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MESSAGES FROM ROADSIDE INFRASTRUCTURE OF OTHER VEHICLES

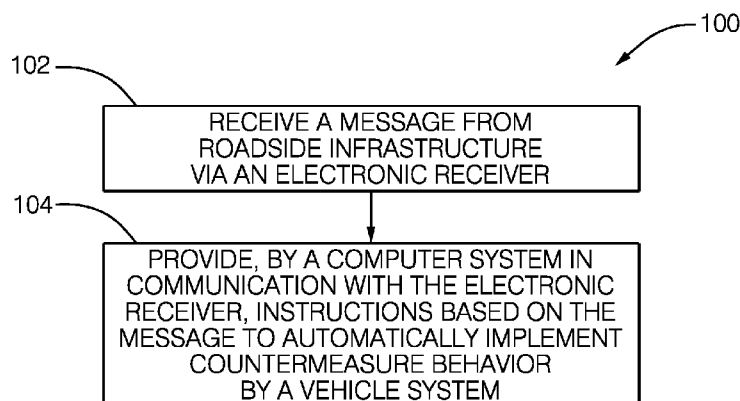


FIG. 2

(57) Abstract: A method (100) of operating a vehicle, such as an autonomous vehicle (10), includes the steps of receiving a message from roadside infrastructure via an electronic receiver (102) and providing, by a computer system in communication with said electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system (104). Additionally or alternatively, the method (200) may include the steps of receiving a message from another vehicle via an electronic receiver (202) and providing, by a computer system in communication with said electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system (204).

**METHOD OF AUTOMATICALLY CONTROLLING AN AUTONOMOUS
VEHICLE BASED ON ELECTRONIC MESSAGES FROM ROADSIDE
INFRASTRUCTURE OR OTHER VEHICLES**

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 62/112786, filed 06-Feb-2017, the entire disclosure of which is hereby incorporated herein by reference.

TECHNICAL FIELD OF THE INVENTION

[0002] The invention relates to a method of automatically controlling an autonomous vehicle, particularly to a method based on receiving electronic messages from roadside infrastructure or other vehicles.

BACKGROUND OF THE INVENTION

[0003] Some vehicles are configured to operate automatically so that the vehicle navigates through an environment with little or no input from a driver. Such vehicles are often referred to as “autonomous vehicles”. These autonomous vehicles typically include one or more sensors that are configured to sense information about the environment. The autonomous vehicle may use the sensed information to navigate through the environment. For example, if the sensors sense that the autonomous vehicle is approaching an intersection with a traffic signal, the sensors must determine the state of the traffic signal to determine whether the autonomous vehicle needs to stop at the intersection. The traffic signal may be obscured to the sensor by weather conditions, roadside foliage, or other vehicles between

the sensor and the traffic signal. Therefore, a more reliable method of determining the status of roadside infrastructure is desired.

[0004] The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may also be inventions.

BRIEF SUMMARY OF THE INVENTION

[0005] In accordance with an embodiment of the invention, a method of operating an autonomous vehicle is provided. The method includes the step of receiving a message from roadside infrastructure via an electronic receiver and the step of providing, by a computer system in communication with the electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system.

[0006] According to a first example, the roadside infrastructure is a traffic signaling device and data contained in the message includes a device location, a signal phase, and a phase timing. The vehicle system is a braking system. The step of providing instructions includes the sub-steps of:

- determining a vehicle speed,
- determining the signal phase in a current vehicle path, determining a distance between the vehicle and the device location, and

- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, the signal phase of the current vehicle path, and the distance between the vehicle and the device location.

[0007] According to a second example, the roadside infrastructure is a construction zone warning device and data contained in the message includes the information of a zone location, a zone direction, a zone length, a zone speed limit, and/or lane closures. The vehicle system may be a braking system, a steering system, and/or a powertrain system. The step of providing instructions may include the sub-steps of:

- determining a vehicle speed,
- determining a lateral vehicle location within a roadway,
- determining a distance between the vehicle and the zone location,
- determining a difference between the vehicle speed and the zone speed limit,
- providing, by the computer system, instructions to apply vehicle brakes based on the difference between the vehicle speed and the zone speed limit and the distance between the vehicle and the zone location,
- determining a steering angle based on the lateral vehicle location, the lane closures, the vehicle speed, and the distance between the vehicle and the zone location,
- providing, by the computer system, instructions to the steering system to adjust a vehicle path based on the steering angle, and
- providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so the vehicle speed is less than or equal to the zone speed limit.

[0008] According to a third example, the roadside infrastructure is a stop sign and data contained in the message includes sign location and stop direction. The vehicle system is a braking system. The step of providing instructions may include the sub-steps:

- determining vehicle speed,
- determining the stop direction of a current vehicle path,
- determining a distance between the vehicle and the sign location, and
- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on a vehicle speed, the stop direction of the current vehicle path, and the distance between the vehicle and the sign location.

[0009] According to a fourth example, the roadside infrastructure is a railroad crossing warning device and data contained in the message includes device location and warning state. The vehicle system is a braking system. The step of providing instructions includes the sub-steps of:

- determining vehicle speed,
- determining the warning state,
- determining a distance between the vehicle and the device location, and
- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, warning state, and the distance between the vehicle and the device location.

[0010] According to a fifth example, the roadside infrastructure is an animal crossing zone warning device and data contained in the message includes zone location, zone direction, and zone length. The vehicle system is a forward looking sensor. The step of providing instructions includes the sub-step of providing, by the computer system,

instructions to the forward looking sensor to widen a field of view so as to include at least both road shoulders within the field of view.

[0011] According to a sixth example, the roadside infrastructure is a pedestrian crossing warning device and data contained in the message may be crossing location and/or warning state. The vehicle system may be a braking system and/or a forward looking sensor. The step of providing instructions may include the sub-steps of:

- providing, by the computer system, instructions to the forward looking sensor to widen a field of view so as to include at least both road shoulders within the field of view,
- determining vehicle speed,
- determining a distance between the vehicle and the crossing location, and
- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, warning state, and the distance between the vehicle and the crossing location.

[0012] According to a seventh example, the roadside infrastructure is a school crossing warning device and data contained in the message a device location and a warning state. The vehicle system is a braking system. The step of providing instructions includes the sub-steps of:

- determining vehicle speed,
- determining a lateral location of the device location within a roadway,
- determining a distance between the vehicle and the device location, and

- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on a vehicle speed, the lateral location, the warning state, and the distance between the vehicle and the device location.

[0013] According to an eighth example, the roadside infrastructure is a lane direction indicating device and data contained in the message is a lane location and a lane direction. The vehicle system is a roadway mapping system. The step of providing instructions includes the sub-step of providing, by the computer system, instructions to the roadway mapping system to dynamically update the roadway mapping system's lane direction information.

[0014] According to a ninth example, the roadside infrastructure is a speed limiting device and data contained in the message includes a speed zone location, a speed zone direction, a speed zone length, and a zone speed limit. The vehicle system is a powertrain system. The step of providing instructions includes the sub-steps of:

- determining a vehicle speed,
- determining a distance between the vehicle and the speed zone location, and
- providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the zone speed limit.

[0015] According to a tenth example, the roadside infrastructure is a no passing zone device and data contained in the message includes a no passing zone location, a no passing zone direction, and a no passing zone length. The vehicle system includes a powertrain system, a forward looking sensor and/or a braking system. The step of providing instructions may include the sub-steps of:

- detecting another vehicle ahead of the vehicle via the forward looking sensor,

- determining a vehicle speed,
- determining an another vehicle speed.
- determine a safe passing distance for overtaking the another vehicle,
- determining a distance between the vehicle and the no passing zone location,
- providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the another vehicle speed when the safe passing distance would end within the no passing zone, and
- providing, by the computer system, instructions to the braking system to adjust the vehicle speed so that the vehicle speed is less than or equal to the another vehicle speed when the safe passing distance would end within the no passing zone.

[0016] In accordance with another embodiment, another method of operating an autonomous vehicle is provided. The method comprises the step of receiving a message from another vehicle via an electronic receiver, and the step of providing, by a computer system in communication with said electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system.

[0017] According to a first example, the other vehicle is a school bus and data contained in the message includes school bus location and stop signal status. The vehicle system is a braking system. The step of providing instructions includes the sub-steps of:

- determining a vehicle speed,
- determining the stop signal status,
- determining a distance between the vehicle and the school bus location, and

- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, the stop signal status, and the distance between the vehicle and the school bus location.

[0018] According to a second example, the other vehicle is a maintenance vehicle and data contained in the message includes a maintenance vehicle location and a safe following distance. The vehicle system is a powertrain system and/or a braking system. The step of providing instructions may include the sub-steps of:

- determining a distance between the vehicle and the maintenance vehicle location,
- determining a difference between the safe following distance and the distance between the vehicle and the maintenance vehicle location by subtracting the distance between the vehicle and the maintenance vehicle location from the safe following distance,
- providing, by the computer system, instructions to the braking system to apply vehicle brakes when the difference is less than zero, and
- providing, by the computer system, instructions to the powertrain system to adjust a vehicle speed so that the difference is less than or equal to zero.

[0019] According to a third example, the other vehicle is an emergency vehicle and data contained in the message may include information regarding an emergency vehicle location, an emergency vehicle speed, and a warning light status. The vehicle system is a braking system, a steering system, a forward looking sensor, and/or a powertrain system. The step of providing instructions may include the sub-steps:

- determining a distance between the vehicle and the emergency vehicle,

- determine a location of an unobstructed portion of a road shoulder via the forward looking sensor based on the distance between the vehicle and the emergency vehicle, the emergency vehicle speed, and warning light status,
- providing, by the computer system, instructions to apply vehicle brakes based on the distance between the vehicle and the emergency vehicle, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder,
- determining a steering angle based on the distance between the vehicle and the emergency vehicle, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder,
- providing, by the computer system, instructions to the steering system to adjust a vehicle path based on the steering angle, and
- providing, by the computer system, instructions to the powertrain system to adjust a vehicle speed based on the distance between the vehicle and the emergency vehicle, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0020] The present invention will now be described, by way of example with reference to the accompanying drawings, in which:

[0021] Fig. 1 is a diagram of an operating environment for an autonomous vehicle;

[0022] Fig. 2 is flowchart of a method of operating a autonomous vehicle according to a first embodiment;

[0023] Fig. 3 is flowchart of a first set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0024] Fig. 4 is flowchart of a second set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0025] Fig. 5 is flowchart of a third set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0026] Fig. 6 is flowchart of a fourth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0027] Fig. 7 is flowchart of a fifth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0028] Fig. 8 is flowchart of a sixth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0029] Fig. 9 is flowchart of a seventh set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0030] Fig. 10 is flowchart of an eighth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0031] Fig. 11 is flowchart of a ninth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0032] Fig. 12 is flowchart of a tenth set of sub-steps of STEP 104 of the method illustrated in Fig. 2;

[0033] Fig. 13 is flowchart of a method of operating a autonomous vehicle according to a second embodiment;

[0034] Fig. 14 is flowchart of a first set of sub-steps of STEP 204 of the method illustrated in Fig. 13;

[0035] Fig. 15 is flowchart of a second set of sub-steps of STEP 204 of the method illustrated in Fig. 13; and

[0036] Fig. 16 is flowchart of a third set of sub-steps of STEP 204 of the method illustrated in Fig. 13.

DETAILED DESCRIPTION OF THE INVENTION

[0037] Because portions of the driving environment may be obscured to environmental sensors, such as forward looking sensors, it is desirable to supplement sensor inputs. Presented herein is a method of operating an automatically controlled or “autonomous” vehicle wherein the vehicle receives electronic messages from various elements of the transportation infrastructure, such as traffic signals, signage, or other vehicles. The infrastructure contains wireless transmitters that broadcast information about the state of each element of the infrastructure, such as location and operational state. The information may be broadcast by a separate transmitter associated with each element of infrastructure or it may be broadcast by a central transmitter. The infrastructure information is received by the autonomous vehicle and a computer system on-board the autonomous vehicle then determines whether countermeasures are required by the autonomous vehicle and sends instructions to the relevant vehicle system, e.g. the braking system, to perform the appropriate actions.

[0038] Fig. 1 illustrates a non-limiting example of an environment in which an automatically controlled vehicle 10, hereinafter referred to as the autonomous vehicle 10, may operate. The autonomous vehicle 10 travels along a roadway 12 having various associated infrastructure elements. The illustrated examples of infrastructure elements include:

- a traffic signaling device 14, e.g. “stop light”. The traffic signaling device 14 transmits an electronic signal that includes information regarding the traffic signaling device’s

location, signal phase, e.g. direction of stopped traffic, direction of flowing traffic, left or right turn indicators active, and phase timing, i.e. time remaining until the next phase change.

- a construction zone warning device 16 that may include signage, barricades, traffic barrels, barriers, or flashers. The construction zone warning device 16 transmits an electronic signal that may include information regarding the location of the construction zone, the construction zone direction, e.g. northbound lanes, the length of the construction zone, the speed limit within the construction zone, and an indication of any roadway lanes that are closed.
- a stop sign 18. The stop sign 18 transmits an electronic signal that may include information regarding the sign location, stop direction, i.e. the autonomous vehicle 10 needs to stop or cross traffic needs to stop, and number of stop directions, i.e. two or four way stop.
- a railroad crossing signal 20. The railroad crossing signal 20 transmits an electronic signal that may include information regarding the railroad crossing signal location and warning state.
- an animal crossing zone warning device 22, e.g. a deer area or moose crossing sign. The animal crossing zone warning device 22 transmits an electronic signal that may include information regarding the animal crossing zone location, animal crossing zone direction, , e.g. southbound lanes, and animal crossing zone length
- a pedestrian crossing warning device 24. The pedestrian warning device may be a sign marking a pedestrian crossing or it may incorporate a warning system activated by the pedestrian when entering the crossing. The pedestrian crossing warning

device 24 transmits an electronic signal that may include information regarding the pedestrian crossing location and warning state, e.g. pedestrian in walkway.

- a school crossing warning device 26. The school crossing warning device 26 may be a handheld sign used by a school crossing guard. A warning signal, in the form of flashing lights may be activated by the crossing guard when a child is in the crossing. The school crossing warning device 26 transmits an electronic signal that may include information regarding the school crossing warning device location and warning state.
- a lane direction indicating device 28. The lane direction indicating device 28 transmits an electronic signal that may include information regarding the lane location and a lane direction of each lane location.
- a speed limiting device 30, e.g. a speed limit sign. The speed limiting device 30 transmits an electronic signal that may include information regarding the speed zone's location, the speed zone's direction, the speed zone length, and the speed limit within the speed zone.
- a no passing zone device 32, e.g. a no passing zone sign. The no passing zone device 32 transmits an electronic signal that may include information regarding the no passing zone's location, the no passing zone's direction, and the no passing zone's length.

[0039] The environment in which the autonomous vehicle 10 operates may also include other vehicles with which the autonomous vehicle 10 may interact. The illustrated examples of other vehicles include:

- a school bus 34. The school bus 34 transmits an electronic signal that includes information regarding the school bus' location and stop signal status.

- a maintenance vehicle 36, e.g. snow plow or lane marker. The maintenance vehicle 36 transmits an electronic signal that includes information regarding the maintenance vehicle's location and the safe following distance required.
- an emergency vehicle 38, e.g. police car or ambulance. The emergency vehicle 38 transmits an electronic signal that includes information regarding the emergency vehicle's location, the emergency vehicle's speed, and the emergency vehicle's warning light status.

[0040] The autonomous vehicle 10 includes a computer system connected to a wireless receiver that is configured to receive the electronic messages from the transmitters associated with the infrastructure and/or other vehicles. The transmitters and receivers may be configured to communicate using any of a number of protocols, including Dedicated Short Range Communication (DSRC) or WIFI (IEEE 802.11x). The transmitters and receivers may alternatively be transceivers allowing two-way communication between the infrastructure and/or other vehicles and the autonomous vehicle 10. The computer system is interconnected to various sensors and actuators responsible for controlling the various systems in the autonomous vehicle 10, such as the braking system, the powertrain system, and the steering system. The computer system may be a central processing unit or may be several distributed processors communication over a communication bus, such as a Controller Area Network (CAN) bus.

[0041] The autonomous vehicle 10 further includes a locating device configured to determine both the geographical location of the autonomous vehicle 10 as well as the vehicle speed. An example of such a device is a Global Positioning System (GPS) receiver.

[0042] The autonomous vehicle 10 may also include a forward looking sensor 40 configured to identify objects in the forward path of the autonomous vehicle 10. Such a

sensor 40 may be a visible light camera, an infrared camera, a radio detection and ranging (RADAR) transceiver, and/or a laser imaging, detecting and ranging (LIDAR) transceiver.

[0043] Fig. 2 illustrates a non-limiting example of a method 100 of automatically operating an autonomous vehicle 10. The method 100 includes STEP 102, RECEIVE A MESSAGE FROM ROADSIDE INFRASTRUCTURE VIA AN ELECTRONIC RECEIVER, that include receiving a message transmitted from roadside infrastructure via an electronic receiver within the autonomous vehicle 10. As used herein, roadside infrastructure may refer to controls, signage, sensors, or other components of the roadway 12 on which the autonomous vehicle 10 travels.

[0044] The method 100 further includes STEP 104, PROVIDE, BY A COMPUTER SYSTEM IN COMMUNICATION WITH THE ELECTRONIC RECEIVER, INSTRUCTIONS BASED ON THE MESSAGE TO AUTOMATICALLY IMPLEMENT COUNTERMEASURE BEHAVIOR BY A VEHICLE SYSTEM, that includes providing instructions to a vehicle system to automatically implement countermeasure behavior. The instructions are sent to the vehicle system by a computer system that is in communication with the electronic receiver and the instruction are based on the information contained within a message received from the roadside infrastructure by the receiver.

[0045] Fig. 3 illustrates a first set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically stop the autonomous vehicle 10 when approaching a traffic signaling device 14, e.g. stop light. SUB-STEP 1102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. SUB-STEP 1104, DETERMINE THE SIGNAL PHASE IN A CURRENT VEHICLE PATH, includes determining the signal phase, e.g. red, yellow, green, of the traffic signaling device 14 along the autonomous vehicle's desired path. SUB-STEP 1106,

DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE DEVICE

LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the traffic signaling device 14 contained within the message received from the traffic signaling device 14. SUB-STEP 1108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, THE SIGNAL PHASE OF THE CURRENT VEHICLE PATH, AND THE DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a stop at the intersection controlled by the traffic signaling device 14 based on the traffic signal phase, the time remaining before the next phase change, the vehicle speed, the distance between the autonomous vehicle and the traffic signaling device location. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped at the intersection controlled by the traffic signaling device 14.

[0046] Fig. 4 illustrates a second set of sub-steps that may be included in STEP 104.

This set of sub-steps are used to automatically control the autonomous vehicle 10 when approaching a construction zone. SUB-STEP 2102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle via the locating device. SUB-STEP 2104, DETERMINE A LATERAL VEHICLE LOCATION WITHIN A ROADWAY, includes determine the lateral vehicle location within a roadway 12 via the locating device so that it may be determined in which road lane the autonomous vehicle 10 is traveling. SUB-STEP 2106, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE ZONE LOCATION, includes calculating the distance between the current

location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the construction zone contained within the message received from the construction zone warning device 16. SUB-STEP 2108, DETERMINE A DIFFERENCE BETWEEN THE VEHICLE SPEED AND THE ZONE SPEED LIMIT, includes calculating the difference between the speed of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the speed limit of the construction zone contained within the message received from the construction zone warning device 16. SUB-STEP 2110, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, THE ZONE SPEED LIMIT, AND THE DISTANCE BETWEEN THE VEHICLE AND THE ZONE LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a reduce speed before reaching the construction zone based on the vehicle speed, the speed limit within the construction zone, and the distance between the autonomous vehicle 10 and the construction zone location. SUB-STEP 2112, DETERMINE A STEERING ANGLE BASED ON THE LATERAL VEHICLE LOCATION, THE LANE CLOSURES, THE VEHICLE SPEED, AND THE DISTANCE BETWEEN THE VEHICLE AND THE ZONE LOCATION, includes determining a steering angle to change lanes from a lane that is closed in the construction zone to a lane that is open within the construction zone when it is determined by the lateral location of the autonomous vehicle that the autonomous vehicle 10 is traveling in a lane that is indicated as closed in the message received from the construction zone warning device 16. SUB-STEP 2114, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE STEERING SYSTEM TO ADJUST A VEHICLE PATH BASED ON THE

STEERING ANGLE, includes sending instructions from the computer system to the steering system to adjust the vehicle path based on the steering angle determined in SUB-STEP 2112. SUB-STEP 2116, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE POWERTRAIN SYSTEM TO ADJUST THE VEHICLE SPEED SO THAT THE VEHICLE SPEED IS LESS THAN OR EQUAL TO THE ZONE SPEED LIMIT, includes sending instructions from the computer system to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the speed limit for the construction zone contained in the message received from the construction zone warning device 16.

[0047] Fig. 5 illustrates a third set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically stop the autonomous vehicle 10 when approaching a stop sign 18. SUB-STEP 3102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. Sub-step 3104, DETERMINE THE STOP DIRECTION OF A CURRENT VEHICLE PATH, includes determining whether the autonomous vehicle 10 needs to stop at the intersection controlled by the stop sign 18 based on the current direction of travel determined by the autonomous vehicle's locating device and direction of traffic required to stop reported in the message received from the stop sign transmitter. SUB-STEP 3106, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE SIGN LOCATION, includes calculating the distance between the current location of the autonomous vehicle determined by the autonomous vehicle's locating device and the location of the stop sign 18 contained within the message received from the stop sign transmitter. SUB-STEP 3108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, THE SIGNAL

PHASE OF THE CURRENT VEHICLE PATH, AND THE DISTANCE BETWEEN THE VEHICLE AND THE SIGN LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a stop at the intersection controlled by the stop sign 18 based on the direction of traffic required to stop reported in the message received from the stop sign transmitter, the vehicle speed, and the distance between the autonomous vehicle 10 and the stop sign 18 location. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped at the intersection controlled by the stop sign 18.

[0048] Fig. 6 illustrates a fourth set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically stop the autonomous vehicle 10 when approaching a railroad crossing. SUB-STEP 4102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle via the locating device. SUB-STEP 4104, DETERMINE THE WARNING STATE, includes determining the warning state of the railroad crossing warning device 20. SUB-STEP 4106, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the railroad crossing warning device 20 contained within the message received from the railroad crossing warning device 20. SUB-STEP 4108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, WARNING STATE, AND THE DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will

need to come to a stop at the railroad crossing based on the warning state, the vehicle speed, the distance between the autonomous vehicle 10 and the railroad crossing warning device location. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped at the railroad crossing.

[0049] Fig. 7 illustrates a fifth set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically increase the field of view of the forward looking sensor 40 when the autonomous vehicle is approaching an animal crossing zone. SUB-STEP 5102, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE FORWARD LOOKING SENSOR TO WIDEN A FIELD OF VIEW SO AS TO INCLUDE AT LEAST BOTH ROAD SHOULDERS WITHIN THE FIELD OF VIEW, includes sending instructions to the forward looking sensor 40 to widen the field of view of the sensor 40 to include at least both shoulders of the roadway 12 when the receiver receives a message from an animal crossing zone warning device 22 and it is determined that the autonomous vehicle 10 has entered the animal crossing zone. Increasing the field of view will increase the likelihood that the forward looking sensor 40 will detect an animal entering the roadway 12.

[0050] Fig. 8 illustrates a sixth set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically increase the field of view of the forward looking sensor 40 when the autonomous vehicle is approaching a pedestrian crosswalk. SUB-STEP 6102, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE FORWARD LOOKING SENSOR TO WIDEN A FIELD OF VIEW SO AS TO INCLUDE AT LEAST BOTH ROAD SHOULDERS WITHIN THE FIELD OF VIEW, includes sending instructions to the forward looking sensor 40 to widen the field of view of the sensor 40 to include at least both shoulders of the roadway 12 when the receiver receives

a message from a pedestrian crossing warning device 24 and it is determined that the autonomous vehicle 10 is near the crosswalk controlled by the pedestrian crossing warning device 24. Increasing the field of view will increase the likelihood that the forward looking sensor 40 will detect pedestrian entering the crosswalk. SUB-STEP 6104, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. SUB-STEP 6106, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the pedestrian crossing warning device 24 contained within the message received from the pedestrian crossing warning device 24. SUB-STEP 6108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, WARNING STATE, AND THE DISTANCE BETWEEN THE VEHICLE AND THE CROSSING LOCATION, includes sending instructions to the autonomous vehicle 10 braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a stop at the crosswalk based on the warning state, the vehicle speed, the distance between the autonomous vehicle and the crosswalk location. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped at the crosswalk.

[0051] Fig. 9 illustrates a seventh set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically stop the autonomous vehicle when approaching a school crossing. SUB-STEP 7102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. Sub-step 7104, DETERMINE A LATERAL LOCATION OF THE DEVICE LOCATION

WITHIN A ROADWAY, includes determining the lateral position of the school crossing warning device location within the roadway 12 based on the device location reported in the message received from the school crossing warning device 26 by the receiver. If it is determined that the lateral location of the school crossing warning device 26 is within the roadway 12, the autonomous vehicle 10 will be instructed to stop regardless of the warning state received from the school crossing warning device 26. This is to ensure that failure to activate the warning state by the crossing guard operating the school crossing warning device 26 will not endanger students in the school crossing. SUB-STEP 7106, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the school crossing warning device 26 contained within the message received from the school crossing warning device 26. SUB-STEP 7108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON DATA SELECTED FROM THE GROUP CONSISTING OF: A VEHICLE SPEED, THE LATERAL LOCATION, THE WARNING STATE, AND THE DISTANCE BETWEEN THE VEHICLE AND THE DEVICE LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a stop at the school crossing based on the warning state and/or lateral location of the school crossing warning device 26, the vehicle speed, the distance between the autonomous vehicle 10 and the location of the school crossing warning device 26. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped at the crossing.

[0052] Fig. 10 illustrates a eighth set of sub-steps that may be included in STEP 104.

This set of sub-steps are used to automatically update the roadway mapping system to accommodate temporary lane direction changes. Sub-step 8102, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE ROADWAY MAPPING SYSTEM TO DYNAMICALLY UPDATE THE ROADWAY MAPPING SYSTEM'S LANE DIRECTION INFORMATION, includes providing by the instructions from the computer system to the roadway mapping system to dynamically update the roadway mapping system's lane direction information based on information received by the receiver from the lane direction indicating device 28. As used herein, a lane direction indicating device 28 controls the direction of travel of selected roadway lanes, such as roadway lanes that are reversed to accommodate heavy traffic during rush hours or at entrances and exits of large sporting events.

[0053] Fig. 11 illustrates a ninth set of sub-steps that may be included in STEP 104.

This set of sub-steps are used to automatically set the vehicle speed to match the speed limit of the section of roadway 12 on which the autonomous vehicle 10 is travelling. SUB-STEP 9102, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. SUB-STEP 9104, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE SPEED ZONE LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the speed zone contained within the message received from the speed limiting device 30. SUB-STEP 9106, DETERMINE A DIFFERENCE BETWEEN THE VEHICLE SPEED AND THE ZONE SPEED LIMIT, includes calculating the difference between the speed of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the

speed limit of the speed zone contained within the message received from the speed limiting device 30. SUB-STEP 9108, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE POWERTRAIN SYSTEM TO ADJUST THE VEHICLE SPEED SO THAT THE VEHICLE SPEED IS LESS THAN OR EQUAL TO THE ZONE SPEED LIMIT, includes sending instructions from the computer system to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the speed limit for the speed zone contained in the message received from the speed limiting device 30.

[0054] Fig. 11 illustrates a tenth set of sub-steps that may be included in STEP 104. This set of sub-steps are used to automatically inhibit passing of another vehicle if the passing maneuver cannot be completed before the autonomous vehicle enters a no passing zone. Sub-step 10102, DETECT ANOTHER VEHICLE AHEAD OF THE VEHICLE VIA THE FORWARD LOOKING SENSOR, includes detecting the presence of another vehicle in the same traffic lane ahead of the autonomous vehicle via the forward looking sensor 40. SUB-STEP 10104, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. SUB-STEP 10106, DETERMINE AN ANOTHER VEHICLE SPEED AND A DISTANCE BETWEEN THE VEHICLE AND THE ANOTHER VEHICLE, includes determining a speed differential between the autonomous vehicle 10 and the other vehicle it is trailing via a RADAR or LIDAR based on data from the forward looking sensor 40. SUB-STEP 10108, DETERMINE A SAFE PASSING DISTANCE FOR OVERTAKING THE ANOTHER VEHICLE, includes calculating a safe passing distance for overtaking the other vehicle based on the vehicle speed and the speed differential. SUB-STEP 10110, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE NO PASSING ZONE

LOCATION, includes calculating the distance between the current location of the autonomous vehicle 10 determined by the autonomous vehicle's locating device and the location of the no passing zone contained within the message received from the no passing zone warning device 32, if the safe passing distance would end within the no passing zone, the method proceeds to SUB-STEPS 10112 and/or 10114. SUB-STEP 10112, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE POWERTRAIN SYSTEM TO ADJUST THE VEHICLE SPEED SO THAT THE VEHICLE SPEED IS LESS THAN OR EQUAL TO THE ANOTHER VEHICLE SPEED WHEN THE SAFE PASSING DISTANCE WOULD END WITHIN THE NO PASSING ZONE, includes sending instructions from the computer system to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the another vehicle speed when it is determined that the safe passing distance would end within the no passing zone. SUB-STEP 10114, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO ADJUST THE VEHICLE SPEED SO THAT THE VEHICLE SPEED IS LESS THAN OR EQUAL TO THE ANOTHER VEHICLE SPEED WHEN THE SAFE PASSING DISTANCE WOULD END WITHIN THE NO PASSING ZONE, includes sending instructions from the computer system to the braking system to adjust the vehicle speed so that the vehicle speed is less than or equal to the another vehicle speed when it is determined that the safe passing distance would end within the no passing zone and that the speed differential between the vehicles exceeds the ability of the speed to be adjusted by the autonomous vehicle's powertrain system alone.

[0055] Fig. 13 illustrates a non-limiting example of a method 200 of automatically operating a autonomous vehicle. The method 200 includes STEP 202, RECEIVE A MESSAGE FROM ANOTHER VEHICLE VIA AN ELECTRONIC RECEIVER, that

includes receiving a message transmitted from another vehicle via an electronic receiver within the another vehicle.

[0056] The method 200 further includes STEP 204, PROVIDE, BY A COMPUTER SYSTEM IN COMMUNICATION WITH THE ELECTRONIC RECEIVER, INSTRUCTIONS BASED ON THE MESSAGE TO AUTOMATICALLY IMPLEMENT COUNTERMEASURE BEHAVIOR BY A VEHICLE SYSTEM, that includes providing instructions to a vehicle system to automatically implement countermeasure behavior. The instructions are sent to the vehicle system by a computer system that is in communication with the electronic receiver and the instruction are based on the information contained within a message received from the other vehicle by the receiver.

[0057] Fig. 14 illustrates a first set of sub-steps that may be included in STEP 204. This set of sub-steps are used to automatically stop the autonomous vehicle 10 when approaching a school bus 34 that has it's stop lights activated. SUB-STEP 1202, DETERMINE A VEHICLE SPEED, includes determining the speed of the autonomous vehicle 10 via the locating device. SUB-STEP 1204, DETERMINE THE stop SIGNAL status, includes determining the status of the stop signal, e.g. off, caution, stop, reported in the message received by the receiver. SUB-STEP 1206, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE SCHOOL BUS LOCATION, includes calculating the distance between the current location of the autonomous vehicle determined by the autonomous vehicle's locating device and the location of the school bus 34 contained within the message received from the school bus transmitter. SUB-STEP 1208, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES BASED ON THE VEHICLE SPEED, THE STOP SIGNAL STATUS, AND THE DISTANCE BETWEEN THE VEHICLE AND THE SCHOOL

BUS LOCATION, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the autonomous vehicle 10 will need to come to a stop at the school bus location based on the stop signal status, the vehicle speed, and the distance between the autonomous vehicle 10 and school bus location. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped for the school bus 34.

[0058] Fig. 15 illustrates a second set of sub-steps that may be included in STEP 204. This set of sub-steps are used to automatically establish a safe following distance behind a maintenance vehicle 36. SUB-STEP 2202, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE MAINTENANCE VEHICLE LOCATION, includes determining the distance between the autonomous vehicle 10 and the maintenance vehicle location by comparing the location of the autonomous vehicle 10 determined by the locating device with the location of the maintenance vehicle 36 contained in the message received by the receiver. SUB-STEP 2204, DETERMINE A DIFFERENCE BETWEEN THE SAFE FOLLOWING DISTANCE AND THE DISTANCE BETWEEN THE VEHICLE AND THE MAINTENANCE VEHICLE LOCATION, includes calculating the difference between the safe following distance contained in the message from the maintenance vehicle transmitter and the distance calculated in SUB-STEP 2202. SUB-STEP 2206, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO APPLY VEHICLE BRAKES WHEN THE DIFFERENCE IS LESS THAN ZERO, includes sending instructions to the vehicle braking system to apply brakes when it is determined that the distance between the autonomous vehicle 10 and the maintenance vehicle 36 is less than the safe following distance. Sub-step 2208, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE POWERTRAIN SYSTEM TO

ADJUST A VEHICLE SPEED SO THAT THE DIFFERENCE IS LESS THAN OR EQUAL TO ZERO, includes sending instructions from the computer system to the powertrain system to adjust the vehicle speed so that the difference in the distance between the autonomous vehicle 10 and the maintenance vehicle 36 and the safe following distance is less than or equal to zero, thus maintaining the safe following distance.

[0059] Fig. 16 illustrates a second set of sub-steps that may be included in STEP 204.

This set of sub-steps are used to automatically park the autonomous vehicle 10 on the shoulder of the road so that an emergency vehicle 38 that has its warning lights activated can safely pass the autonomous vehicle. This vehicle behavior is required by law in various states. SUB-STEP 3202, DETERMINE A DISTANCE BETWEEN THE VEHICLE AND THE EMERGENCY VEHICLE, includes determining the distance between the autonomous vehicle 10 and the emergency vehicle location by comparing the location of the autonomous vehicle 10 determined by the locating device with the location of the emergency vehicle 38 contained in the message received by the receiver. SUB-STEP 3204, DETERMINE A LOCATION OF AN UNOBSTRUCTED PORTION OF A ROAD SHOULDER VIA THE FORWARD LOOKING SENSOR BASED ON THE DISTANCE BETWEEN THE VEHICLE AND THE EMERGENCY VEHICLE, THE EMERGENCY VEHICLE SPEED, AND WARNING LIGHT STATUS, includes using the forward looking sensor 40 to find a unobstructed portion of the shoulder of the roadway 12 in which the autonomous vehicle 10 can park in order to allow the emergency vehicle 38 to pass safely. The unobstructed location is based on the data from the forward looking sensor 40, the distance between the autonomous vehicle 10 and the emergency vehicle 38, the emergency vehicle speed, and the warning light status. SUB-STEP 3206, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE BRAKING SYSTEM TO

APPLY VEHICLE BRAKES BASED ON THE DISTANCE BETWEEN THE VEHICLE AND THE EMERGENCY VEHICLE, THE EMERGENCY VEHICLE SPEED, AND THE LOCATION OF THE UNOBSTRUCTED PORTION OF THE ROAD SHOULDER, includes sending instructions to the vehicle braking system to apply brakes to stop the autonomous vehicle 10 within the unobstructed location based on the distance between the autonomous vehicle 10 and the emergency vehicle 38, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder. The forward looking sensor 40 may also be employed to adjust the braking rate to accommodate other vehicles already stopped in the road shoulder. SUB-STEP 3208, DETERMINE A STEERING ANGLE BASED ON THE DISTANCE BETWEEN THE VEHICLE AND THE EMERGENCY VEHICLE, THE EMERGENCY VEHICLE SPEED, AND THE LOCATION OF THE UNOBSTRUCTED PORTION OF THE ROAD SHOULDER, includes determining a steering angle based on the distance between the autonomous vehicle 10 and the emergency vehicle 38, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder. SUB-STEP 3210, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE STEERING SYSTEM TO ADJUST A VEHICLE PATH BASED ON THE STEERING ANGLE, includes sending instructions to the vehicle steering system to steer the autonomous vehicle 10 into the unobstructed location based on the steering angle determined in SUB-STEP 3208. SUB-STEP 3212, PROVIDE, BY THE COMPUTER SYSTEM, INSTRUCTIONS TO THE POWERTRAIN SYSTEM TO ADJUST A VEHICLE SPEED BASED ON THE DISTANCE BETWEEN THE VEHICLE AND THE EMERGENCY VEHICLE, THE EMERGENCY VEHICLE SPEED, AND THE LOCATION OF THE UNOBSTRUCTED PORTION OF THE ROAD SHOULDER, includes sending

instructions to the vehicle powertrain system to adjust the vehicle speed based on the distance between the autonomous vehicle 10 and the emergency vehicle 38, the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder.

[0060] The embodiments described herein are described in terms of an autonomous vehicle 10. However, elements of the embodiments may also be applied to warning systems that alert the driver to manually take these identified countermeasures.

[0061] Accordingly a method 100 of automatically operating a autonomous vehicle 10 is provided. The method 100 provides the benefits of allowing automatic control of the autonomous vehicle 10 when forward looking sensors 40 are be obscured.

[0062] While this invention has been described in terms of the preferred embodiments thereof, it is not intended to be so limited, but rather only to the extent set forth in the claims that follow. Moreover, the use of the terms first, second, etc. does not denote any order of importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items.

WE CLAIM:

1. A method (100) of operating a vehicle (10), comprising the steps of:
 - receiving a message from roadside infrastructure via an electronic receiver (102); and
 - providing, by a computer system in communication with said electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system (104).

2. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a traffic signaling device (14) and data contained in the message includes a device location, a signal phase, and a phase timing, wherein the vehicle system is a braking system, and wherein the step of providing instructions includes the sub-steps of:
 - determining a vehicle speed (1102);
 - determining the signal phase in a current vehicle path (1104);
 - determining a distance between the vehicle (10) and the device location (1106); and
 - providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, the signal phase of the current vehicle path, and the distance between the vehicle (10) and the device location (1108).

3. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a construction zone warning device (16) and data contained in the message includes information selected from the group consisting of: a zone location, a zone direction, a zone length, a zone speed limit, and lane closures, wherein the vehicle system is selected from the group consisting of: a braking system, a steering system, and a powertrain system,

and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

- determining a vehicle speed (2102);
- determining a lateral vehicle location within a roadway (2104);
- determining a distance between the vehicle (10) and the zone location (2106);
- providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the difference between the vehicle speed and the zone speed limit, and the distance between the vehicle (10) and the zone location (2110);
- determining a steering angle based on the lateral vehicle location, the lane closures, the vehicle speed, and the distance between the vehicle (10) and the zone location (2112);
- providing, by the computer system, instructions to the steering system to adjust a vehicle path based on the steering angle (2114); and
- providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the zone speed limit (2116).

4. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a stop sign (18) and data contained in the message includes sign location and stop direction, wherein the vehicle system is a braking system, and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

- determining vehicle speed (3102);
- determining the stop direction of a current vehicle path (3104);
- determining a distance between the vehicle (10) and the sign location (3106); and

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on a vehicle speed, the stop direction of the current vehicle path, and the distance between the vehicle (10) and the sign location (3108).

5. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a railroad crossing warning device (20) and data contained in the message includes device location and warning state, wherein the vehicle system is a braking system, and wherein the step of providing instructions includes the sub-steps of:

determining vehicle speed (4102);

determining the warning state (4104);

determining a distance between the vehicle (10) and the device location (4106); and

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, warning state, and the distance between the vehicle (10) and the device location (4108).

6. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is an animal crossing zone warning device (22) and data contained in the message includes zone location, zone direction, and zone length, wherein the vehicle system is a forward looking sensor (40), and wherein the step of providing instructions includes the sub-step of providing, by the computer system, instructions to the forward looking sensor (40) to widen a field of view so as to include at least both road shoulders within the field of view (5102).

7. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a pedestrian crossing warning device (24) and data contained in the message is selected from the group consisting of: crossing location and warning state, wherein the vehicle system is selected from the group consisting of: a braking system and a forward looking sensor (40), and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

providing, by the computer system, instructions to the forward looking sensor (40) to widen a field of view so as to include at least both road shoulders within the field of view (6102);

determining vehicle speed (6104);

determining a distance between the vehicle (10) and the crossing location (6106); and

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, warning state, and the distance between the vehicle (10) and the crossing location (6108).

8. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a school crossing warning device (26) and data contained in the message is selected from the group consisting of: device location and warning state, wherein the vehicle system is a braking system, and wherein the step of providing instructions includes the sub-steps of:

determining vehicle speed (7102);

determining a lateral location of the device location within a roadway (7104);

determining a distance between the vehicle (10) and the device location (7106); and

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on data selected from the group consisting of: a vehicle speed, the lateral location, the warning state, and the distance between the vehicle and the device location (7108).

9. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a lane direction indicating device (28) and data contained in the message is a lane location and a lane direction, wherein the vehicle system is a roadway mapping system, and wherein the step of providing instructions includes the sub-step of:

providing, by the computer system, instructions to the roadway mapping system to dynamically update the roadway mapping system's lane direction information (8102).

10. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a speed limiting device (30) and data contained in the message includes a speed zone location, a speed zone direction, a speed zone length, and a zone speed limit, wherein the vehicle system is a powertrain system, and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

determining a vehicle speed (9102);

determining a distance between the vehicle location and the speed zone location (9104); and

providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so that the vehicle speed is less than or equal to the zone speed limit (9108).

11. The method (100) of operating a vehicle (10) according to claim 1, wherein the roadside infrastructure is a no passing zone device (32) and data contained in the message includes a no passing zone location, a no passing zone direction, and a no passing zone length wherein the vehicle system includes selected from the group consisting of: a powertrain system, a forward looking sensor (40) and a braking system, and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

- detecting another vehicle ahead of the vehicle (10) via the forward looking sensor (40) (10102);

- determining a vehicle speed (10104);

- determining an another vehicle speed and a distance between the vehicle (10) and the another vehicle (10106);

- determine a safe passing distance for overtaking the another vehicle (10108);

- determining a distance between the vehicle (10) and the no passing zone location (10110);

- providing, by the computer system, instructions to the powertrain system to adjust the vehicle speed so that the speed differential is less than or equal to zero when the safe passing distance would end within the no passing zone (10112); and

- providing, by the computer system, instructions to the braking system to adjust the vehicle speed so that the vehicle speed is less than or equal to the another vehicle speed when the safe passing distance would end within the no passing zone (10114).

12. A method (200) of operating a vehicle (10), comprising the steps of:

- receiving a message from another vehicle via an electronic receiver (202); and

providing, by a computer system in communication with said electronic receiver, instructions based on the message to automatically implement countermeasure behavior by a vehicle system (204).

13. The method (200) of operating a vehicle (10) according to claim 12, wherein the another vehicle is a school bus (34) and data contained in the message includes school bus location and stop signal status, wherein the vehicle system is a braking system, and wherein the step of providing instructions includes the sub-steps of:

determining a vehicle speed (1202);

determining the stop signal status (1204);

determining a distance between the vehicle (10) and the school bus location (1206);

and

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the vehicle speed, the stop signal status, and the distance between the vehicle (10) and the school bus location (1208).

14. The method (200) of operating a vehicle (10) according to claim 12, wherein the another vehicle is a maintenance vehicle (36) and data contained in the message includes maintenance vehicle location and safe following distance, the vehicle system is selected from the group consisting of: a powertrain system and a braking system, and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

determining a distance between the vehicle (10) and the maintenance vehicle location (2202);

determining a difference between the safe following distance and the distance between the vehicle (10) and the maintenance vehicle location (2204);

providing, by the computer system, instructions to the braking system to apply vehicle brakes when the difference is less than zero (2206); and

providing, by the computer system, instructions to the powertrain system to adjust a vehicle speed so that the difference is less than or equal to zero (2208).

15. The method (200) of operating a vehicle (10) according to claim 12, wherein the another vehicle is an emergency vehicle (38) and data contained in the message includes information selected from the group consisting of: an emergency vehicle location, an emergency vehicle speed, and a warning light status, wherein the vehicle system is selected from the group consisting of: a braking system, a steering system, a forward looking sensor (40), and a powertrain system, and wherein the step of providing instructions includes the sub-steps selected from the group consisting of:

determining a distance between the vehicle (10) and the emergency vehicle (38) (3202);

determine a location of an unobstructed portion of a road shoulder via the forward looking sensor (40) based on the distance between the vehicle (10) and the emergency vehicle (38), the emergency vehicle speed, and warning light status (3204);

providing, by the computer system, instructions to the braking system to apply vehicle brakes based on the distance between the vehicle (10) and the emergency vehicle (38), the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder (3206);

determining a steering angle based on the distance between the vehicle (10) and the emergency vehicle (38), the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder (3208);

providing, by the computer system, instructions to the steering system to adjust a vehicle path based on the steering angle (3210); and

providing, by the computer system, instructions to the powertrain system to adjust a vehicle speed based on the distance between the vehicle (10) and the emergency vehicle (38), the emergency vehicle speed, and the location of the unobstructed portion of the road shoulder (3212).

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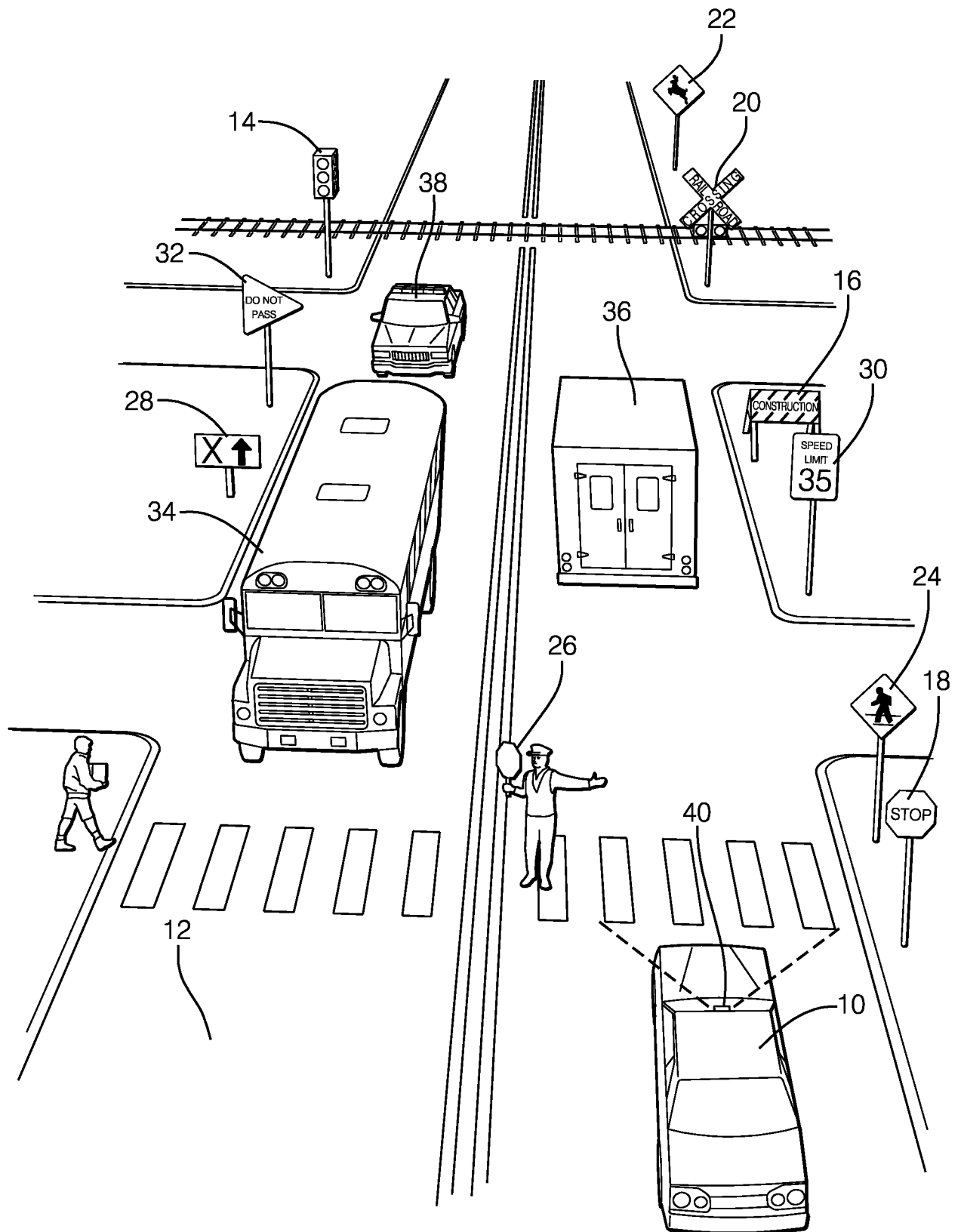
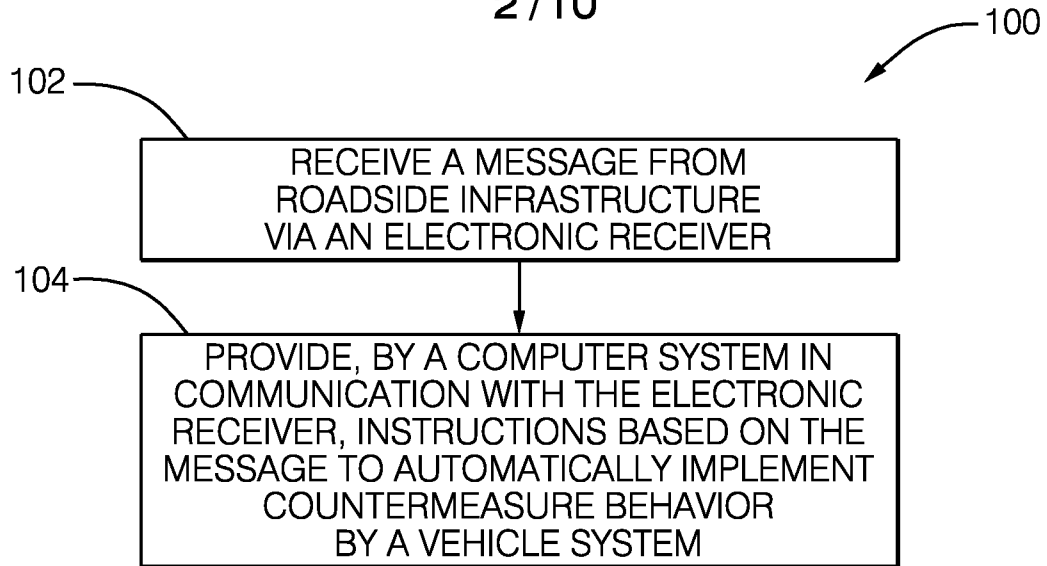
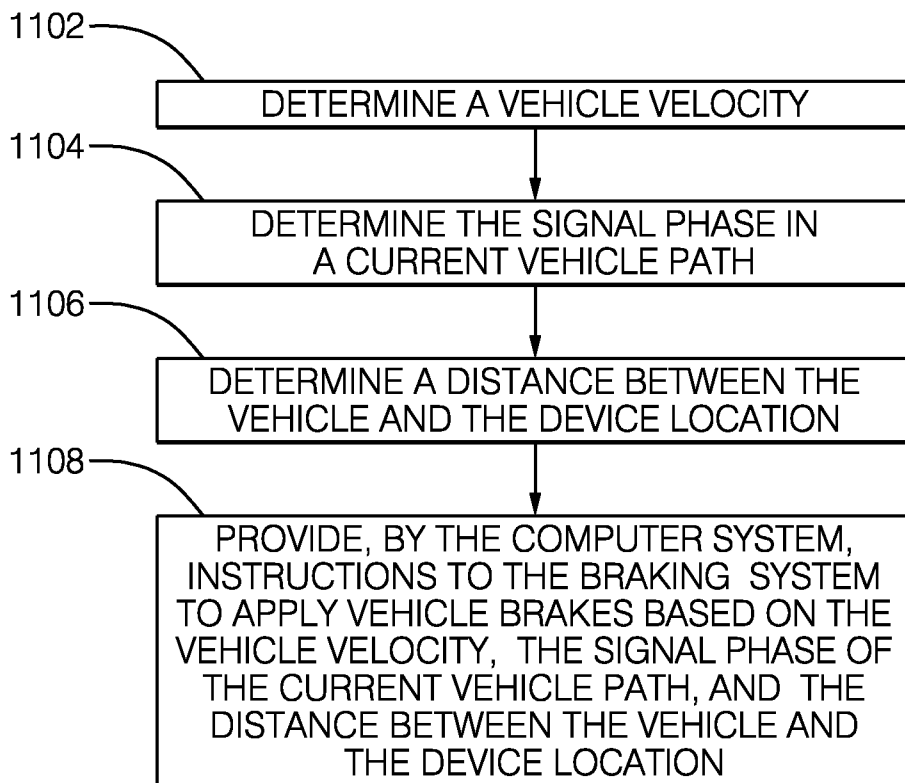


FIG. 1

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**FIG. 2****FIG. 3**

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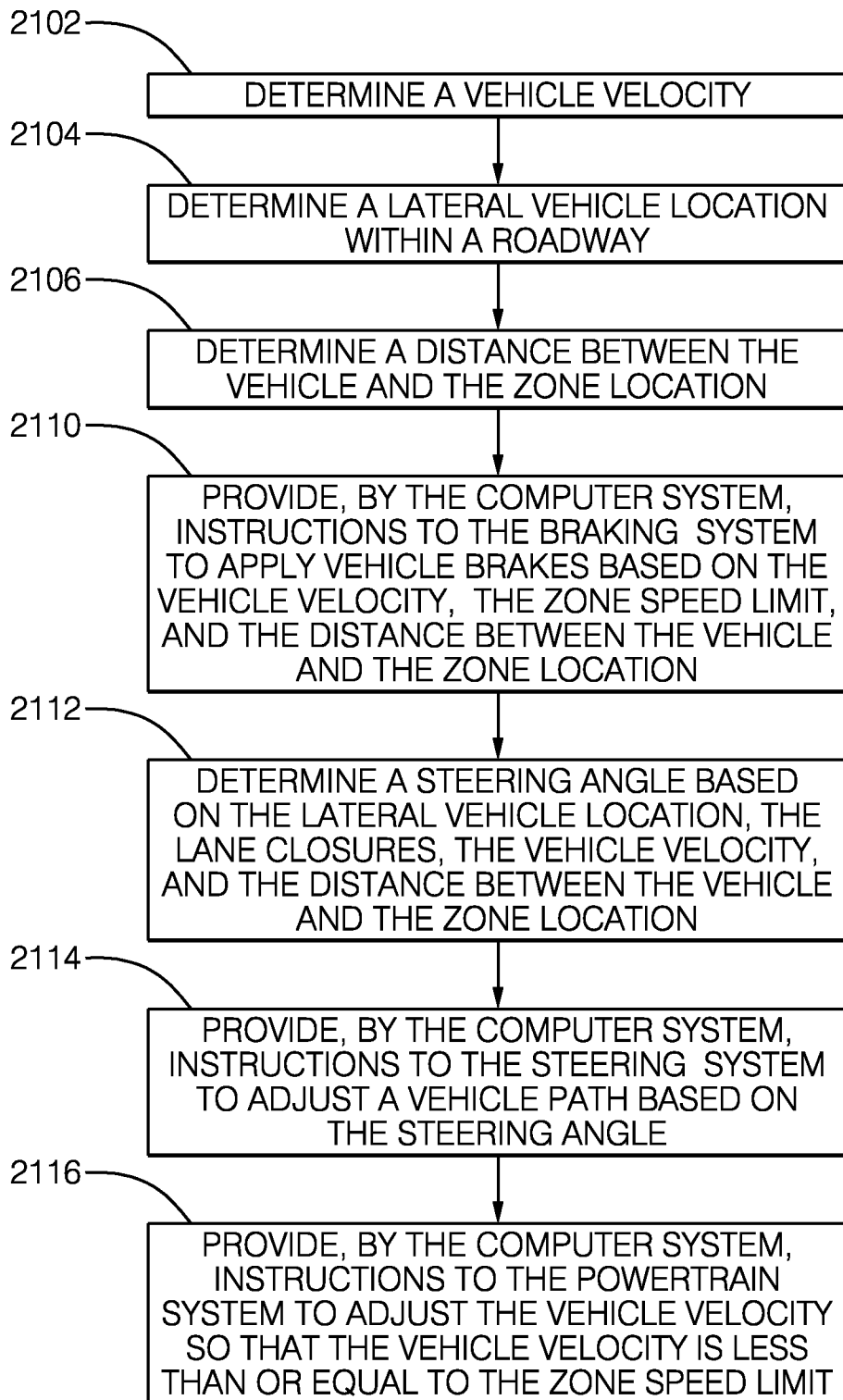
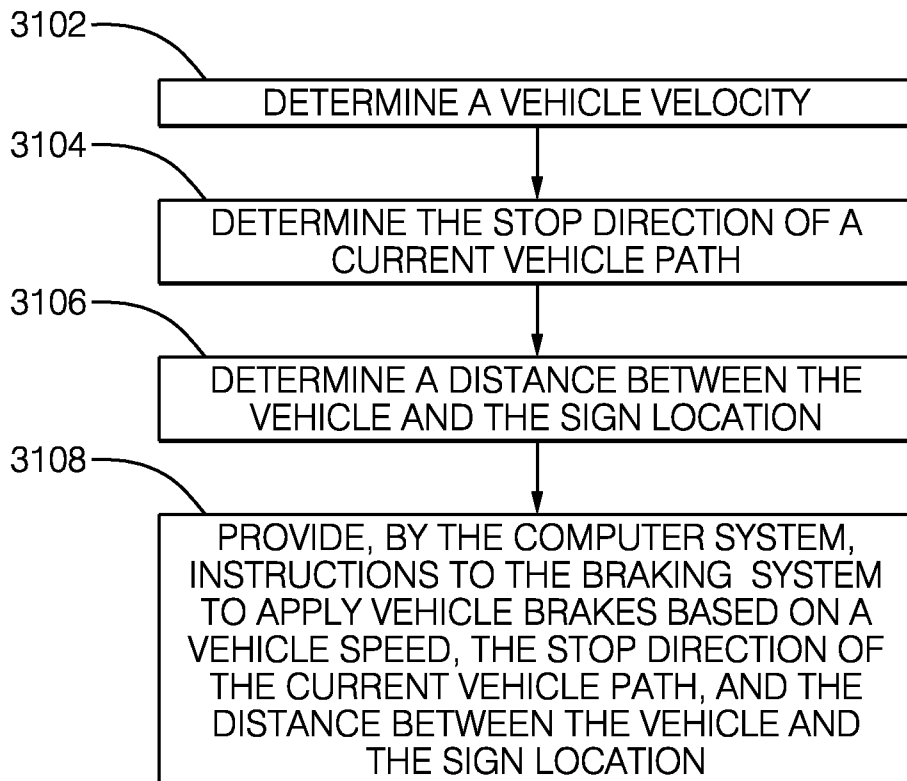
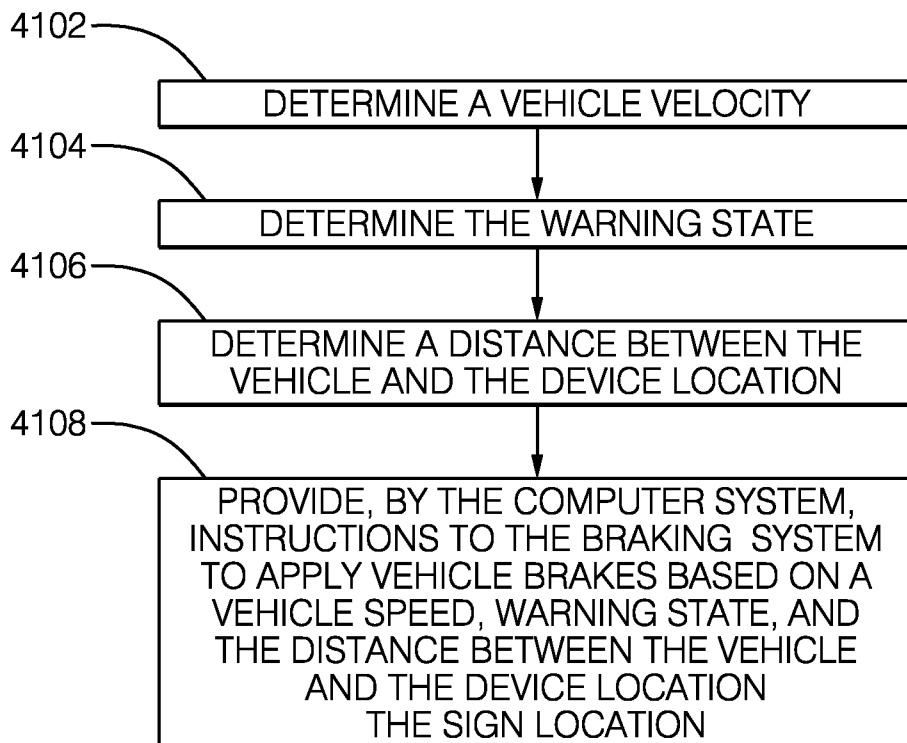
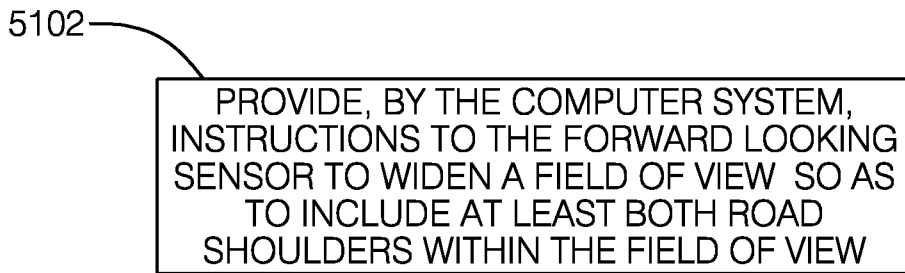
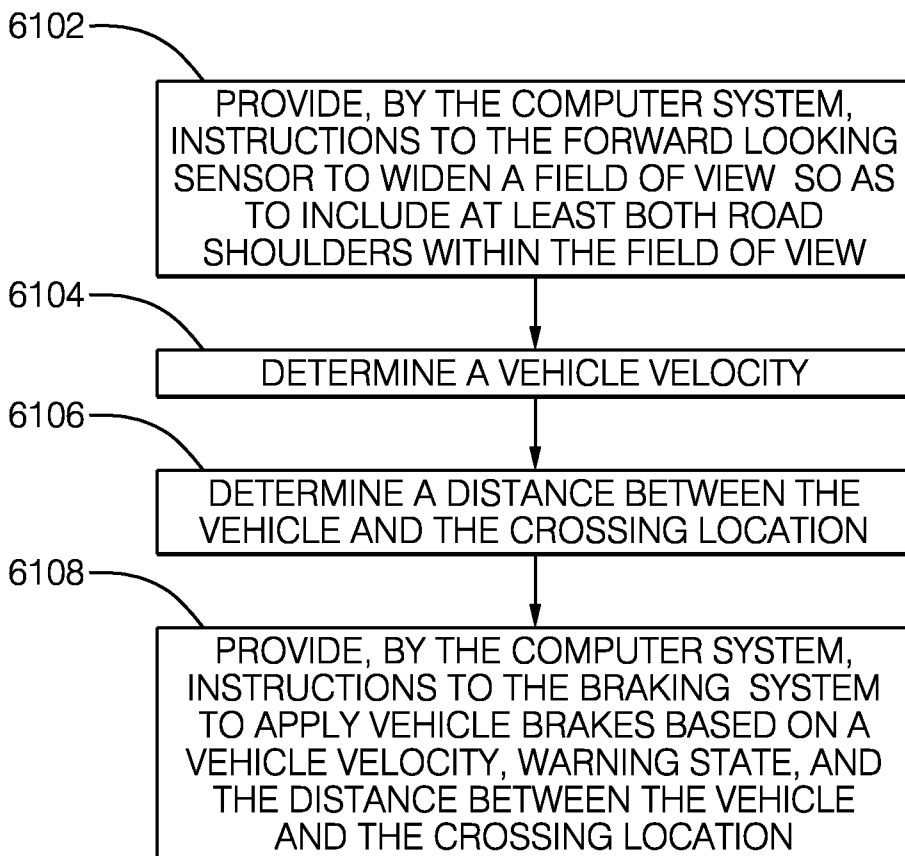


FIG. 4

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**FIG. 5****FIG. 6**

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**FIG. 7****FIG. 8**

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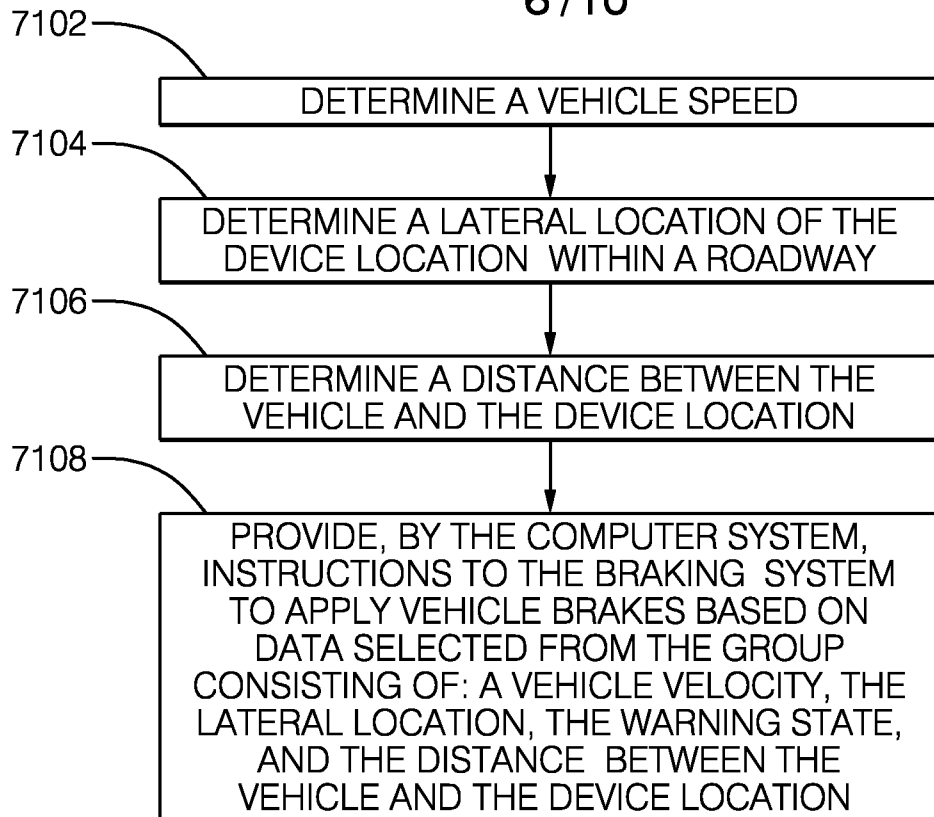


FIG. 9

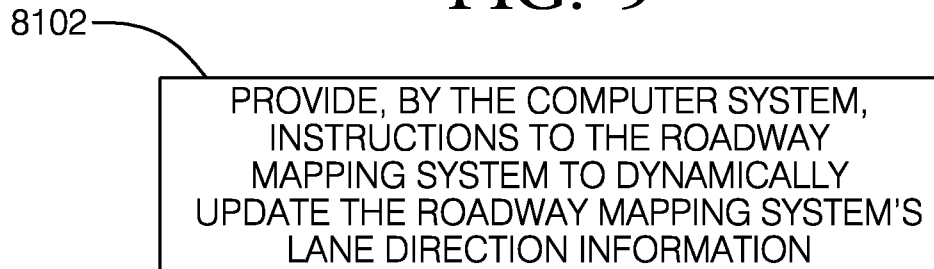


FIG. 10

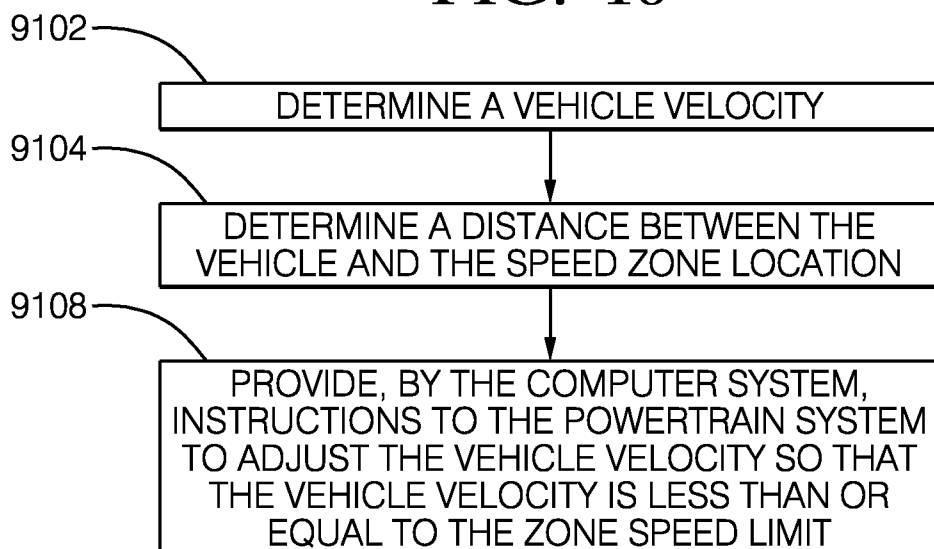


FIG. 11

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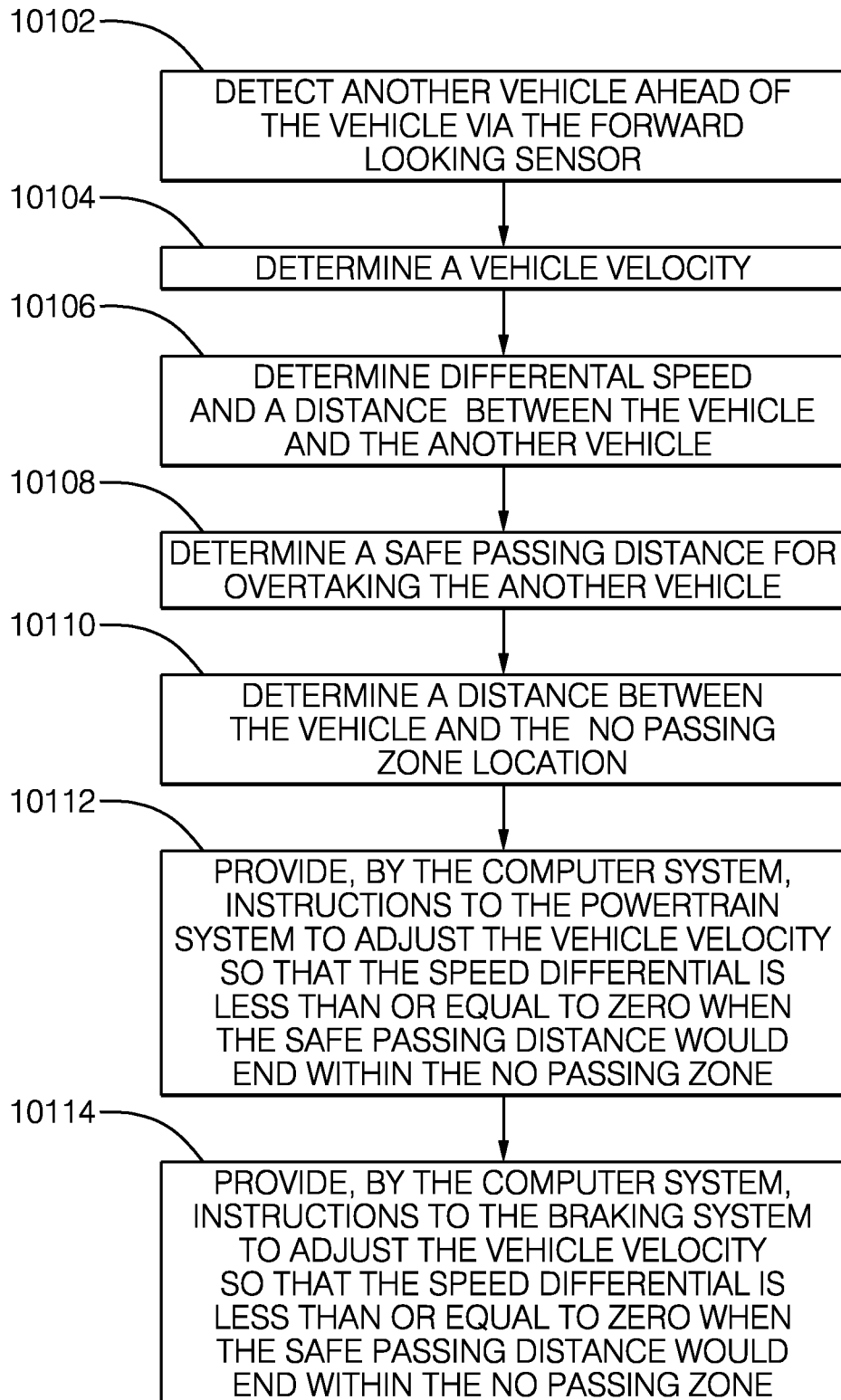


FIG. 12

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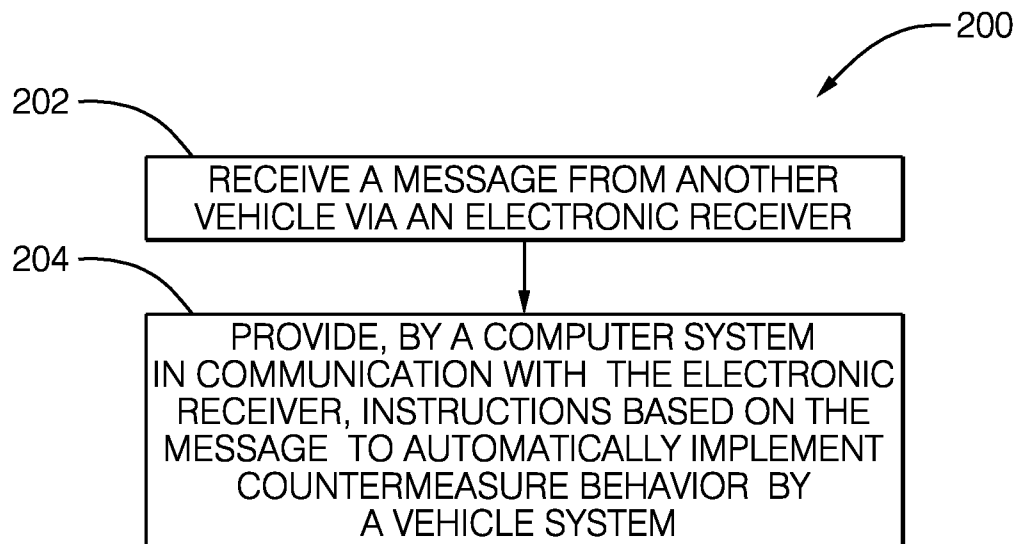


FIG. 13

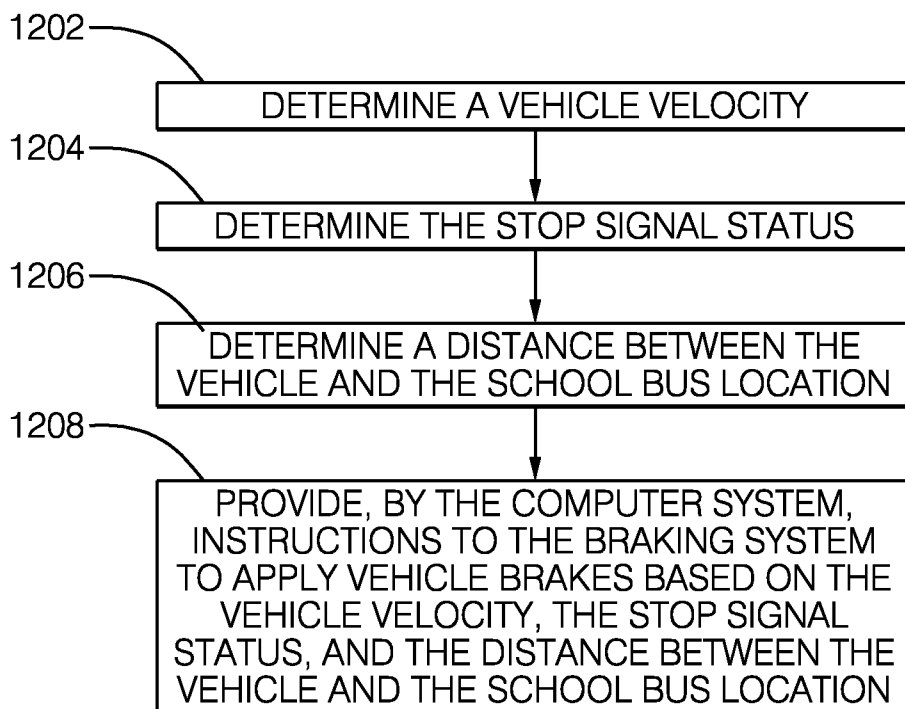


FIG. 14

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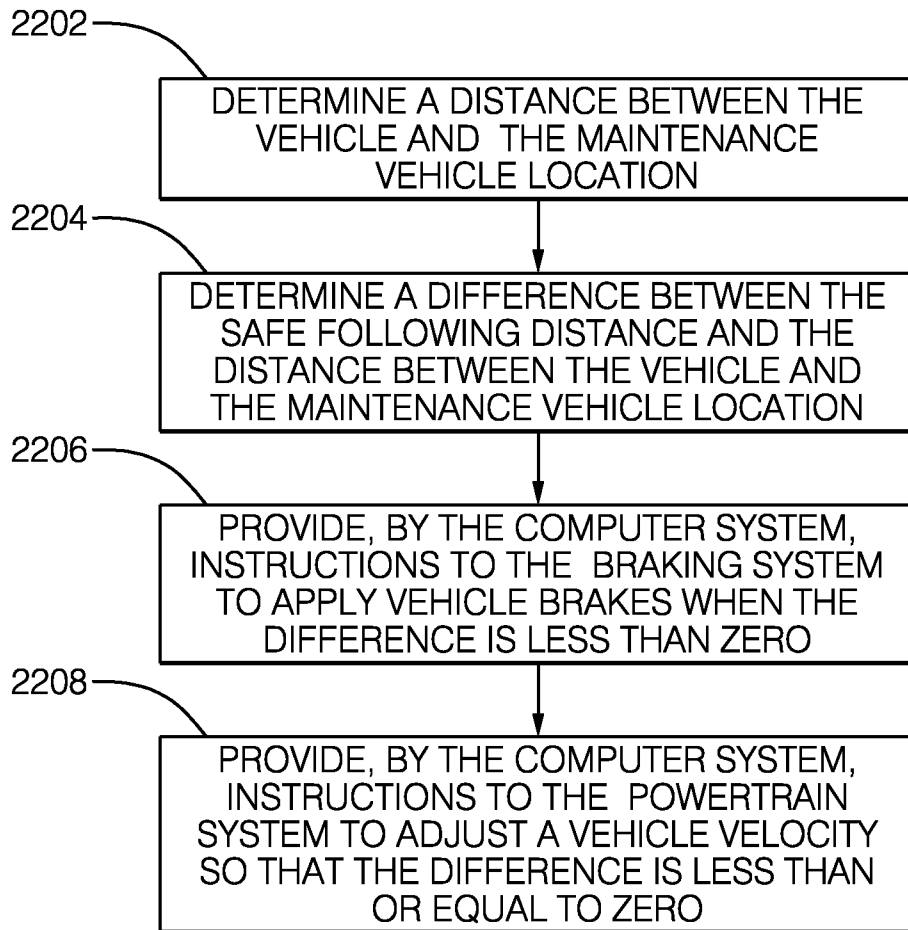


FIG. 15

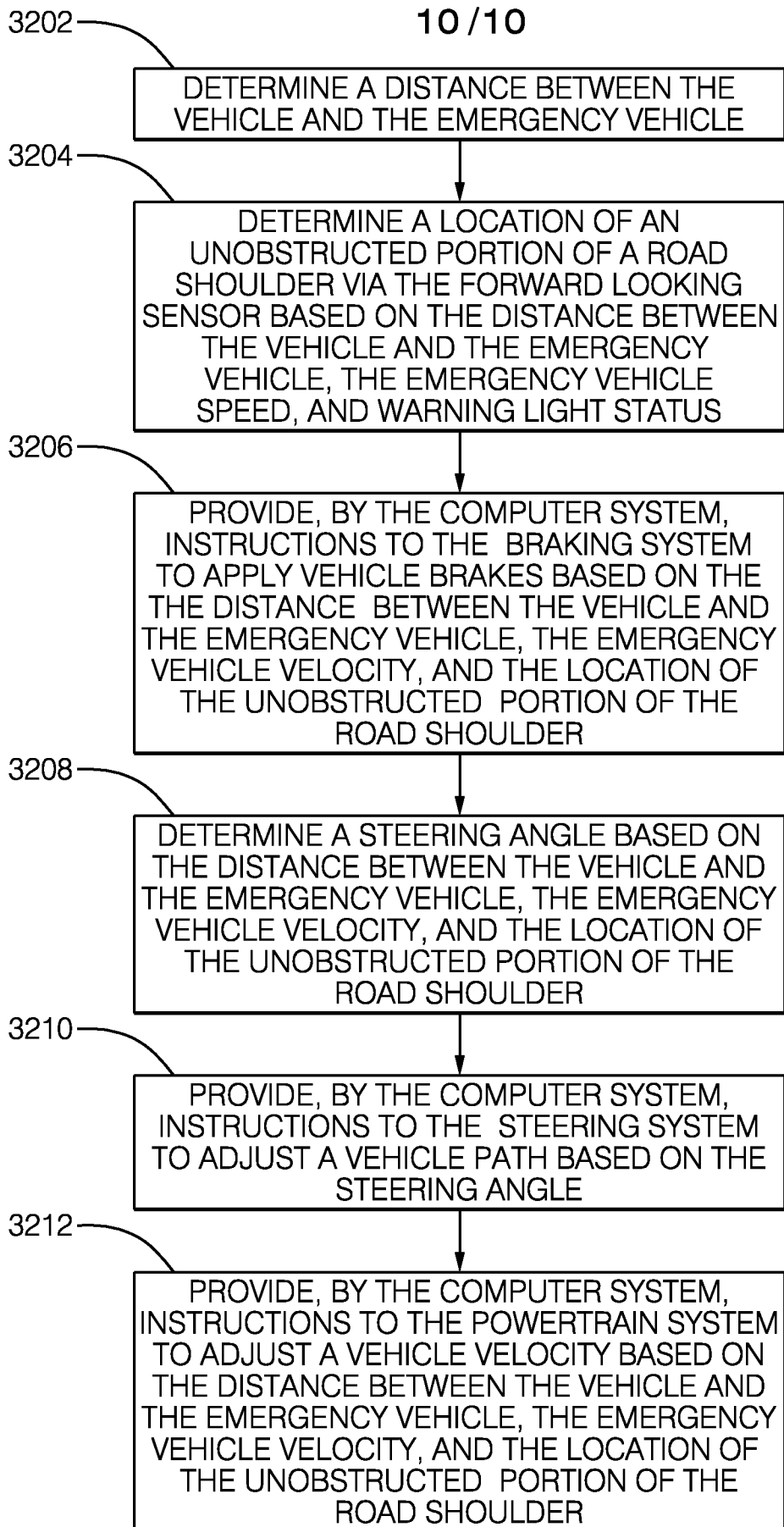


FIG. 16

A. CLASSIFICATION OF SUBJECT MATTER**G05D 1/02(2006.01)i, G08G 1/0965(2006.01)i, G08G 1/0968(2006.01)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)

G05D 1/02; G08G 1/16; G06K 9/48; G06F 7/00; G06G 7/78; G01C 21/34; B60W 40/06; G08G 1/0965; G08G 1/0968

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: autonomous vehicle, roadside, traffic signal, instruction, intersection

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0104199 A1 (WENDE ZHANG et al.) 29 April 2010 See paragraphs [0106]-[0139], claim 1 and figure 15.	1,3,12
Y		2,4-11,13-15
Y	US 2012-0296539 A1 (TROY OTIS COOPRIDER et al.) 22 November 2012 See paragraphs [0022]-[0046], claim 1 and figure 2.	2,4-11
Y	US 2015-0006005 A1 (STEVEN SOUNYOUNG YU et al.) 01 January 2015 See paragraphs [0029]-[0042], claim 1 and figures 1A, 1B.	13-15
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A	KR 10-2012-0072020 A (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE) 03 July 2012 See paragraphs [0036]-[0047], claim 1 and figure 1.	1-15



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

21 March 2016 (21.03.2016)

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

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International application No.

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