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(54) **Title:** A MUTUAL NUDGE ALGORITHM FOR SELF-REVERSE LANE OF AUTONOMOUS DRIVING

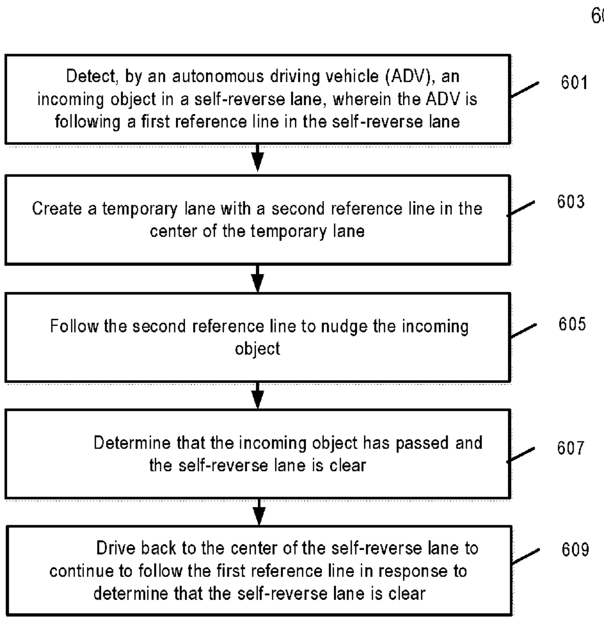

FIG. 6

(57) **Abstract:** According to various embodiments, systems and methods are provided for use by an ADV to nudge incoming objects in a self-reverse lane. In an embodiment, an ADV determines that a self-reverse lane has a predetermined width before entering the self-reverse lane. After entering the self-reverse lane, the ADV can follow a first reference line at the center of the self-reverse lane. In response to detecting an incoming object, the ADV creates an alternative lane in the self-reverse lane by temporarily modifying a high definition map. The ADV subsequently follows a second reference line in the alternative lane to nudge the incoming object. In response to detecting that the incoming object has passed and the self-reverse lane is clear, the ADV can drive back to the center of the self-reverse lane, to continue to follow the first reference line in the self-reverse lane.

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A MUTUAL NUDGE ALGORITHM FOR SELF-REVERSE LANE OF AUTONOMOUS DRIVING

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate generally to operating autonomous vehicles. More particularly, embodiments of the disclosure relate to a method for nudging an incoming vehicle in a self-reverse lane during autonomous driving.

BACKGROUND

[0002] Vehicles operating in an autonomous mode (e.g., driverless) can relieve occupants, especially the driver, from some driving-related responsibilities. When operating in an autonomous mode, the vehicle can navigate to various locations using onboard sensors and high-definition maps, allowing the vehicle to travel with minimal human interaction or in some cases without any passengers.

[0003] An autonomous driving vehicle (ADV) relies on various modules and lane markers in a high definition map to plan trajectories. In some special road segments in a high definition map, lane traffics in a single lane can travel in both directions. One such example is a self-reverse lane, which does not have lane markers for an ADV to track, and where the ADV can encounter incoming objects anytime in a single lane. Since such special road segments are generally infrequent in a high definition map, it would not be cost-efficient to modify well-tested modules in the ADV to navigate through these special road segments.

SUMMARY

[0004] In an aspect of the disclosure, embodiments of the disclosure provide a computer-implemented method for nudging incoming objects by an autonomous driving vehicle (ADV), including: detecting, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane; creating a temporary lane with a second reference line in the center of the temporary lane, following the second reference line to nudge the incoming object; determining that the incoming object has passed and the self-reverse lane is clear; and driving back to the center of the self-reverse lane to continue to follow the first reference line in response to determining that the first lane is clear.

[0005] In another aspect of the disclosure, embodiments of the disclosure provide a non-transitory machine-readable medium having instructions stored therein for nudging incoming objects by an autonomous driving vehicle (ADV), the instructions, when executed by a processor, causing the processor to perform operations, the operations comprising: determining, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane; creating a temporary lane and a second reference line in the temporary lane; following the second reference line to nudge the incoming object; determining that the incoming object has passed and the self-reverse lane is clear; and continuing to follow the first reference line in response to determining that the self-reverse lane is clear.

[0006] In another aspect of the disclosure, embodiments of the disclosure provide a data processing system, the system includes a processor; and a memory coupled to the processor to store instructions, which when executed by a processor, causing the processor to perform operations of nudging incoming objects by an autonomous driving vehicle (ADV), the operations including: determining, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane, creating a temporary lane with a second reference line in the center of the temporary lane, following the second reference line to nudge the incoming object, determining that the incoming object has passed and the self-reverse lane is clear, and continuing to follow the first reference line in response to determining that the self-reverse lane is clear.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of the disclosure are illustrated by way of example and not limitation in the figures of the accompanying drawings in which like references indicate similar elements.

[0008] Figure 1 is a block diagram illustrating a networked system according to one embodiment.

[0009] Figure 2 is a block diagram illustrating an example of an autonomous vehicle according to one embodiment.

[0010] Figures 3A-3B are block diagrams illustrating an example of a perception and planning system used with an autonomous vehicle according to one embodiment.

[0011] Figure 4 illustrates a system for nudging incoming vehicles in a self-reverse lane in accordance with an embodiment.

[0012] Figures 5A-5B illustrate an example process of nudging an incoming vehicle in a self-reverse lane in accordance with an embodiment.

[0013] Figure 6 is a flow diagram illustrating an example process of nudging incoming vehicles in a self-reverse lane in accordance with an embodiment.

[0014] Figure 7 is a block diagram illustrating an example of a da ta processing system which may be used with one embodiment.

DETAILED DESCRIPTION

[0015] Various embodiments and aspects of the disclosures will be described with reference to details discussed below, and the accompanying drawings will illustrate the various embodiments. The following description and drawings are illustrative of the disclosure and are not to be construed as limiting the disclosure. Numerous specific details are described to provide a thorough understanding of various embodiments of the present disclosure. However, in certain instances, well-known or conventional details are not described in order to provide a concise discussion of embodiments of the present disclosures.

[0016] Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in conjunction with the embodiment can be included in at least one embodiment of the disclosure. The appearances of the phrase "in one embodiment" in various places in the specification do not necessarily all refer to the same embodiment.

[0017] According to various embodiments, systems and methods are provided for use by an ADV to nudge incoming objects in a self-reverse lane. In an embodiment, an ADV determines that a self-reverse lane has a predetermined width before entering the self-reverse lane. After entering the self-reverse lane, the ADV can follow a first reference line at the center of the self-reverse lane. In response to detecting an incoming object, the ADV creates an alternative lane in the self-reverse lane by temporarily modifying a high definition map. The ADV subsequently follows a second reference line in the alternative lane to nudge the incoming object. In response to detecting that the incoming object has passed and the self-reverse lane is clear, the ADV can drive back to the center of the self-reverse lane, to continue to follow the first reference line in the self-reverse lane.

[0018] In an embodiment, the temporary lane is created in the high definition map that the ADV uses in generating trajectories. The temporary lane is created by generating a temporary lane boundary at a predetermined angle from a lane boundary of the self-reverse lane. When detecting that the self-reserve lane is clear, the ADV can follow a third reference line to drive back to the center of the self-reverse lane to continue to follow the first reference line.

[0019] In an embodiment, before entering the self-reverse lane, the ADV can determine whether the self-reverse lane that has a width that is bigger than the total of a width of the ADV, a width of the incoming object, and a predetermined buffer width. Although some of the embodiments of the disclosure are described using an incoming vehicle as example of the incoming object, the incoming object can be a bicycle, a motorcycle, a pedestrian, or another type of object.

[0020] Embodiments of the invention described herein can provide a mechanism for nudging incoming vehicles in a self-reverse lane without modifying planning algorithms used in an ADV. Instead, when the ADV enters a self-reverse lane, a separate module can be invoked to nudge incoming vehicles by dynamically updating a high definition map. As used herein, nudging an obstacle means taking actions to avoid colliding with or avoiding touching an obstacle. An example of a nudging action is to pass a vehicle on a high way.

Autonomous Driving Vehicle

[0021] Figure 1 is a block diagram illustrating an autonomous vehicle network configuration according to one embodiment of the disclosure. Referring to Figure 1, network configuration 100 includes autonomous vehicle 101 that may be communicatively coupled to one or more servers 103-104 over a network 102. Although there is one autonomous vehicle shown, multiple autonomous vehicles can be coupled to each other and/or coupled to servers 103-104 over network 102. Network 102 may be any type of networks such as a local area network (LAN), a wide area network (WAN) such as the Internet, a cellular network, a satellite network, or a combination thereof, wired or wireless. Server(s) 103-104 may be any kind of servers or a cluster of servers, such as Web or cloud servers, application servers, backend servers, or a combination thereof. Servers 103-104 may be data analytics servers, content servers, traffic information servers, map and point of interest (MPOI) servers, or location servers, etc.

[0022] An autonomous vehicle refers to a vehicle that can be configured to in an autonomous mode in which the vehicle navigates through an environment with little or no input from a driver. Such an autonomous vehicle can include a sensor system having one or more sensors that are configured to detect information about the environment in which the vehicle operates. The vehicle and its associated controller(s) use the detected information to navigate through the environment. Autonomous vehicle 101 can operate in a manual mode, a full autonomous mode, or a partial autonomous mode.

[0023] In one embodiment, autonomous vehicle 101 includes, but is not limited to, perception and planning system 110, vehicle control system 111, wireless communication system 112, user interface system 113, infotainment system 114, and sensor system 115. Autonomous vehicle 101 may further include certain common components included in ordinary vehicles, such as, an engine, wheels, steering wheel, transmission, etc., which may be controlled by vehicle control system 111 and/or perception and planning system 110 using a variety of communication signals and/or commands, such as, for example, acceleration signals or commands, deceleration signals or commands, steering signals or commands, braking signals or commands, etc.

[0024] Components 110-115 may be communicatively coupled to each other via an interconnect, a bus, a network, or a combination thereof. For example, components 110-115 may be communicatively coupled to each other via a controller area network (CAN) bus. A CAN bus is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. It is a message-based protocol, designed originally for multiplex electrical wiring within automobiles, but is also used in many other contexts.

[0025] Referring now to Figure 2, in one embodiment, sensor system 115 includes, but it is not limited to, one or more cameras 211, global positioning system (GPS) unit 212, inertial measurement unit (IMU) 213, radar unit 214, and a light detection and range (LIDAR) unit 215. GPS system 212 may include a transceiver operable to provide information regarding the position of the autonomous vehicle. IMU unit 213 may sense position and orientation changes of the autonomous vehicle based on inertial acceleration. Radar unit 214 may represent a system that utilizes radio signals to sense objects within the local environment of the autonomous vehicle. In some embodiments, in addition to sensing objects, radar unit 214 may additionally sense the speed and/or heading of the objects. LIDAR unit 215 may sense objects in the environment in which the autonomous vehicle is located using lasers. LIDAR unit 215 could include one or more laser sources, a laser scanner, and one or more detectors, among other system components. Cameras 211 may include one or more devices to capture images of the environment surrounding the autonomous vehicle. Cameras 211 may be still cameras and/or video cameras. A camera may be mechanically movable, for example, by mounting the camera on a rotating and/or tilting a platform.

[0026] Sensor system 115 may further include other sensors, such as, a sonar sensor, an infrared sensor, a steering sensor, a throttle sensor, a braking sensor, and an audio sensor (e.g., microphone). An audio sensor may be configured to capture sound from the environment surrounding the autonomous vehicle. A steering sensor may be configured to sense the steering angle of a steering wheel, wheels of the vehicle, or a combination thereof. A throttle sensor and a braking sensor sense the throttle position and braking position of the vehicle, respectively. In some situations, a throttle sensor and a braking sensor may be integrated as an integrated throttle/braking sensor.

[0027] In one embodiment, vehicle control system 111 includes, but is not limited to, steering unit 201, throttle unit 202 (also referred to as an acceleration unit), and braking unit 203. Steering unit 201 is to adjust the direction or heading of the vehicle. Throttle unit 202 is to control the speed of the motor or engine that in turn control the speed and acceleration of the vehicle. Braking unit 203 is to decelerate the vehicle by providing friction to slow the wheels or tires of the vehicle. Note that the components as shown in Figure 2 may be implemented in hardware, software, or a combination thereof.

[0028] Referring back to Figure 1, wireless communication system 112 is to allow communication between autonomous vehicle 101 and external systems, such as devices, sensors, other vehicles, etc. For example, wireless communication system 112 can wirelessly communicate with one or more devices directly or via a communication network, such as servers 103-104 over network 102. Wireless communication system 112 can use any cellular communication network or a wireless local area network (WLAN), e.g., using WiFi to communicate with another component or system. Wireless communication system 112 could communicate directly with a device (e.g., a mobile device of a passenger, a display device, a speaker within vehicle 101), for example, using an infrared link, Bluetooth, etc. User interface system 113 may be part of peripheral devices implemented within vehicle 101 including, for example, a keyboard, a touch screen display device, a microphone, and a speaker, etc.

[0029] Some or all of the functions of autonomous vehicle 101 may be controlled or managed by perception and planning system 110, especially when operating in an autonomous driving mode. Perception and planning system 110 includes the necessary hardware (e.g., processor(s), memory, storage) and software (e.g., operating system, planning and routing programs) to receive information from sensor system 115, control system 111, wireless communication system 112, and/or user interface system 113, process the received information, plan a route or path from a starting point to a destination point, and then drive vehicle 101 based on the planning and control information. Alternatively, perception and planning system 110 may be integrated with vehicle control system 111.

[0030] For example, a user as a passenger may specify a starting location and a destination of a trip, for example, via a user interface. Perception and planning system 110 obtains the trip related data. For example, perception and planning system 110 may obtain location and route information from an MPOI server, which may be a part of servers 103-104. The location server provides location services and the MPOI server provides map services and the POIs of certain locations. Alternatively, such location and MPOI information may be cached locally in a persistent storage device of perception and planning system 110.

[0031] While autonomous vehicle 101 is moving along the route, perception and planning system 110 may also obtain real-time traffic information from a traffic information system or server (TIS). Note that servers 103-104 may be operated by a third party entity. Alternatively, the functionalities of servers 103-104 may be integrated with perception and planning system 110. Based on the real-time traffic information, MPOI information, and location information, as well as real-time local environment data detected or sensed by sensor system 115 (e.g., obstacles, objects, nearby vehicles), perception and planning system 110 can plan an optimal route and drive vehicle 101, for example, via control system 111, according to the planned route to reach the specified destination safely and efficiently.

[0032] Server 103 may be a data analytics system to perform data analytics services for a variety of clients. In one embodiment, data analytics system 103 includes data collector 121 and machine learning engine 122. Data collector 121 collects driving statistics 123 from a variety of vehicles, either autonomous vehicles or regular vehicles driven by human drivers. Driving statistics 123 include information indicating the driving commands (e.g., throttle, brake, steering commands) issued and responses of the vehicles (e.g., speeds, accelerations, decelerations, directions) captured by sensors of the vehicles at different points in time. Driving statistics 123 may further include information describing the driving environments at different points in time, such as, for example, routes (including starting and destination locations), MPOIs, road conditions, weather conditions, etc.

[0033] Based on driving statistics 123, machine learning engine 122 generates or trains a set of rules, algorithms, and/or predictive models 124 for a variety of purposes, including algorithms for mutual nudging of incoming traffic. Algorithms 124 can then be uploaded on ADVs to be utilized during autonomous driving in real-time.

[0034] Figures 3A and 3B are block diagrams illustrating an example of a perception and planning system used with an autonomous vehicle according to one embodiment. System 300 may be implemented as a part of autonomous vehicle 101 of Figure 1 including, but is not limited to, perception and planning system 110, control system 111, and sensor system 115.

Referring to Figures 3A-3B, perception and planning system 110 includes, but is not limited to, localization module 301, perception module 302, prediction module 303, decision module 304, planning module 305, control module 306, routing module 307, and mutual nudge module 309.

[0035] Some or all of modules 301-309 may be implemented in software, hardware, or a combination thereof. For example, these modules may be installed in persistent storage device 352, loaded into memory 351, and executed by one or more processors (not shown). Note that some or all of these modules may be communicatively coupled to or integrated with some or all modules of vehicle control system 111 of Figure 2. Some of modules 301-309 may be integrated together as an integrated module.

[0036] Localization module 301 determines a current location of autonomous vehicle 300 (e.g., leveraging GPS unit 212) and manages any data related to a trip or route of a user. Localization module 301 (also referred to as a map and route module) manages any data related to a trip or route of a user. A user may log in and specify a starting location and a destination of a trip, for example, via a user interface. Localization module 301 communicates with other components of autonomous vehicle 300, such as map and route information 311, to obtain the trip related data. For example, localization module 301 may obtain location and route information from a location server and a map and POI (MPOI) server. A location server provides location services and an MPOI server provides map services and the POIs of certain locations, which may be cached as part of map and route information 311. While autonomous vehicle 300 is moving along the route, localization module 301 may also obtain real-time traffic information from a traffic information system or server.

[0037] Based on the sensor data provided by sensor system 115 and localization information obtained by localization module 301, a perception of the surrounding environment is determined by perception module 302. The perception information may represent what an ordinary driver would perceive surrounding a vehicle in which the driver is driving. The perception can include the lane configuration, traffic light signals, a relative position of another vehicle, a pedestrian, a building, crosswalk, or other traffic related signs (e.g., stop signs, yield signs), etc., for example, in a form of an object. The lane configuration includes information describing a lane or lanes, such as, for example, a shape of the lane (e.g., straight or curvature), a width of the lane, how many lanes in a road, one-way or two-way lane, merging or splitting lanes, exiting lane, etc.

[0038] Perception module 302 may include a computer vision system or functionalities of a computer vision system to process and analyze images captured by one or more cameras in order to identify objects and/or features in the environment of autonomous vehicle. The objects can include traffic signals, road way boundaries, other vehicles, pedestrians, and/or obstacles, etc. The computer vision system may use an object recognition algorithm, video tracking, and other computer vision techniques. In some embodiments, the computer vision system can map an environment, track objects, and estimate the speed of objects, etc. Perception module 302 can also detect objects based on other sensors data provided by other sensors such as a radar and/or LIDAR.

[0039] For each of the objects, prediction module 303 predicts what the object will behave under the circumstances. The prediction is performed based on the perception data perceiving the driving environment at the point in time in view of a set of map/rout information 311 and traffic rules 312. For example, if the object is a vehicle at an opposing direction and the current driving environment includes an intersection, prediction module 303 will predict whether the vehicle will likely move straight forward or make a turn. If the perception data indicates that the intersection has no traffic light, prediction module 303 may predict that the vehicle may have to fully stop prior to enter the intersection. If the perception data indicates that the vehicle is currently at a left-turn only lane or a right-turn only lane, prediction module 303 may predict that the vehicle will more likely make a left turn or right turn respectively.

[0040] For each of the objects, decision module 304 makes a decision regarding how to handle the object. For example, for a particular object (e.g., another vehicle in a crossing route) as well as its metadata describing the object (e.g., a speed, direction, turning angle), decision module 304 decides how to encounter the object (e.g., overtake, yield, stop, pass). Decision module 304 may make such decisions according to a set of rules such as traffic rules or driving rules 312, which may be stored in persistent storage device 352.

[0041] Routing module 307 is configured to provide one or more routes or paths from a starting point to a destination point. For a given trip from a start location to a destination location, for example, received from a user, routing module 307 obtains route and map information 311 and determines all possible routes or paths from the starting location to reach the destination location. Routing module 307 may generate a reference line in a form of a topographic map for each of the routes it determines from the starting location to reach the destination location.

[0042] A reference line refers to an ideal route or path without any interference from others such as other vehicles, obstacles, or traffic condition. That is, if there is no other vehicle, pedestrians, or obstacles on the road, an ADV should exactly or closely follows the reference line. The topographic maps are then provided to decision module 304 and/or planning module 305. Decision module 304 and/or planning module 305 examine all of the possible routes to select and modify one of the most optimal routes in view of other data provided by other modules such as traffic conditions from localization module 301, driving environment perceived by perception module 302, and traffic condition predicted by prediction module 303. The actual path or route for controlling the ADV may be close to or different from the reference line provided by routing module 307 dependent upon the specific driving environment at the point in time.

[0043] Based on a decision for each of the objects perceived, planning module 305 plans a path or route for the autonomous vehicle, as well as driving parameters (e.g., distance, speed, and/or turning angle), using a reference line provided by routing module 307 as a basis. That is, for a given object, decision module 304 decides what to do with the object, while planning module 305 determines how to do it. For example, for a given object, decision module 304 may decide to pass the object, while planning module 305 may determine whether to pass on the left side or right side of the object. Planning and control data is generated by planning module 305 including information describing how vehicle 300 would move in a next moving cycle (e.g., next route/path segment). For example, the planning and control data may instruct vehicle 300 to move 10 meters at a speed of 30 mile per hour (mph), then change to a right lane at the speed of 25 mph.

[0044] Based on the planning and control data, control module 306 controls and drives the autonomous vehicle, by sending proper commands or signals to vehicle control system 111, according to a route or path defined by the planning and control data. The planning and control data include sufficient information to drive the vehicle from a first point to a second point of a route or path using appropriate vehicle settings or driving parameters (e.g., throttle, braking, steering commands) at different points in time along the path or route.

[0045] In one embodiment, the planning phase is performed in a number of planning cycles, also referred to as driving cycles, such as, for example, in every time interval of 100 milliseconds (ms). For each of the planning cycles or driving cycles, one or more control commands will be issued based on the planning and control data. That is, for every 100 ms, planning module 305 plans a next route segment or path segment, for example, including a target position and the time required for the ADV to reach the target position. Alternatively, planning module 305 may further specify the specific speed, direction, and/or steering angle, etc. In one embodiment, planning module 305 plans a route segment or path segment for the next predetermined period of time such as 5 seconds. For each planning cycle, planning module 305 plans a target position for the current cycle (e.g., next 5 seconds) based on a target position planned in a previous cycle. Control module 306 then generates one or more control commands (e.g., throttle, brake, steering control commands) based on the planning and control data of the current cycle.

[0046] Note that decision module 304 and planning module 305 may be integrated as an integrated module. Decision module 304/planning module 305 may include a navigation system or functionalities of a navigation system to determine a driving path for the autonomous vehicle. For example, the navigation system may determine a series of speeds and directional headings to affect movement of the autonomous vehicle along a path that substantially avoids perceived obstacles while generally advancing the autonomous vehicle along a roadway-based path leading to an ultimate destination. The destination may be set according to user inputs via user interface system 113. The navigation system may update the driving path dynamically while the autonomous vehicle is in operation. The navigation system can incorporate data from a GPS system and one or more maps so as to determine the driving path for the autonomous vehicle.

[0047] The mutual nudge module 309 can implement a process for nudging incoming objects in a self-reverse lane by creating a temporary lane, and a drive-back lane by only modifying a high-definition map. Mutual nudge module 309 may be implemented or integrated as a part of planning module 305.

[0048] Note that some or all of the components as shown and described above may be implemented in software, hardware, or a combination thereof. For example, such components can be implemented as software installed and stored in a persistent storage device, which can be loaded and executed in a memory by a processor (not shown) to carry out the processes or operations described throughout this disclosure. Alternatively, such components can be implemented as executable code programmed or embedded into dedicated hardware such as an integrated circuit (e.g., an application specific IC or ASIC), a digital signal processor (DSP), or a field programmable gate array (FPGA), which can be accessed via a corresponding driver and/or operating system from an application. Furthermore, such components can be implemented as specific hardware logic in a processor or processor core as part of an instruction set accessible by a software component via one or more specific instructions.

Nudging Incoming Vehicles in a Self-Reverse Lane

[0049] Figure 4 illustrates a system for nudging incoming vehicles in a self-reverse lane in accordance with an embodiment. As shown in Figure 4, the mutual nudge module 309 can be provided in the ADV for planning trajectories when the ADV enters a self-reverse lane. In one embodiment, the planning module 305 can detect from a high definition map that the ADV has entered the self-reverse lane, and can pass the trajectory planning of the ADV to the mutual nudge module 309. After the ADV leaves the self-reverse lane, the trajectory planning can again be passed to the planning module 305.

[0050] In one embodiment, the ADV can enter a self-reverse lane in response to the ADV determining that the width of the self-reverse lane exceeds a predetermined limit. In one example, the predetermined limit can be twice the width of the ADV plus a fixed value (e.g., 1 meter), and this predetermined limit can be adjusted based on traffic data collected over time.

[0051] In one embodiment, the mutual nudge module 309 can implement a process using a temporarily modified map to nudge incoming objects in a self-reverse lane. Although this figure uses an incoming vehicle as an example of the incoming object, the process described herein can similarly be used to nudge other types of objects, e.g., motorcycles and bicycles, in a self-reverse lane.

[0052] In an embodiment, after entering the self-reverse lane, the ADV can follow a first reference line at the lane center. In response to detecting an incoming object, the ADV can temporarily modify a high definition map stored in the map and route information database 311 to create an alternative lane 403 in the self-reverse lane. The ADV can subsequently follow a second reference line at the center of the alternative lane 403. The high definition map can also be modified to create a drive-back lane 405, for use by the ADV to drive back to the center of the self-reverse lane when the incoming object has passed and the self-reverse lane is clear.

[0053] Figures 5A-5B illustrate an example process of nudging an incoming vehicle in a self-reverse lane in accordance with an embodiment. In Figure 5A, self-reverse lane boundary A 505 and self-reverse lane boundary B 507 mark a self-server lane, in which a master ADV (also referred to as an ego ADV) 501 is travelling at the center of the self-reverse lane by following a main reference line 513. When detecting an incoming vehicle 503 in the self-reverse lane, the master ADV 501 can determine whether the width of the self-reverse lane exceeds a predetermined threshold, e.g., the sum of the width of the master ADV 501, the width of the incoming vehicle 503, and/or a safety buffer (e.g., 1 meter). If the width of the self-reverse lane does not exceed the threshold, the master ADV can back out of the self-reverse lane. However, if the width of the self-reverse lane exceeds the threshold, the mutual nudge module in the master ADV can modify a high definition map that the master ADV is using to create a temporary lane, which can have a temporary lane boundary 511 as one lane boundary, and self-reverse lane boundary B 507 as the other lane boundary. When creating the temporary lane 511, the mutual nudge module can simultaneously create a secondary reference line 515 at the center of the temporary lane.

[0054] In an embodiment, a nudge angle (e.g., 30°) 509 can be used to create the temporary lane. Accordingly, the master ADV needs to turn the nudge angle towards self-reverse lane boundary B 507 to follow the secondary reference line 515. In an embodiment, the nudge angle is determined based on past data and can be changed to another angle if historical data shows a different angle might be more appropriate.

[0055] In Figure 5B, the incoming vehicle 505 has passed the master ADV 501, and the self-reverse lane is clear to the master ADV 501. The master ADV 501 is to return to the center of the self-reverse lane to continue to follow the main reference line 513. As shown in Figure 5B, the mutual nudge module can create a drive-back lane marked by temporary lane boundary 519 and the secondary reference line 515. When the drive-back lane is created, a drive-back reference line 516 can be simultaneously created for the master ADV to follow to drive towards the main reference line 513. In one embodiment, the temporary lane boundary 519 can be created at a drive-back angle 517. In one embodiment, the drive-back angle can be the same as the nudge angle 508 described in Figure 5A.

[0056] In an embodiment, after the master ADV leave the self-reverse lane, the trajectory planning for the ADV can again be passed back to a regular planning module, such as the planning module 304 in Figure 4.

[0057] Figure 6 is a flow diagram illustrating an example process of nudging incoming vehicles in a self-reverse lane in accordance with an embodiment. Process 600 may be performed by processing logic that may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, a processor, a processing device, a central processing unit (CPU), a system-on-chip (SoC), etc.), software (e.g., instructions running/executing on a processing device), firmware (e.g., microcode), or a combination thereof. In some embodiments, process 600 may be performed by one or more of perception module 302, planning module 305, routing module 307, and mutual nudge module 309 illustrated in Figure 3A and Figure 3B.

[0058] Referring to Figure 6, in operation 601, an ADV detects an incoming object in a self-reverse lane, where the ADV is travelling by following a reference line at the center of the self-reverse lane. The incoming object is driving towards the ADV, and its width plus the width the ADV and a predetermined buffer width would not exceed the width the self-reverse lane. Otherwise, the ADV may need to back out of the self-reverse lane to avoid scratching, or colliding with, the incoming object, which can be a vehicle, a bicycle, or a pedestrian.

[0059] In operation 603, a temporary lane is created by the ADV by temporarily modifying a high definition map that the ADV is using for generating trajectories. The temporary lane can be created at a nudge angle from a boundary of the self-reverse lane. When creating the temporary lane, the ADV simultaneously creates a secondary reference line at the center of the temporary lane.

[0060] In operation 605, the ADV turns at a predetermined nudge angle to follow the second reference line. The nudge angle can be determined based on historical data. In one example, the nudge angle is 30°. In operation 607, the ADV determines that the incoming object has been successfully nudged and the self-reverse lane is clear.

[0061] In operation 609, the ADV can return to the center of the self-reverse lane to continue to follow the first reference line. In an embodiment, the ADV can create a drive-back lane with a third reference line at the center for the ADV to follow in getting back to the center of the self-reverse lane. The temporary lane boundary 611 can be created at a drive-back angle 609. In one embodiment, the drive-back angle can be the same as the nudge angle.

[0062] Note that some or all of the components as shown and described above may be implemented in software, hardware, or a combination thereof. For example, such components can be implemented as software installed and stored in a persistent storage device, which can be loaded and executed in a memory by a processor (not shown) to carry out the processes or operations described throughout this disclosure. Alternatively, such components can be implemented as executable code programmed or embedded into dedicated hardware such as an integrated circuit (e.g., an application specific IC or ASIC), a digital signal processor (DSP), or a field programmable gate array (FPGA), which can be accessed via a corresponding driver and/or operating system from an application. Furthermore, such components can be implemented as specific hardware logic in a processor or processor core as part of an instruction set accessible by a software component via one or more specific instructions.

[0063] Figure 7 a block diagram illustrating an example of a data processing system which may be used with one embodiment of the disclosure. For example, system 1500 may represent any of data processing systems described above performing any of the processes or methods described above, such as, for example, the mutual nudge module 309 of Figure 3A. System 1500 can include many different components. These components can be implemented as integrated circuits (ICs), portions thereof, discrete electronic devices, or other modules adapted to a circuit board such as a motherboard or add-in card of the computer system, or as components otherwise incorporated within a chassis of the computer system.

[0064] Note also that system 1500 is intended to show a high level view of many components of the computer system. However, it is to be understood that additional components may be present in certain implementations and furthermore, different arrangement of the components shown may occur in other implementations. System 1500 may represent a desktop, a laptop, a tablet, a server, a mobile phone, a media player, a personal digital assistant (PDA), a Smartwatch, a personal communicator, a gaming device, a network router or hub, a wireless access point (AP) or repeater, a set-top box, or a combination thereof. Further, while only a single machine or system is illustrated, the term “machine” or “system” shall also be taken to include any collection of machines or systems that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

[0065] In one embodiment, system 1500 includes processor 1501, memory 1503, and devices 1505-1508 connected via a bus or an interconnect 1510. Processor 1501 may represent a single processor or multiple processors with a single processor core or multiple processor cores included therein. Processor 1501 may represent one or more general-purpose processors such as a microprocessor, a central processing unit (CPU), or the like. More particularly, processor 1501 may be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or processor implementing other instruction sets, or processors implementing a combination of instruction sets. Processor 1501 may also be one or more special-purpose processors such as an application specific integrated circuit (ASIC), a cellular or baseband processor, a field programmable gate array (FPGA), a digital signal processor (DSP), a network processor, a graphics processor, a communications processor, a cryptographic processor, a co-processor, an embedded processor, or any other type of logic capable of processing instructions.

[0066] Processor 1501, which may be a low power multi-core processor socket such as an ultra-low voltage processor, may act as a main processing unit and central hub for communication with the various components of the system. Such processor can be implemented as a system on chip (SoC). Processor 1501 is configured to execute instructions for performing the operations and steps discussed herein. System 1500 may further include a graphics interface that communicates with optional graphics subsystem 1504, which may include a display controller, a graphics processor, and/or a display device.

[0067] Processor 1501 may communicate with memory 1503, which in one embodiment can be implemented via multiple memory devices to provide for a given amount of system memory. Memory 1503 may include one or more volatile storage (or memory) devices such as random access memory (RAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), static RAM (SRAM), or other types of storage devices. Memory 1503 may store information including sequences of instructions that are executed by processor 1501, or any other device. For example, executable code and/or data of a variety of operating systems, device drivers, firmware (e.g., input output basic system or BIOS), and/or applications can be loaded in memory 1503 and executed by processor 1501. An operating system can be any kind of operating systems, such as, for example, Robot Operating System (ROS), Windows® operating system from Microsoft®, Mac OS®/iOS® from Apple, Android® from Google®, LINUX, UNIX, or other real-time or embedded operating systems.

[0068] System 1500 may further include IO devices such as devices 1505-1508, including network interface device(s) 1505, optional input device(s) 1506, and other optional IO device(s) 1507. Network interface device 1505 may include a wireless transceiver and/or a network interface card (NIC). The wireless transceiver may be a WiFi transceiver, an infrared transceiver, a Bluetooth transceiver, a WiMax transceiver, a wireless cellular telephony transceiver, a satellite transceiver (e.g., a global positioning system (GPS) transceiver), or other radio frequency (RF) transceivers, or a combination thereof. The NIC may be an Ethernet card.

[0069] Input device(s) 1506 may include a mouse, a touch pad, a touch sensitive screen (which may be integrated with display device 1504), a pointer device such as a stylus, and/or a keyboard (e.g., physical keyboard or a virtual keyboard displayed as part of a touch sensitive screen). For example, input device 1506 may include a touch screen controller coupled to a touch screen. The touch screen and touch screen controller can, for example, detect contact and movement or break thereof using any of a plurality of touch sensitivity technologies, including but not limited to capacitive, resistive, infrared, and surface acoustic wave technologies, as well as other proximity sensor arrays or other elements for determining one or more points of contact with the touch screen.

[0070] IO devices 1507 may include an audio device. An audio device may include a speaker and/or a microphone to facilitate voice-enabled functions, such as voice recognition, voice replication, digital recording, and/or telephony functions. Other IO devices 1507 may further include universal serial bus (USB) port(s), parallel port(s), serial port(s), a printer, a network interface, a bus bridge (e.g., a PCI-PCI bridge), sensor(s) (e.g., a motion sensor such as an accelerometer, gyroscope, a magnetometer, a light sensor, compass, a proximity sensor, etc.), or a combination thereof. Devices 1507 may further include an imaging processing subsystem (e.g., a camera), which may include an optical sensor, such as a charged coupled device (CCD) or a complementary metal-oxide semiconductor (CMOS) optical sensor, utilized to facilitate camera functions, such as recording photographs and video clips. Certain sensors may be coupled to interconnect 1510 via a sensor hub (not shown), while other devices such as a keyboard or thermal sensor may be controlled by an embedded controller (not shown), dependent upon the specific configuration or design of system 1500.

[0071] To provide for persistent storage of information such as data, applications, one or more operating systems and so forth, a mass storage (not shown) may also couple to processor 1501. In various embodiments, to enable a thinner and lighter system design as well as to improve system responsiveness, this mass storage may be implemented via a solid state device (SSD). However in other embodiments, the mass storage may primarily be implemented using a hard disk drive (HDD) with a smaller amount of SSD storage to act as a SSD cache to enable non-volatile storage of context state and other such information during power down events so that a fast power up can occur on re-initiation of system activities. Also a flash device may be coupled to processor 1501, e.g., via a serial peripheral interface (SPI). This flash device may provide for non-volatile storage of system software, including BIOS as well as other firmware of the system.

[0072] Storage device 1508 may include computer-accessible storage medium 1509 (also known as a machine-readable storage medium or a computer-readable medium) on which is stored one or more sets of instructions or software (e.g., module, unit, and/or logic 1528) embodying any one or more of the methodologies or functions described herein. Processing module/unit/logic 1528 may represent any of the components described above, such as, for example, planning module 305, control module 306, and virtual vehicle module 309. Processing module/unit/logic 1528 may also reside, completely or at least partially, within memory 1503 and/or within processor 1501 during execution thereof by data processing system 1500, memory 1503 and processor 1501 also constituting machine-accessible storage media. Processing module/unit/logic 1528 may further be transmitted or received over a network via network interface device 1505.

[0073] Computer-readable storage medium 1509 may also be used to store the some software functionalities described above persistently. While computer-readable storage medium 1509 is shown in an exemplary embodiment to be a single medium, the term "computer-readable storage medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The terms "computer-readable storage medium" shall also be taken to include any medium that is capable of storing or encoding a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure. The term "computer-readable storage medium" shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media, or any other non-transitory machine-readable medium.

[0074] Processing module/unit/logic 1528, components and other features described herein can be implemented as discrete hardware components or integrated in the functionality of hardware components such as ASICS, FPGAs, DSPs or similar devices. In addition, processing module/unit/logic 1528 can be implemented as firmware or functional circuitry within hardware devices. Further, processing module/unit/logic 1528 can be implemented in any combination hardware devices and software components.

[0075] Note that while system 1500 is illustrated with various components of a data processing system, it is not intended to represent any particular architecture or manner of interconnecting the components; as such details are not germane to embodiments of the present disclosure. It will also be appreciated that network computers, handheld computers, mobile phones, servers, and/or other data processing systems which have fewer components or perhaps more components may also be used with embodiments of the disclosure.

[0076] Some portions of the preceding detailed descriptions have been presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the ways used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities.

[0077] It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the above discussion, it is appreciated that throughout the description, discussions utilizing terms such as those set forth in the claims below, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0078] Embodiments of the disclosure also relate to an apparatus for performing the operations herein. Such a computer program is stored in a non-transitory computer readable medium. A machine-readable medium includes any mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a machine-readable (e.g., computer-readable) medium includes a machine (e.g., a computer) readable storage medium (e.g., read only memory ("ROM"), random access memory ("RAM"), magnetic disk storage media, optical storage media, flash memory devices).

[0079] The processes or methods depicted in the preceding figures may be performed by processing logic that comprises hardware (e.g. circuitry, dedicated logic, etc.), software (e.g., embodied on a non-transitory computer readable medium), or a combination of both. Although the processes or methods are described above in terms of some sequential operations, it should be appreciated that some of the operations described may be performed in a different order. Moreover, some operations may be performed in parallel rather than sequentially.

[0080] Embodiments of the present disclosure are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of embodiments of the disclosure as described herein.

[0081] In the foregoing specification, embodiments of the disclosure have been described with reference to specific exemplary embodiments thereof. It will be evident that various modifications may be made thereto without departing from the broader spirit and scope of the disclosure as set forth in the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

CLAIMS

What is claimed is:

1. A computer-implemented method for nudging incoming objects by an autonomous driving vehicle (ADV), comprising:

detecting, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane;

creating a temporary lane with a second reference line in the center of the temporary lane,

following the second reference line to nudge the incoming object;

determining that the incoming object has passed and the self-reverse lane is clear; and

driving back to the center of the self-reverse lane to continue to follow the first reference line in response to determining that the first lane is clear.

2. The method of claim 1, further comprising determining, prior to creating the temporary lane to nudge the incoming object, that the self-reserve lane has a width that is wider than a sum of a width of the ADV, a width of the incoming object, and a width of a predetermined buffer.

3. The method of claim 1, wherein the temporary lane is created by modifying a high definition map that the ADV uses in generating trajectories.

4. The method of claim 3, wherein the temporary lane is created by generating a temporary

lane boundary at a predetermined angle from a lane boundary of the self-reverse lane.

5. The method of claim 1, wherein the ADV follows a third reference line to drive back to the center of the self-reverse lane after the ADV determines that the self-reverse lane is clear.

6. The method of claim 1, wherein the first reference line is at the center of the self-reverse lane, and the second reference line is at the center of the temporary lane.

7. The method of claim 1, wherein the ADV determines that the self-reverse lane has a predetermined width before entering the self-reverse lane.

8. The method of claim1, wherein the incoming object is one of a vehicle, a bicycle, a motorcycle, or a pedestrian.

9. A non-transitory machine-readable medium having instructions stored therein for nudging incoming objects by an autonomous driving vehicle (ADV), the instructions, when executed by a processor, causing the processor to perform operations, the operations comprising:

determining, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane;

creating a temporary lane and a second reference line in the temporary lane;

following the second reference line to nudge the incoming object;

determining that the incoming object has passed and the self-reverse lane is clear; and continuing to follow the first reference line in response to determining that the self-reverse lane is clear.

10. The machine-readable medium of claim 9, further comprising determining, prior to creating the temporary lane to nudge the incoming object, that the self-reserve lane has a width that is wider than a sum of a width of the ADV, a width of the incoming object, and a width of a predetermined buffer.

11. The machine-readable medium of claim 9, wherein the temporary lane is created by modifying a high definition map that the ADV uses in generating trajectories.

12. The machine-readable medium of claim 11, wherein the temporary lane is created by generating a temporary lane boundary at a predetermined angle from a lane boundary of the self-reverse lane.

13. The machine-readable medium of claim 9, wherein the ADV follows a third reference line to drive back to the center of the self-reverse lane after the ADV determines that the self-reverse lane is clear.

14. The machine-readable medium of claim 9, wherein the first reference line is at the center of the self-reverse lane, and the second reference line is at the center of the temporary lane.

15. The machine-readable medium of claim 9, wherein the ADV determines that the self-reverse lane has a predetermined width before entering the self-reverse lane.

16. The machine-readable medium of claim 9, wherein the incoming object is one of a vehicle, a bicycle, a motorcycle, or a pedestrian.

17. A data processing system, comprising:

a processor; and

a memory coupled to the processor to store instructions, which when executed by a processor, causing the processor to perform operations of nudging incoming objects by an autonomous driving vehicle (ADV), the operations comprising:

determining, by the ADV, an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane,

creating a temporary lane with a second reference line in the center of the temporary lane,

following the second reference line to nudge the incoming object,

determining that the incoming object has passed and the self-reverse lane is clear, and

continuing to follow the first reference line in response to determining that the self-reverse lane is clear.

18. The system of claim 17, further comprising determining, prior to creating the temporary lane to nudge the incoming object, that the self-reserve lane has a width that is wider than a sum

of a width of the ADV, a width of the incoming object, and a width of a predetermined buffer.

19. The system of claim 17, wherein the temporary lane is created by modifying a high definition map that the ADV uses in generating trajectories.

20. The system of claim 17, wherein the temporary lane is created by modifying a high definition map that the ADV uses in generating trajectories.

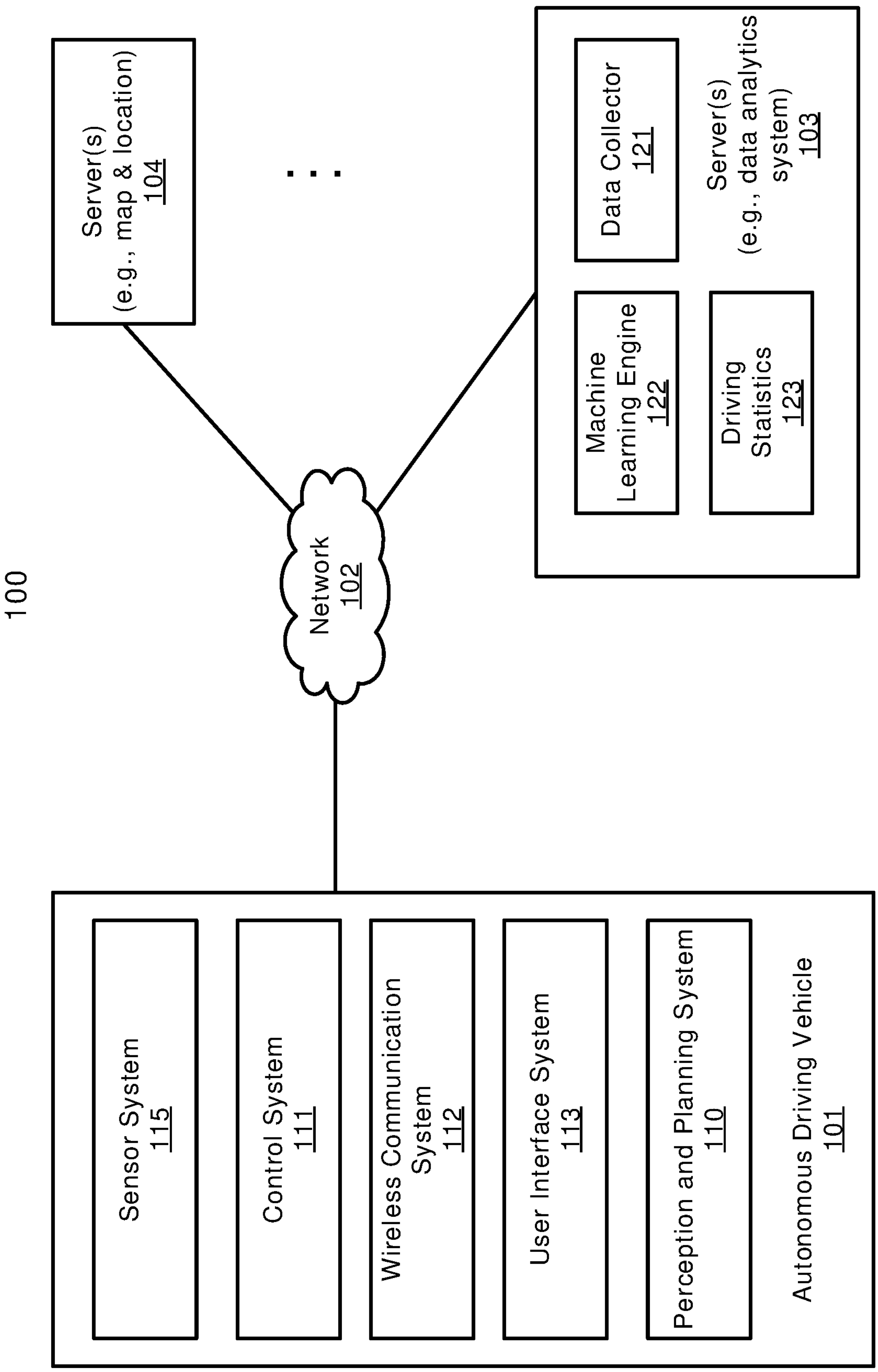
100
Server(s)
(e.g., map & location)
104
. . .
Network
102
Data Collector
121
Machine
Learning Engine
122
Driving
Statistics
123
Server(s)
(e.g., data analytics
system)
103
Sensor System
115
Control System
111
Wireless Communication
System
112
User Interface System
113
Perception and Planning System
110
Autonomous Driving Vehicle
101

FIG. 1

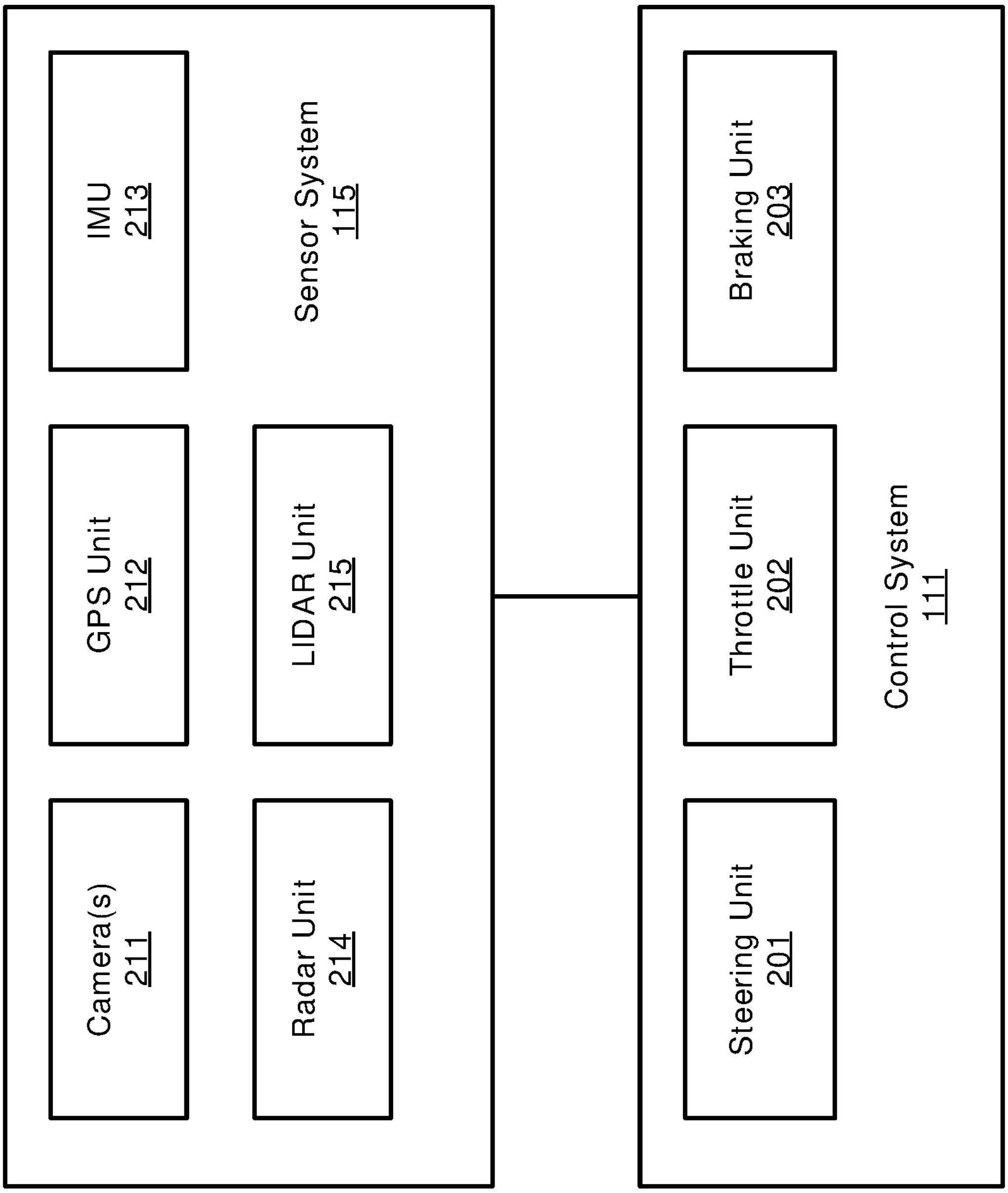
Sensor System
115
Camera(s)
211
GPS Unit
212
IMU
213
Radar Unit
214
LIDAR Unit
215
Control System
111
Steering Unit
201
Throttle Unit
202
Braking Unit
203

FIG. 2

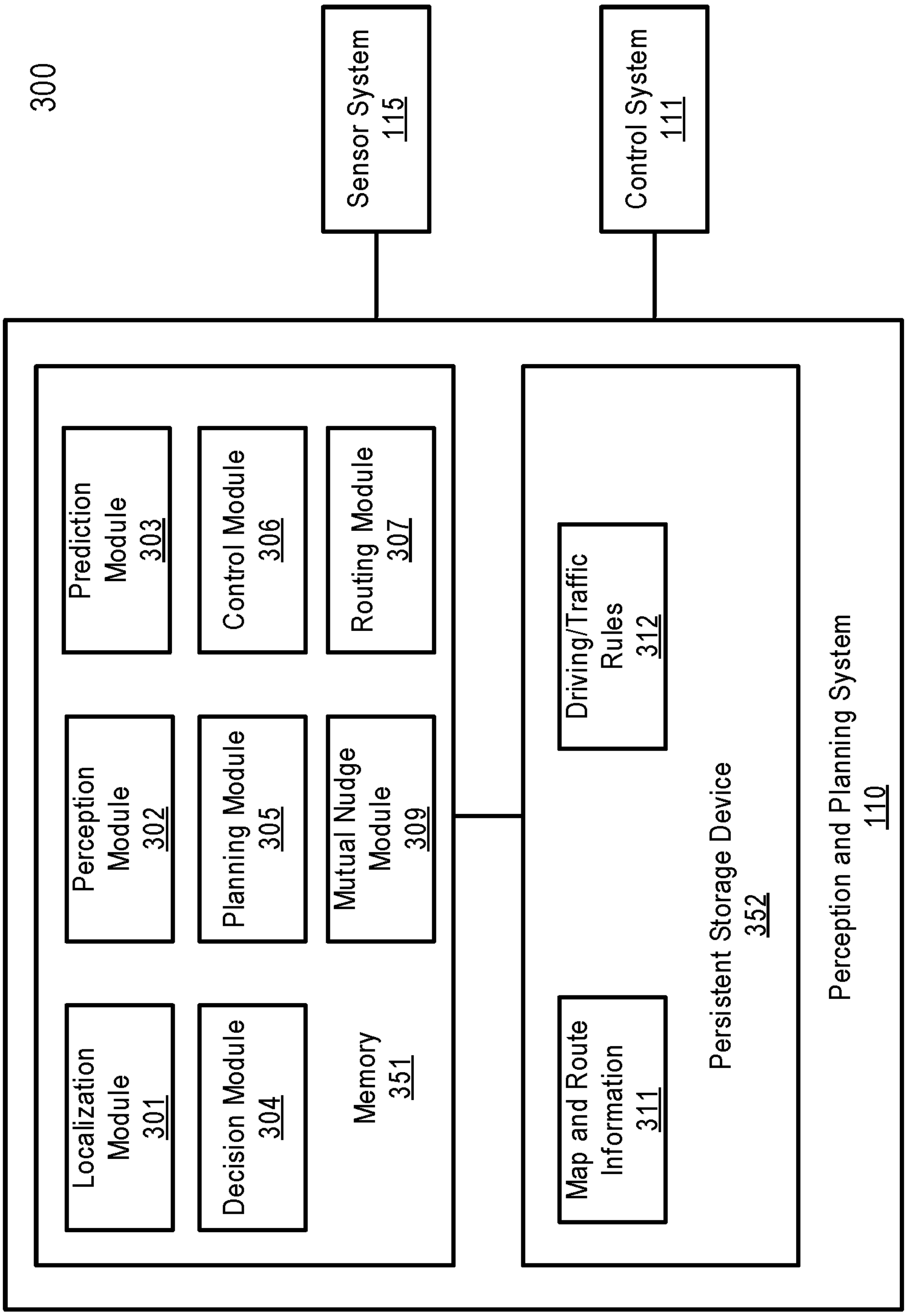
300
Sensor System
115
Control System
111
Localization Module
301
Perception Module
302
Prediction Module
303
Decision Module
304
Planning Module
305
Control Module
306
Routing Module
307
Mutual Nudge Module
309
Memory
351
Map and Route Information
311
Driving/Traffic Rules
312
Persistent Storage Device
352
Perception and Planning System
110

FIG. 3A

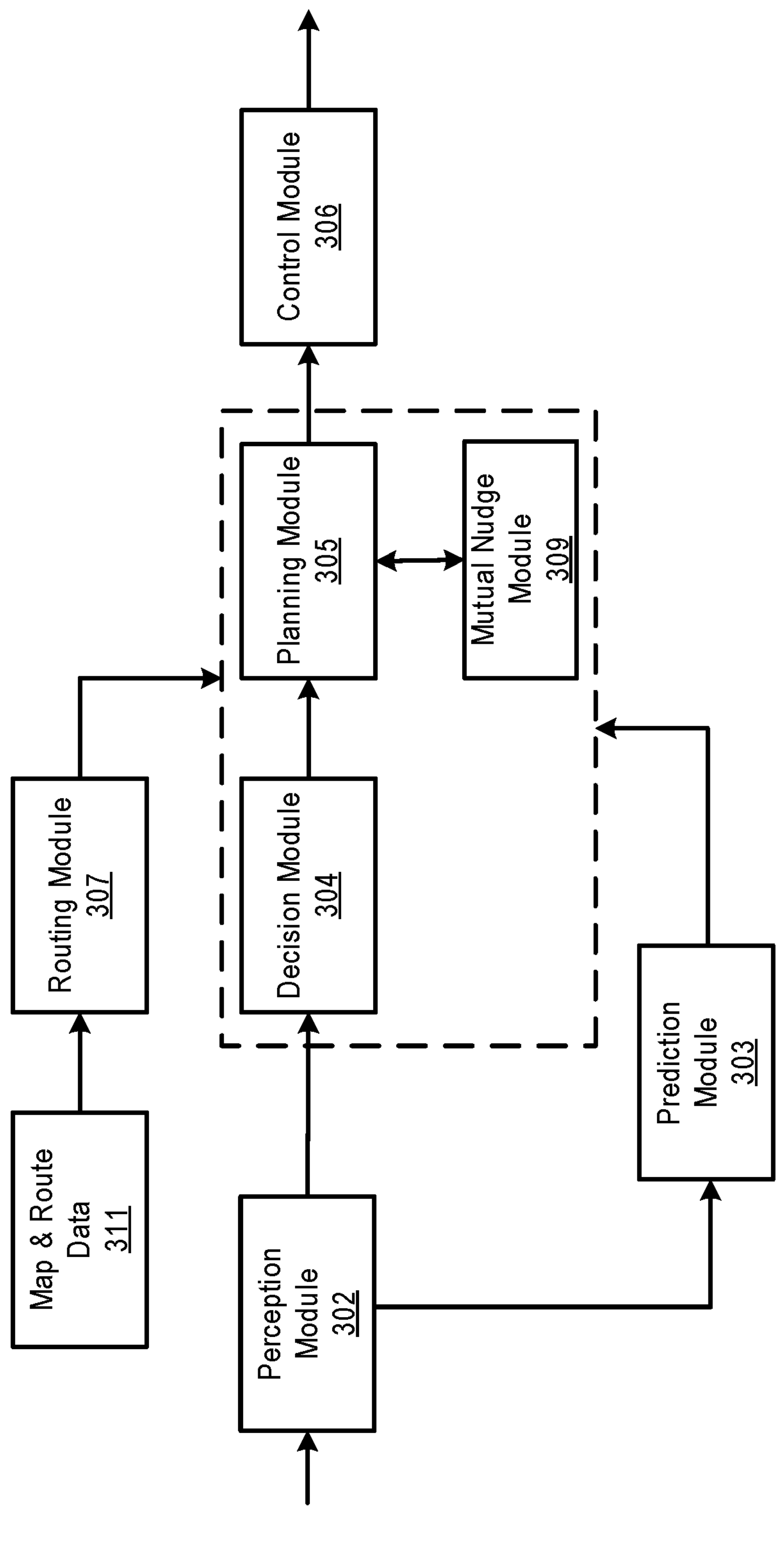
Control Module
306
Planning Module
305
Mutual Nudge
Module
309
Routing Module
307
Decision Module
304
Map & Route
Data
311
Perception
Module
302
Prediction
Module
303

FIG. 3B

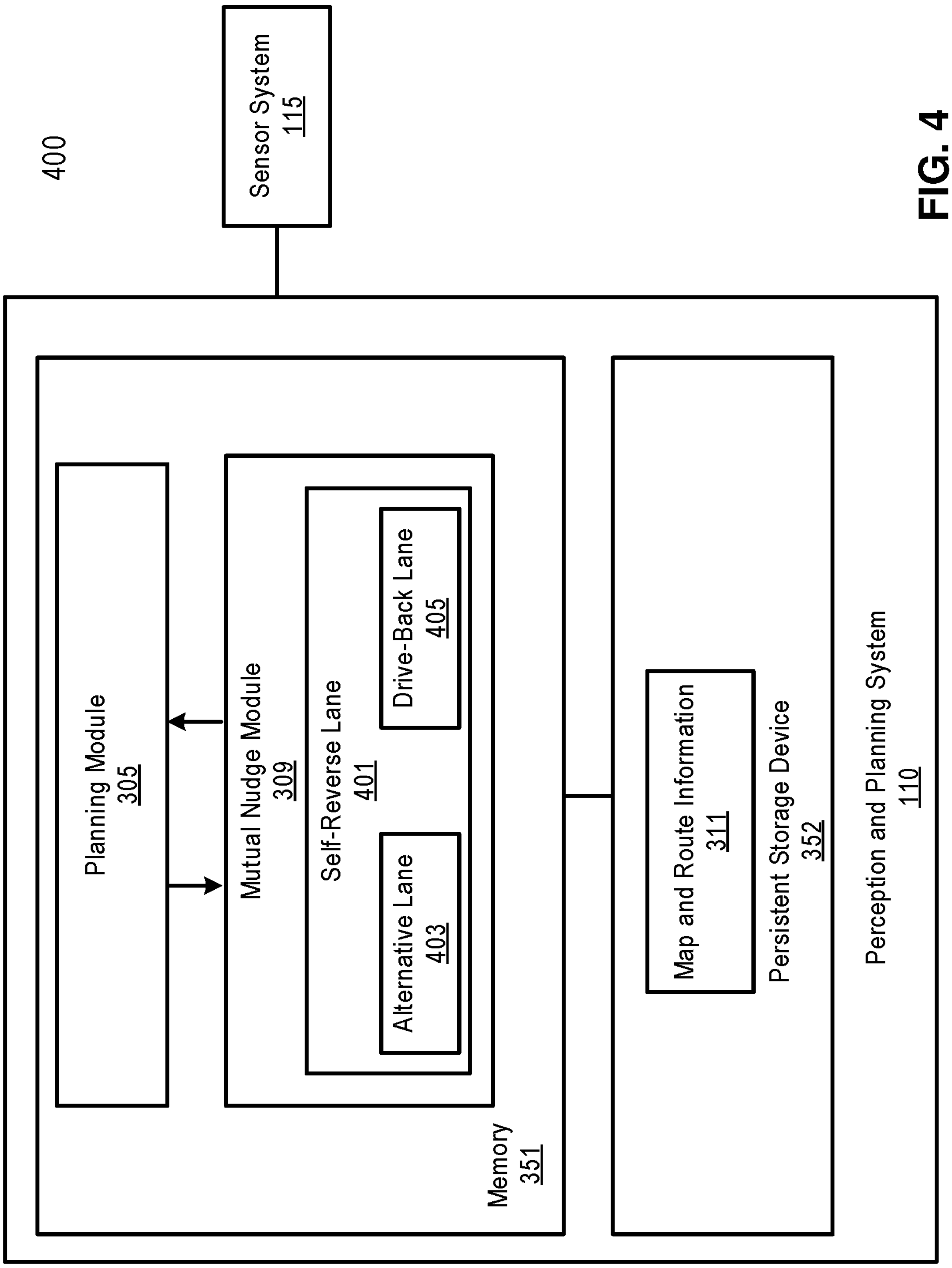
400
Sensor System
115
Planning Module
305
Mutual Nudge Module
309
Self-Reverse Lane
401
Alternative Lane
403
Drive-Back Lane
405
Memory
351
Map and Route Information
311
Persistent Storage Device
352
Perception and Planning System
110

FIG. 4

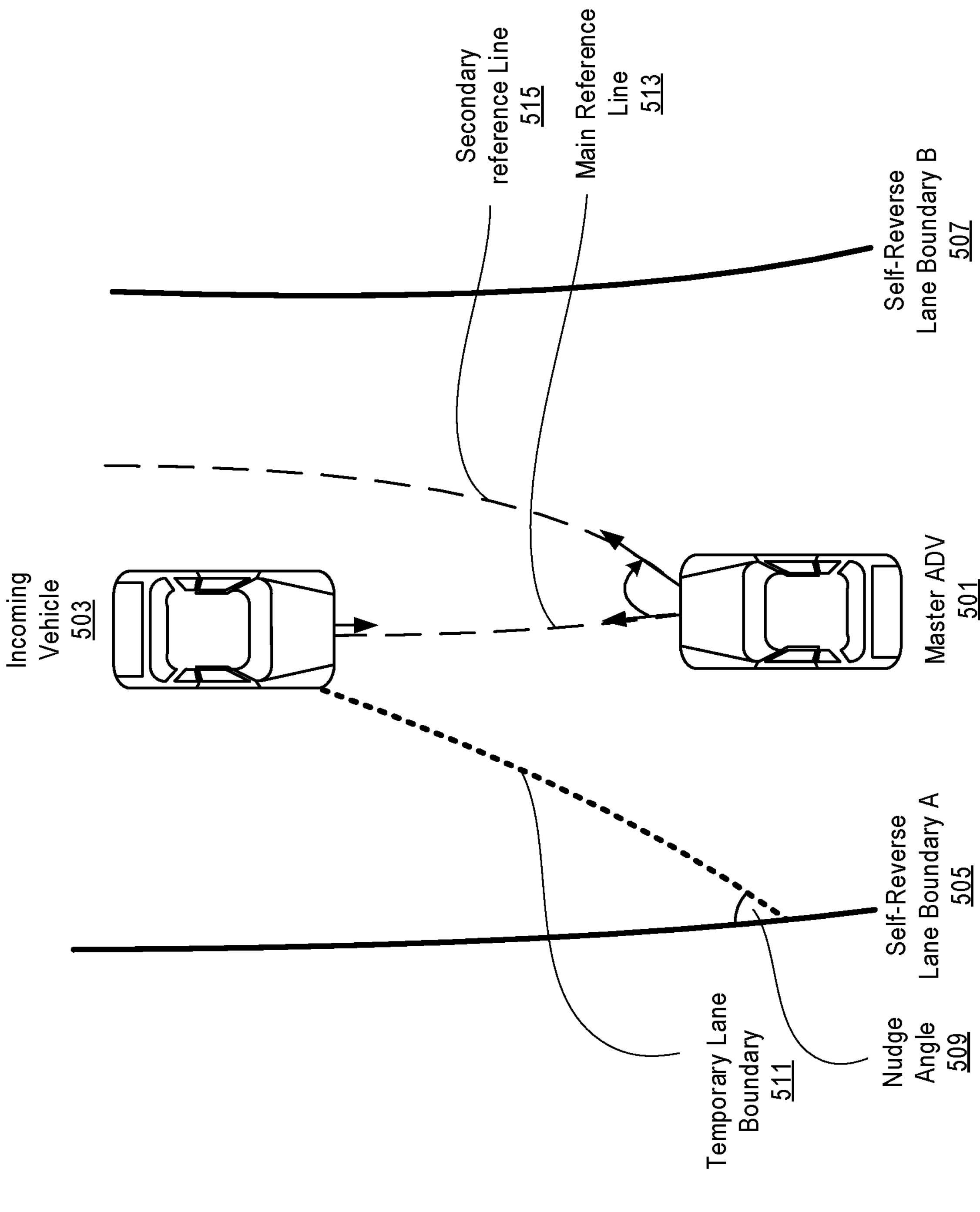
Incoming
Vehicle
503
Secondary
reference Line
515
Main Reference
Line
513
Self-Reverse
Lane Boundary B
507
Master ADV
501
Temporary Lane
Boundary
511
Nudge
Angle
509
Self-Reverse
Lane Boundary A
505

FIG. 5A

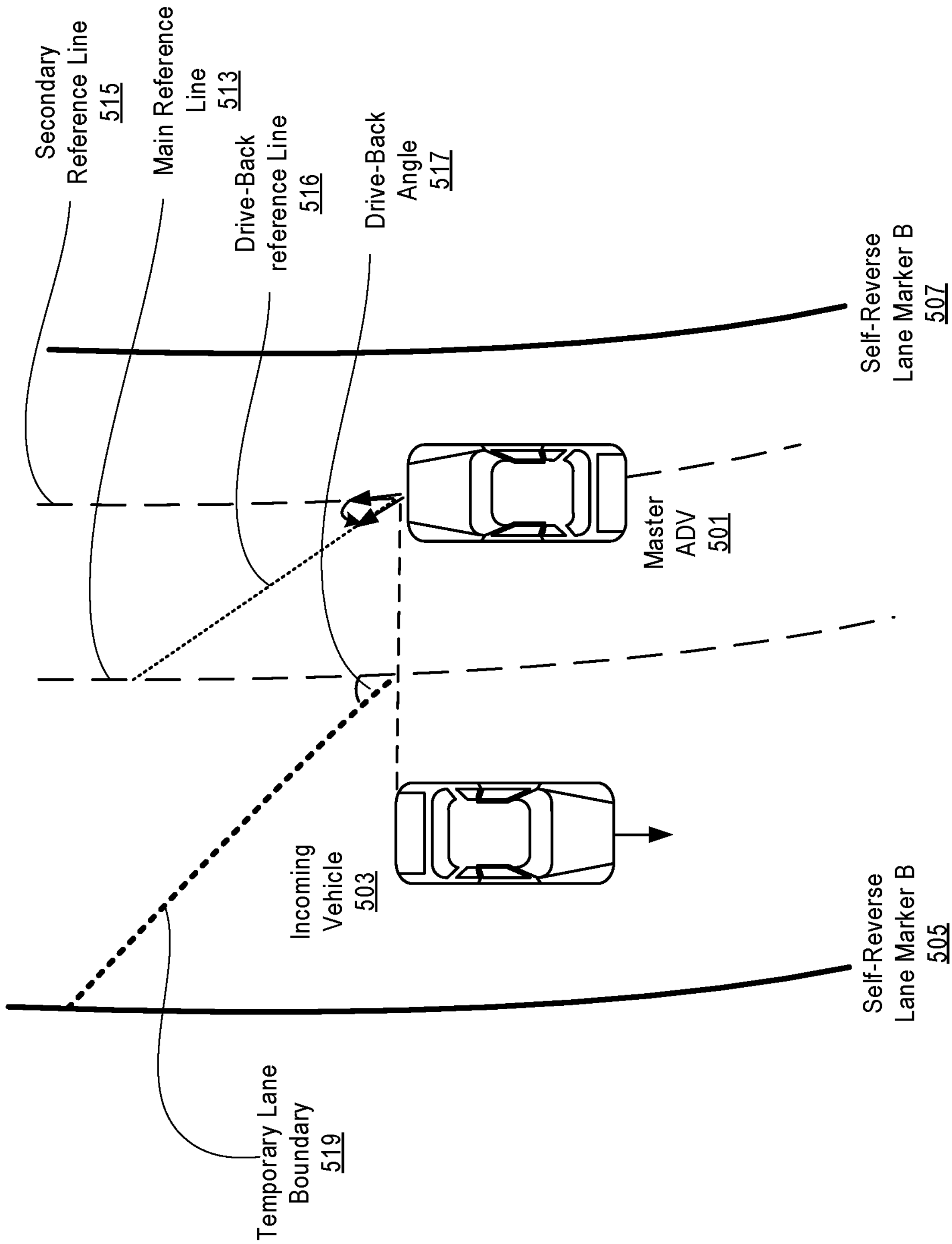
Secondary Reference Line 515
Main Reference Line 513
Drive-Back reference Line 516
Drive-Back Angle 517
Self-Reverse Lane Marker B 507
Master ADV 501
Incoming Vehicle 503
Self-Reverse Lane Marker B 505
Temporary Lane Boundary 519

FIG. 5B

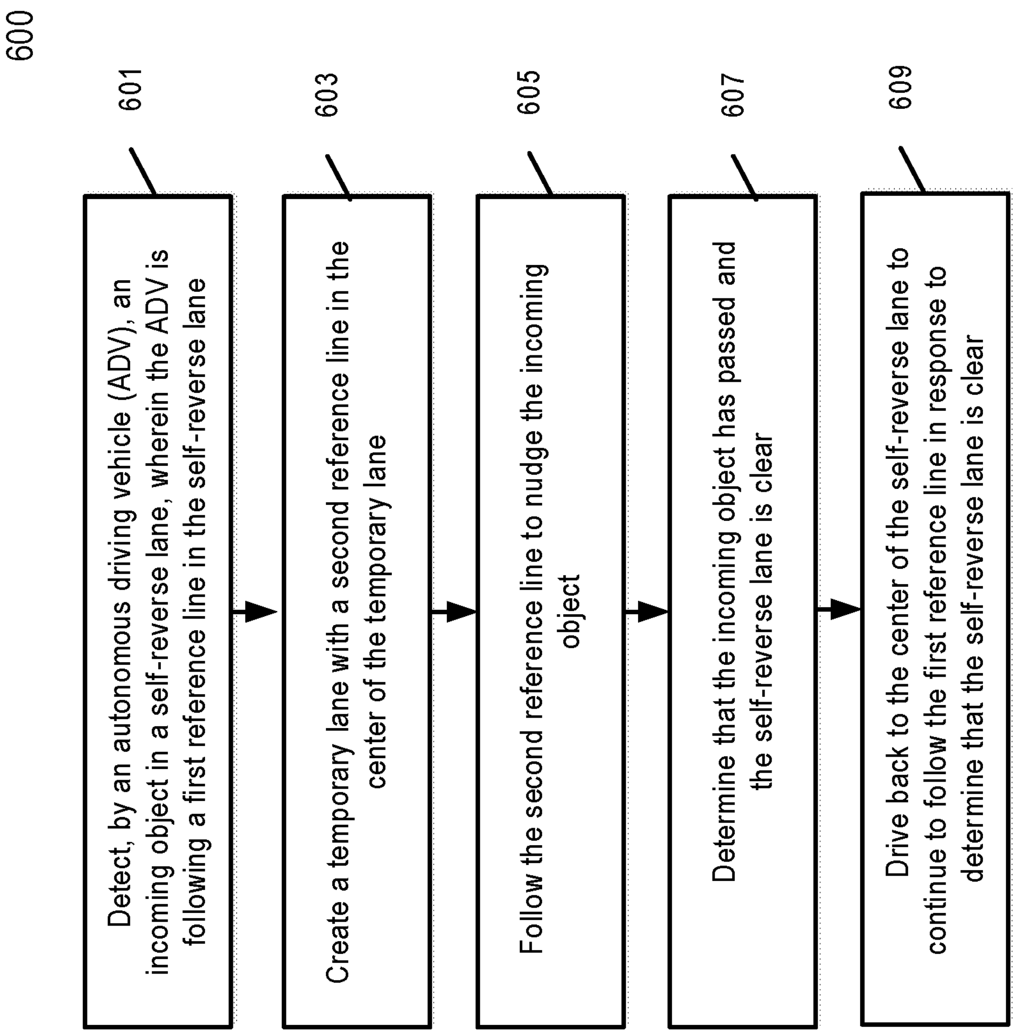
600
601
Detect, by an autonomous driving vehicle (ADV), an incoming object in a self-reverse lane, wherein the ADV is following a first reference line in the self-reverse lane
603
Create a temporary lane with a second reference line in the center of the temporary lane
605
Follow the second reference line to nudge the incoming object
607
Determine that the incoming object has passed and the self-reverse lane is clear
609
Drive back to the center of the self-reverse lane to continue to follow the first reference line in response to determine that the self-reverse lane is clear

FIG. 6

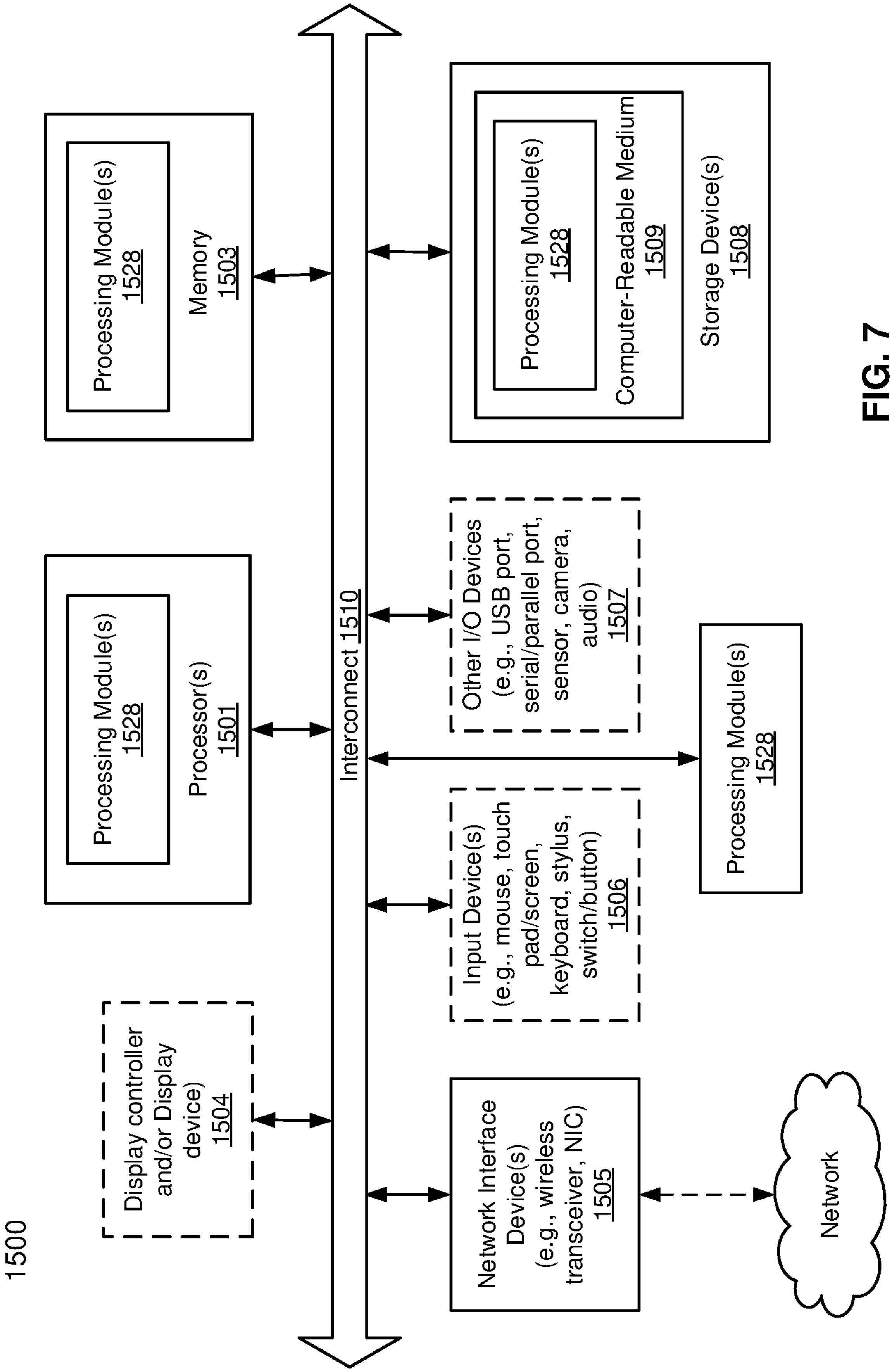
1500
Display controller and/or Display device) 1504
Processing Module(s) 1528
Processor(s) 1501
Processing Module(s) 1528
Memory 1503
Interconnect 1510
Network Interface Device(s) (e.g., wireless transceiver, NIC) 1505
Input Device(s) (e.g., mouse, touch pad/screen, keyboard, stylus, switch/button) 1506
Other I/O Devices (e.g., USB port, serial/parallel port, sensor, camera, audio) 1507
Processing Module(s) 1528
Computer-Readable Medium 1509
Storage Device(s) 1508
Processing Module(s) 1528
Network

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/123896

A. CLASSIFICATION OF SUBJECT MATTER

B60W 30/08(2012.01)i； G08G 1/16(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60W; G08G

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

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

SIPOABS;DWPI;CNABS;CNTXT;CNKI:autonomous, unmanned, reverse, obstacle, lane, avoid, width

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 104334427 A (BOSCH GMBH ROBERT) 04 February 2015 (2015-02-04) see description paragraphs [0039]-[0041] and figure 3	1-20
A	CN 107031619 A (HYUNDAI MOTOR CO LTD) 11 August 2017 (2017-08-11) see the whole document	1-20
A	US 2018095465 A1 (GM GLOBAL TECH OPERATIONS LLC) 05 April 2018 (2018-04-05) see the whole document	1-20
A	CN 106527452 A (GUANGZHOU AUTOMOBILE GROUP CO) 22 March 2017 (2017-03-22) see the whole document	1-20
A	CN 107415941 A (OPEL ADAM AG) 01 December 2017 (2017-12-01) see the whole document	1-20
A	CN 102815298 A (HYUNDAI MOBIS CO LTD) 12 December 2012 (2012-12-12) see the whole document	1-20

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 September 2019	**20 September 2019**

Name and mailing address of the ISA/CN

National Intellectual Property Administration, PRC
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