(54) Title: OPERATOR SKILL SCORING BASED ON COMPARISON TO AUTOMATED VEHICLE OPERATION
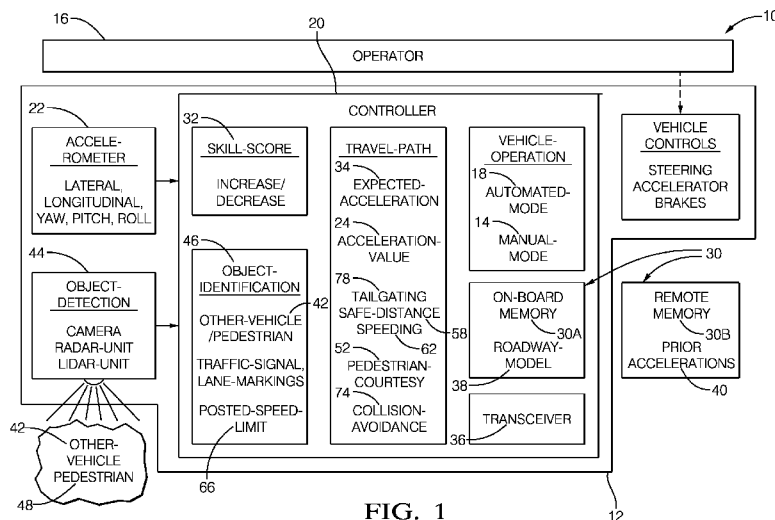
FIG. 1

(57) Abstract: A skill-scoring system (10) suitable for use on an automated vehicle (12) includes an accelerometer (22) and a con-
troller (20). The accelerometer (22) is used to determine an acceleration-value (24) experienced by an operator (16) of a host-vehicle
(12) while the operator (16) operates the host-vehicle (12) in a manual-mode (14) along a travel-path (26). The controller (20) is in
communication with the accelerometer (22). The controller (20) is configured to determine a skill-score (32) based on a comparison
of the acceleration- value (24) to an expected-acceleration (34) that the operator (16) would experience when the host-vehicle (12) is
operated in an automated-mode (18) along the travel-path (26).

OPERATOR SKILL SCORING BASED ON COMPARISON TO AUTOMATED

VEHICLE OPERATION

TECHNICAL FIELD OF INVENTION

[0001] This disclosure generally relates to a skill-scoring system suitable for use on an automated vehicle, and more particularly relates to a system that determines a skill-score based on a comparison of the accelerations of a host-vehicle when an operator drives the host-vehicle in a manual-mode to accelerations when the host-vehicle is operated in an automated-mode.

BACKGROUND OF INVENTION

[0002] Some vehicle operators (i.e. drivers) exhibit less than desirable driving skills such as frequent speed changes and erratic steering. Remarks by passengers that such driving skills need to be improved may be ignored and/or cause offense. What is needed is an impartial observer that provides a measurement of an operator's driving skills.

SUMMARY OF THE INVENTION

[0003] In accordance with one embodiment, a skill-scoring system suitable for use on an automated vehicle is provided. The system includes an accelerometer and a controller. The accelerometer is used to determine an acceleration-value experienced by an operator of a host-vehicle while the operator operates the host-vehicle in a manual-mode along a travel-path. The controller is in communication with the accelerometer. The controller is configured to determine a skill-score based on a comparison of the acceleration-value to

an expected-acceleration that the operator would experience when the host-vehicle is operated in an automated-mode along the travel-path.

[0004]   Further features and advantages will appear more clearly on a reading of the following detailed description of the preferred embodiment, which is given by way of non-limiting example only and with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0005]   The present invention will now be described, by way of example with reference to the accompanying drawings, in which:

[0006]   Fig. 1 is a diagram of a skill-scoring system in accordance with one embodiment;

[0007]   Fig. 2 is a traffic scenario encountered by the system of Fig. 1 in accordance with one embodiment;

[0008]   Fig. 3 is a traffic scenario encountered by the system of Fig. 1 in accordance with one embodiment; and

[0009]   Fig. 4 is a traffic scenario encountered by the system of Fig. 1 in accordance with one embodiment.

DETAILED DESCRIPTION

[0010]   Fig. 1 illustrates a non-limiting example of a skill-scoring system 10, hereafter referred to as the system 10, which is suitable for use on an automated vehicle 12, hereafter referred to as the host-vehicle 12. The host-vehicle 12 is generally configured to be operated in, but not limited to, a manual-mode 14 where an operator 16 manually

operates vehicle inputs to control the steering, accelerator, and brakes of the host-vehicle 12, and an automated-mode 18 (i.e. autonomous operation) where the operator 16 is little more than a passenger of the host-vehicle and a controller 20 has control of the steering, accelerator, and brakes of the host-vehicle 12. As will be explained in more detail below, the skill-scoring aspect of the system 10 is intended to provide a means for improving the manual driving habits of the operator 16 by comparing the motion or operation of the host-vehicle 12 when operated in the manual-mode by the operator 16 to the motion or operation of the host-vehicle 12 when operated in the automated-mode by the controller 20.

[0011]   The system 10 includes an accelerometer 22 used to determine an acceleration-value 24 experienced by the operator 16 or passenger of a host-vehicle 12 as the host-vehicle travels along a travel-path 26. As used herein, the acceleration-value 24 may characterize any type of change in velocity, i.e. a change in speed and/or change in direction of the host-vehicle 12. That is, braking or slowing the speed of the host-vehicle 12 may be characterized by the acceleration-value 24 just as accelerating or increasing the speed of the host-vehicle 12 and/or steering the host-vehicle to change direction may be characterized by the acceleration-value 24. Accordingly, the accelerometer 22 may include, but is not limited to, the means to measure or detect lateral acceleration, longitudinal acceleration, and/or changes in the yaw, pitch, and/or roll angles of the host-vehicle 12. As such, the acceleration-value 24 may include or tally the effects of, for example, longitudinal acceleration caused by undesirable variations in speed, lateral acceleration caused by frequent steering corrections, and/or combinations or sequences thereof.

[0012]   As used herein, the travel-path 26 will typically be a roadway 28 (Figs. 2-4)

with relatively well defined boundaries that determine the shape of the travel-path 26.

However, off-road scenarios such mining or farming operations are envisioned where

skill-scoring of an operator may be helpful to improve operational efficiency. As will

become apparent in the description that follows, the acceleration-value 24 is of particular

interest while the operator 16 operates the host-vehicle 12 in the manual-mode 14 along

the travel-path 26 so, for example, how smoothly or efficiently the operator 16 operates

the host-vehicle 12 can be compared to how smoothly or efficiently the controller 20

operates the host-vehicle 12 along the same or similar section of the travel-path 26. If the

travel-path 26 is relatively smooth and straight, the comparison of operation over

different sections of the roadway 28 may be useful. However, if a particular section of

the roadway 28 has irregular features, then the comparison of operation during the

manual-mode 14 and the automated-mode 18 while traveling the same section of the

roadway 28 may be necessary.

[0013]   As mentioned above, the system 10 includes the controller 20 which is in

communication with the accelerometer 22, typically via wires. The controller 20 may

include a processor (not specifically shown) such as a microprocessor or other control

circuitry such as analog and/or digital control circuitry including an application specific

integrated circuit (ASIC) for processing data as should be evident to those in the art. The

controller 20 may include memory 30, such as on-board memory 30A in the form of non-

volatile electrically erasable programmable read-only memory (EEPROM) for storing

one or more routines, thresholds, and captured data. The one or more routines may be

executed by the processor to perform steps to determine a skill-score 32 based on a

comparison of the acceleration-value 24 to an expected-acceleration 34 that the operator 16 and/or the host-vehicle 12 would experience when the host-vehicle 12 is operated in the automated-mode 18 along the travel-path 26. That is, the skill-score 32 is an indicator of differences in motion or movement of the host-vehicle 12 when operated in the manual-mode 14 by the operator and when operated in the automated-mode 18 by the controller 20 over the same or comparable sections of the travel-path 26 of the roadway 28.

[0014]   The memory 30, which may include the on-board memory 30A and/or a remote memory 30B accessed via a transceiver 36, may be used to store the expected-acceleration 34 for the travel-path 26. In one embodiment of the system 10 the expected-acceleration 34 may be determined based on a roadway-model 38 that calculates the expected-acceleration 34 based on, for example, the radius and bank-angle of a curve, and/or a change in ramp-angle (e.g. uphill/downhill) of the travel-path 26. Alternatively, and believed to be preferable, the expected-acceleration 34 may be determined based on prior-accelerations 40 recorded in other-vehicles 42 (Fig. 2) previously operated along the travel-path 26.

[0015]   While it may be preferable that the other-vehicles 42 were operated in an automated-mode so the roadway-model 38 is not the only way to determine the expected-acceleration, instances of the prior-accelerations 40 experienced by the other-vehicles 42 while being operated in a manual-mode may also be useful to make comparisons of the driving skills of the operator 16 to the driving skills of the other-operators (not shown) of the other-vehicles 42. That is, the expected-acceleration 34 may be determined from the prior-accelerations 40 experienced by the other-operators on prior travels through a

particular portion, intersection, or lane of the travel-path 26, and the expected-acceleration 34 may be determined by the controller 20 and/or a remote computer in communication with the remote memory 30B, i.e. determined and stored 'in the cloud'.

[0016] By way of further example and not limitation, the skill-score 32 may start with a value of one-hundred (100) and then be increased or decreased based on subsequent comparisons of the acceleration-value 24 to the expected-acceleration 34. For example, the skill-score 32 may be decreased, indicating poor driving skills, when the operator 16 does not operate the host-vehicle smoothly. Excessive steering corrections that cause lateral accelerations, and excessive speed variation that cause longitudinal accelerations are but two examples of poor driving skills. In these two examples the skill-score 32 may be decreased because the acceleration-value 24 is greater than or exceeds the expected-acceleration 34. However, certain circumstances may require a significant steering correction and/or change in speed to, for example, avoid a collision. As such, it may be advantageous to equip the system 10 so that instances when it is justifiable for the acceleration-value 24 to exceed the expected-acceleration 34 may be detected and the skill-score properly adjusted.

[0017] To this end, the system 10 may include an object-detection-device 44 operable to detect various objects proximate to the host-vehicle 12. The object-detection-device 44 may include, but is not limited to, a camera, a radar-unit, a lidar-unit, and/or any combination thereof. Accordingly, the controller 20 may be equipped or programmed with an object-identification block 46 that can process signals from the object-detection-device 44 to distinguish, for example, the other-vehicle 42 from a pedestrian 48.

Algorithms to process signals from the object-detection-device 44 for identifying or classifying objects are known to those in the art.

[0018]   By way of further example and in reference to Fig. 2, if the object-detection-device 44 detects the pedestrian 48 proximate to the host-vehicle 12 as the host-vehicle 12 approaches a cross-walk 50 across the travel-path 26, the operator 16 may elect to slow or stop the host-vehicle 12 to allow the pedestrian to cross the travel-path 26. The controller 20 may be preferably programmed to adjust (e.g. incrementally increase) the skill-score 32 when a pedestrian-courtesy-event 52 is detected which corresponds to an instance where actions by the operator 16 during operation in the manual-mode 14 made way for the pedestrian 48. I.e. the skill-score 32 is increased because the deceleration that influenced the acceleration-value 24 was due to being courteous to the pedestrian 48.

[0019]   By way of further example, the system 10 may be further configured to use the object-detection-device 44 and/or the roadway-model 38 to determine a lane-centerline 76 of the roadway. For example, the lane-centerline 76 may be determined based on lane-markings present along the travel-path 26 that are detected by the object-detection-device 44, and the image may be processed by the object-identification block 46 to determine the lateral position of the center of a lane. Alternatively, the lane-centerline 76 of the travel-path 26 may be included in a digital map data stored in the memory 30. The skill-score 32 may be adjusted downward based on the detected lateral distance from the lane-centerline 76. I.e. – the skill-score 32 may be decreased when the operator 16 continuously drives with a non-lane-center bias, and the system 10 did not detect a valid reason for such behavior.

[0020]   Like in the previous paragraph, other ways that skill scoring could be accomplished without the use of an accelerometer are contemplated. Some additional non-limiting examples include: measuring the time it takes the operator 16 to take over manual-driving of the host-vehicle 12 (i.e. operate in the manual-mode 14) from the automated-mode 18 once the system 10 has notified the operator 16 that the manual-mode 14 is needed (e.g. the skill-score 32 is decreased for long take-over time); scoring how well the operator keeps a proper gap/distance from the leading-vehicle 54 (Fig. 3) at all times; determine how often the operator 16 checks the rear-view and side-view mirrors of the host-vehicle 12 (more frequent checks increase the skill-score 32; and/or determine a state of alertness of the operator (e.g. reduce the skill-score if the operator 16 appears to be tired.

[0021]   Fig. 3 illustrates another non-limiting example of a scenario that may be experienced by the system 10 and may influence the skill-score 32. By way of further example, the object-detection-device 44 may be used to detect a leading-vehicle 54 located forward of the host-vehicle 12. The skill-score 32 may be adjusted downward or decreased when a tailgating-event 78 is detected by the controller 20, the detection of which may be based on or characterized by the host-vehicle 12 following the leading-vehicle 54 at a following-distance 56 less than a safe-distance 58 (Fig. 1). That is, the skill-score 32 may be decreased when operator 16 tailgates even though no deceleration indicated by the acceleration-value 24 was detected. The safe-distance 58 may be a variable value determined from, for example, the speed of the host-vehicle 12 and an estimate of traction available to the host-vehicle 12 from the travel-path 26.

[0022]   By way of further example, the system 10 may include a speed-limit-detection-means 60. The speed-limit-detection-means 60 may be provided via the object-detection-device 44 capturing an image of a speed-limit-sign 64 adjacent the travel-path 26, and the image may be processed by the object-identification block 46 to determine a posted-speed-limit 66. Alternatively, the speed-limit of the travel-path 26 may be included in a digital map data stored in the memory 30. The skill-score 32 may be adjusted downward based on the detection of a speeding-event 62 when the controller 20 determines that the host-vehicle 12 is exceeding a posted-speed-limit 66. I.e. – the skill-score 32 may be decreased when operator 16 drives faster than the posted-speed-limit 66 even though no excessive instance of the acceleration-value 24 is detected.

[0023]   Fig. 4 illustrates another non-limiting example of a scenario that may be experienced by the system 10 and may influence the skill-score 32. By way of further example, the object-detection-device 44 may be used to detect an approaching-vehicle 68 proximate to the host-vehicle 12, and the skill-score 32 is adjusted based on a collision-avoidance-event 74 where actions by the operator 16 during operation in the manual-mode 14 avoided a collision with the approaching-vehicle 68. The path of the approaching-vehicle 68 crossed a center-line 70 of the roadway 28 so the host-vehicle 12 had to temporarily travel on the shoulder 72 of the roadway 28 to avoid a collision with the approaching-vehicle 68. Steering onto the shoulder 72 and then back to the travel-pate 26 may cause the acceleration-value 24 to increase which would normally cause a corresponding decrease in the skill-score 32. However, since the steering maneuver was effective to avoid a collision, the controller 20 may increase the skill-score if the maneuver was done in a smooth and controlled manner, or at least not change the skill-

score 32 if the maneuver was not smooth. I.e. – the skill-score 32 may be increased when operator 16 successfully avoids a collision not due to the operator's own fault even though a sudden in acceleration-value 24 is detected.

[0024]   Accordingly, a skill-scoring system 10, a controller 20 for the system 10 and a method of operating the system 10 is provided. As the operator 16 operates the host-vehicle 12 in the manual-mode 14, the skill-score 32 may be increased if host-vehicle 12 is operated in a smooth and well-controlled manner. However, if the operator 16 is distracted or has poor driving skills, sudden steering corrections, and/or frequent unnecessary speed changes may cause the skill-score 32 to decrease. By monitoring the skill-score 32, the operator 16 may be able to improve his/her driving skills. The skill-score 32 may become a source of pride for the operator 16 that can be shared with friends in an effort to improve the driving skills of other operators.

[0025]   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.

WE CLAIM:

1. A skill-scoring system (10) suitable for use on an automated vehicle (12), said

    system (10) comprising:

an accelerometer (22) used to determine an acceleration-value (24) experienced by an

    operator (16) of a host-vehicle (12) while the operator (16) operates the host-

    vehicle (12) in a manual-mode (14) along a travel-path (26); and

a controller (20) in communication with the accelerometer (22), said controller (20)

    configured to determine a skill-score (32) based on a comparison of the

    acceleration-value (24) to an expected-acceleration (34) that the operator (16)

    would experience when the host-vehicle (12) is operated in an automated-mode

    (18) along the travel-path (26).

2. The system (10) in accordance with claim 1, wherein the system (10) includes

    memory (30) that stores the expected-acceleration (34), and the expected-

    acceleration (34) is determined based on prior-accelerations (40) recorded in

    other-vehicles (42) previously operated in the automated-mode (18) along the

    travel-path (26).

3. The system (10) in accordance with claim 2, wherein the expected-acceleration (34)

    is further determined based on prior-accelerations (40) recorded in other-vehicles

    (42) when operated in the manual-mode (14) by other-operators during prior

    travel on the travel-path (26).

4. The system (10) in accordance with claim 1, wherein the system (10) includes an

    object-detection-device (44) used to detect a pedestrian (48) proximate to the

    host-vehicle (12), and the skill-score (32) is adjusted based on a pedestrian-

    courtesy-event (52) where actions by the operator (16) during operation in the

    manual-mode (14) made way for a pedestrian (48).

5. The system (10) in accordance with claim 1, wherein the system (10) includes an

    object-detection-device (44) used to detect a leading-vehicle (54) forward of the

    host-vehicle (12), and the skill-score (32) is adjusted based on a tailgating-event

    (78) characterized by the host-vehicle (12) following the leading-vehicle (54) at a

    following-distance (56) less than a safe-distance (58).

6. The system (10) in accordance with claim 1, wherein the system (10) includes a

    speed-limit-detection-means (60), and the skill-score (32) is adjusted based on a

    speeding-event (62) characterized by the host-vehicle (12) exceeding a posted-

    speed-limit (66).

7. The system (10) in accordance with claim 1, wherein the system (10) includes an

    object-detection-device (44) used to detect an approaching-vehicle (68) proximate

    to the host-vehicle (12), and the skill-score (32) is adjusted based on a collision-

    avoidance-event (74) where actions by the operator (16) during operation in the

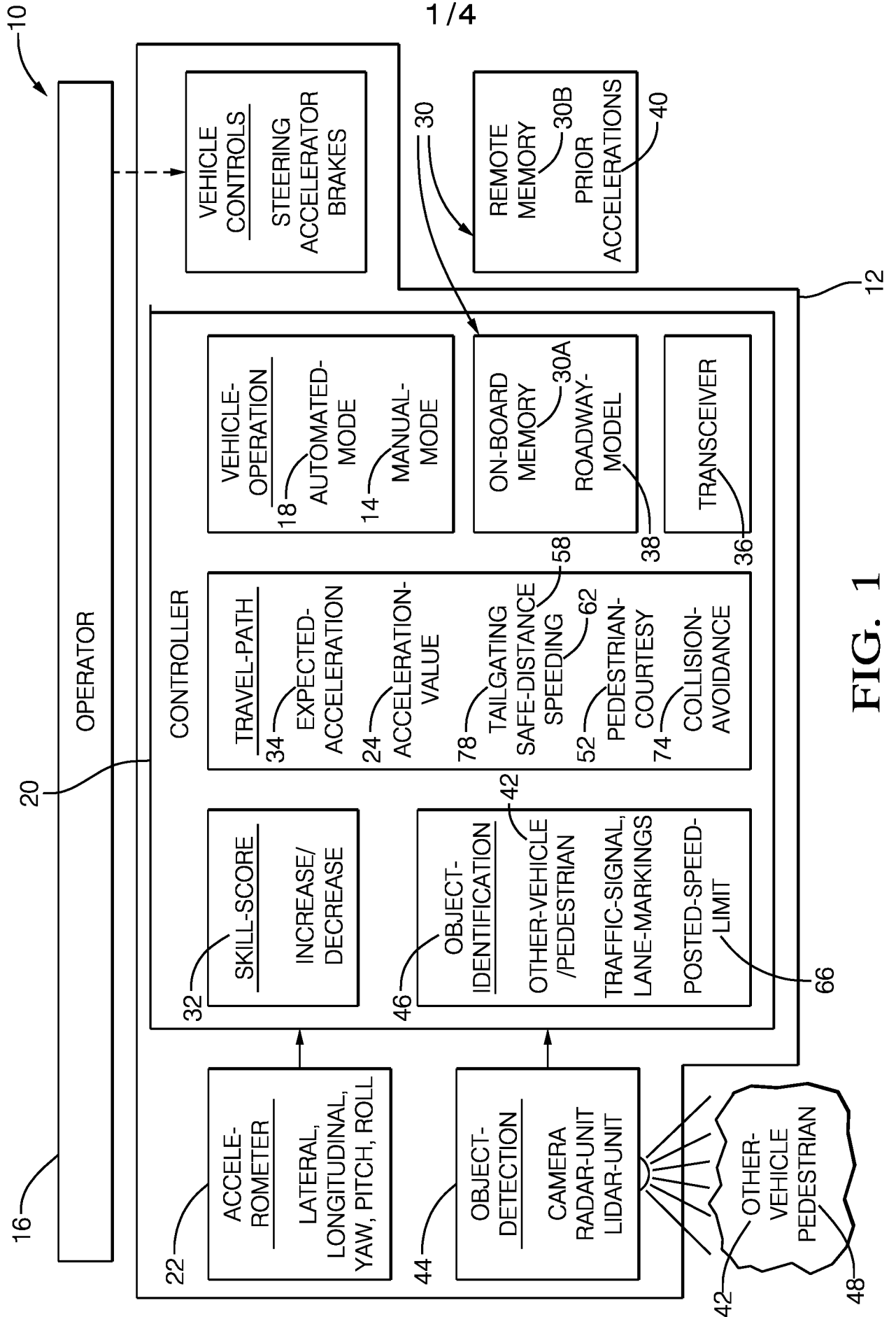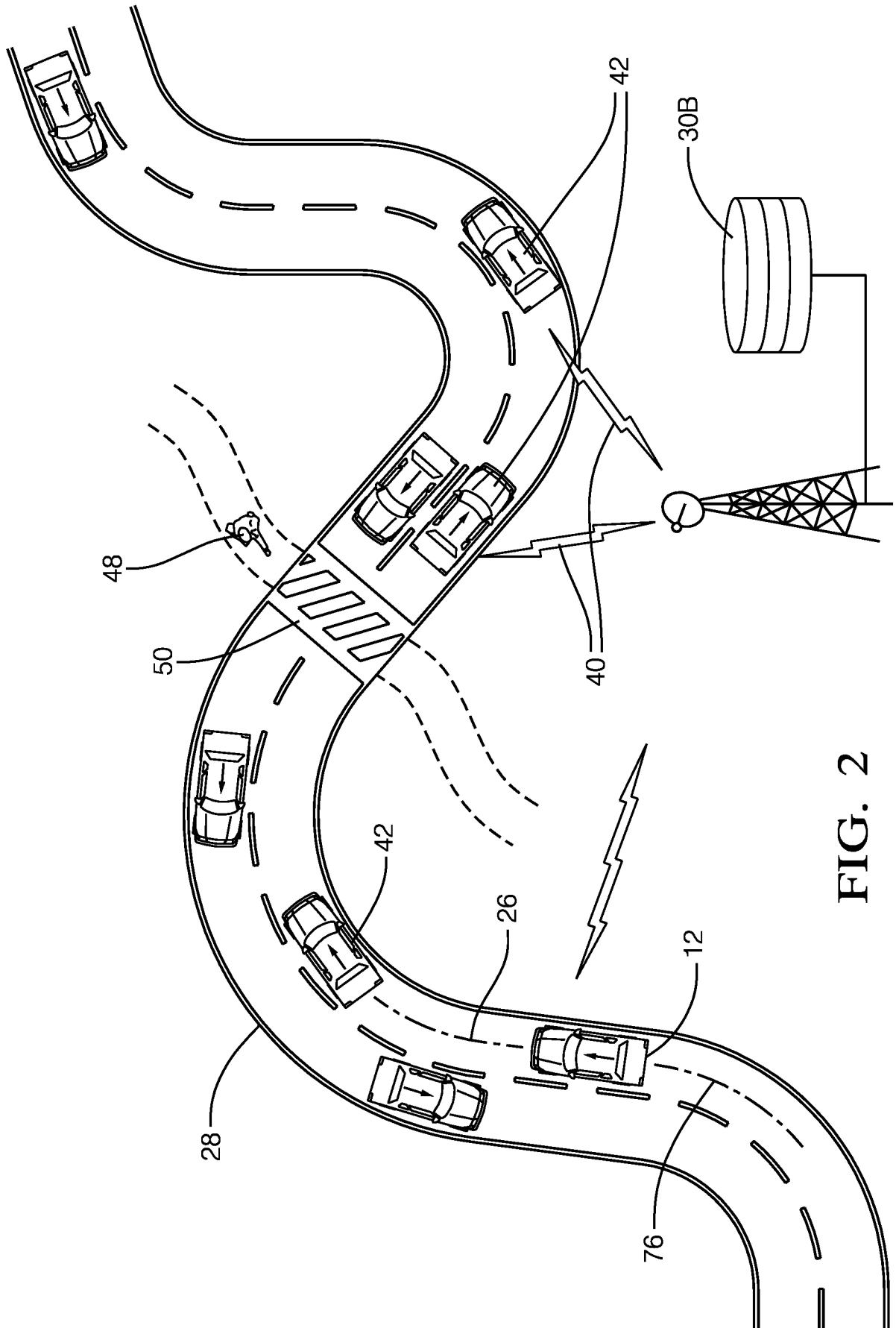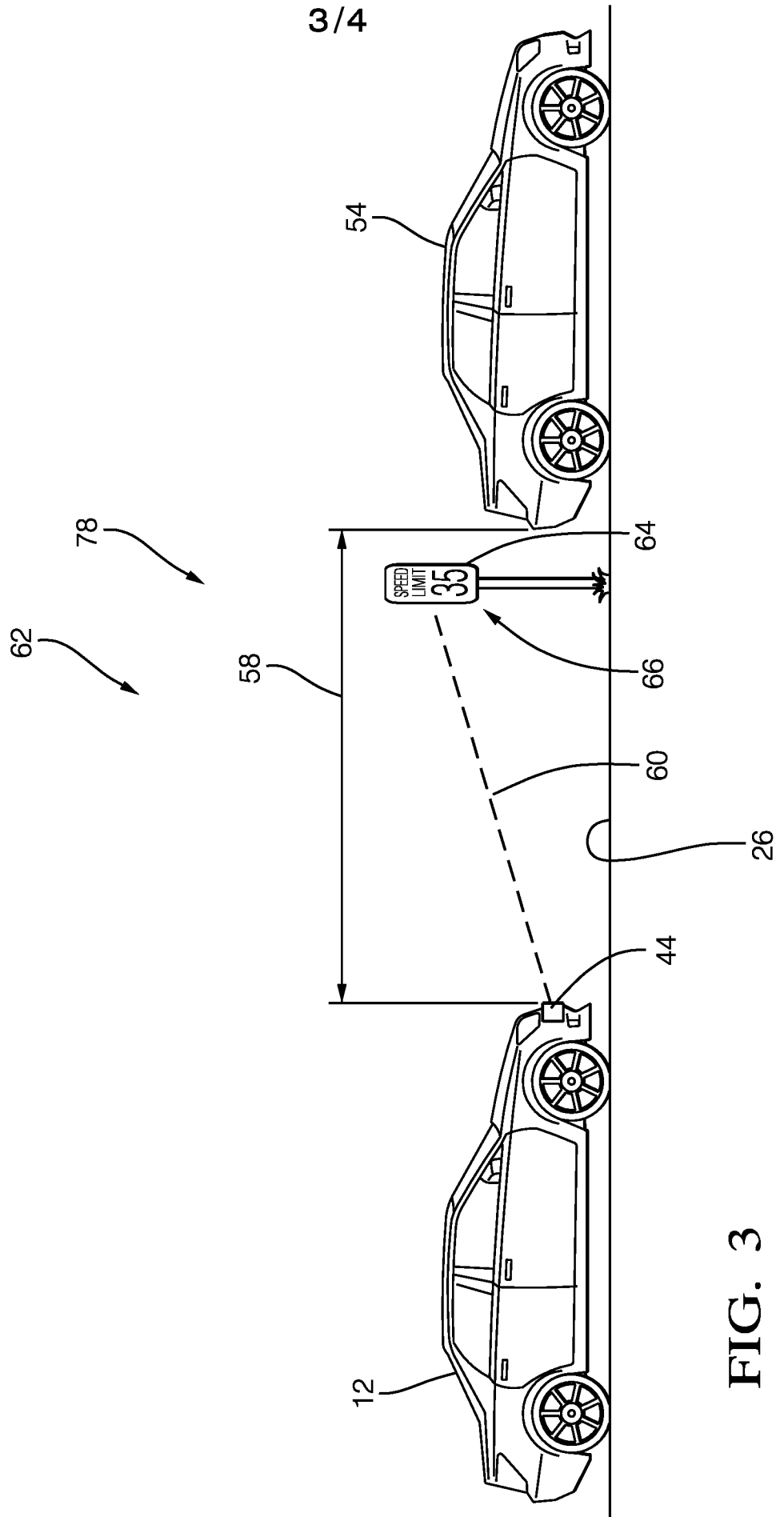   manual-mode (14) avoided a collision with the approaching-vehicle (68).
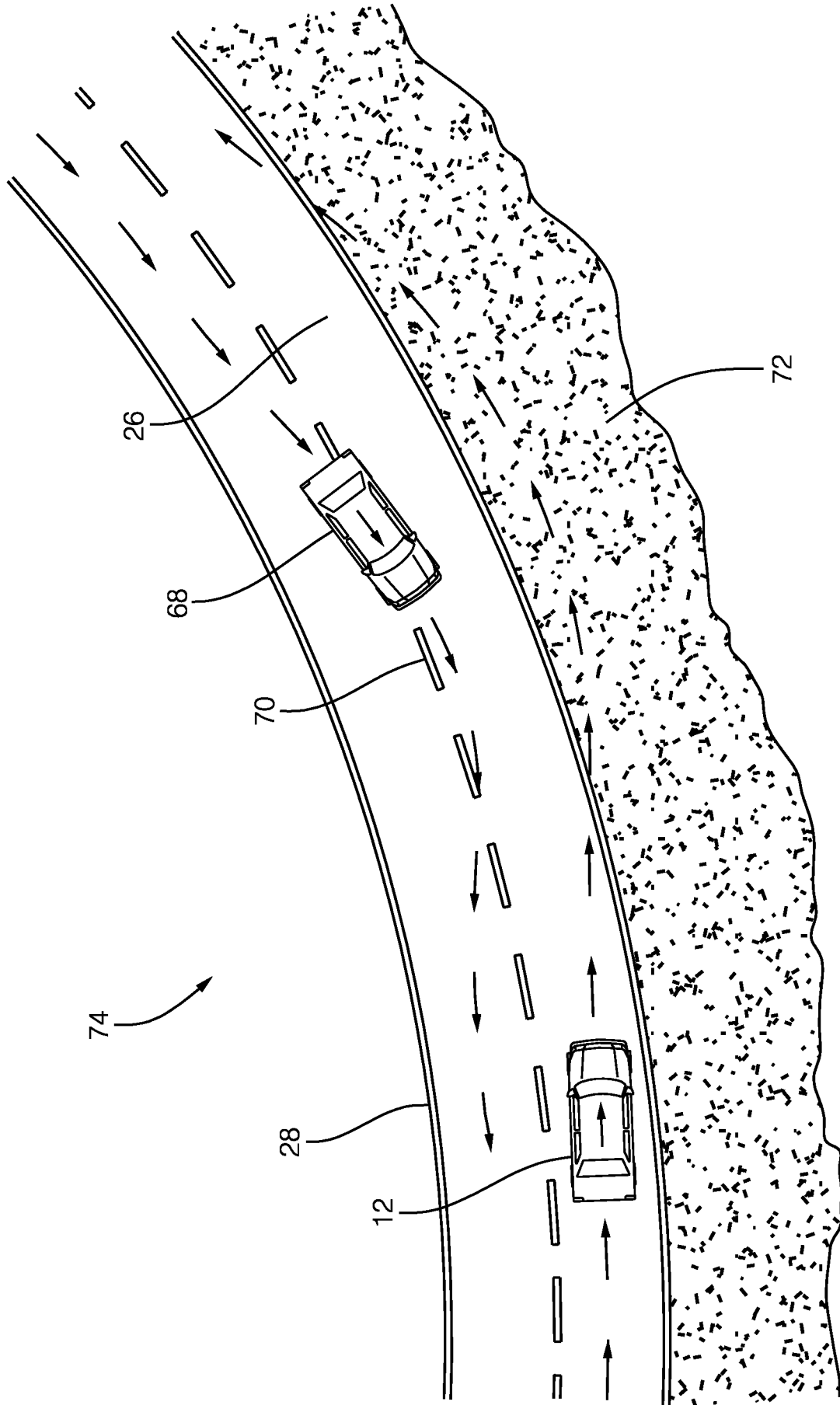
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FIG. 1

FIG. 2

FIG. 3

FIG. 4

A.	CLASSIFICATION OF SUBJECT MATTER

B60W 40/09(2012.01)i, B60W 30/10(2006.01)i, B60W 30/16(2006.01)i, B60W 30/14(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 40/09; G08G 1/16; G06F 19/00; G01S 17/88; G07C 5/00; B60T 7/12; G01B 11/00; B60W 30/10; B60W 30/16; B60W 30/14

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: driver, scoring, accelerometer, and object detection

C.	DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0372017 A1 (CARTASITE, INC.) 18 December 2014 See paragraphs [0047]-[0049], [0052]-[0059] and figures 5, 6.	1-3
Y		4-7
Y	US 2008-0162027 A1 (MURPHY et al.) 03 July 2008 See claims 1, 5, 8, 14.	4,6
Y	WO 94-19705 A1 (SILICON HEIGHTS LTD. et al.) 01 September 1994 See claim 1 and figures 1, 11.	5,7
A	US 2015-0046197 A1 (STATE FARM MUTUAL AUTOMOBILE INSURANCE COMPANY) 12 February 2015 See paragraphs [0019]-[0021], [0025], [0026] and figures 1, 2.	1-7
A	US 2011-0184617 A1 (HEGEMANN et al.) 28 July 2011 See paragraphs [0037], [0038] and figure 1.	1-7

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

*	Special categories of cited documents:	"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
"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	"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
"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)	"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
"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	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2017 (10.04.2017)	**10 April 2017 (10.04.2017)**

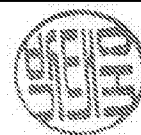| Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea	PARK, Tae Wook
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