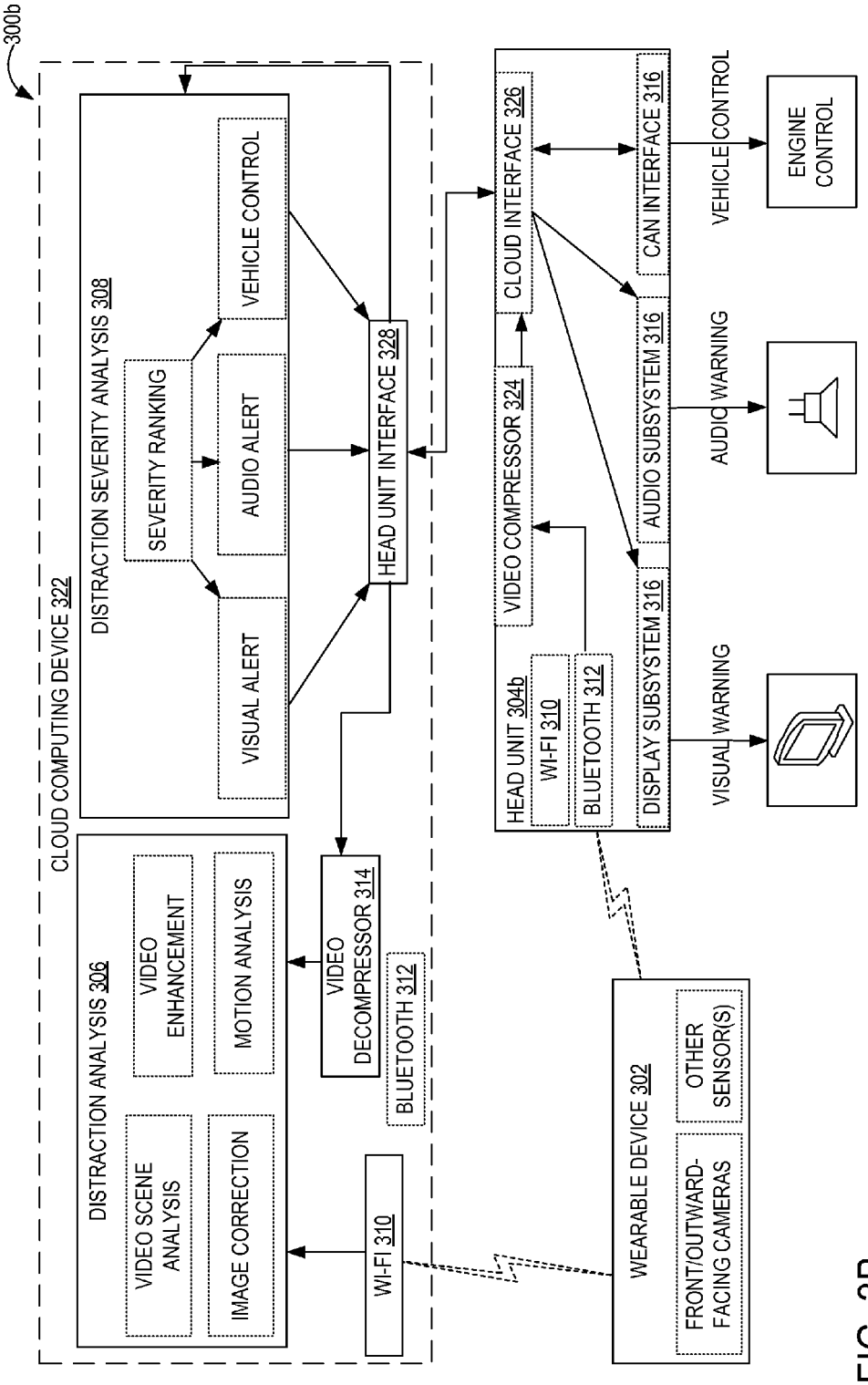

300b
CLOUD COMPUTING DEVICE 322
DISTRACTION SEVERITY ANALYSIS 308
SEVERITY RANKING
VEHICLE CONTROL
AUDIO ALERT
VISUAL ALERT
HEAD UNIT INTERFACE 328
CLOUD INTERFACE 326
VIDEO COMPRESSOR 324
HEAD UNIT 304b
WI-FI 310
BLUETOOTH 312
CAN INTERFACE 316
AUDIO SUBSYSTEM 316
DISPLAY SUBSYSTEM 316
VEHICLE CONTROL
ENGINE CONTROL
AUDIO WARNING
VISUAL WARNING
DISTRACTION ANALYSIS 306
VIDEO SCENE ANALYSIS
VIDEO ENHANCEMENT
IMAGE CORRECTION
MOTION ANALYSIS
VIDEO DECOMPRESSOR 314
BLUETOOTH 312
WI-FI 310
WEARABLE DEVICE 302
FRONT/OUTWARD-FACING CAMERAS
OTHER SENSOR(S)

FIG. 3B

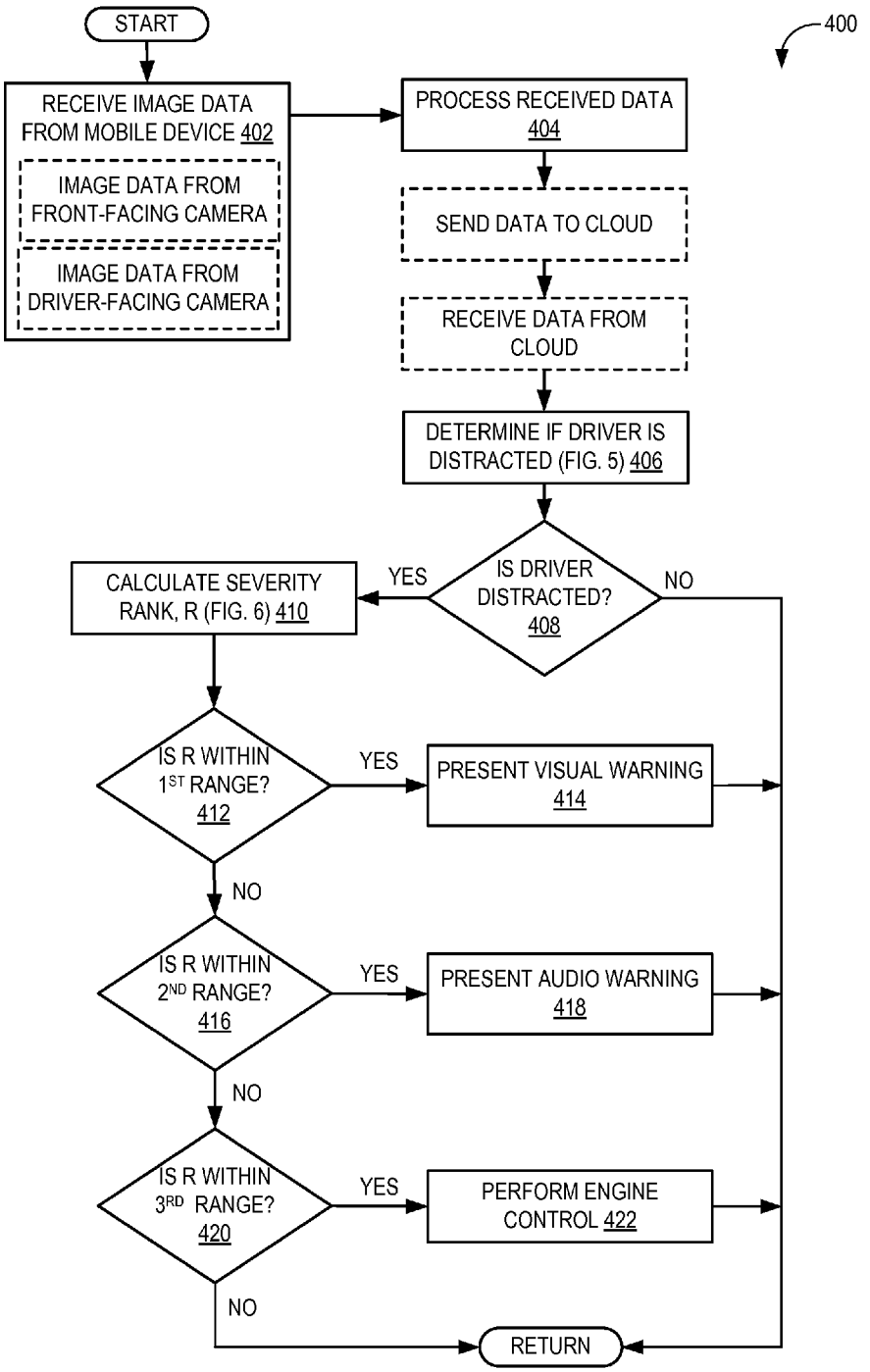

400
START
RECEIVE IMAGE DATA FROM MOBILE DEVICE 402
IMAGE DATA FROM FRONT-FACING CAMERA
IMAGE DATA FROM DRIVER-FACING CAMERA
PROCESS RECEIVED DATA 404
SEND DATA TO CLOUD
RECEIVE DATA FROM CLOUD
DETERMINE IF DRIVER IS DISTRACTED (FIG. 5) 406
IS DRIVER DISTRACTED? 408
YES
NO
CALCULATE SEVERITY RANK, R (FIG. 6) 410
IS R WITHIN 1ST RANGE? 412
YES
PRESENT VISUAL WARNING 414
NO
IS R WITHIN 2ND RANGE? 416
YES
PRESENT AUDIO WARNING 418
NO
IS R WITHIN 3RD RANGE? 420
YES
PERFORM ENGINE CONTROL 422
NO
RETURN

FIG. 4

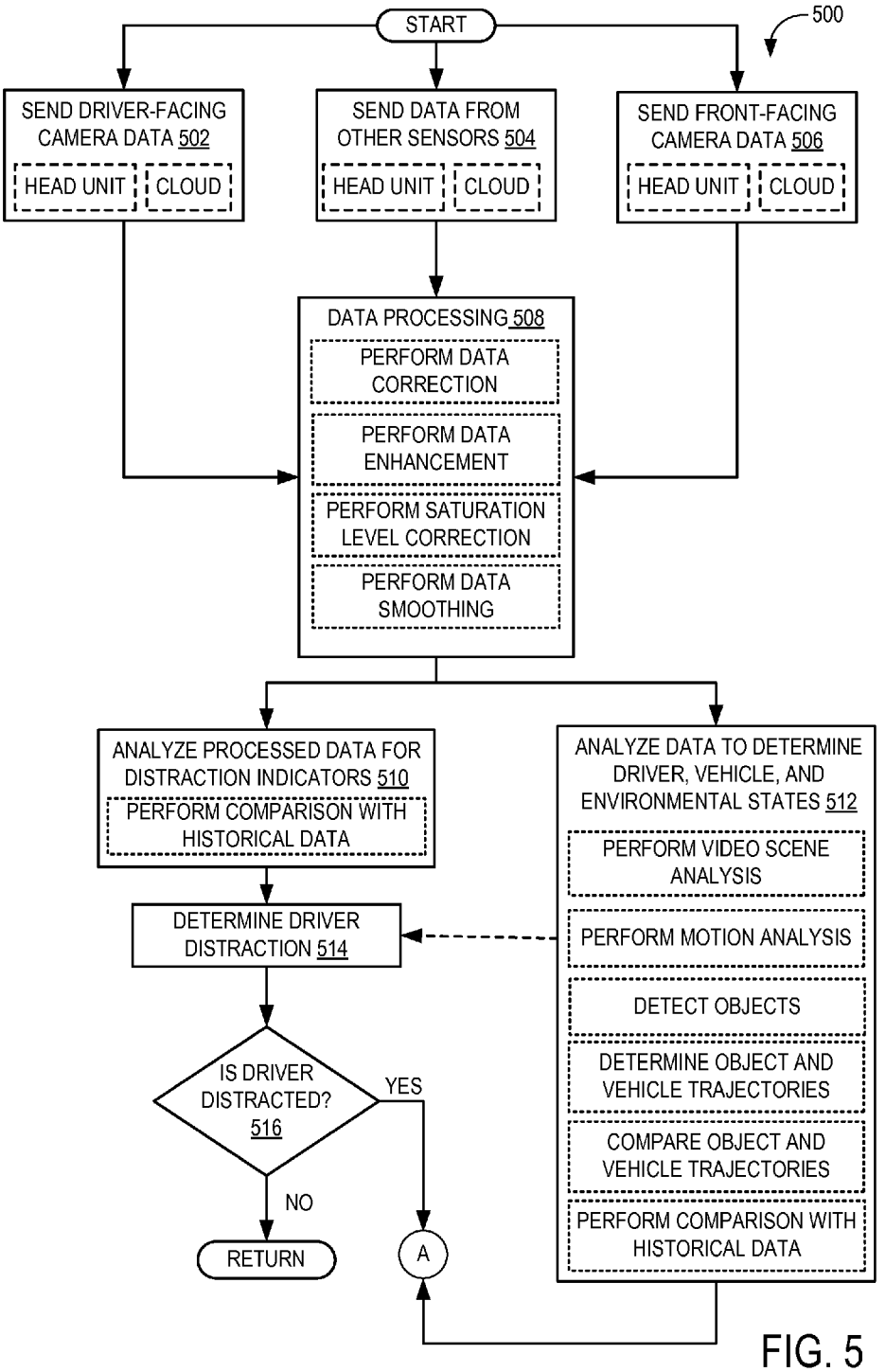

500
START
SEND DRIVER-FACING CAMERA DATA 502
HEAD UNIT
CLOUD
SEND DATA FROM OTHER SENSORS 504
HEAD UNIT
CLOUD
SEND FRONT-FACING CAMERA DATA 506
HEAD UNIT
CLOUD
DATA PROCESSING 508
PERFORM DATA CORRECTION
PERFORM DATA ENHANCEMENT
PERFORM SATURATION LEVEL CORRECTION
PERFORM DATA SMOOTHING
ANALYZE PROCESSED DATA FOR DISTRACTION INDICATORS 510
PERFORM COMPARISON WITH HISTORICAL DATA
ANALYZE DATA TO DETERMINE DRIVER, VEHICLE, AND ENVIRONMENTAL STATES 512
PERFORM VIDEO SCENE ANALYSIS
PERFORM MOTION ANALYSIS
DETECT OBJECTS
DETERMINE OBJECT AND VEHICLE TRAJECTORIES
COMPARE OBJECT AND VEHICLE TRAJECTORIES
PERFORM COMPARISON WITH HISTORICAL DATA
DETERMINE DRIVER DISTRACTION 514
IS DRIVER DISTRACTED? 516
YES
NO
RETURN
A

FIG. 5

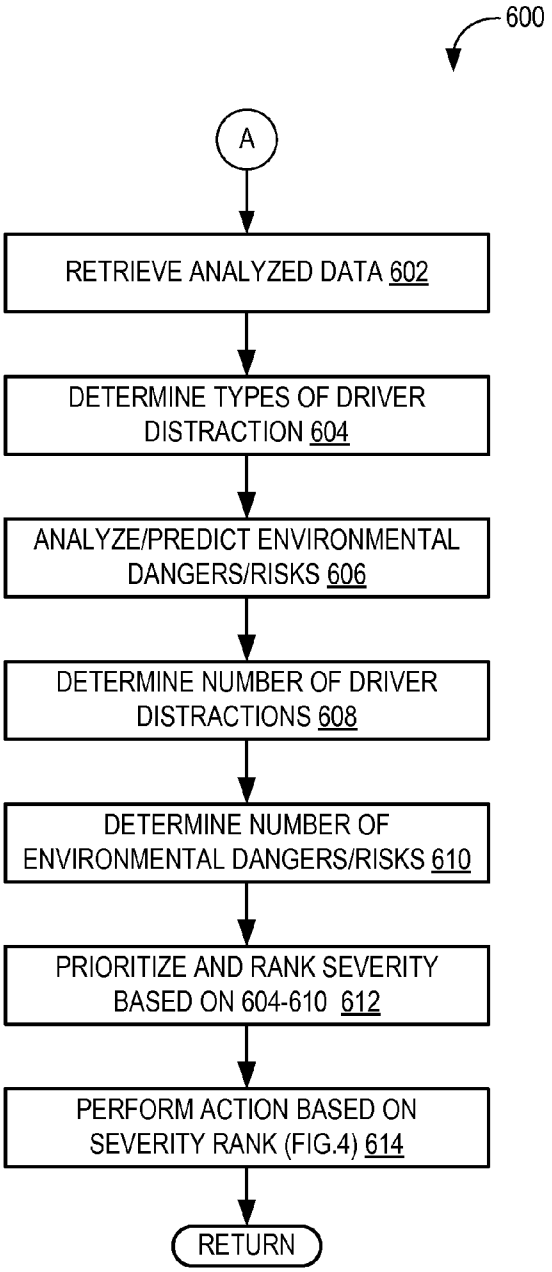

600
A
RETRIEVE ANALYZED DATA 602
DETERMINE TYPES OF DRIVER DISTRACTION 604
ANALYZE/PREDICT ENVIRONMENTAL DANGERS/RISKS 606
DETERMINE NUMBER OF DRIVER DISTRACTIONS 608
DETERMINE NUMBER OF ENVIRONMENTAL DANGERS/RISKS 610
PRIORITIZE AND RANK SEVERITY BASED ON 604-610 612
PERFORM ACTION BASED ON SEVERITY RANK (FIG.4) 614
RETURN

FIG. 6

700

Distraction	Road/Vehicle Condition	Severity Rank (R)
Driver not looking ahead	Vehicle stopped at traffic signal	1
Parking light off	Vehicle parked in garage	1
Driver talking on the phone	Using hands free, freeway, no upcoming turns, medium speed	4
Parking light off	Vehicle parked on side of freeeway	5
Driver not looking ahead	Vehicle not in reverese gear, high vehicle speed, upcoming turn within city limits	8
Driver talking on the phone	Not using hands free, upcoming turns within city limits, high speed	8

FIG. 7

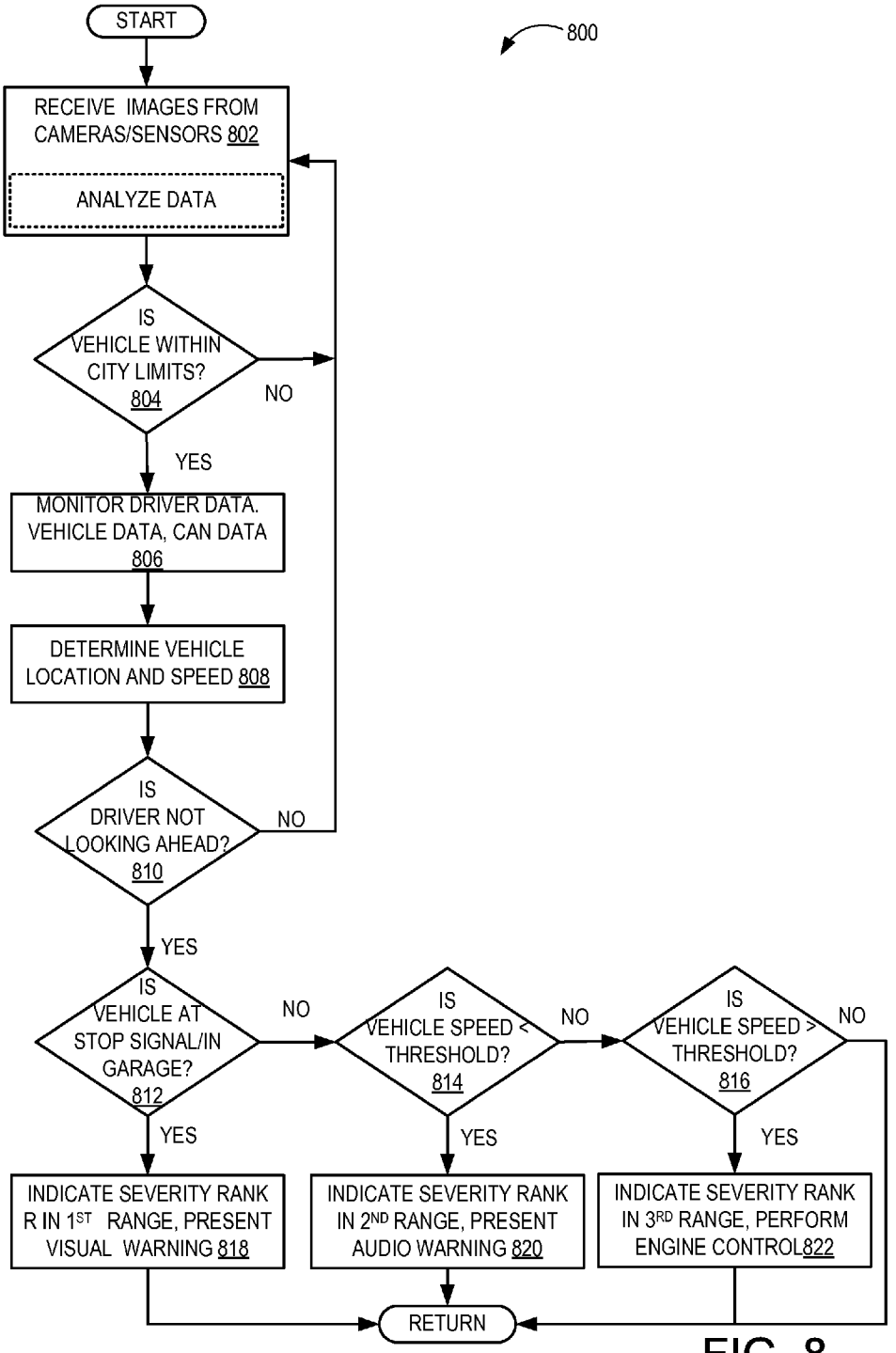

800
START
RECEIVE IMAGES FROM CAMERAS/SENSORS 802
ANALYZE DATA
IS VEHICLE WITHIN CITY LIMITS? 804
NO
YES
MONITOR DRIVER DATA. VEHICLE DATA, CAN DATA 806
DETERMINE VEHICLE LOCATION AND SPEED 808
IS DRIVER NOT LOOKING AHEAD? 810
NO
YES
IS VEHICLE AT STOP SIGNAL/IN GARAGE? 812
NO
IS VEHICLE SPEED < THRESHOLD? 814
NO
IS VEHICLE SPEED > THRESHOLD? 816
NO
YES
YES
YES
INDICATE SEVERITY RANK R IN 1ST RANGE, PRESENT VISUAL WARNING 818
INDICATE SEVERITY RANK IN 2ND RANGE, PRESENT AUDIO WARNING 820
INDICATE SEVERITY RANK IN 3RD RANGE, PERFORM ENGINE CONTROL 822
RETURN

FIG. 8

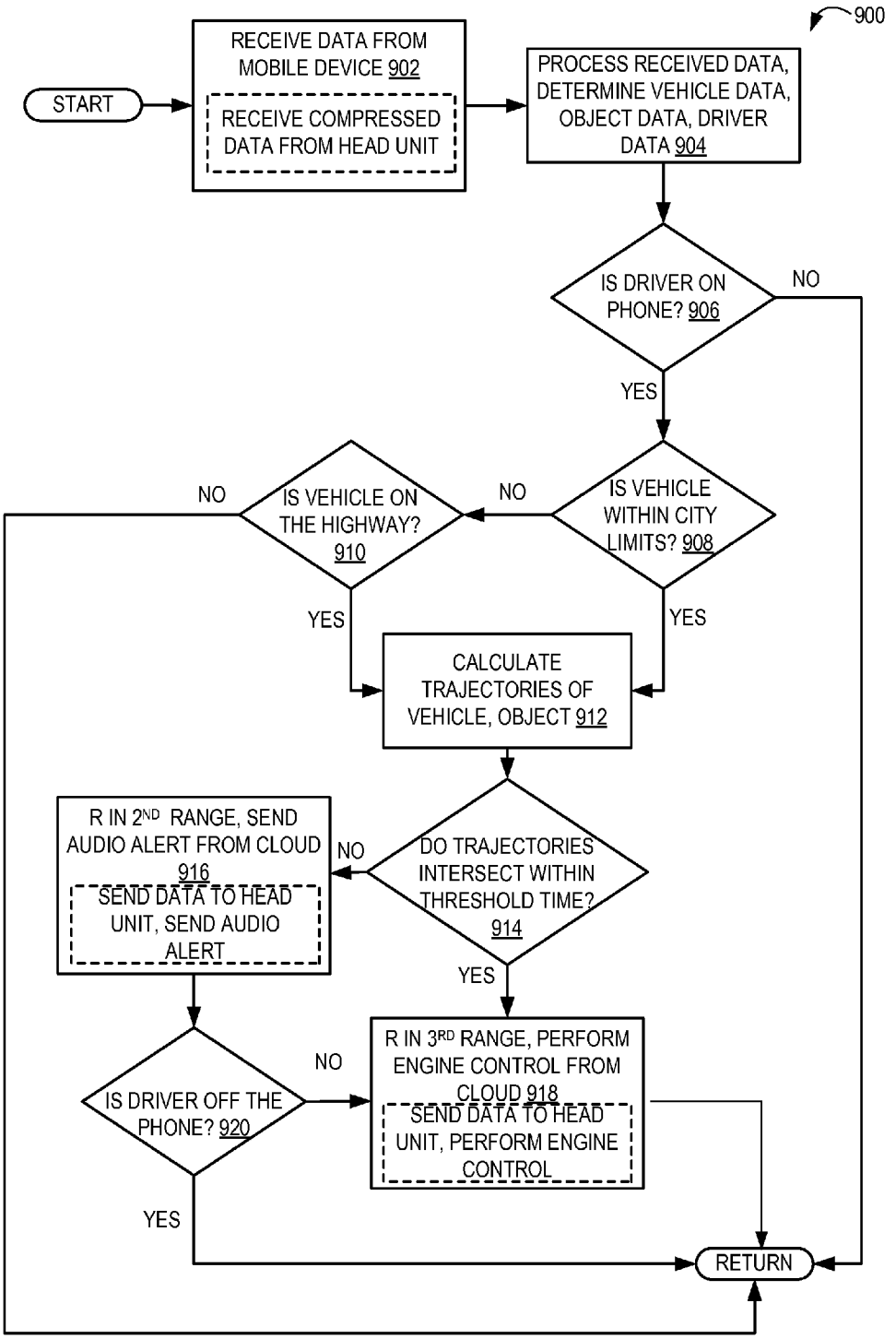

900
START
RECEIVE DATA FROM MOBILE DEVICE 902
RECEIVE COMPRESSED DATA FROM HEAD UNIT
PROCESS RECEIVED DATA, DETERMINE VEHICLE DATA, OBJECT DATA, DRIVER DATA 904
IS DRIVER ON PHONE? 906
NO
YES
IS VEHICLE WITHIN CITY LIMITS? 908
NO
IS VEHICLE ON THE HIGHWAY? 910
NO
YES
YES
CALCULATE TRAJECTORIES OF VEHICLE, OBJECT 912
DO TRAJECTORIES INTERSECT WITHIN THRESHOLD TIME? 914
NO
R IN 2ND RANGE, SEND AUDIO ALERT FROM CLOUD 916
SEND DATA TO HEAD UNIT, SEND AUDIO ALERT
YES
R IN 3RD RANGE, PERFORM ENGINE CONTROL FROM CLOUD 918
SEND DATA TO HEAD UNIT, PERFORM ENGINE CONTROL
IS DRIVER OFF THE PHONE? 920
NO
YES
RETURN

FIG. 9

DRIVER DISTRACTION DETECTION SYSTEM

FIELD

[0001] The disclosure relates to assessing driver distraction based on the output of a wearable device and other sensors.

BACKGROUND

[0002] Distracted driving may include any activity that could divert a person's attention away from the primary task of driving. All distractions endanger driver, passenger, and bystander safety and could increase the chance of a motor vehicle crash. Some types of distraction include visual distraction, where the driver takes his/her eyes off the road, manual distraction, where the driver takes his/her hands off the wheel, and cognitive distraction, where the driver takes his/her mind off of driving. The severity of the distraction could depend on both the level and duration of these distractions and may be compounded by external factors such as speed and location of vehicle and objects in the path of the vehicle, for example.

SUMMARY

[0003] Embodiments are described for determining and responding to driver distractions. An example in-vehicle computing system of a vehicle includes an external device interface communicatively connecting the in-vehicle computing system to a mobile device, an inter-vehicle system communication module communicatively connecting the in-vehicle computing system to one or more vehicle systems of the vehicle, a processor, and a storage device storing instructions executable by the processor to receive image data from the mobile device via the external device interface, the image data imaging a driver and a driver environment, and determine a driver state based on the received image data. The instructions are further executable to, responsive to determining that the driver state indicates that the driver is distracted, receive vehicle data from one or more of the vehicle systems via the inter-vehicle system communication module, determine a vehicle state based on the vehicle data, determine a distraction severity level based on the driver state and the vehicle state, and control one or more devices of the vehicle to perform a selected action based on the distraction severity level.

[0004] An example method of determining driver distraction includes receiving driver data from a wearable device, the driver data including image data from a driver-facing camera, receiving object data from one or more imaging devices of at least one of the wearable device and the vehicle, the object data including image data of a vehicle environment, and receiving vehicle data from one or more vehicle systems, the vehicle data including an indication of an operating condition of the vehicle. The example method further includes determining whether a driver is distracted by correlating the driver data with the object data, responsive to determining that the driver is distracted, selecting an action based on correlating the driver data with the object data and the vehicle data and performing the selected action, and responsive to determining that the driver is not distracted, maintaining current operating parameters.

[0005] An example distraction monitoring system includes a wearable device including a driver-facing camera, an outward-facing camera, and one or more sensors, an in-vehicle computing system communicatively connected to the wearable device and one or more vehicle systems, the in-vehicle computing system comprising a first processor and a first storage device, and a cloud computing device remote from the in-vehicle computing system and communicatively connected to the in-vehicle computing system via a network, the cloud computing device comprising a second processor and a second storage device. One or more of the first storage device and the second storage device storing first instructions executable by a respective one or more of the first processor and the second processor to receive image data from the driver-facing camera and sensor data from the one or more sensors of the wearable device indicating a driver state, receive image data from the outward-facing camera of the wearable device indicating object states of one or more objects, receive vehicle data from one or more vehicle systems to indicate vehicle state, and select an action to be performed based on the indicated driver state, object states, and vehicle state. The first storage device may store second instructions executable by the first processor to transmit a command to one or more of a display device of the in-vehicle computing system, an audio device of the vehicle, and an engine control unit of the vehicle to perform the selected action.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The disclosure may be better understood from reading the following description of non-limiting embodiments, with reference to the attached drawings, wherein below:

[0007] FIG. **1** shows an example partial view of a vehicle cabin in accordance with one or more embodiments of the present disclosure;

[0008] FIG. **2** shows an example in-vehicle computing system in accordance with one or more embodiments of the present disclosure;

[0009] FIG. **3**A shows a block diagram of an example distraction determination system in accordance with one or more embodiments of the present disclosure;

[0010] FIG. **3**B shows a block diagram of an example distraction determination system in accordance with one or more embodiments of the present disclosure;

[0011] FIG. **4** is a flow chart of an example method for generating warnings based on a calculated severity rank range from the perspective of a head unit in accordance with one or more embodiments of the present disclosure;

[0012] FIG. **5** is a flow chart for an example method of determining a distraction level of a driver in accordance with one or more embodiments of the present disclosure;

[0013] FIG. **6** is a flow chart for an example method of determining a distraction severity rank in accordance with one or more embodiments of the present disclosure;

[0014] FIG. **7** shows an example table mapping severity rank R to driver states and vehicle conditions in accordance with one or more embodiments of the present disclosure;

[0015] FIG. **8** is a flow chart for an example method of determining an action to be performed responsive to example driver states and vehicle conditions in accordance with one or more embodiments of the present disclosure; and

[0016] FIG. **9** is a flow chart for an example method of determining an action to be performed responsive to example driver states, object states, and vehicle conditions in accordance with one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0017] As described above, driver distraction may be dangerous to occupants of a vehicle, as well as people in a vicinity of the vehicle. However, by only monitoring a driver state, or by monitoring only a small number of distraction-related behaviors of a driver, an inappropriate response to a distracted driver may be provided. For example, if a driver is nodding off to sleep, a visual warning may be insufficient to correct the distracted behavior. As another example, if a driver briefly looks away from the road, but there are no objects in the path of the vehicle, a loud, audible warning of driver distraction may be unnecessary and instead startle the driver, causing the driver to lose control of the vehicle. A distraction monitoring system that not only monitors the level of driver distraction, but also effectively responds to such distraction in a timely manner may address the issue of distracted driving and the major traffic safety issue that such driving poses.

[0018] Accordingly, the disclosure provides a distraction monitoring system including one or more of an in-vehicle computing system and a cloud computing device that receives sensor data from a wearable device and/or other sensor devices to determine a driver state and a state of objects in a vehicle environment. The in-vehicle computing system and/or cloud computing device may also receive data from vehicle systems in order to determine a vehicle state. By correlating the driver, object(s), and vehicle state, the distraction monitoring system may first determine whether the driver is distracted, and then determine a severity of that distraction. The distraction monitoring system may perform a different action (e.g., provide a visual alert, provide an audible alert, and/or perform a vehicle control) responsive to different levels of distraction severity, as different types of distractions may benefit from different types of warnings/responses. In this way, a driver may be alerted to his/her distraction in an appropriate manner based on an intelligent combination of the different types of data.

[0019] FIG. **1** shows an example partial view of one type of environment for a communication system: an interior of a cabin **100** of a vehicle **102**, in which a driver and/or one or more passengers may be seated. Vehicle **102** of FIG. **1** may be a motor vehicle including drive wheels (not shown) and an internal combustion engine **104**. Internal combustion engine **104** may include one or more combustion chambers, which may receive intake air via an intake passage and exhaust combustion gases via an exhaust passage. Vehicle **102** may be a road automobile, among other types of vehicles. In some examples, vehicle **102** may include a hybrid propulsion system including an energy conversion device operable to absorb energy from vehicle motion and/or the engine and convert the absorbed energy to an energy form suitable for storage by an energy storage device. Vehicle **102** may include a fully electric vehicle, incorporating fuel cells, solar energy capturing elements, and/or other energy storage systems for powering the vehicle.

[0020] As shown, an instrument panel **106** may include various displays and controls accessible to a driver (also referred to as the user) of vehicle **102**. For example, instrument panel **106** may include a touch screen **108** of an in-vehicle computing system **109** (e.g., an infotainment system), an audio system control panel, and an instrument cluster **110**. While the example system shown in FIG. **1** includes audio system controls that may be performed via a user interface of in-vehicle computing system **109**, such as touch screen **108** without a separate audio system control panel, in other embodiments, the vehicle may include an audio system control panel, which may include controls for a conventional vehicle audio system such as a radio, compact disc player, MP3 player, etc. The audio system controls may include features for controlling one or more aspects of audio output via speakers **112** of a vehicle speaker system. For example, the in-vehicle computing system or the audio system controls may control a volume of audio output, a distribution of sound among the individual speakers of the vehicle speaker system, an equalization of audio signals, and/or any other aspect of the audio output. In further examples, in-vehicle computing system **109** may adjust a radio station selection, a playlist selection, a source of audio input (e.g., from radio or CD or MP3), etc., based on user input received directly via touch screen **108**, or based on data regarding the user (such as a physical state and/or environment of the user) received via external devices **150** and/or mobile device **128**.

[0021] In some embodiments, one or more hardware elements of in-vehicle computing system **109**, such as touch screen **108**, a display screen, various control dials, knobs and buttons, memory, processor(s), and any interface elements (e.g., connectors or ports) may form an integrated head unit that is installed in instrument panel **106** of the vehicle. The head unit may be fixedly or removably attached in instrument panel **106**. In additional or alternative embodiments, one or more hardware elements of the in-vehicle computing system may be modular and may be installed in multiple locations of the vehicle.

[0022] The cabin **100** may include one or more sensors for monitoring the vehicle, the user, and/or the environment. For example, the cabin **100** may include one or more seat-mounted pressure sensors configured to measure the pressure applied to the seat to determine the presence of a user, door sensors configured to monitor door activity, humidity sensors to measure the humidity content of the cabin, microphones to receive user input in the form of voice commands, to enable a user to conduct telephone calls, and/or to measure ambient noise in the cabin **100**, etc. It is to be understood that the above-described sensors and/or one or more additional or alternative sensors may be positioned in any suitable location of the vehicle. For example, sensors may be positioned in an engine compartment, on an external surface of the vehicle, and/or in other suitable locations for providing information regarding the operation of the vehicle, ambient conditions of the vehicle, a user of the vehicle, etc. Information regarding ambient conditions of the vehicle, vehicle status, or vehicle driver may also be received from sensors external to/separate from the vehicle (that is, not part of the vehicle system), such as from sensors coupled to external devices **150** and/or mobile device **128**.

[0023] Cabin **100** may also include one or more user objects, such as mobile device **128**, that are stored in the vehicle before, during, and/or after travelling. The mobile device may include a smart phone, a tablet, a laptop computer, a portable media player, and/or any suitable mobile computing device. The mobile device **128** may be connected to the in-vehicle computing system via communication link **130**. The communication link **130** may be wired (e.g., via Universal Serial Bus [USB], Mobile High-Definition Link [MHL], High-Definition Multimedia Interface [HDMI], Ethernet, etc.) or wireless (e.g., via BLUETOOTH, WI-FI, Near-Field Communication [NFC], cellular connectivity, etc.) and configured to provide two-way communication between the mobile device and the in-vehicle computing system. For

example, the communication link **130** may provide sensor and/or control signals from various vehicle systems (such as vehicle audio system, climate control system, etc.) and the touch screen **108** to the mobile device **128** and may provide control and/or display signals from the mobile device **128** to the in-vehicle systems and the touch screen **108**. The communication link **130** may also provide power to the mobile device **128** from an in-vehicle power source in order to charge an internal battery of the mobile device.

[0024] In-vehicle computing system **109** may also be communicatively coupled to additional devices operated and/or accessed by the user but located external to vehicle **102**, such as one or more external devices **150**. In the depicted embodiment, external devices **150** are located outside of vehicle **102** though it will be appreciated that in alternate embodiments, external devices may be located inside cabin **100**. The external devices may include a server computing system, personal computing system, portable electronic device, electronic wrist band, electronic head band, portable music player, electronic activity tracking device, pedometer, smart-watch, GPS system, etc. External devices **150** may be connected to the in-vehicle computing system via communication link **136**, which may be wired or wireless, as discussed with reference to communication link **130**, and configured to provide two-way communication between the external devices and the in-vehicle computing system. For example, external devices **150** may include one or more sensors and communication link **136** may transmit sensor output from external devices **150** to in-vehicle computing system **109** and touch screen **108**. External devices **150** may also store and/or receive information regarding contextual data, user behavior/preferences, operating rules, etc. and may transmit such information from the external devices **150** to in-vehicle computing system **109** and touch screen **108**.

[0025] In-vehicle computing system **109** may analyze the input received from external devices **150**, mobile device **128**, and/or other input sources and select settings for various in-vehicle systems (such as climate control system or audio system), provide output via touch screen **108** and/or speakers **112**, communicate with mobile device **128** and/or external devices **150**, and/or perform other actions based on the assessment. In some embodiments, all or a portion of the assessment may be performed by the mobile device **128** and/or the external devices **150**.

[0026] In some embodiments, one or more of the external devices **150** may be communicatively coupled to in-vehicle computing system **109** indirectly, via mobile device **128** and/or another of the external devices **150**. For example, communication link **136** may communicatively couple external devices **150** to mobile device **128** such that output from external devices **150** is relayed to mobile device **128**. Data received from external devices **150** may then be aggregated at mobile device **128** with data collected by mobile device **128**, the aggregated data then transmitted to in-vehicle computing system **109** and touch screen **108** via communication link **130**. Similar data aggregation may occur at a server system and then transmitted to in-vehicle computing system **109** and touch screen **108** via communication link **136/130**.

[0027] In the example environment illustrated in FIG. **1**, the in-vehicle computing system **109** may be connected to one or more vehicle systems, such as speakers **112**, display **108**, vehicle sensors, and/or other suitable vehicle systems via any suitable network. In some examples, the in-vehicle computing system **109** includes a talker device configured to transmit audio/video data to listener devices, such as speakers **112** and display **108** via a network. The network may be configured in accordance with Layer 2 of the Open Systems Interconnection (OSI) model, in which routing and forwarding decisions or determinations in the network may be performed on a media access control (MAC) addressing basis. An example Layer 2 network may be an Ethernet Audio/Video Bridging (AVB) network. For Layer 2 networks configured as AVB networks, the talkers and the listeners may be configured to communicate over the AVB network using various AVB standards and protocols, including the Institute of Electrical and Electronics Engineers (IEEE) 802.1AS-2011 (gPTP) for network timing and synchronization, IEEE 802.1Q-2011 clause 34 for queuing and forwarding streaming data, IEEE 802.1Q-2011 clause 35 (Stream Reservation Protocol (SRP)) for reserving a network connection or path and/or resources such as bandwidth for communication over the network connection, and/or IEEE 1722-2011 related to a possible data streaming format. Other AVB-related standards and protocols, and/or other versions of the AVB standards and protocols, previously, currently, or later developed, may additionally or alternatively be used.

[0028] It is to be understood that FIG. **1** depicts one example environment, however the communication systems and methods described herein may be utilized in any suitable environment. Any suitable devices that transmit and/or receive information, sense data, and/or otherwise contribute to a driver distraction detection and/or alert system may be utilized as the systems and/or to perform the methods described herein.

[0029] FIG. **2** shows a block diagram of an in-vehicle computing system **200** configured and/or integrated inside vehicle **201**. In-vehicle computing system **200** may be an example of in-vehicle computing system **109** of FIG. **1** and/or may perform one or more of the methods described herein in some embodiments. In some examples, the in-vehicle computing system may be a vehicle infotainment system configured to provide information-based media content (audio and/or visual media content, including entertainment content, navigational services, etc.) to a vehicle user to enhance the operator's in-vehicle experience. The vehicle infotainment system may include, or be coupled to, various vehicle systems, subsystems, hardware components, as well as software applications and systems that are integrated in, or integratable into, vehicle **201** in order to enhance an in-vehicle experience for a driver and/or a passenger.

[0030] In-vehicle computing system **200** may include one or more processors including an operating system processor **214** and an interface processor **220**. Operating system processor **214** may execute an operating system on the in-vehicle computing system, and control input/output, display, playback, and other operations of the in-vehicle computing system. Interface processor **220** may interface with a vehicle control system **230** via an inter-vehicle system communication module **222**.

[0031] Inter-vehicle system communication module **222** may output data to other vehicle systems **231** and vehicle control elements **261**, while also receiving data input from other vehicle components and systems **231**, **261**, e.g. by way of vehicle control system **230**. When outputting data, inter-vehicle system communication module **222** may provide a signal via a bus corresponding to any status of the vehicle, the vehicle surroundings, or the output of any other information source connected to the vehicle. Vehicle data outputs may

include, for example, analog signals (such as current velocity), digital signals provided by individual information sources (such as clocks, thermometers, location sensors such as Global Positioning System [GPS] sensors, etc.), digital signals propagated through vehicle data networks (such as an engine controller area network [CAN] bus through which engine related information may be communicated, a climate control CAN bus through which climate control related information may be communicated, and a multimedia data network through which multimedia data is communicated between multimedia components in the vehicle). For example, the in-vehicle computing system may retrieve from the engine CAN bus the current speed of the vehicle estimated by the wheel sensors, a power state of the vehicle via a battery and/or power distribution system of the vehicle, an ignition state of the vehicle, etc. In addition, other interfacing means such as Ethernet may be used as well without departing from the scope of this disclosure.

[0032] A non-volatile storage device **208** may be included in in-vehicle computing system **200** to store data such as instructions executable by processors **214** and **220** in non-volatile form. The storage device **208** may store application data to enable the in-vehicle computing system **200** to run an application for connecting to a cloud-based server and/or collecting information for transmission to the cloud-based server. The application may retrieve information gathered by vehicle systems/sensors, input devices (e.g., user interface **218**), devices in communication with the in-vehicle computing system (e.g., a mobile device connected via a Bluetooth link), etc. In-vehicle computing system **200** may further include a volatile memory **216**. Volatile memory **216** may be random access memory (RAM). Non-transitory storage devices, such as non-volatile storage device **208** and/or volatile memory **216**, may store instructions and/or code that, when executed by a processor (e.g., operating system processor **214** and/or interface processor **220**), controls the in-vehicle computing system **200** to perform one or more of the actions described in the disclosure.

[0033] A microphone **202** may be included in the in-vehicle computing system **200** to receive voice commands from a user, to measure ambient noise in the vehicle, to determine whether audio from speakers of the vehicle is tuned in accordance with an acoustic environment of the vehicle, etc. A speech processing unit **204** may process voice commands, such as the voice commands received from the microphone **202**. In some embodiments, in-vehicle computing system **200** may also be able to receive voice commands and sample ambient vehicle noise using a microphone included in an audio system **232** of the vehicle.

[0034] One or more additional sensors may be included in a sensor subsystem **210** of the in-vehicle computing system **200**. For example, the sensor subsystem **210** may include a camera, such as a rear view camera for assisting a user in parking the vehicle and/or a cabin camera for identifying a user (e.g., using facial recognition and/or user gestures). Sensor subsystem **210** of in-vehicle computing system **200** may communicate with and receive inputs from various vehicle sensors and may further receive user inputs. For example, the inputs received by sensor subsystem **210** may include transmission gear position, transmission clutch position, gas pedal input, brake input, transmission selector position, vehicle speed, engine speed, mass airflow through the engine, ambient temperature, intake air temperature, etc., as well as inputs from climate control system sensors (such as heat transfer fluid temperature, antifreeze temperature, fan speed, passenger compartment temperature, desired passenger compartment temperature, ambient humidity, etc.), an audio sensor detecting voice commands issued by a user, a fob sensor receiving commands from and optionally tracking the geographic location/proximity of a fob of the vehicle, etc. While certain vehicle system sensors may communicate with sensor subsystem **210** alone, other sensors may communicate with both sensor subsystem **210** and vehicle control system **230**, or may communicate with sensor subsystem **210** indirectly via vehicle control system **230**. A navigation subsystem **211** of in-vehicle computing system **200** may generate and/or receive navigation information such as location information (e.g., via a GPS sensor and/or other sensors from sensor subsystem **210**), route guidance, traffic information, point-of-interest (POI) identification, and/or provide other navigational services for the driver.

[0035] External device interface **212** of in-vehicle computing system **200** may be coupleable to and/or communicate with one or more external devices **240** located external to vehicle **201**. While the external devices are illustrated as being located external to vehicle **201**, it is to be understood that they may be temporarily housed in vehicle **201**, such as when the user is operating the external devices while operating vehicle **201**. In other words, the external devices **240** are not integral to vehicle **201**. The external devices **240** may include a mobile device **242** (e.g., connected via a Bluetooth connection) or an alternate Bluetooth-enabled device **252**. Mobile device **242** may be a mobile phone, smart phone, wearable devices/sensors that may communicate with the in-vehicle computing system via wired and/or wireless communication, or other portable electronic device(s). Other external devices include external services **246**. For example, the external devices may include extra-vehicular devices that are separate from and located externally to the vehicle. Still other external devices include external storage devices **254**, such as solid-state drives, pen drives, USB drives, etc. External devices **240** may communicate with in-vehicle computing system **200** either wirelessly or via connectors without departing from the scope of this disclosure. For example, external devices **240** may communicate with in-vehicle computing system **200** through the external device interface **212** over network **260**, a universal serial bus (USB) connection, a direct wired connection, a direct wireless connection, and/or other communication link. The external device interface **212** may provide a communication interface to enable the in-vehicle computing system to communicate with mobile devices associated with contacts of the driver. For example, the external device interface **212** may enable phone calls to be established and/or text messages (e.g., SMS, MMS, etc.) to be sent (e.g., via a cellular communications network) to a mobile device associated with a contact of the driver.

[0036] One or more applications **244** may be operable on mobile device **242**. As an example, mobile device application **244** may be operated to aggregate user data regarding interactions of the user with the mobile device. For example, mobile device application **244** may aggregate data regarding music playlists listened to by the user on the mobile device, telephone call logs (including a frequency and duration of telephone calls accepted by the user), positional information including locations frequented by the user and an amount of time spent at each location, etc. The collected data may be transferred by application **244** to external device interface **212** over network **260**. In addition, specific user data requests

may be received at mobile device **242** from in-vehicle computing system **200** via the external device interface **212**. The specific data requests may include requests for determining where the user is geographically located, an ambient noise level and/or music genre at the user's location, an ambient weather condition (temperature, humidity, etc.) at the user's location, etc. Mobile device application **244** may send control instructions to components (e.g., microphone, etc.) or other applications (e.g., navigational applications) of mobile device **242** to enable the requested data to be collected on the mobile device. Mobile device application **244** may then relay the collected information back to in-vehicle computing system **200**.

[0037] Likewise, one or more applications **248** may be operable on external services **246**. As an example, external services applications **248** may be operated to aggregate and/or analyze data from multiple data sources. For example, external services applications **248** may aggregate data from one or more social media accounts of the user, data from the in-vehicle computing system (e.g., sensor data, log files, user input, etc.), data from an internet query (e.g., weather data, POI data), etc. The collected data may be transmitted to another device and/or analyzed by the application to determine a context of the driver, vehicle, and environment and perform an action based on the context (e.g., requesting/sending data to other devices).

[0038] Vehicle control system **230** may include controls for controlling aspects of various vehicle systems **231** involved in different in-vehicle functions. These may include, for example, controlling aspects of vehicle audio system **232** for providing audio entertainment to the vehicle occupants, aspects of climate control system **234** for meeting the cabin cooling or heating needs of the vehicle occupants, as well as aspects of telecommunication system **236** for enabling vehicle occupants to establish telecommunication linkage with others.

[0039] Audio system **232** may include one or more acoustic reproduction devices including electromagnetic transducers such as speakers. Vehicle audio system **232** may be passive or active such as by including a power amplifier. In some examples, in-vehicle computing system **200** may be the only audio source for the acoustic reproduction device or there may be other audio sources that are connected to the audio reproduction system (e.g., external devices such as a mobile phone). The connection of any such external devices to the audio reproduction device may be analog, digital, or any combination of analog and digital technologies.

[0040] Climate control system **234** may be configured to provide a comfortable environment within the cabin or passenger compartment of vehicle **201**. Climate control system **234** includes components enabling controlled ventilation such as air vents, a heater, an air conditioner, an integrated heater and air-conditioner system, etc. Other components linked to the heating and air-conditioning setup may include a windshield defrosting and defogging system capable of clearing the windshield and a ventilation-air filter for cleaning outside air that enters the passenger compartment through a fresh-air inlet.

[0041] Vehicle control system **230** may also include controls for adjusting the settings of various vehicle controls **261** (or vehicle system control elements) related to the engine and/or auxiliary elements within a cabin of the vehicle, such as steering wheel controls **262** (e.g., steering wheel-mounted audio system controls, cruise controls, windshield wiper controls, headlight controls, turn signal controls, etc.), instrument panel controls, microphone(s), accelerator/brake/clutch pedals, a gear shift, door/window controls positioned in a driver or passenger door, seat controls, cabin light controls, audio system controls, cabin temperature controls, etc. Vehicle controls **261** may also include internal engine and vehicle operation controls (e.g., engine controller module, actuators, valves, etc.) that are configured to receive instructions via the CAN bus of the vehicle to change operation of one or more of the engine, exhaust system, transmission, and/or other vehicle system. The control signals may also control audio output at one or more speakers of the vehicle's audio system **232**. For example, the control signals may adjust audio output characteristics such as volume, equalization, audio image (e.g., the configuration of the audio signals to produce audio output that appears to a user to originate from one or more defined locations), audio distribution among a plurality of speakers, etc. Likewise, the control signals may control vents, air conditioner, and/or heater of climate control system **234**. For example, the control signals may increase delivery of cooled air to a specific section of the cabin.

[0042] Control elements positioned on an outside of a vehicle (e.g., controls for a security system) may also be connected to computing system **200**, such as via communication module **222**. The control elements of the vehicle control system may be physically and permanently positioned on and/or in the vehicle for receiving user input. In addition to receiving control instructions from in-vehicle computing system **200**, vehicle control system **230** may also receive input from one or more external devices **240** operated by the user, such as from mobile device **242**. This allows aspects of vehicle systems **231** and vehicle controls **261** to be controlled based on user input received from the external devices **240**.

[0043] In-vehicle computing system **200** may further include an antenna **206**. Antenna **206** is shown as a single antenna, but may comprise one or more antennas in some embodiments. The in-vehicle computing system may obtain broadband wireless internet access via antenna **206**, and may further receive broadcast signals such as radio, television, weather, traffic, and the like. The in-vehicle computing system may receive positioning signals such as GPS signals via one or more antennas **206**. The in-vehicle computing system may also receive wireless commands via RF such as via antenna(s) **206** or via infrared or other means through appropriate receiving devices. In some embodiments, antenna **206** may be included as part of audio system **232** or telecommunication system **236**. Additionally, antenna **206** may provide AM/FM radio signals to external devices **240** (such as to mobile device **242**) via external device interface **212**.

[0044] One or more elements of the in-vehicle computing system **200** may be controlled by a user via user interface **218**. User interface **218** may include a graphical user interface presented on a touch screen, such as touch screen **108** of FIG. **1**, and/or user-actuated buttons, switches, knobs, dials, sliders, etc. For example, user-actuated elements may include steering wheel controls, door and/or window controls, instrument panel controls, audio system settings, climate control system settings, and the like. A user may also interact with one or more applications of the in-vehicle computing system **200** and mobile device **242** via user interface **218**. In addition to receiving a user's vehicle setting preferences on user interface **218**, vehicle settings selected by in-vehicle control system may be displayed to a user on user interface **218**. Notifi-

cations and other messages (e.g., received messages), as well as navigational assistance, may be displayed to the user on a display of the user interface. User preferences/information and/or responses to presented messages may be performed via user input to the user interface.

[0045] FIG. **3**A shows a block diagram of a distraction monitoring system **300***a*, including an in-vehicle computing system (also referred to herein as a head unit) **304***a* configured and/or integrated inside of a vehicle, such as vehicle **102** of FIG. **1**. The distraction monitoring system **300***a* may further include a mobile device, such as a wearable device **302** for example. In some example embodiments, the wearable device **302** may include a head-mounted display system that is mounted to the driver's face via the driver's nose and ears. In additional or alternative examples, the wearable device **302** may include a smartwatch or other wrist- or body-worn computing device. The wearable device **302** may additionally or alternatively be a self-containing unit that may be clipped on to an existing frame for glasses or another accessory, for example. Although only one wearable device **302** is shown in FIG. **3**A, it is to be understood that any number of wearable or other mobile devices may be included in the distraction monitoring system **300***a*.

[0046] The wearable device **302** may be fitted with microphones to detect audio signals within the vehicle environment and may include additional sensors such as a biometric sensor, a perspiration level sensor, body temperature, electrocardiogram, glucometer, blood pressure, muscle sensor, weather sensor, etc. The wearable device **302** may additionally include plurality of cameras, with one or more cameras facing inside towards the driver wearing the device (inward- or driver-facing camera), and one or more cameras facing the outside of the driver/vehicle (front- or outward-facing camera). The driver-facing camera in the wearable device **302** may monitor the driver's movement when inside the vehicle and the front-facing camera may capture images of the environment surrounding the vehicle (e.g., the vehicle environment, which may include the cabin of the vehicle and/or an area around the exterior of the vehicle). The cameras of the wearable device **302** may further be equipped to capture raw static and/or motion image frames and the wearable device **302** may be capable of streaming the raw image frames and/or compressed video images over Wi-Fi (e.g., to a Wi-Fi interface **310** of head unit **304***a*), Bluetooth (e.g., to a Bluetooth interface **312** of the head unit), and/or any other suitable communication mechanism to the head unit **304**.

[0047] The head unit **304** in embodiment shown in FIG. **3**A may include the Wi-Fi interface **310**, the Bluetooth interface **312**, a video decompressor **314**, a distraction analysis block **306**, a distraction severity analysis block **308**, a display subsystem **316**, an audio subsystem **318**, and a controller area network (CAN) interface **320**. The distraction analysis block **306** may include instructions for performing video scene analysis, video enhancement, image correction, motion analysis, and/or any other suitable data processing and analysis to determine whether or not a driver is distracted.

[0048] In operation, any raw video signals from the wearable device **302** may be received by Wi-Fi interface **310** and/or Bluetooth interface **312** in the head unit **304***a* and passed to the distraction analysis block **306**. Any compressed video signals may be received via Wi-Fi interface **310** and/or Bluetooth interface **312** in the head unit **304***a* and then decompressed in the video decompressor unit **314**. In some examples, compressed video signals may be sent via Bluetooth due to the reduced bandwidth usage relative to uncompressed/raw data.

[0049] The data received by the distraction analysis block **306** may undergo correction like video stabilization at the image correction unit. As an example, bumps on the roads may shake, blur, or distort the signals. The image correction unit may stabilize the images against horizontal and/or vertical shake, and/or may correct for panning, rotation, and/or zoom, as an example. The video enhancement unit of the distraction analysis block **306** may perform additional enhancement in situations where there is poor lighting or high compression. Video processing and enhancement may include gamma correction, de-hazing, and/or de-blurring, and the video processing enhancement algorithms may operate to reduce noise in the input of low lighting video followed by contrast enhancement techniques such as tone-mapping, histogram stretching and equalization, and gamma correction to recover visual information in low lighting videos. The video scene analysis unit of the distraction analysis block **306** may recognize the content of the video coming in from the wearable device **302**, which may further be used in the distraction severity analysis block **306**. Analysis of the video sequences may involve a wide spectrum of techniques from low-level content analysis such as feature extraction, structure analysis, object detection, and tracking, to high-level semantic analysis such as scene analysis, event detection, and video mining. For example, by recognizing the content of the incoming video signals, it may be determined if the vehicle is in a freeway or within city limits, if there are any pedestrians, animals, or other objects/obstacles on the road, etc. The motion analysis unit may determine the ego motion and the motion of objects in the path of the vehicle. Ego motion estimation includes estimating a vehicle's moving position relative to lines on the road or street signs as being observed from the vehicle itself and may be determined by analyzing the associated camera images. By performing image processing (e.g., image correction, video enhancement, etc.) prior to or alongside performing image analysis (e.g., video scene analysis, motion analysis, etc.), the image data may be prepared in a suitable manner that is tuned to the type of analysis being performed. For example, image correction to reduce blur may allow video scene analysis to be performed more accurately by clearing up the appearance of edge lines used for object recognition.

[0050] The distraction severity analysis block **308** may receive the output of the distraction analysis block **306** after the signals have undergone processing and analysis as described above and may estimate the severity of distraction using additional parameters such as vehicle speed, vehicle lighting (internal and/or external), and vehicle location derived from the controller area network (CAN) interface **320** of the head unit **304***a*. The severity ranking may depend on the level of distraction of the driver. Some examples of driver distraction include the driver not looking at the road for prolonged periods of time while driving, the driver not looking at the road for upcoming turns, the driver being distracted by music, etc. Other examples may include the driver being distracted while handling (e.g., providing user input to) infotainment units for prolonged period of time, the driver being sleepy or tired, and/or other driver states. Once the level of driver distraction is determined, the distraction severity analysis block **308** determines severity ranking R. The action performed by the system may vary as per the severity of the

distraction. The severity ranking R may also be dependent on various factors such as the criticality of the event and the amount of time for which the driver is distracted. Some example scenarios and the resulting severity rank R that is generated is shown in FIG. **7** and described below.

[0051] If the severity rank R is in the first range (e.g., low), a visual alert may be indicated which may either be displayed in the display subsystem **316** of the head unit **304***a* and/or be sent out to any system capable of displaying the visual warning to the driver (e.g., another display in the vehicle, a display on the wearable device **302**, a display of another mobile device in the vehicle, etc.). If the severity rank R is in the second range (e.g., medium), an audio alert may be indicated. The audio alert signal may either be used to generate an audio signal in the audio subsystem of the head unit **304***a* or may further be used to generate an audio alert in any system capable of generating the audio warning to the driver (e.g., a speaker system of the vehicle, a speaker of the wearable device **302**, a speaker of another mobile device in the vehicle, etc.). In the embodiment shown in FIG. **3**A, most of the data processing may occur in the head unit **304***a*. However, it may be possible to perform at least some of the data processing and/or analysis in a system outside the head unit **304***a*.

[0052] FIG. **3**B shows an example block diagram of a distraction monitoring system **300***b* that may be used in such an example scenario, where some of the data processing may occur in a cloud computing device **322**. Elements in FIG. **3**B having the same number as a corresponding element of FIG. **3**A are similar to those described in FIG. **3**A in all aspects except that there may be additional elements to account for the location of units in the cloud computing device **322** instead of the head unit **304***b*. Although shown as including fewer elements than head unit **304***a* of FIG. **3**A, it is to be understood that head unit **304***b* may additionally include one or more data processing/analysis units (e.g., the distraction analysis block **306**, the video decompressor **314**, and/or the distraction severity analysis block **308**) included in head unit **304***a* of FIG. **3**A. For example, the distraction monitoring system **300***b* as shown in FIG. **3**B may represent units utilized when performing substantially all processing/analysis in the cloud computing device **322**. However, in other scenarios, the data processing/analysis may be shared by both the cloud computing device **322** and the head unit **304***b*. For example, a first portion of the data from wearable device **302** may be processed and analyzed by the cloud computing device **322** and a second portion of the data from the wearable device **302** may be processed and analyzed by the head unit **304***b*. In other examples, certain types of processing and/or analysis may be performed for all data by one of the cloud computing device **322** and the head unit **304***b* and certain other types of processing and/or analysis may be performed for all data by the other one of the cloud computing device **322** and the head unit **304***b*.

[0053] The wearable device **302** may include a plurality of cameras and microphone, capable of streaming the raw or compressed video images similar to the one described in FIG. **3**A. The raw images from the wearable device may be sent to the cloud computing device **322** via Wi-Fi interface **310** and/or Bluetooth interface **312**. Additionally or alternately, the data from the wearable device **302** may be sent the head unit **304***b* via Bluetooth interface **312** and/or Wi-Fi interface **310**. The data received by the head unit **304***b* may additionally be compressed by a video compressor **324**, which may then be sent to cloud computing device **322** through a cloud interface **326**. The cloud interface **326** in the head unit **304***b* may be capable of bi-directional communication with the head unit interface **328** located in the cloud computing device. The compressed data received by the head unit interface **328** in the cloud computing device may undergo video decompression as explained in FIG. **3**A by the video decompressor unit **314**. Similar to the embodiment shown in FIG. **3**A, the data received from Wi-Fi interface **310** and/or Bluetooth interface **312** and the decompressed data received from the video decompressor **314**, each of which are located in the cloud computing device **322**, may further be processed and analyzed by the distraction analysis block **306** in much the same way as described in FIG. **3**A. In addition, the distraction severity analysis unit **308**, also located in the cloud computing device **322** may perform additional analysis and generate severity ranking, R. Depending on the severity ranking, different warning signals may be issued, which may then be communicated back to the head unit **304***b* through the head unit interface **328**, and the corresponding warnings may be generated in the respective systems as explained in FIG. **3**A.

[0054] FIG. **4** is a flow chart of a method **400** of operating an in-vehicle computing system for generating warnings based on a calculated severity rank range from the perspective of a head unit of a vehicle. For example, method **400** may be performed by the in-vehicle computing system **200** of FIG. **2**, based on the output of mobile device **242** (e.g., a wearable device, such as wearable device **302** of FIGS. **3**A and **3**B).

[0055] Method **400** includes, at **402**, receiving data from the mobile device. In one example, the mobile device may be a wearable device **302** described in FIGS. **3**A and **3**B. The data may include image data from the front-facing camera and the driver-facing camera, for example. Specifically, the data may be received at the in-vehicle computing system from one or more wearable devices. The wearable devices worn by a driver of a vehicle may include one or more sensors such as a biometric sensor, a temperature sensor, a perspiration level sensor, etc.

[0056] At **404**, the method includes processing the data, which may be processed in the head unit (e.g., head unit **304***a* of FIG. **3**A) itself as described in FIG. **3**A or may be sent to the cloud for further processing as explained in FIG. **3**B, in which case, the processed data may be received back from the cloud to the head unit (e.g., head unit **304***b* of FIG. **3**B). At **406**, the method includes determining the distraction of the driver (as will be explained below with respect to FIG. **5**). At **408**, the method checks if the driver is distracted. If the driver is distracted, then the method proceeds to **410**, where the severity rank R is calculated (e.g., based on a correlation of data from various sources, as explained below with respect to FIG. **6**). If it is determined at **408** that the driver is not distracted then the method returns to continue receiving image data and monitoring driver distraction.

[0057] At **412**, the method checks if the calculated severity rank R is within a first range. The first range may be a value of severity rank R that indicates a relatively low level of severity of the driver distraction. For example, the first range may correspond to an indication of driver distraction while the vehicle is not in any immediate danger of collision, an indication of driver distraction that is predicted to be short-lived, etc. If the severity rank is in the first range (e.g., "YES" at **412**), then the method proceeds to **414**, where the head unit instructs a display device to present a visual warning. A visual warning may include, but is not limited to, a warning displayed on the heads up display or on the main infotainment

screen. If the severity rank R is not within the first range, then the method proceeds to **416**, where the system determines if R is in the second range. For example, the second range may correspond to a relatively medium level of severity of driver distraction. An example medium level of severity may include a serious driver distraction (e.g., droopy eyes indicating sleepiness) while the vehicle is in an otherwise safe environment (e.g., no objects within a trajectory/path of the vehicle, driving at a low speed, etc.). If the severity rank R is within the second range (e.g., "YES" at **416**), then the method proceeds to **418**, where the head unit instructs an audio playback device to present an audio warning. In one example, an audio warning may be played on all the available audio zones in the system. If at **416**, it is determined that R is not within the second range, then the method proceeds to **420**, where the system checks if R is within the third range. The third range may correspond to a relatively high level of severity of driver distraction. An example high level of severity of driver distraction may include any driver distraction while an object in a vehicle environment is on a colliding course with the vehicle (e.g., an estimated trajectory of the object intersects with an estimated trajectory of the vehicle). If the severity ranking R is within the third range (e.g., "YES" at **420**), then the method proceeds to **422**, where the head unit instructs a vehicle system to perform engine control operations or other vehicle control operations. The engine operations may include automatically controlling the vehicle speed or braking for example (e.g., without driver or other user instruction to perform such vehicle control), while other vehicle control operations may include reducing multimedia related system volume for example. For extreme cases, an engine control operation performed at **422** may include automatically bringing the vehicle to a complete stop without driver or other user intervention. If R is not within the third range when checked at **420**, the method returns. For example, the first range may correspond to a lowest range of severity ranking, and the second range may correspond to a higher range of severity rankings starting with a severity ranking immediately above the highest severity ranking in the first range. The third range may correspond to a range of severity rankings from the highest severity rank of the second range to a maximum possible severity rank. Therefore, any severity rank outside of the three ranges may correspond to a low enough severity rank to forego any warnings. In other examples, a severity rank outside of the checked severity ranks may result in a default action being performed (e.g., an audio and/or visual warning). Although three ranges are illustrated in FIG. **4**, it is to be understood that any number of ranges and associated types of actions may be analyzed in the performance of method **400**.

[0058] FIG. **5** is a flow chart of a method **500** for processing and analyzing the data received from a mobile device (e.g., wearable device **302** of FIGS. **3**A and **3**B) and includes further determining a distraction level of a driver from the perspective of the mobile device. At **502** of method **500**, the mobile device sends out the data from a driver-facing camera of the mobile device. In one example, this may include data from the wearable device **302** of FIGS. **3**A and **3**B. The driver-facing camera data may include images that provide details about the driver head position, his/her stance, his/her eye position and may even include details such as gaze direction, pupil location, etc. that are able to be determined based on image analysis performed at one or more of a head unit (e.g., head unit **304***a* of FIG. **3**A) and a cloud computing device (e.g., cloud computing device **322** of FIG. **3**B). The image data may be sent to the head unit and/or the cloud to be processed and analyzed. At **504** of method **500**, the mobile device sends out data from other sensors. These other sensors may include one or more wearable sensors, such as biometric sensors, a heart rate sensor, a temperature sensor, a perspiration level sensor, etc. This data may be sent to the head unit and/or to the cloud for further processing and analysis. At **506** of method **500**, the mobile device may be instructed to send the data from the front-facing camera. This data includes image data that provides information about the external environment of the vehicle. For example, this data may include, images of the landscape around the vehicle, location of stop signs and signals, other vehicles in the path of the vehicle of interest, objects in the path of the vehicle of interest, objects including people, animals, etc. that are able to be determined based on image analysis performed at one or more of the head unit and the cloud computing device. This data is again sent to the head unit and/or the cloud. At **508** of method **500**, the data from **502**, **504**, and **506** are processed as explained below.

[0059] The driver-facing camera data from **502** of method **500** may be processed at **508**. Processing data at **508** may include performing data correction, data enhancement, performing saturation level correction, data smoothing etc. Performing data correction may include performing image processing designed to correct local defects in the image, for example. For example, this may include removing very small portions of the image that may be considered error or dust particles or anything else that may not be part of the actual image data. Additionally, the data correction may include luminance correction, color correction, aperture and exposure correction, white balance correction etc. At **508**, the data from the front-facing camera may undergo data enhancement, in order to identify the driver's facial features clearly. Data enhancement may include adjusting contrast, gain, threshold etc., for example. The data from **502** may further be subjected to saturation level correction and smoothing. The data processing steps performed in **508** may render the image data from the driver-facing camera ready for further analysis in **510** and **512**.

[0060] The data from the sensors sent at **504** may undergo similar processing at **508**. As described in FIGS. **3**A and **3**B, the wearable device may include additional sensors such as a biometric sensor, a perspiration level sensor, etc. The biometric sensor or perspiration level sensor, for example may provide a trove of real-time medical information about the person wearing them. The perspiration level sensor monitors the sweat that it collects in a small patch, analyzes it, and can further used it for monitoring level of physical fatigue, and alerting the driver if they are overexerted, for example. A biometric sensor may be used for monitoring pulse or heart rate, and again, can be used to determine the health conditions of the driver. Other sensors such as body temperature sensor, electrocardiogram, glucometer, etc., may also be used to monitor the health conditions of the driver. The information from these sensors may be used to monitor in real time the state of the driver, which may be further processed in **508** using various signal processing techniques to extract useful data from such measurements.

[0061] The front-facing camera data from **506** of method **500** may be processed at **508**. Processing data at **508** may include performing data correction, data enhancement, performing saturation level correction, data smoothing etc. as explained above. The data may include information about the

vehicle trajectory, objects in the path of the vehicle, trajectory of the objects in the path of the vehicle, for example. Additionally, it may also include information about upcoming signals/stop signs, speed limits, school zone/hospital area, etc. The data processing steps performed in **508** may further render the image data from the driver-facing camera ready for further analysis in **510** and **512**.

[0062] The data received from the driver-facing camera at **502**, data from the other sensors at **504** and data from front-facing camera at **506** may be processed at **508** as explained above, and further analyzed at **510** and **512**. For example, the data from the driver-facing camera that is processed at **508**, may be used to determine the facial features of the driver for example. This may include, determining if the eyelids are closed or partially closed for prolonged periods of time for example. If the eyelids remain closed when compared with historical data, such eyelids' position compared to earlier times, for example, then it may be determined at **514** that the driver is distracted. As another example, the driver data may include position of the head. If it is determined that the position of the head is moving constantly by comparing with historical data at **510**, which in one example, may be due to head nodding, it may be determined that the driver is distracted at **514**. If, in another example, the driver data indicates that the driver's eye is looking in a direction other along the trajectory of the vehicle, for prolonged times (as derived from comparing with historical data at **510**), it may be determined that the driver is distracted at **514**.

[0063] The data from other sensors received from **504** may include information regarding the driver's health condition, for example, or weather conditions as another example. The information from the biometric sensors may be used to monitor in real time the state of the driver, which may be further used to determine if the driver is distracted at **514**. The heart or pulse rate monitor may determine the rate at which the heart is beating. The heart of a healthy adult beats within the range of 60-100 times per minute at rest and an abnormally high pulse rate may include rates above 100 beats per minute. Rapid heart rates for prolonged periods of time ma lead to dizziness, lightheadedness, fainting spells, palpitations, chest pains, and shortness of breath. By comparing the pulse rate with historical data at **510**, and analyzed at **512** to determine the state of the driver, and may further be used to determine if the driver is distracted at **514**. As another example, the weather condition information as determined from a weather sensor may be used to determine the driving conditions.

[0064] The data from the front-facing camera received from **506** may include information about the vehicle trajectory, objects in the path of the vehicle, trajectory of the objects in the path of the vehicle etc. as explained above. Additionally, it may also include information about upcoming signals/stop signs, speed limits, school zone/hospital area, etc. At **512**, this data may be further analyzed by performing video scene analysis, performing motion analysis, detecting objects, determining object and vehicle trajectories, comparing object and vehicle trajectories and performing comparison with historical data, for example. As an example, if the data from the front-facing camera indicates that the driver is within city limits (from video scene analysis, for example), and that there is an upcoming stop signal (from object detection) and that a pedestrian is across the road (from object detection), waiting to cross the pedestrian crossing at the stop signal. At **512**, the trajectories of the vehicle and the pedestrian may be determined and further compared and may be subsequently analyzed in the performance of the flow chart illustrated in FIG. **6** to determine the distraction severity rank R as explained below in reference to FIG. **6**. As another example, if the vehicle is determined to be on the highway (from video scene analysis), and there are vehicles in the next lanes (object detection), with indicators blinking to indicate lane change (video scene analysis), the trajectories of all the vehicles may be determined and compared and may be subsequently analyzed in the performance of the flow chart illustrated in FIG. **6**. At **516**, it may be checked if the diver is distracted, if yes, then the method **500** proceeds to the method illustrated in FIG. **6**, if not, the method **500** returns.

[0065] FIG. **6** is a flow chart of a method **600** for determining distraction severity rank. At **602** of method **600**, the analyzed data from FIG. **5** may be retrieved. This may include the data from the driver-facing camera, the data from other sensors and the data from the front-facing camera that are further processed and analyzed. At **604**, the types of driver distraction may be determined. For example, it may be determined from the driver-facing camera that the driver is not looking in the path of the vehicle, indicating that he/she may have a visual distraction. For example, if the driver is looking at a billboard or a cell phone, or looking at objects inside the vehicle, it may be determined that the driver is distracted. Alternately, the driver may have taken his/her hands from the driving wheel, which may be determined by the front-facing camera, for example, indicating that the driver may have a manual distraction. Other example manual distractions may include the driver using a cell phone for texting or dialing, or picking up objects that may have fallen to the floor of the vehicle. The driver may additionally or alternatively have taken his mind off driving, indicating a cognitive distraction. For example, the driver may be nodding his head while listening to loud music, both which may be determined from the driver-facing camera and microphone in the mobile device. At **606** of method **600**, the data may be analyzed or may be used to predict the environmental dangers or risks. The environmental dangers or risks may include the number of vehicles in front of the vehicle in which the head unit/wearable device of the distraction monitoring system resides, in one example. Additionally or alternately, the environmental dangers or risks may include whether the vehicle is in a school or hospital zone, for example. The environmental dangers or risks may also include the weather conditions as determined by weather sensors, and may indicate whether it is raining or snowing, or if the outside temperatures are freezing, for example. Additionally or alternately, environmental risks or dangers may include determining if there are objects in the path of the vehicle, and determining if there is a possibility of the trajectories of the objects and vehicle intersecting. At **608** of method **600**, the number of driver distractions may be determined. For example, the driver may be texting on his phone, which may include both visual and manual distraction. There may be more than one distraction at any given time, and the total number of distractions of the driver may be determined at **608**. Likewise, there may be several environmental risks or dangers and at **610**, the total number of environmental risks or dangers may be determined. For example, the number of objects in the path of the vehicle (or having a trajectory that intersects the trajectory of the vehicle) may be determined at **610**. At **612** of method **600**, the distraction severity may be determined by prioritizing and calculating a severity rank R based on the analysis performed at **604**-**610** of FIG. **6**, examples of which are shown in FIG. **7**. The prioriti-

zation and ranking may yield an integer severity rank, R, which may have values and/or value ranges mapped to different actions (e.g., presenting visual alerts, audio alerts, performing vehicle control, etc.). At **614**, the method includes performing an action based on the severity rank (e.g., as described above with respect to FIG. **4**).

[0066] FIG. **7** is a table **700** for calculating severity rank R, based on the driver distraction and environmental risks/dangers as discussed above. As an example scenario, if it is determined that the driver is not looking ahead, indicating a visual distraction and that the vehicle is stopped at a traffic signal, then the severity rank assigned is low, say R=1, for example. However, if it is determined that the driver is not looking ahead, and that the vehicle is approaching a turn in the city at high speed, then the severity rank is determined to be high, R=8, for example. As another example, if the driver is on the phone, but is using hands free and is on the freeway, then a medium severity rank such as R=4 may be determined. However, if the driver is on the phone, but not using hands free, and is approaching a turn in the city at high speed, a high severity rank such as R=8, may be determined More example scenarios and the corresponding severity rank are shown in FIG. **7**. At **612** of method **600**, the severity rank is determined and prioritized as explained and the method **600** proceeds to **614** where the appropriate action based on the severity rank R as explained in FIG. **4** may be performed. Briefly, if the severity rank R is within a first range (i.e., low), a visual warning may be presented to the driver. If the severity rank R is within a second range, then an audio warning may be presented to the driver. If the severity rank is within a third range, then engine control operations may be performed as explained in FIG. **4**. It is to be understood that the values and scenarios described in FIG. **7** are examples and are not intended to be limiting. Any suitable action may be mapped to any suitable severity ranking, which may be mapped to any suitable combination of driver states, object states, and vehicle states.

[0067] FIG. **8** is a flow chart of an example method **800** for determining the severity rank R and performing an associated action. Method **800** may be performed by a distraction monitoring system, such as systems **300***a* and **300***b* of FIGS. **3**A and **3**B. Method **800** includes receiving data from the cameras and sensors at **802**, and further analyzing the data as explained in FIG. **5**. At **804**, it may be determined if the vehicle is within city limits. This may be determined by performing video scene analysis on the data received from the front-facing camera, for example. If the vehicle is not within city limits, the method **800** returns to **802** where the system continues to receive and analyze data. If at **804** of method **800**, it is determined that the vehicle is within city limits, then the method **800** proceeds to **806**, where the driver data, vehicle data and CAN (e.g., vehicle) data may be monitored. At **808**, the method **800** includes determining vehicle speed and location information. For example, the vehicle speed information may be determined from the CAN, and the vehicle location may be determined from the video scene analysis performed on the images from the front-facing camera. At **810** of method **800** includes checking if driver is not looking ahead. This may be determined by analyzing the images from the driver-facing camera, for example. If it is determined that the driver is looking ahead, then the method **800** proceeds to **802**, where it continues to receive and analyze data as explained earlier. If at **810**, it is determined that the driver is not looking ahead, then the method **800** proceeds to **812**, where it is checked if the vehicle is at a stop signal or in a garage, for example. If from the front-facing camera and the CAN data it is determined that the vehicle is in a garage, or at a stop signal, then the method **800** proceeds to **818**, where it may be indicated that the severity rank is in the first range (low) and a visual warning may be presented to the driver. The visual warning serves as a first level warning to the driver, especially if the vehicle is at a stop signal, indicating to the driver that he may want to start looking ahead. If the vehicle is in a garage, the visual warning may serve as a reminder for the driver to check that the vehicle is in reverse gear for example. Alternately, the driver may be sitting in the vehicle and looking at a map, for example, in which case, the visual warning may serve as a reminder for the driver to turn off the unit. At **812**, if it is determined that the vehicle is not at a stop signal or garage, then the method **800** proceeds to **814**, where the vehicle speed as determined from the CAN data, may be compared with a threshold. The threshold may be determined from the city speed limit, with additional information about the traffic conditions, as an example. If the vehicle speed is less than the threshold speed, then the method **800** proceeds to **820**, where it may be indicated that the severity rank is within the second range (medium), and an audio warning may be presented. When the audio warning is presented, the driver may be warned to take appropriate action, which in this case may be to start looking ahead, in order to avoid an accident, for example. If at **814**, it is determined that the vehicle speed is not less than the threshold, then the method **800** proceeds to **816**, where it is checked if the vehicle speed is greater than the threshold. If no, then the method **800** returns. If yes, then the method **800** proceeds to **822** where it may be indicated that the severity rank R is within the third range (high) and engine control actions may be performed. This may include reducing vehicle speed, for example.

[0068] FIG. **9** is a flow chart of another example method **900** of determining a severity rank for a set of driver, object, and vehicle data. For example, method **900** may be performed by distraction monitoring system **300***a*/**300***b* of FIGS. **3**A and **3**B. At **902**, the method includes receiving data from a mobile device. For example, if performed at a cloud computing device of the distraction monitoring system (e.g., cloud computing device **322** of FIG. **3**B), the method may include receiving compressed data from a head unit of the distraction monitoring system (e.g., head unit **302***b* of FIG. **3**B). At **904**, the method includes processing the received data to determine vehicle data/state, object data/state, and driver data/state. At **906**, the method includes determining if the driver is on the phone. For example, the system may evaluate the driver data to determine if the driver is talking and/or evaluate the vehicle data to determine whether a phone call is detected (e.g., if the driver's phone is communicatively connected to the head unit). If the driver is not on the phone (and if no other driver distraction is detected), the method returns to continue monitoring data from the mobile device without performing an action. Accordingly, if no distraction is detected, the system does not perform an action that is selected based on correlating vehicle, object, and driver data/states.

[0069] Conversely, if the driver is determined to be on the phone, the method proceeds to **908** to determine if the vehicle is within city limits. If the vehicle is not within city limits, the method proceeds to **910** to determine if the vehicle is on the highway. If the vehicle is not on the highway, the vehicle may be determined to be stopped and/or in a stationary location, and thus driver distraction may not be severe enough to war-

rant taking action. It is to be understood that other parameters may be evaluated, such as engine status (e.g., whether the engine is stopped) in order to validate the determination that the vehicle is stopped and out of danger. If, however, the vehicle is determined to be within city limits or on the highway, the method proceeds to **912** to calculate trajectories of the vehicle and any objects imaged in the vehicle environment. At **914**, the method includes determining if the estimated trajectories intersect within a threshold time. For example, trajectories that are estimated to intersect at a relatively nearby time may result in a higher severity ranking than severity rankings that result from trajectories that are estimated to intersect at a relatively far away time. If the trajectories do not intersect within the threshold time at **914**, the method proceeds to set R to a value within a second (e.g., medium) range, and send an audio alert at **916**. For example, the cloud computing device may send a command to the head unit to send an audio alert.

[0070] If the trajectories intersect within the threshold time, the ranking is set to a third range (e.g., high), and an engine control is performed at **918**. For example, the cloud computing device may send a command to the head unit to send a control instruction via the CAN bus to a vehicle control system to change an engine operating condition. If the severity ranking was indicated to be in the second range at **916**, the method further includes determining if the driver is off of the phone at **920**. For example, after presenting the audio alert, the system may wait a threshold period of time, then determine if the driver responded to the alert by ending the phone call. If the driver ended the phone call responsive to the alert, the method returns to continue monitoring driver, object, and vehicle states. Conversely, if the driver did not end the phone call, the method proceeds to **918** to upgrade the severity ranking from the second range to the third range. It is to be understood that in other examples, the upgrade may be to a different type of audio alert (e.g., a heightened volume, a different recorded tone or message, a different frequency, etc.), a combination of an audio and a visual alert, and/or any other suitable change to the alert.

[0071] By correlating data from multiple sources as described above, the distraction monitoring systems of this disclosure may provide an appropriate response to both a type and a severity of driver distraction. In this way, the driver may be more likely to positively correct the distraction relative to systems that only rely on one type of data to drive distraction alerts.

[0072] In one example, an in-vehicle computing system of a vehicle comprises an external device interface communicatively connecting the in-vehicle computing system to a mobile device, an inter-vehicle system communication module communicatively connecting the in-vehicle computing system to one or more vehicle systems of the vehicle, a processor, and a storage device. The storage device stores instructions executable by the processor to receive image data from the mobile device via the external device interface, the image data imaging a driver and a driver environment, determine a driver state based on the received image data, and, responsive to determining that the driver state indicates that the driver is distracted, receive vehicle data from one or more of the vehicle systems via the inter-vehicle system communication module, determine a vehicle state based on the vehicle data, determine a distraction severity level based on the driver state and the vehicle state, and control one or more devices of the vehicle to perform a selected action based on the distraction severity level.

[0073] In the above example, the instructions of the in-vehicle computing system may additionally or alternatively be further executable to perform the selected action by: presenting a visual warning responsive to the distraction severity level being within a first range, presenting an audio warning responsive to the distraction severity level being within a second range, and performing the selected action comprises performing an automatic adjustment of a vehicle control warning responsive to the distraction severity level being within a third range.

[0074] In either of the above examples, the in-vehicle computing system may additionally or alternatively further comprise a display device, and the visual warning may additionally or alternatively comprise a visual alert presented via the display device.

[0075] In any of the above examples, the audio warning may additionally or alternatively comprise an audio alert presented via one or more speakers in the vehicle.

[0076] In any of the above examples, the automatic adjustment of the vehicle control may additionally or alternatively comprise automatic adjustment of engine operation.

[0077] In any of the above examples, the mobile device may additionally or alternatively comprise a wearable device including at least an outward-facing camera having a field of view that includes a vehicle environment, and a user-facing camera having a field of view that includes the driver of the vehicle.

[0078] In any of the above examples, the instructions may additionally or alternatively be further executable to receive position and motion data from the head-mounted device, determine the driver state based on image data and the position and motion data, and transmit image data comprising video data including one or more of the driver as imaged from the user-facing camera and the vehicle environment as imaged from the outward-facing camera.

[0079] In any of the above examples, the image data may additionally or alternatively include an indication of driver gaze and objects of interest in a travel path of the vehicle, and the driver state may additionally or alternatively indicate that the driver is distracted responsive to determining that the driver gaze is directed to one or more objects of interest for a threshold period of time.

[0080] In another example, a method for an in-vehicle computing system of a vehicle comprises receiving driver data from a wearable device, the driver data including image data from a driver-facing camera, receiving object data from one or more imaging devices of at least one of the wearable device and the vehicle, the object data including image data of a vehicle environment, receiving vehicle data from one or more vehicle systems, the vehicle data including an indication of an operating condition of the vehicle, and determining whether a driver is distracted by correlating the driver data with the object data. The method further includes, responsive to determining that the driver is distracted, selecting an action based on correlating the driver data with the object data and the vehicle data and performing the selected action, and, responsive to determining that the driver is not distracted, maintaining current operating parameters.

[0081] In the above example, the object data may additionally or alternatively include a total number of objects in a vehicle environment as determined from the image data from

the one or more outward-facing cameras, and object trajectory information for each of the objects in the vehicle environment as determined from a comparison of a plurality of frames of image data from the one or more outward-facing cameras, the object trajectory information indicating an estimated trajectory of each of the objects.

[0082] In either of the above examples, vehicle data may additionally or alternatively include vehicle trajectory information determined from one or more of a navigational system of the vehicle, sensor output of the wearable device, and image data from the one or more outward-facing cameras, the vehicle trajectory information indicating an estimated trajectory of the vehicle.

[0083] In any of the above examples, the method may additionally or alternatively further comprise comparing the estimated trajectory of each of the objects and the estimated trajectory of the vehicle to determine intersections between the estimated trajectories of the objects and the estimated trajectory of the vehicle, wherein the selected action is selected based on the number of intersections between the estimated trajectories of the objects and the estimated trajectory of the vehicle.

[0084] In any of the above examples, the selected action may additionally or alternatively be further selected based on a vehicle speed and a gaze direction of the driver.

[0085] In any of the above examples, a first action may additionally or alternatively be selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle and the vehicle speed is below a speed threshold, and a second action may additionally or alternatively be selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle, the vehicle speed is above the speed threshold, and the gaze direction of the driver intersected the current location of each of the at least one objects within a threshold time period and for a threshold duration.

[0086] In any of the above examples, a third action may additionally or alternatively be selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle, the vehicle speed is above the speed threshold, and the gaze direction of the driver did not intersect the current location of each of the at least one objects within the threshold time period or for the threshold duration.

[0087] In any of the above examples, the first action may additionally or alternatively be a visual alert presented via a display in the vehicle, the second action may additionally or alternatively be an audible alert presented via one or more speakers in the vehicle, and the third action may additionally or alternatively be a vehicle control command issued from the in-vehicle computing system to a vehicle system to control engine operation of the vehicle.

[0088] In any of the above examples, maintaining the current operating parameters may additionally or alternatively comprise not performing an action that is based on correlating the driver data with the object data and the vehicle data.

[0089] In still another example, a system for identifying driver distraction comprises a wearable device including a driver-facing camera, an outward-facing camera, and one or more sensors, an in-vehicle computing system communicatively connected to the wearable device and one or more vehicle systems, the in-vehicle computing system comprising a first processor and a first storage device, and a cloud computing device remote from the in-vehicle computing system and communicatively connected to the in-vehicle computing system via a network. The cloud computing device comprises a second processor and a second storage device, and one or more of the first storage device and the second storage device storing first instructions executable by a respective one or more of the first processor and the second processor to: receive image data from the driver-facing camera and sensor data from the one or more sensors of the wearable device indicating a driver state, receive image data from the outward-facing camera of the wearable device indicating object states of one or more objects, and receive vehicle data from one or more vehicle systems to indicate vehicle state. The first instructions are further executable by a respective one or more of the first processor and the second processor to select an action to be performed based on the indicated driver state, object states, and vehicle state. The first storage device stores second instructions executable by the first processor to transmit a command to one or more of a display device of the in-vehicle computing system, an audio device of the vehicle, and an engine control unit of the vehicle to perform the selected action.

[0090] In the above example, the vehicle state may additionally or alternatively include a trajectory of the vehicle, the object states may additionally or alternatively include trajectories of the one or more objects, and the driver state may additionally or alternatively include a gaze direction of the driver.

[0091] The description of embodiments has been presented for purposes of illustration and description. Suitable modifications and variations to the embodiments may be performed in light of the above description or may be acquired from practicing the methods. For example, unless otherwise noted, one or more of the described methods may be performed by a suitable device and/or combination of devices, such as the distraction monitoring system **300***a*/**300***b*, the head unit **304***a*/**304***b*, and/or cloud computing device **322** described with reference to FIGS. **3**A and **3**B. The methods may be performed by executing stored instructions with one or more logic devices (e.g., processors) in combination with one or more additional hardware elements, such as storage devices, memory, hardware network interfaces/antennas, switches, actuators, clock circuits, etc. The described methods and associated actions may also be performed in various orders in addition to the order described in this application, in parallel, and/or simultaneously. The described systems are exemplary in nature, and may include additional elements and/or omit elements. The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various systems and configurations, and other features, functions, and/or properties disclosed.

[0092] As used in this application, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is stated. Furthermore, references to "one embodiment" or "one example" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. The terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements or a particular positional order on their objects. The following claims particularly point out subject matter from the above disclosure that is regarded as novel and non-obvious.

1. An in-vehicle computing system of a vehicle, the in-vehicle computing system comprising:

an external device interface communicatively connecting the in-vehicle computing system to a mobile device;

an inter-vehicle system communication module communicatively connecting the in-vehicle computing system to one or more vehicle systems of the vehicle;

a processor; and

a storage device storing instructions executable by the processor to:

receive image data from the mobile device via the external device interface, the image data imaging a driver and a driver environment;

determine a driver state based on the received image data;

responsive to determining that the driver state indicates that the driver is distracted:

receive vehicle data from one or more of the vehicle systems via the inter-vehicle system communication module;

determine a vehicle state based on the vehicle data;

determine a distraction severity level based on the driver state and the vehicle state; and

control one or more devices of the vehicle to perform a selected action based on the distraction severity level.

2. The in-vehicle computing system of claim **1**, wherein

performing the selected action comprises presenting a visual warning responsive to the distraction severity level being within a first range;

performing the selected action comprises presenting an audio warning responsive to the distraction severity level being within a second range; and

performing the selected action comprises performing an automatic adjustment of a vehicle control warning responsive to the distraction severity level being within a third range.

3. The in-vehicle computing system of claim **2**, further comprising a display device, wherein the visual warning comprises visual alert presented via the display device.

4. The in-vehicle computing system of claim **2**, wherein the audio warning comprises an audio alert presented via one or more speakers in the vehicle.

5. The in-vehicle computing system of claim **2**, wherein automatic adjustment of the vehicle control comprises automatic adjustment of engine operation.

6. The in-vehicle computing system of claim **1**, wherein the mobile device comprises a wearable device including at least an outward-facing camera having a field of view that includes a vehicle environment, and a user-facing camera having a field of view that includes the driver of the vehicle.

7. The in-vehicle computing system of claim **6**, wherein the instructions are further executable to receive position and motion data from the head-mounted device, determine the driver state based on image data and the position and motion data, and transmit image data comprising video data including one or more of the driver as imaged from the user-facing camera and the vehicle environment as imaged from the outward-facing camera.

8. The in-vehicle computing system of claim **7**, wherein the image data includes an indication of driver gaze and objects of interest in a travel path of the vehicle, and wherein the driver state indicates that the driver is distracted responsive to determining that the driver gaze is directed to one or more objects of interest for a threshold period of time.

9. The in-vehicle computing system of claim **8**, wherein the image data includes an indication of a trajectory of the objects of interest, and wherein the distraction severity level is based on a comparison of the trajectory of the objects of interest and the travel path of the vehicle.

10. A method for an in-vehicle computing system of a vehicle, the method comprising:

receiving driver data from a wearable device, the driver data including image data from a driver-facing camera;

receiving object data from one or more imaging devices of at least one of the wearable device and the vehicle, the object data including image data of a vehicle environment;

receiving vehicle data from one or more vehicle systems, the vehicle data including an indication of an operating condition of the vehicle;

determining whether a driver is distracted by correlating the driver data with the object data;

responsive to determining that the driver is distracted, selecting an action based on correlating the driver data with the object data and the vehicle data and performing the selected action; and

responsive to determining that the driver is not distracted, maintaining current operating parameters.

11. The method of claim **10**, wherein the object data includes:

a total number of objects in a vehicle environment as determined from the image data from the one or more outward-facing cameras, and

object trajectory information for each of the objects in the vehicle environment as determined from a comparison of a plurality of frames of image data from the one or more outward-facing cameras, the object trajectory information indicating an estimated trajectory of each of the objects.

12. The method of claim **11**, wherein vehicle data includes vehicle trajectory information determined from one or more of a navigational system of the vehicle, sensor output of the wearable device, and image data from the one or more outward-facing cameras, the vehicle trajectory information indicating an estimated trajectory of the vehicle.

13. The method of claim **12**, further comprising comparing the estimated trajectory of each of the objects and the estimated trajectory of the vehicle to determine intersections between the estimated trajectories of the objects and the estimated trajectory of the vehicle, wherein the selected action is selected based on the number of intersections between the estimated trajectories of the objects and the estimated trajectory of the vehicle.

14. The method of claim **13**, wherein the selected action is further selected based on a vehicle speed and a gaze direction of the driver.

15. The method of claim **13**, wherein a first action is selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle and the vehicle speed is below a speed threshold, and a second action is selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle, the vehicle speed is above the speed threshold, and the gaze

direction of the driver intersected the current location of each of the at least one objects within a threshold time period and for a threshold duration.

16. The method of claim **15**, wherein a third action is selected responsive to determining that the estimated trajectory of at least one of the objects intersects the estimated trajectory of the vehicle, the vehicle speed is above the speed threshold, and the gaze direction of the driver did not intersect the current location of each of the at least one objects within the threshold time period or for the threshold duration.

17. The method of claim **16**, wherein the first action is a visual alert presented via a display in the vehicle, the second action is an audible alert presented via one or more speakers in the vehicle, and the third action is a vehicle control command issued from the in-vehicle computing system to a vehicle system to control engine operation of the vehicle.

18. The method of claim **10**, wherein maintaining the current operating parameters comprises not performing an action that is based on correlating the driver data with the object data and the vehicle data.

19. A system for identifying driver distraction, the system comprising:

a wearable device including a driver-facing camera, an outward-facing camera, and one or more sensors;

an in-vehicle computing system communicatively connected to the wearable device and one or more vehicle systems, the in-vehicle computing system comprising a first processor and a first storage device; and

a cloud computing device remote from the in-vehicle computing system and communicatively connected to the in-vehicle computing system via a network, the cloud computing device comprising a second processor and a second storage device,

one or more of the first storage device and the second storage device storing first instructions executable by a respective one or more of the first processor and the second processor to:

receive image data from the driver-facing camera and sensor data from the one or more sensors of the wearable device indicating a driver state,

receive image data from the outward-facing camera of the wearable device indicating object states of one or more objects,

receive vehicle data from one or more vehicle systems to indicate vehicle state, and

select an action to be performed based on the indicated driver state, object states, and vehicle state,

the first storage device storing second instructions executable by the first processor to transmit a command to one or more of a display device of the in-vehicle computing system, an audio device of the vehicle, and an engine control unit of the vehicle to perform the selected action.

20. The system of claim **19**, wherein the vehicle state includes a trajectory of the vehicle, the object states include trajectories of the one or more objects, and the driver state includes a gaze direction of the driver.

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