United States Patent Application Publication	20250256710
Kind Code	A1
Publication Date	August 14, 2025
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TRIGGER EVENT PERSONALIZED ADAPTIVE CRUISE CONTROL (P-ACC)

Abstract

Systems and methods are provided for learning a driving behavior during a cut-in cut-out event or other triggering event to create a profile that adjusts operation of the adaptive cruise control (ACC) component of the vehicle to mimic the preferences of the driver. The profile may be based on data collected during a previous cut-in cut-out event or other triggering event. The data may be transmitted to an adaptive cruise control system that uses the data as input to a machine learning model. Output of the machine learning model may update the profile for the driver that operates the vehicle in ACC during the cut-in cut-out event. When the vehicle is operating in ACC and an event is within a threshold value of the cut-in cut-out event occurs at a later time, the vehicle may apply rules defined in the profile.

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Appl. No.: **18/438129**

Filed: **February 09, 2024**

Publication Classification

Int. Cl.: **B60W30/14** (20060101); **B60W30/16** (20200101); **B60W40/09** (20120101); **B60W50/00** (20060101)

U.S. Cl.:

CPC **B60W30/143** (20130101); **B60W30/16** (20130101); **B60W40/09** (20130101); **B60W50/0097** (20130101); B60W2050/0028 (20130101); B60W2050/0083 (20130101); B60W2540/049 (20200201); B60W2540/30 (20130101); B60W2554/404 (20200201); B60W2554/802 (20200201)

Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates generally to providing personalized Adaptive Cruise Control (ACC) in a vehicle corresponding to observed driving behaviors of a driver in a vehicle.

DESCRIPTION OF RELATED ART

[0002] Many motor vehicles have the ability to activate and deactivate cruise control. Cruise control is an electronic device in the vehicle that can be switched on to maintain a selected constant speed without the use of the accelerator. The brake pedal may deactivate the cruise control functionality and the vehicle can return to a decreasing speed until the accelerator or the cruise control functionality is reactivated.

BRIEF SUMMARY OF THE DISCLOSURE

[0003] ACCording to various embodiments of the disclosed technology implement personalized adaptive cruise control (ACC). The personalized ACC may be implemented by a vehicle control system. The vehicle control system may comprise, for example, an ACC circuit, a processor, and a memory coupled to the processor to store instructions. When the instructions are executed by the processor, the processor may capture event data comprising driver operations and traffic events associated with a cut-in cut-out event. The processor may transmit the event data associated with the vehicle to an adaptive cruise control system, where the adaptive cruise control system uses the event data as input to a machine learning model, and training of the machine learning model updates a profile for the driver that characterizes an observed driving style of the driver in the vehicle during the cut-in cut-out event. The profile may define rules to operate the vehicle in ACC to speed up or slow down the vehicle during a future cut-in cut-out event. The processor may receive, from the adaptive cruise control system, the profile at the vehicle. The processor may identify the future cut-in cut-out event when the vehicle is operating in ACC and an event is within a threshold value of the cut-in cut-out event. The processor may apply rules defined in the profile to correspond with the observed driving style of the driver.

[0004] In some examples, applying the rules defined in the profile include slowing down the vehicle to widen a gap between the vehicle and a second vehicle in front of the vehicle.

[0005] In some examples, applying the rules defined in the profile include increasing speed of the vehicle to close a gap between the vehicle and a second vehicle in front of the vehicle.

[0006] In some examples, the machine learning model comprises an event classifier that detects events while ACC is activated, a filtering module that separates cut-in cut-out events from other events while ACC is activated, and an acceleration and braking pattern classifier.

[0007] In some examples, metadata is generated and transmitted with the event data, and the metadata identifies a location where the event data is captured.

[0008] In some examples, metadata is generated and transmitted with the event data, and the metadata identifies a number of passengers that are traveling in the vehicle with the driver when the event data is captured.

[0009] In some examples, the vehicle comprises weight sensors incorporated with seats of the vehicle or image sensors to detect passengers in the vehicle in addition to the driver, and

incorporates the passengers with the driver with adjusting the profile.
[0010] In some examples, metadata is generated and transmitted with the event data, and the metadata comprises location information collected from a global positioning system (GPS) sensor or other location-based sensor.
[0011] In some examples, metadata is generated and transmitted with the event data, and the metadata identifies a type of sensor that is generating information that is stored and transmitted as the metadata.
[0012] In some examples, the adaptive cruise control system is located remote from the vehicle in a cloud-based server.
[0013] In some examples, the adaptive cruise control system is located locally at the vehicle to update the machine learning model and the profile for future use.
[0014] In some examples, the ACC circuit is part of an advanced driver-assistance system (ADAS).
[0015] Other features and aspects of the disclosed technology will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the features in accordance with embodiments of the disclosed technology. The summary is not intended to limit the scope of any inventions described herein, which are defined solely by the claims attached hereto.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0016] The present disclosure, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The figures are provided for purposes of illustration only and merely depict typical or example embodiments.
[0017] FIG. **1** is a schematic representation of an example vehicle with which some embodiments of the systems and methods disclosed herein may be implemented.
[0018] FIG. **2** illustrates an example architecture for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein.
[0019] FIG. **3** is an illustrative process for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein.
[0020] FIG. **4** illustrates examples of activating and deactivating adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein.
[0021] FIG. **5** illustrates a cut-in event in accordance with some embodiments of the systems and methods described herein.
[0022] FIG. **6** illustrates a cut-out event in accordance with some embodiments of the systems and methods described herein.
[0023] FIG. **7** illustrates two vehicle driver profiles in accordance with some embodiments of the systems and methods described herein.
[0024] FIG. **8** is an illustrative process for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein.
[0025] FIG. **9** is an example computing component that may be used to implement various features of embodiments described in the present disclosure.
[0026] The figures are not exhaustive and do not limit the present disclosure to the precise form disclosed.
DETAILED DESCRIPTION
[0027] Some motor vehicles have improved traditional cruise control functionality with the use of adaptive cruise control (ACC). ACC can increase or decrease the speed of the vehicle based data received from sensors incorporated with the vehicle. The sensors may comprise cameras, lasers, radar equipment, infrared sensors and other sensors in order to measure the distance between the

ego vehicle and other vehicles on the roadway. When the ego vehicle is within a predetermined distance to a second vehicle in front of it, the sensors may detect the distance between the vehicles that is within a threshold value and the ACC component may activate/alert the driver to slow down and the ACC component may actively slow the vehicle down itself. The alert may comprise visual alerts such as flashing lights interior to the vehicle, an interface display that identifies the warning (e.g., “slow down” or an appropriate icon), an audible warning, or a tactile warning (e.g., vibrating the accelerator pedal). However, in each of these instances, the distance between the ego vehicle and the second vehicle is predetermined in order to initiate the alert to the driver. Instead, the driver of the ego vehicle may have different preferences to speed up or slow down than the predetermined threshold value.

[0028] In some instances, personalized adaptive cruise control (PACC) may be implemented. For example, the personalized adaptive cruise control system can learn driver behavior and adaptively control the vehicle based on the learned behavior rather than based on pre-programmed operations. Examples of learned behavior may include a driver's reactions to a cut-in or cut-out event, upcoming curve in the road or road hazard, weather event, or other trigger event that may cause the cruise control system to adapt to surroundings or the environment. For ease of understanding and to provide context in which embodiments may be disclosed, this disclosure describes various embodiments in terms of a cut in or cut out event as a triggering event. As such, cut in events and cut out events may correspond with triggering events. As will be apparent to one of ordinary skill in the art based on the teachings herein, the operation of these embodiments may be applied in other scenarios.

[0029] In cut-in events, the ego vehicle is operating with ACC activated, and a gap forms between the ego vehicle and a second vehicle in front of the ego vehicle. A third vehicle moves into the lane between the ego vehicle and the second vehicle, which may cause the ego vehicle ACC component to ease off the accelerator or apply the brakes (e.g., to widen the gap between the ego vehicle and the new third vehicle) in response to the cut-in event and increase the distance between the third vehicle and the ego vehicle which is less than the distance between the second vehicle (now in front of the third vehicle) and the ego vehicle. In some cases, the driver's preference may not match the change in acceleration initiated by the ACC component, and the driver may choose to deactivate the ACC component and resume driving without the ACC activated which may be a technical limitation with traditional adaptive cruise control systems.

[0030] In cut-out events, the ego vehicle is operating with ACC activated and the second vehicle in front of the ego vehicle moves out of the lane, leaving a large gap between the ego vehicle and the vehicle in front of it. The ego vehicle ACC component may accelerate the vehicle to speed up and close the newly available space in response to the cut-out event (e.g., to close the gap so a third vehicle may cut-in front of the ego vehicle). In some cases, the acceleration may be stronger than the vehicle operator might otherwise prefer and, as discussed with cut-in events, the driver may choose to deactivate the ACC component and resume driving without the ACC activated.

[0031] The learned behavior by the driver of the ego vehicle during a trigger event, such as a cut-in or cut-out event, may be determined using reinforcement learning or other machine learning model, where the driver's demonstrated driving data is matched to a profile or otherwise used to train the model to best characterize the observed driving style. In some examples, the driver has its own personal profile of driving characteristics. Embodiments of the systems can further personalize the profile of the driver while using PACC based on event data, gap distance, and other characteristics of the environment.

[0032] Embodiments of the systems and methods disclosed herein can capture event data comprising driver operations and traffic events associated with a cut-in event, cut-out event, or other ACC trigger event. The vehicle or other device may also collect or generate metadata associated with the event data. The metadata and event data may be transmitted to an adaptive cruise control system that uses the metadata and the event data as input to a machine learning model. Output of the machine learning model may update a profile for the driver of the vehicle that operates the vehicle in ACC in accordance with the metadata and event data. The profile may be received at the vehicle from the adaptive cruise control system and, when the vehicle is operating in ACC and an event is within a threshold value of cut-in event, cut-out event, or other ACC trigger event, the vehicle may apply rules defined in the profile. With an updated profile corresponding closer to the preferences of the driver, the improved learning process may help prevent deactivation of ACC at the vehicle.

[0033] As an illustrative example, drivers responses to ACC trigger events such as cut-in and cut-out events may vary, with millions of drivers having slight, moderate or significant differences in behavior. Some may try to block the cut-in, some may get upset and exhibit road rage. In another example, there are merging freeways, and the merging cars may want to get into the fast lane as soon as possible and cross several lanes of traffic in front of other vehicles. That may create instances where other vehicles may need to allow a cut-in because one has to constantly brake and even the ACC has to constantly be on alert for cut-in events. These cut-in events may cause the driver to feel anxious or be annoyed by or have lower confidence in the ACC. In such cases, some drivers may narrow the gap between itself and the vehicle in front of it so that other cars are unable to cut-in at higher speeds. Another driver may decide to change to a slower lane and avoid the situation of constant cut-ins. In some embodiments of the disclosure, the profile for the personalized ACC may incorporate the personalized behavior of each driver, the personalized speed of the driver in a cut-in event, and the time range that the driver implements slowing down (e.g., to allow a cut-in) or speeding up to close the gap (e.g., to not allow a cut-in).

[0034] As another illustrative example, when an ego car is driving in traffic at 45 miles per hour (mph) and the car in front of the ego vehicle performs a cut-out event, the ego vehicle may accelerate to close the gap. The ego vehicle may increase the speed from 45 mph to 65 mph to close the gap quicker while the vehicle is operating with ACC activated. When the driver does not want to speed up that quickly, the driver may press the brake pedal and deactivate the ACC to avoid the ego vehicle from increasing speed so quickly. In some embodiments of the disclosure, the profile may identify that the driver does not prefer to increase the speed of the vehicle so quickly, and instead increase the speed at a slower rate in response to a cut-out event.

[0035] As another illustrative example, the driver prefers activation of ACC in stop-and-go traffic, the profile for the driver can set a rule corresponding to the desired speed in the stop-and-go traffic. The traditional ACC setting may be 30 mph but in traffic, the traditional ACC setting may be set to 20 mph, irrespective of the driver's preference. Again, a cut-out event may cause the ego vehicle to suddenly accelerate and the driver, if uncomfortable with the acceleration, would deactivate the ACC. In some embodiments of the disclosure, the profile may identify that the driver does not prefer to increase the speed of the vehicle so quickly, and instead increase the speed at a slower rate in response to a cut-out event in the stop-and-go traffic.

[0036] In the case of the ACC slowing for curves in the road, some drivers may be uncomfortable and apply the brakes to slow more. Other drivers may press the accelerator, effectively overriding the ACC to maintain a higher level of speed through the curve. The curves in the road or other roadway conditions may correspond with the ACC trigger event. The driver's reactions to the trigger event and other information may be collected for the driver's profile and behavior of the PACC adjusted to account for the driver's preferences.

[0037] There are many such contexts where different drivers prefer different gaps, acceleration, braking, and other behavior in various situations. In some embodiments of the disclosure, the PACC rules may be personalized to the driver preferences or styles (e.g., based on the profile of the driver) so that vehicle operators and passengers have a better experience and so that ACC trigger events are less likely to lead to deactivation of the ACC.

[0038] The systems and methods disclosed herein may be implemented with any of a number of different vehicles and vehicle types. For example, the systems and methods disclosed herein may be used with automobiles, trucks, motorcycles, recreational vehicles and other like on- or off-road vehicles. In addition, the principals disclosed herein may also extend to other vehicle types as well. An example hybrid electric vehicle (HEV) in which embodiments of the disclosed technology may be implemented is illustrated in FIG. **1**. Although the example described with reference to FIG. **1** is a hybrid type of vehicle, the systems and methods for a trigger event (e.g., cut-in cut-out event, etc.) personalized adaptive cruise control (P-ACC) can be implemented in other types of vehicle including gasoline- or diesel-powered vehicles, fuel-cell vehicles, electric vehicles, or other vehicles.

[0039] FIG. **1** illustrates a drive system of a vehicle **100** that may include an internal combustion engine **14** and one or more electric motors **22** (which may also serve as generators) as sources of motive power. Driving force generated by the internal combustion engine **14** and motors **22** can be transmitted to one or more wheels **34** via a torque converter **16**, a transmission **18**, a differential gear device **28**, and a pair of axles **30**.

[0040] As an HEV, vehicle **100** may be driven/powered with either or both of engine **14** and the motor(s) **22** as the drive source for travel. For example, a first travel mode may be an engine-only travel mode that only uses internal combustion engine **14** as the source of motive power. A second travel mode may be an EV travel mode that only uses the motor(s) **22** as the source of motive power. A third travel mode may be an HEV travel mode that uses engine **14** and the motor(s) **22** as the sources of motive power. In the engine-only and HEV travel modes, vehicle **100** relies on the motive force generated at least by internal combustion engine **14**, and a clutch **15** may be included to engage engine **14**. In the EV travel mode, vehicle **100** is powered by the motive force generated by motor **22** while engine **14** may be stopped and clutch **15** disengaged.

[0041] Engine **14** can be an internal combustion engine such as a gasoline, diesel or similarly powered engine in which fuel is injected into and combusted in a combustion chamber. A cooling system **12** can be provided to cool the engine **14** such as, for example, by removing excess heat from engine **14**. For example, cooling system **12** can be implemented to include a radiator, a water pump and a series of cooling channels. In operation, the water pump circulates coolant through the engine **14** to absorb excess heat from the engine. The heated coolant is circulated through the radiator to remove heat from the coolant, and the cold coolant can then be recirculated through the engine. A fan may also be included to increase the cooling capacity of the radiator. The water pump, and in some instances the fan, may operate via a direct or indirect coupling to the driveshaft of engine **14**. In other applications, either or both the water pump and the fan may be operated by electric current such as from battery **44**.

[0042] An output control circuit **14**A may be provided to control drive (output torque) of engine **14**. Output control circuit **14**A may include a throttle actuator to control an electronic throttle valve that controls fuel injection, an ignition device that controls ignition timing, and the like. Output control circuit **14**A may execute output control of engine **14** according to a command control signal(s) supplied from an electronic control unit **50**, described below. Such output control can include, for example, throttle control, fuel injection control, and ignition timing control.

[0043] Motor **22** can also be used to provide motive power in vehicle **100** and is powered electrically via a battery **44**. Battery **44** may be implemented as one or more batteries or other power storage devices including, for example, lead-acid batteries, nickel-metal hydride batteries, lithium ion batteries, capacitive storage devices, and so on. Battery **44** may be charged by a battery charger **45** that receives energy from internal combustion engine **14**. For example, an alternator or generator may be coupled directly or indirectly to a drive shaft of internal combustion engine **14** to generate an electrical current as a result of the operation of internal combustion engine **14**. A clutch can be included to engage/disengage the battery charger **45**. Battery **44** may also be charged by motor **22** such as, for example, by regenerative braking or by coasting during which time motor **22** operate as generator.

[0044] Motor **22** can be powered by battery **44** to generate a motive force to move the vehicle and adjust vehicle speed. Motor **22** can also function as a generator to generate electrical power such as, for example, when coasting or braking. Battery **44** may also be used to power other electrical or electronic systems in the vehicle. Motor **22** may be connected to battery **44** via an inverter **42**. Battery **44** can include, for example, one or more batteries, capacitive storage units, or other storage reservoirs suitable for storing electrical energy that can be used to power motor **22**. When battery **44** is implemented using one or more batteries, the batteries can include, for example, nickel metal hydride batteries, lithium ion batteries, lead acid batteries, nickel cadmium batteries, lithium ion polymer batteries, and other types of batteries.

[0045] An electronic control unit **50** (described below) may be included and may control the electric drive components of the vehicle as well as other vehicle components. For example, electronic control unit **50** may control inverter **42**, adjust driving current supplied to motor **22**, and adjust the current received from motor **22** during regenerative coasting and breaking. As a more particular example, output torque of the motor **22** can be increased or decreased by electronic control unit **50** through the inverter **42**.

[0046] A torque converter **16** can be included to control the application of power from engine **14** and motor **22** to transmission **18**. Torque converter **16** can include a viscous fluid coupling that transfers rotational power from the motive power source to the driveshaft via the transmission. Torque converter **16** can include a conventional torque converter or a lockup torque converter. In other embodiments, a mechanical clutch can be used in place of torque converter **16**.

[0047] Clutch **15** can be included to engage and disengage engine **14** from the drivetrain of the vehicle. In the illustrated example, a crankshaft **32**, which is an output member of engine **14**, may be selectively coupled to the motor **22** and torque converter **16** via clutch **15**. Clutch **15** can be implemented as, for example, a multiple disc type hydraulic frictional engagement device whose engagement is controlled by an actuator such as a hydraulic actuator. Clutch **15** may be controlled such that its engagement state is complete engagement, slip engagement, and complete disengagement complete disengagement, depending on the pressure applied to the clutch. For example, a torque capacity of clutch **15** may be controlled according to the hydraulic pressure supplied from a hydraulic control circuit (not illustrated). When clutch **15** is engaged, power transmission is provided in the power transmission path between the crankshaft **32** and torque converter **16**. On the other hand, when clutch **15** is disengaged, motive power from engine **14** is not delivered to the torque converter **16**. In a slip engagement state, clutch **15** is engaged, and motive power is provided to torque converter **16** according to a torque capacity (transmission torque) of the clutch **15**.

[0048] As alluded to above, vehicle **100** may include an electronic control unit **50**. Electronic control unit **50** may include circuitry to control various aspects of the vehicle operation. Electronic control unit **50** may include, for example, a microcomputer that includes a one or more processing units (e.g., microprocessors), memory storage (e.g., RAM, ROM, etc.), and I/O devices. The processing units of electronic control unit **50**, execute instructions stored in memory to control one or more electrical systems or subsystems in the vehicle. Electronic control unit **50** can include a plurality of electronic control units such as, for example, an electronic engine control module, a powertrain control module, a transmission control module, a suspension control module, a body control module, and so on. As a further example, electronic control units can be included to control systems and functions such as doors and door locking, lighting, human-machine interfaces, cruise control, telematics, braking systems (e.g., ABS or ESC), battery management systems, and so on. These various control units can be implemented using two or more separate electronic control units, or using a single electronic control unit.

[0049] In the example illustrated in FIG. **1**, electronic control unit **50** receives information from a plurality of sensors included in vehicle **100**. For example, electronic control unit **50** may receive signals that indicate vehicle operating conditions or characteristics, or signals that can be used to derive vehicle operating conditions or characteristics. These may include, but are not limited to

accelerator operation amount, A.sub.CC, a revolution speed, N.sub.E, of internal combustion engine **14** (engine RPM), a rotational speed, N.sub.MG, of the motor **22** (motor rotational speed), and vehicle speed, N.sub.V. These may also include torque converter **16** output, N.sub.T (e.g., output amps indicative of motor output), brake operation amount/pressure, B, battery SOC (i.e., the charged amount for battery **44** detected by an SOC sensor). Accordingly, vehicle **100** can include a plurality of sensors **52** that can be used to detect various conditions internal or external to the vehicle and provide sensed conditions to engine control unit **50** (which, again, may be implemented as one or a plurality of individual control circuits). In one embodiment, sensors **52** may be included to detect one or more conditions directly or indirectly such as, for example, fuel efficiency, E.sub.F, motor efficiency, E.sub.MG, hybrid (internal combustion engine **14**+MG **12**) efficiency, acceleration, A.sub.CC, etc.
[0050] In some embodiments, one or more of the sensors **52** may include their own processing capability to compute the results for additional information that can be provided to electronic control unit **50**. In other embodiments, one or more sensors may be data-gathering-only sensors that provide only raw data to electronic control unit **50**. In further embodiments, hybrid sensors may be included that provide a combination of raw data and processed data to electronic control unit **50**. Sensors **52** may provide an analog output or a digital output.
[0051] Sensors **52** may be included to detect not only vehicle conditions but also to detect external conditions as well. Sensors that might be used to detect external conditions can include, for example, sonar, radar, lidar or other vehicle proximity sensors, and cameras or other image sensors. Image sensors can be used to detect, for example, traffic signs indicating a current speed limit, road curvature, obstacles, and so on. Still other sensors may include those that can detect road grade. While some sensors can be used to actively detect passive environmental objects, other sensors can be included and used to detect active objects such as those objects used to implement smart roadways that may actively transmit and/or receive data or other information.
[0052] The example of FIG. **1** is provided for illustration purposes only as one example of vehicle systems with which embodiments of the disclosed technology may be implemented. One of ordinary skill in the art reading this description will understand how the disclosed embodiments can be implemented with this and other vehicle platforms.
[0053] FIG. **2** illustrates an example architecture for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein. In example **200**, illustrative vehicle components are provided including adaptive cruise control circuit **210**, a plurality of sensors **152**, and a plurality of vehicle systems **158**. Sensors **152** and vehicle systems **158** can communicate with adaptive cruise control circuit **210** via a wired or wireless communication interface. Although sensors **152** and vehicle systems **158** are depicted as communicating with adaptive cruise control circuit **210**, they can also communicate with each other as well as with other vehicle systems. Adaptive cruise control circuit **210** can be implemented as an ECU or as part of an ECU such as, for example electronic control unit **50**. In other embodiments, adaptive cruise control circuit **210** can be implemented independently of the ECU.
[0054] Adaptive cruise control circuit **210** in this example includes a communication circuit **201**, a decision circuit **203** (including a processor **206** and memory **208** in this example) and a power supply **212**. Components of adaptive cruise control circuit **210** are illustrated as communicating with each other via a data bus, although other communication in interfaces can be included. Adaptive cruise control circuit **210** in this example also includes a manual assist switch **205** that can be operated by the driver to manually select the ACC mode. Illustrative examples of manual assist switch **205** are provided in FIG. **4**.
[0055] Processor **206** can include one or more GPUs, CPUs, microprocessors, or any other suitable processing system. Processor **206** may include a single core or multicore processors. Memory **208** may include one or more various forms of memory or data storage (e.g., flash, RAM, etc.) that may be used to store the calibration parameters, images (analysis or historic), point parameters,

instructions and variables for processor **206** as well as any other suitable information. Memory **208**, can be made up of one or more modules of one or more different types of memory, and may be configured to store data and other information as well as operational instructions that may be used by the processor **206** to adaptive cruise control circuit **210**.

[0056] Although the example of FIG. **2** is illustrated using processor and memory circuitry, as described below with reference to circuits disclosed herein, decision circuit **203** can be implemented utilizing any form of circuitry including, for example, hardware, software, or a combination thereof. By way of further example, one or more processors, controllers, ASICs, PLAS, PALs, CPLDs, FPGAs, logical components, software routines or other mechanisms might be implemented to make up a adaptive cruise control circuit **210**.

[0057] Communication circuit **201** either or both a wireless transceiver circuit **202** with an associated antenna **205** and a wired I/O interface **204** with an associated hardwired data port (not illustrated). As this example illustrates, communications with adaptive cruise control circuit **210** can include either or both wired and wireless communications circuits **201**. Wireless transceiver circuit **202** can include a transmitter and a receiver (not shown) to allow wireless communications via any of a number of communication protocols such as, for example, Wifi, Bluetooth, near field communications (NFC), Zigbee, and any of a number of other wireless communication protocols whether standardized, proprietary, open, point-to-point, networked or otherwise. Antenna **205** is coupled to wireless transceiver circuit **202** and is used by wireless transceiver circuit **202** to transmit radio signals wirelessly to wireless equipment with which it is connected and to receive radio signals as well. These RF signals can include information of almost any sort that is sent or received by adaptive cruise control circuit **210** to/from other entities such as sensors **152** and vehicle systems **158**.

[0058] Wired I/O interface **204** can include a transmitter and a receiver (not shown) for hardwired communications with other devices. For example, wired I/O interface **204** can provide a hardwired interface to other components, including sensors **152** and vehicle systems **158**. Wired I/O interface **204** can communicate with other devices using Ethernet or any of a number of other wired communication protocols whether standardized, proprietary, open, point-to-point, networked or otherwise.

[0059] Power supply **212** can include one or more of a battery or batteries (such as, e.g., Li-ion, Li-Polymer, NiMH, NiCd, NiZn, and NiH2, to name a few, whether rechargeable or primary batteries,), a power connector (e.g., to connect to vehicle supplied power, etc.), an energy harvester (e.g., solar cells, piezoelectric system, etc.), or it can include any other suitable power supply.

[0060] Sensors **152** can include, for example, sensors **52** such as those described above with reference to the example of FIG. **1**. Sensors **152** can include additional sensors that may or may not otherwise be included on a standard vehicle **100** with which adaptive cruise control circuit **210** is implemented. In the illustrated example, sensors **152** include vehicle acceleration sensors **212**, vehicle speed sensors **214**, wheelspin sensors **216** (e.g., one for each wheel), a tire pressure monitoring system (TPMS) **220**, accelerometers such as a 3-axis accelerometer **222** to detect roll, pitch and yaw of the vehicle, vehicle clearance sensors **224**, left-right and front-rear slip ratio sensors **226**, and environmental sensors **228** (e.g., to detect salinity or other environmental conditions). Some sensors **152** may comprise cameras, lasers, and radar equipment in order to measure the distance between the ego vehicle and other vehicles on the roadway. In some examples, sensors **152** may comprise weight sensors incorporated with the seats of the vehicle or camera/image sensors to detect passengers in the vehicle in addition to the driver. Additional sensors **232** can also be included as may be appropriate for a given implementation of the adaptive cruise control (ACC) system.

[0061] Vehicle systems **158** can include any of a number of different vehicle components or subsystems used to control or monitor various aspects of the vehicle and its performance. In this example, the vehicle systems **158** include a GPS or other vehicle positioning system **272**; torque splitters **274** that can control distribution of power among the vehicle wheels such as, for example, by controlling front/rear and left/right torque split; engine control circuits **276** to control the operation of engine (e.g. Internal combustion engine **14**); cooling systems **278** to provide cooling for the motors, power electronics, the engine, or other vehicle systems; suspension system **280** such as, for example, an adjustable-height air suspension system, or an adjustable-damping suspension system; and other vehicle systems **282**.

[0062] During operation, adaptive cruise control circuit **210** can receive information from various vehicle sensors to determine whether the adaptive cruise control should be activated. Also, the driver may manually activate the adaptive cruise control by operating ACC switch **205**. Communication circuit **201** can be used to transmit and receive information between adaptive cruise control circuit **210** and sensors **152**, and adaptive cruise control circuit **210** and vehicle systems **158**. Also, sensors **152** may communicate with vehicle systems **158** directly or indirectly (e.g., via communication circuit **201** or otherwise).

[0063] In various embodiments, communication circuit **201** can be configured to receive data and other information from sensors **152** that is used in determining whether to activate the assist mode. Additionally, communication circuit **201** can be used to send an activation signal or other activation information to various vehicle systems **158** as part of entering the assist mode. For example, as described in more detail below, communication circuit **201** can be used to send signals to one or more of: torque splitters **274** to control front/rear torque split and left/right torque split; motor controllers **276** to, for example, control motor torque, motor speed of the various motors in the system; ICE control circuit **276** to, for example, control power to engine **14** (e.g., to shut down the engine so all power goes to the rear motors, to ensure the engine is running to charge the batteries or allow more power to flow to the motors); cooling system (e.g., **278** to increase cooling system flow for one or more motors and their associated electronics); suspension system **280** (e.g., to increase ground clearance such as by increasing the ride height using the air suspension). The decision regarding what action to take via these various vehicle systems **158** can be made based on the information detected by sensors **152**. Examples of this are described in more detail below.

[0064] FIG. **3** is an illustrative process for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein. In example **300**, a vehicle that implements adaptive cruise control (ACC) and an adaptive cruise control system for enabling the ACC are illustrated. In some examples, the ACC is part of an advanced driver-assistance system (ADAS). In some examples, the adaptive cruise control system is stored in a cloud-based architecture, although other implementations are available without diverting from the scope of the disclosure.

[0065] For example, the ADAS may receive the personalized adaptive cruise control profile from the adaptive cruise control system and use it to instruct the vehicle to implement particular operations in response to receiving instructions to comply with the profile. The ADAS may provide haptic, audible, or visual feedback to the driver to continue operations of the vehicle. In some examples, the ADAS may operate the vehicle under the supervision of the driver. In some examples, the ADAS may take over control of the vehicle from the driver.

[0066] At block **305**, the vehicle may include a plurality of sensors to determine characteristics about the driver of the vehicle and traffic events on the roadway. In some examples, the driver data and traffic events may be stored as event data.

[0067] Event data may comprise any detectable attributes of the environment surrounding or within the vehicle, which can be captured by the vehicle itself or another device. For example, the vehicle may include an image sensor (e.g., associated with a camera or with LIDAR) to detect light/darkness internal and external to the vehicle, a number of passengers in the vehicle, a number of vehicles surrounding the ego vehicle (e.g., to detect light or heavy traffic), recognizable landmarks (e.g., to detect urban or rural settings), paved or unpaved roadways, or other images that may be captured by the image sensors associated with the vehicle. In another example, the vehicle may comprise weight sensors in the seats of the vehicle to detect passengers in addition to the driver in the vehicle. In another example, the vehicle may comprise sensors to detect weather (e.g., sunny, rainy, 72 degrees, etc.) or receive weather reports from a third party source.

[0068] In some examples, the data may comprise metadata that is collected or generated with the event data. The metadata may identify, for example, location information collected from a global positioning system (GPS) sensor or other location-based sensor. In some examples, the metadata may identify the type of sensor that is generating the information that is stored and transmitted as metadata.

[0069] In some examples, the detection of a ACC trigger event, such as a cut-in or a cut-out event, may trigger storing of the event data. For example, the vehicle may have previously received a trained machine learning model that can categorize and detect a cut-in or a cut-out event. The vehicle may receive sensor input to provide to the machine learning model. The sensor input and other relevant information, along with the driver action and traffic event information, are captured and stored.

[0070] At block **310**, the vehicle may include a plurality of sensors facing outside the vehicle (e.g., forward-, backward-, side-, downward-looking sensors, etc.) to determine characteristics about the environment, ego vehicle, and other vehicles on the roadway. The vehicle may also include sensors to detect vehicle and environmental parameters. For example, illustrated in FIG. **2**, sensors **152** include vehicle acceleration sensors **212**, vehicle speed sensors **214**, wheelspin sensors **216** (e.g., one for each wheel), a tire pressure monitoring system (TPMS) **220**, accelerometers such as a 3-axis accelerometer **222** to detect roll, pitch and yaw of the vehicle, vehicle clearance sensors **224**, left-right and front-rear slip ratio sensors **226**, and environmental sensors **228** (e.g., to detect salinity or other environmental conditions).

[0071] At block **315**, the event data is sent to the adaptive cruise control system, including driver data and traffic events determined at block **305** and sensor data determined at block **310**.

[0072] At block **320**, the data store may receive multiple transmissions of data from multiple vehicles and drivers. In some examples, multiple or all of these vehicles may comprise adaptive cruise control circuit **210** illustrated in FIG. **2**.

[0073] At block **325**, the process may initiate data cleaning and feature selection. For example, data cleaning may identify and correct errors, inconsistencies, and inaccuracies in the transmissions of data from multiple vehicles and drivers. The data cleaning may comprise, for example, identifying missing data points. Once the missing data points are identified, the process may impute values or remove instances of the data transmitted from the vehicle sensors with missing information. The data cleaning may remove duplicate records to help avoid redundancy and potential biases. The data cleaning may detect outliers in the data, which can be removed or transmitted to a separate process to determine whether the outliers are accurate and should be used to retrain the machine learning model to incorporate the outlier. The data cleaning may initiate standardizing or normalizing numerical features of the data. The data cleaning process may remove typos, correct formatting issues, or remove/replace conflicting information. The process may also initiate feature selection to determine a subset of relevant features from a larger set of features in a dataset. The feature selection may reduce the dimensionality of the data while retaining important information for model training.

[0074] At block **330**, the process may initiate data labeling to help improve the training process for a supervised machine learning model. For example, the data labels can map correlations between input features and the corresponding output labels. The labeled data can be provided as a training data set for the machine learning model.

[0075] At block **355**, the process may provide the cleaned and labeled to a multi-step machine learning training pipeline. The machine learning algorithm clusters events and acceleration and braking behavior and filters out those for the cut-in and cut-out events. The multi-step machine learning training pipeline may comprise, for example, driver ACC event classifier **335**, cut-in cut-out event filtering **340**, acceleration and breaking pattern classifier **345**, and anomaly detection **350**.

[0076] Driver ACC event classifier **335** is configured to classify an event (e.g., with a start and end) based on a classification of the event by a trained, supervised machine learning model. For example, event data and metadata is received by driver ACC event classifier **335** and the output of the classifier is a label or other classification of the type of event based on a classification score associated with the event. In this sense, events that are classified with the same label (e.g., over a threshold value) can be clustered with other similar events.

[0077] Cut-in cut-out event filtering **340** is configured to determine the events that have been classified as corresponding with a cut-in event or an event corresponding with a cut-out event from the labels generated by driver ACC event classifier **335**. These events may be filtered and separately analyzed as part of the machine learning model training in generating a profile that models the driver's reactions to cut-in and cut-out events (e.g., speed up, slow down, etc.) with acceleration and breaking pattern classifier **345**.

[0078] Acceleration and breaking pattern classifier **345** is configured to determine a pattern of vehicle operations that detect the driver's reactions in speeding up or slowing down the vehicle in response to particular event data, metadata, or other factors. As an illustrative example, the driver may allow vehicles to cut-in when other passengers are in the vehicle or the vehicle is in a rural area, yet may not allow vehicles to cut-in when the driver is on a highway traveling at least 60 mph. When the event data is detected, the driver may exhibit a pattern of speeding up to not allow the cut-in event (e.g., with a threshold amount of space between the ego vehicle and a second vehicle directly in front if it). An aggregation of data is correlated to the acceleration and breaking pattern for the driver.

[0079] Anomaly detection **350** is configured to detect a driver's behavior that deviates from the driver's standard behavior (e.g., reactions or operations defined or predicted in a corresponding profile). For instance, during a cut-in event, a driver might slow down. In an anomalous situation, the driver might react differently, like changing lanes or speeding up unexpectedly.

[0080] The anomalous behavior may be detected and aggregated by a counter. When the counter exceeds a predetermined threshold, the anomalous behavior may be used to update the profile of the driver as recurring/predicted behavior. The anomalous operations may be removed from the profile as anomalies and added to a set of predicted future actions by the driver. The anomalous behavior may remain as an anomaly until the counter meets or exceeds the threshold value.

[0081] In some examples, block **355** is configured to create a personalized ACC profile for cut-in and cut-out events that aggregates/combines the output from driver ACC event classifier **335**, cut-in cut-out event filtering **340**, acceleration and breaking pattern classifier **345**, and anomaly detection **350**. The combination of each of the events/characteristics of the driver of the vehicle, the vehicle itself, the environment surrounding the vehicle or internal to the vehicle, and other factors may be used to create the profile.

[0082] At block **360**, a profile of personalized responses of the driver during cut-in and cut-out events is created. In some examples, the profile may identify a speed up or slow down action to perform by the vehicle when a set of characteristics are present in an environment, based on the driver's previous actions under similar settings.

[0083] At block **365**, the profile of personalized responses of the driver during cut-in and cut-out events is sent to a data repository of machine learning models. The machine learning model at block **365** may train a model to provide generalized responses to triggering events and other environment scenarios. For example, the machine learning models may be used for ADAS for multiple vehicles in addition to the personalized profile for the ego vehicle.

[0084] At block **370**, the profile of personalized responses of the driver during cut-in and cut-out events is sent to a personalization action engine. The machine learning models may be further tuned to be used for ADAS for a particular vehicle. As a comparison, block **365** can represent generalized machine learning models that handle event triggers, anomaly detection, and classification among other types of predictions, while block **370** may be tailored to a particular/individual drivers' preferences including gap maintenance, braking intensity, reaction time, etc.

[0085] At block **375**, the profile of personalized responses of the driver may be used during future cut-in events, cut-out events, or other trigger events by the vehicle. Using the profile while the vehicle is in operation, the profile provides rules/instructions for the vehicle to take while it is operating in ACC, which may be implemented by the ADAS. For example, if the driver prefers a slower and faster acceleration, the rule will instruct the ACC/vehicle to determine the environmental factors and provide slower and faster acceleration while the ACC is activated. If the driver prefers not to allow vehicles that are predicted to cut-in, the profile sends action information to the ADAS system to close the gap. The driver can deactivate the ACC and stop implementation of these actions determined by the profile, which again are detected/stored and sent to the adaptive cruise control system for training.

[0086] For faster response and in vehicles with suitable compute power, the adaptive cruise control system can be implemented at the vehicle. In turn, the machine learning training can be performed locally at the vehicle and locally update the models and personalized profile for future use.

[0087] FIG. **4** illustrates examples of activating and deactivating adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein. In example **400**, a driver of a vehicle may change the ACC setting in various ways. All of this information may be recorded in the data logger and sent to the adaptive cruise control system for analysis.

[0088] At block **410**, an interface in a vehicle is illustrated. In this example, the interface is incorporated with the dashboard of the vehicle adjacent to the speed of the vehicle, RPMs, odometer, and other features of the vehicle. In various embodiments, the interface may be provided in various other ways such as, for example, in a settings menu or vehicle menu for vehicle systems (e.g., actuated via a head unit, central display, etc.), on the cruise control stalk, via buttons on the steering wheel or console, via voice prompts and so on.

[0089] At block **420**, an ACC switch is illustrated. In this example, the ACC switch may be activated to set an input value for the ACC gap preference between the ego vehicle and a second vehicle directly in front of the ego vehicle. This may be preset by the factory or it may be a user selection based on AC input. The ego vehicle may measure the gap between the ego vehicle and a second vehicle. The second vehicle may be a measurable distance gap in front of ego vehicle during a cut-in or cut-out events.

[0090] At block **430**, the gas pedal may be used to adjust the ACC setting. For example, the gas pedal may override the ACC setting to allow the vehicle to accelerate and then return back to the set speed, but not typically cancel the ACC activation. Depressing the brake pedal, in some cases, will cancel the ACC activation. In some cases, the ACC activation may be set and cancelled via a dedicated interface, such as steering wheel buttons or a stalk.

[0091] In some examples, the gas pedal is used to change the ACC setting from a first speed to a second speed. When the gas pedal is released, the vehicle may return to the pre-set value when ACC was initially activated or remain at the current value when the gas pedal is released. The speed that the vehicle was traveling when the ACC switch was activated, distance between vehicles, and other event data may be determined and transmitted to the adaptive cruise control system (e.g., adaptive cruise control system in FIG. **3**).

[0092] At block **440**, the brake pedal may be used to deactivate the ACC. In this example, the brake pedal deactivates the ACC at a first speed and can immediate press the gas pedal to increase the speed while the ACC is deactivated or continue to press the brake pedal to slow down the vehicle. The driver may reactivate ACC using ACC switch (at block **420** or block **450**). The speed that the vehicle was traveling when the brake pedal was pressed, distance between vehicles, and other event data may be determined and transmitted to the adaptive cruise control system (e.g., adaptive cruise control system in FIG. **3**).

[0093] At block **450**, an ACC switch is illustrated. In this example, the ACC switch is a button attached to the steering wheel column and may activate ACC by pressing the button. In this example, the ACC switch may be activated to set an input value for the ACC gap preference between the ego vehicle and a second vehicle directly in front of the ego vehicle. The second vehicle may be a vehicle that is used to measure the gap in front of ego vehicle during a cut-in or cut-out event. The speed that the vehicle was traveling when the ACC switch was activated, distance between vehicles, and other event data may be determined and transmitted to the adaptive cruise control system (e.g., adaptive cruise control system in FIG. **3**).

[0094] FIG. **5** illustrates a cut-in event in accordance with some embodiments of the systems and methods described herein. In example **500**, personalized behavior of the driver of a vehicle is shown, including deactivation and reactivation of the ACC due to a second vehicle performing a "cut-in" in front of the ego vehicle. For example, the ADAS system may not recognize the cut-in fast enough, so the driver presses the brake pedal and deactivates the ACC. Then, the driver continues to accelerate and reactivates the ACC and sets a new, longer gap. As the speed increases, the driver may increase the gap even more.

[0095] In some embodiments of the disclosure, the series of events illustrated in example **500** may be used to train a machine learning model to generate a profile for the driver. For example, the event data and metadata that is generated at the time of these events may be correlated to the driver's reaction to the cut-in event illustrated in example **500**, to create a profile for the vehicle. When the event data and metadata is detected at a second time that is similar within a threshold value of the these events, the profile may instruct the vehicle to operate in accordance with the actions that the driver previously took under similar circumstances.

[0096] As illustrated, a first set of events may correspond with a time frame up to the time that the driver of the vehicle activates ACC. At block **505**, the ego vehicle is operating at 0 mph speed with a 0 foot gap in front of the vehicle. At block **510**, the ego vehicle is operating at 10 mph speed with a 50 foot gap in front of the vehicle. At block **515**, the ego vehicle is operating at 30 mph speed with a 100 foot gap in front of the vehicle. ACC is activated using one of the interfaces or buttons illustrated in FIG. **4**.

[0097] A second set of events may correspond with a time frame while the vehicle is operating with ACC activated and reacting to a cut-in event. At block **520**, the ego vehicle is operating at 40 mph speed with a 100 foot gap in front of the vehicle. The brake pedal is pressed, which slows the vehicle. The event data associated with the brake pedal and deactivation of the ACC is generated and stored, including the speed of the vehicle, driver/passenger characteristics, gap between the ego vehicle and other vehicles, location/time of the event, and other event data discussed herein. At block **525**, the ego vehicle is operating at 15 mph speed with a 150 foot gap in front of the vehicle, which corresponds with the vehicle slowing while ACC is deactivated.

[0098] A third set of events may correspond with the vehicle speeding up and reactivating ACC. At block **530**, the ego vehicle is operating at 30 mph speed with a 160 foot gap in front of the vehicle. At block **535**, the ego vehicle is operating at 38 mph speed with a 170 foot gap in front of the vehicle. At block **540**, the ego vehicle is operating at 45 mph speed with a 180 foot gap in front of the vehicle. At block **545**, the ego vehicle is operating at 50 mph speed with a 200 foot gap in front of the vehicle. ACC is activated using one of the interfaces or buttons illustrated in FIG. **4**. The event data associated with the reactivation of the ACC is generated and stored, as discussed herein.

[0099] A fourth set of events may correspond with increasing the gap between the ego vehicle and a second vehicle while ACC is active, and also detected an increased gap distance corresponding with an increased speed of the vehicle. At block **550**, the ego vehicle is operating at 60 mph speed with a 200 foot gap in front of the vehicle. At block **555**, the ego vehicle is operating at 70 mph speed with a 300 foot gap in front of the vehicle. At block **560**, the ego vehicle is operating at 80 mph speed with a 400 foot gap in front of the vehicle.

[0100] FIG. **6** illustrates a cut-out event in accordance with some embodiments of the systems and methods described herein. In example **600**, personalized behavior of the driver of a vehicle is shown, including deactivation and reactivation of the ACC due to a cut-out of a second vehicle in front of the ego vehicle. For example, the car suddenly accelerates and the driver has to brake and deactivate the ACC. Then, the driver continues to accelerate and reactivates the ACC and sets a new, longer gap. As the speed increases, the driver may increase the gap even more.

[0101] In some embodiments of the disclosure, the series of events illustrated in example **600** may be used to train a machine learning model to generate a profile for the driver. For example, the event data and metadata that is generated at the time of these events may be correlated to the driver's reaction to the cut-out event illustrated in example **600**, to create a profile for the vehicle. When the event data and metadata is detected at a second time that is similar within a threshold value of the these events, the profile may instruct the vehicle to operate in accordance with the actions that the driver previously took under similar circumstances.

[0102] As illustrated, a first set of events may correspond with a time frame up to the time that the driver of the vehicle activates ACC. At block **605**, the ego vehicle is operating at 0 mph speed with a 0 foot gap in front of the vehicle. At block **610**, the ego vehicle is operating at 15 mph speed with a 40 foot gap in front of the vehicle. At block **615**, the ego vehicle is operating at 30 mph speed with a 100 foot gap in front of the vehicle. ACC is activated using one of the interfaces or buttons illustrated in FIG. **4**.

[0103] A second set of events may correspond with a time frame while the vehicle is operating with ACC activated and reacting to a cut-out event. At block **620**, the ego vehicle is operating at 40 mph speed with a 100 foot gap in front of the vehicle. The second vehicle in front of ego vehicle initiates a cut-out operation. At block **625**, the ego vehicle is operating at 50 mph speed with a 140 foot gap in front of the vehicle. The brake pedal is pressed, which slows the vehicle. The event data associated with the brake pedal and deactivation of the ACC is generated and stored, including the speed of the vehicle, driver/passenger characteristics, gap between the ego vehicle and other vehicles, location/time of the event, and other event data discussed herein. At block **630**, the ego vehicle is operating at 38 mph speed with a 180 foot gap in front of the vehicle, which corresponds with the vehicle slowing while ACC is deactivated.

[0104] A third set of events may correspond with the vehicle speeding up and reactivating ACC. At block **635**, the ego vehicle is operating at 45 mph speed with a 190 foot gap in front of the vehicle. At block **640**, the ego vehicle is operating at 52 mph speed with a 190 foot gap in front of the vehicle. At block **645**, the ego vehicle is operating at 60 mph speed with a 190 foot gap in front of the vehicle. ACC is activated using one of the interfaces or buttons illustrated in FIG. **4**. The event data associated with the reactivation of the ACC is generated and stored, as discussed herein.

[0105] A fourth set of events may correspond with increasing the gap between the ego vehicle and a second vehicle while ACC is active, and also detected an increased gap distance corresponding with an increased speed of the vehicle. At block **650**, the ego vehicle is operating at 70 mph speed with a 300 foot gap in front of the vehicle. At block **655**, the ego vehicle is operating at 80 mph speed with a 400 foot gap in front of the vehicle.

[0106] FIG. **7** illustrates two vehicle driver profiles in accordance with some embodiments of the systems and methods described herein. In example **700**, personalized profiles of two different drivers and vehicles are shown. The different drivers have different deceleration and ACC usage. The same is true for cut-outs. These profiles are then stored in the adaptive cruise control system and in each of the ego vehicle and the second vehicle.

[0107] For a first driver, the vehicle encounters a cut-in event and accelerates with an adjusted gap setting after the cut-in event. At block **705**, both the ego vehicle and the second vehicle are operating at 0 mph speed with a 0 foot gap in front of the vehicle. At block **710**, the ego vehicle is operating at 15 mph speed with a 40 foot gap in front of the vehicle. At block **715**, the ego vehicle is operating at 30 mph speed with a 100 foot gap in front of the vehicle. ACC is activated and a gap distance is set. At block **720**, the ego vehicle is operating at 42 mph speed with a 100 foot gap in front of the vehicle. The cut-in event is detected and ACC is deactivated using the brake pedal. At block **725**, the ego vehicle is operating at 20 mph speed with a 150 foot gap in front of the vehicle. The vehicle decelerates after braking. At block **730**, the ego vehicle is operating at 30 mph speed with a 155 foot gap in front of the vehicle. At block **735**, the ego vehicle is operating at 40 mph speed with a 175 foot gap in front of the vehicle. At block **740**, the ego vehicle is operating at 45 mph speed with a 190 foot gap in front of the vehicle. At block **745**, the ego vehicle is operating at 50 mph speed with a 200 foot gap in front of the vehicle. ACC is reactivated and the gap distance is set. At block **750**, the ego vehicle is operating at 60 mph speed with a 200 foot gap in front of the vehicle. At block **755**, the ego vehicle is operating at 70 mph speed with a 300 foot gap in front of the vehicle. ACC is updated with a new gap distance setting. At block **760**, the ego vehicle is operating at 80 mph speed with a 400 foot gap in front of the vehicle. ACC is updated with another new gap distance setting.

[0108] In comparison, a second driver/vehicle also encounters a cut-in event and accelerates with an adjusted gap setting after the cut-in event. At block **770**, the second vehicle is operating at 15 mph speed with a 75 foot gap in front of the vehicle. At block **772**, the second vehicle is operating at 25 mph speed with a 100 foot gap in front of the vehicle. The cut-in event is detected and ACC is deactivated using the brake pedal. At block **774**, the second vehicle is operating at 15 mph speed with a 160 foot gap in front of the vehicle. At block **776**, the second vehicle is operating at 30 mph speed with a 240 foot gap in front of the vehicle. At block **778**, the second vehicle is operating at 40 mph speed with a 260 foot gap in front of the vehicle. At block **780**, the second vehicle is operating at 45 mph speed with a 300 foot gap in front of the vehicle. ACC is reactivated and the gap distance is set. At block **782**, the second vehicle is operating at 58 mph speed with a 310 foot gap in front of the vehicle. At block **784**, the second vehicle is operating at 65 mph speed with a 310 foot gap in front of the vehicle. At block **786**, the second vehicle is operating at 85 mph speed with a 310 foot gap in front of the vehicle. At block **788**, the second vehicle is operating at 100 mph speed with a 310 foot gap in front of the vehicle.

[0109] FIG. **8** is an illustrative process for implementing adaptive cruise control (ACC) in accordance with some embodiments of the systems and methods described herein. In example **800**, a vehicle system may perform various functions described herein, including the vehicle and the adaptive cruise control system illustrated in FIG. **3**. In some examples, the system may perform a series of operations and transmit instructions to vehicles described herein.

[0110] At block **810**, the process may capture event data comprising driver operations and traffic events associated with a cut-in cut-out event. For example, event data associated with driver operations may comprise any detectable attributes of the environment within the vehicle, which can be captured by the vehicle itself or another device. Event data associated with traffic events may comprise any detectable attributes of the environment outside of the vehicle, which can be captured by the vehicle itself or another device.

[0111] The event data may be determined by an image sensor (e.g., associated with a camera or with LIDAR) to detect light/darkness internal and external to the vehicle, a number of passengers in the vehicle, a number of vehicles surrounding the ego vehicle (e.g., to detect light or heavy traffic), recognizable landmarks (e.g., to detect urban or rural settings), paved or unpaved roadways, or other images that may be captured by the image sensors associated with the vehicle. In another example, the vehicle may comprise weight sensors in the seats of the vehicle to detect passengers in addition to the driver in the vehicle. In another example, the vehicle may comprise sensors to detect weather (e.g., sunny, rainy, 72 degrees, etc.) or receive weather reports from a third party source.

[0112] At block **820**, the process may optionally collect or generate metadata with the event data and traffic events. For example, metadata may be generated and transmitted with the event data. The metadata may identify a location where the event data is captured. In some examples, the metadata may identify a number of passengers that are traveling in the vehicle with the driver when the event data is captured. Other information may be stored as metadata, as further discussed herein.

[0113] At block **830**, the process may transmit the event data associated with the vehicle to an adaptive cruise control system. In some examples, the adaptive cruise control system uses the event data as input to a machine learning model. For example, the event data may be provided as input to a trained, supervised machine learning model and the output may be a label or other classification of the type of event based on a classification score associated with the event. In this sense, events that are classified with the same label (e.g., over a threshold value) can be clustered with other similar events.

[0114] In some examples, the process may determine the events that have been classified as corresponding with a cut-in event or an event corresponding with a cut-out event from the labels. These events may be filtered and separately analyzed as part of the machine learning model training in generating a profile that models the driver's reactions to cut-in and cut-out events (e.g., speed up, slow down, etc.).

[0115] In some examples, the profile defines rules to operate the vehicle in ACC to speed up or slow down the vehicle during a future cut-in cut-out event. The process may determine a pattern of vehicle operations that detect the driver's reactions in speeding up or slowing down the vehicle in response to particular event data, traffic events, or metadata. As an illustrative example, the driver may allow vehicles to cut-in when other passengers are in the vehicle or the vehicle is in a rural area, yet may not allow vehicles to cut-in when the driver is on a highway traveling at least 60 mph. When the event data is detected, the driver may exhibit a pattern of speeding up to not allow the cut-in event (e.g., with a threshold amount of space between the ego vehicle and a second vehicle directly in front if it). An aggregation of data is correlated to the acceleration and breaking pattern for the driver.

[0116] In some examples, training of the machine learning model updates a profile for the driver that characterizes an observed driving style of the driver in the vehicle during the cut-in cut-out event. For example, during the training, the process may map correlations between input features and the corresponding output labels. The labeled data can be provided as a training data set for the machine learning model.

[0117] At block **840**, the process may receive the profile at the vehicle. The profile may be received from the adaptive cruise control system. For example, the profile of personalized responses of the driver during cut-in and cut-out events is sent to the vehicle (e.g., a personalization action engine of the vehicle). The machine learning models may be further tuned to be used for ADAS for a particular vehicle.

[0118] At block **850**, the process may identify the future cut-in cut-out event and apply rules defined in the profile to correspond with the observed driving style of the driver. The future cut-in cut-out event may be identified when the vehicle is operating in ACC and the event is within a threshold value of the cut-in cut-out event (e.g., determined through the labeling process). For example, using the profile while the vehicle is in operation, the profile provides rules/instructions for the vehicle to take while it is operating in ACC, which may be implemented by the ADAS.

[0119] For faster response and in vehicles with suitable compute power, the adaptive cruise control system can be implemented at the vehicle. In turn, the machine learning training can be performed locally at the vehicle and locally update the models and personalized profile for future use.

[0120] As used herein, the terms circuit and component might describe a given unit of functionality that can be performed in accordance with one or more embodiments of the present application. As used herein, a component might be implemented utilizing any form of hardware, software, or a combination thereof. For example, one or more processors, controllers, ASICs, PLAS, PALs, CPLDs, FPGAs, logical components, software routines or other mechanisms might be implemented to make up a component. Various components described herein may be implemented as discrete components or described functions and features can be shared in part or in total among one or more components. In other words, as would be apparent to one of ordinary skill in the art after reading this description, the various features and functionality described herein may be implemented in any given application. They can be implemented in one or more separate or shared components in various combinations and permutations. Although various features or functional elements may be individually described or claimed as separate components, it should be understood that these features/functionality can be shared among one or more common software and hardware elements. Such a description shall not require or imply that separate hardware or software components are used to implement such features or functionality.

[0121] Where components are implemented in whole or in part using software, these software elements can be implemented to operate with a computing or processing component capable of carrying out the functionality described with respect thereto. One such example computing component is shown in FIG. **9**. Various embodiments are described in terms of this example-computing component **900**. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the application using other computing components or architectures.

[0122] Referring now to FIG. **9**, computing component **900** may represent, for example, computing or processing capabilities found within a self-adjusting display, desktop, laptop, notebook, and tablet computers. They may be found in hand-held computing devices (tablets, PDA's, smart phones, cell phones, palmtops, etc.). They may be found in workstations or other devices with displays, servers, or any other type of special-purpose or general-purpose computing devices as may be desirable or appropriate for a given application or environment. Computing component **900** might also represent computing capabilities embedded within or otherwise available to a given device. For example, a computing component might be found in other electronic devices such as, for example, portable computing devices, and other electronic devices that might include some form of processing capability.

[0123] Computing component **900** might include, for example, one or more processors, controllers, control components, or other processing devices. This can include a processor, and/or any one or more of the components making up a user device, user system, and non-decrypting cloud service. Processor **904** might be implemented using a general-purpose or special-purpose processing engine such as, for example, a microprocessor, controller, or other control logic. Processor **904** may be connected to a bus **902**. However, any communication medium can be used to facilitate interaction with other components of computing component **900** or to communicate externally.

[0124] Computing component **900** might also include one or more memory components, simply referred to herein as main memory **908**. For example, random access memory (RAM) or other dynamic memory, might be used for storing information and instructions to be executed by processor **904**. Main memory **908** might also be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **904**. Computing component **900** might likewise include a read only memory (“ROM”) or other static storage device coupled to bus **902** for storing static information and instructions for processor **904**.

[0125] The computing component **900** might also include one or more various forms of information storage mechanism **910**, which might include, for example, a media drive **912** and a storage unit interface **920**. The media drive **912** might include a drive or other mechanism to support fixed or removable storage media **914**. For example, a hard disk drive, a solid-state drive, a magnetic tape drive, an optical drive, a compact disc (CD) or digital video disc (DVD) drive (R or RW), or other removable or fixed media drive might be provided. Storage media **914** might include, for example, a hard disk, an integrated circuit assembly, magnetic tape, cartridge, optical disk, a CD or DVD. Storage media **914** may be any other fixed or removable medium that is read by, written to or accessed by media drive **912**. As these examples illustrate, the storage media **914** can include a computer usable storage medium having stored therein computer software or data.

[0126] In alternative embodiments, information storage mechanism **910** might include other similar

instrumentalities for allowing computer programs or other instructions or data to be loaded into computing component **900**. Such instrumentalities might include, for example, a fixed or removable storage unit **922** and an interface **920**. Examples of such storage units **922** and interfaces **920** can include a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory component) and memory slot. Other examples may include a PCMCIA slot and card, and other fixed or removable storage units **922** and interfaces **920** that allow software and data to be transferred from storage unit **922** to computing component **900**.
[0127] Computing component **900** might also include a communications interface **924**. Communications interface **924** might be used to allow software and data to be transferred between computing component **900** and external devices. Examples of communications interface **924** might include a modem or softmodem, a network interface (such as Ethernet, network interface card, IEEE 902.XX or other interface). Other examples include a communications port (such as for example, a USB port, IR port, RS232 port Bluetooth® interface, or other port), or other communications interface. Software/data transferred via communications interface **924** may be carried on signals, which can be electronic, electromagnetic (which includes optical) or other signals capable of being exchanged by a given communications interface **924**. These signals might be provided to communications interface **924** via a channel **928**. Channel **928** might carry signals and might be implemented using a wired or wireless communication medium. Some examples of a channel might include a phone line, a cellular link, an RF link, an optical link, a network interface, a local or wide area network, and other wired or wireless communications channels.
[0128] In this document, the terms “computer program medium” and “computer usable medium” are used to generally refer to transitory or non-transitory media. Such media may be, e.g., memory **908**, storage unit **920**, media **914**, and channel **928**. These and other various forms of computer program media or computer usable media may be involved in carrying one or more sequences of one or more instructions to a processing device for execution. Such instructions embodied on the medium, are generally referred to as “computer program code” or a “computer program product” (which may be grouped in the form of computer programs or other groupings). When executed, such instructions might enable the computing component **900** to perform features or functions of the present application as discussed herein.
[0129] It should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described. Instead, they can be applied, alone or in various combinations, to one or more other embodiments, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus, the breadth and scope of the present application should not be limited by any of the above-described exemplary embodiments.
[0130] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing, the term “including” should be read as meaning “including, without limitation” or the like. The term “example” is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof. The terms “a” or “an” should be read as meaning “at least one,” “one or more” or the like; and adjectives such as “conventional,” “traditional,” “normal,” “standard,” “known.” Terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time. Instead, they should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.
[0131] The presence of broadening words and phrases such as “one or more,” “at least,” “but not limited to” or other like phrases in some instances shall not be read to mean that the narrower case

is intended or required in instances where such broadening phrases may be absent. The use of the term “component” does not imply that the aspects or functionality described or claimed as part of the component are all configured in a common package. Indeed, any or all of the various aspects of a component, whether control logic or other components, can be combined in a single package or separately maintained and can further be distributed in multiple groupings or packages or across multiple locations.
[0132] Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams, flow charts and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their accompanying description should not be construed as mandating a particular architecture or configuration.

Claims

1. A vehicle control system in a vehicle configured to implement personalized adaptive cruise control (ACC), the vehicle control system comprising: an ACC circuit; a processor; and a memory coupled to the processor to store instructions, which when executed by the processor, cause the processor to perform operations, the operations comprising capture event data comprising driver operations and traffic events associated with a cut-in cut-out event; transmit the event data associated with the vehicle to an adaptive cruise control system, wherein the adaptive cruise control system uses the event data as input to a machine learning model, wherein training of the machine learning model updates a profile for a driver that characterizes an observed driving style of the driver in the vehicle during the cut-in cut-out event, and wherein the profile defines rules to operate the vehicle in ACC to speed up or slow down the vehicle during a future cut-in cut-out event; receive, from the adaptive cruise control system, the profile at the vehicle; and when the vehicle is operating in ACC and an event is within a threshold value of the cut-in cut-out event, identify the future cut-in cut-out event and apply rules defined in the profile to correspond with the observed driving style of the driver.
2. The vehicle control system of claim 1, wherein applying the rules defined in the profile include slowing down the vehicle to widen a gap between the vehicle and a second vehicle in front of the vehicle.
3. The vehicle control system of claim 1, wherein applying the rules defined in the profile include increasing speed of the vehicle to close a gap between the vehicle and a second vehicle in front of the vehicle.
4. The vehicle control system of claim 1, wherein the machine learning model comprise an event classifier that detects events while ACC is activated, a filtering module that separates cut-in cut-out events from other events while ACC is activated, and an acceleration and braking pattern classifier.
5. The vehicle control system of claim 1, wherein metadata is generated and transmitted with the event data, and the metadata identifies a location where the event data is captured.
6. The vehicle control system of claim 1, wherein metadata is generated and transmitted with the event data, and the metadata identifies a number of passengers that are traveling in the vehicle with the driver when the event data is captured.
7. The vehicle control system of claim 1, wherein the vehicle comprises weight sensors incorporated with seats of the vehicle or image sensors to detect passengers in the vehicle in addition to the driver, and incorporates the passengers with the driver with adjusting the profile.
8. The vehicle control system of claim 1, wherein metadata is generated and transmitted with the event data, and the metadata comprises location information collected from a global positioning system (GPS) sensor or other location-based sensor.
9. The vehicle control system of claim 1, wherein metadata is generated and transmitted with the

event data, and the metadata identifies a type of sensor that is generating information that is stored and transmitted as the metadata.

10. The vehicle control system of claim 1, wherein the adaptive cruise control system is located remote from the vehicle in a cloud-based server.

11. The vehicle control system of claim 1, wherein the adaptive cruise control system is located locally at the vehicle to update the machine learning model and the profile for future use.

12. The vehicle control system of claim 1, wherein the ACC circuit is part of an advanced driver-assistance system (ADAS).

13. A method of implementing personalized adaptive cruise control (ACC), the method comprising: capturing, by a vehicle control system comprising an ACC circuit, processor, and memory, event data comprising driver operations and traffic events associated with a cut-in cut-out event; transmitting, by a vehicle control system, the event data associated with the vehicle to an adaptive cruise control system, wherein the adaptive cruise control system uses the event data as input to a machine learning model, wherein training of the machine learning model updates a profile for a driver that characterizes an observed driving style of the driver in the vehicle during the cut-in cut-out event, and wherein the profile defines rules to operate the vehicle in ACC to speed up or slow down the vehicle during a future cut-in cut-out event; receiving, from the adaptive cruise control system, the profile at the vehicle; and when the vehicle is operating in ACC and an event is within a threshold value of the cut-in cut-out event, identifying the future cut-in cut-out event and applying rules defined in the profile to correspond with the observed driving style of the driver.

14. The method of claim 13, wherein applying the rules defined in the profile include slowing down the vehicle to widen a gap between the vehicle and a second vehicle in front of the vehicle.

15. The method of claim 13, wherein applying the rules defined in the profile include increasing speed of the vehicle to close a gap between the vehicle and a second vehicle in front of the vehicle.

16. The method of claim 13, wherein the machine learning model comprise an event classifier that detects events while ACC is activated, a filtering module that separates cut-in cut-out events from other events while ACC is activated, and an acceleration and braking pattern classifier.

17. The method of claim 13, wherein metadata is generated and transmitted with the event data, and the metadata identifies a location where the event data is captured.

18. The method of claim 13, wherein metadata is generated and transmitted with the event data, and the metadata identifies a number of passengers that are traveling in the vehicle with the driver when the event data is captured.

19. The method of claim 13, wherein the vehicle comprises weight sensors incorporated with seats of the vehicle or image sensors to detect passengers in the vehicle in addition to the driver, and incorporates the passengers with the driver with adjusting the profile.

20. The method of claim 13, wherein metadata is generated and transmitted with the event data, and the metadata comprises location information collected from a global positioning system (GPS) sensor or other location-based sensor.