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Schofield

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(54) **DRIVER ASSISTANCE SYSTEM FOR A VEHICLE**

(71) Applicant: **MAGNA ELECTRONICS INC.**, Auburn Hills, MI (US)

(72) Inventor: **Kenneth Schofield**, Holland, MI (US)

(73) Assignee: **MAGNA ELECTRONICS INC.**, Auburn Hills, MI (US)

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(58) **Field of Classification Search**

None

See application file for complete search history.

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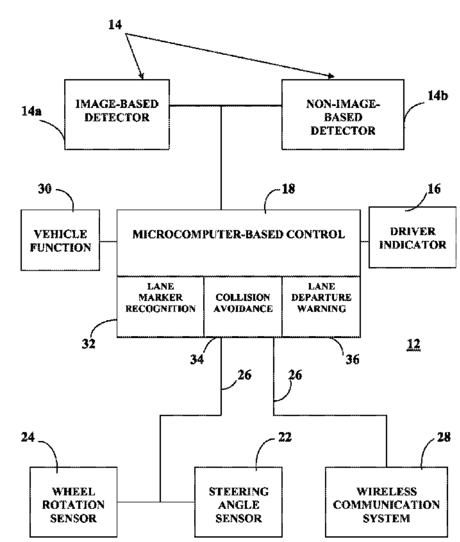
Primary Examiner — Brent Swarthout

(74) *Attorney, Agent, or Firm* — Honigman Miller Schwartz and Cohn, LLP

(57) **ABSTRACT**

A driver assistance system for a vehicle includes a vision system, a sensing system and a control. The vision system includes a camera and the sensing system includes a radar sensor. Image data captured by the camera is provided to the control and is processed by an image processor of the control. Responsive to image processing of captured image data, lane markers on the road being traveled along by the equipped vehicle are detected and the control determines a lane being traveled by the equipped vehicle. Radar data generated by the radar sensor is provided to the control, which receives vehicle data relating to the equipped vehicle via a vehicle bus of the equipped vehicle. Responsive at least in part to processing of generated radar data and captured image data, the control detects another vehicle present on the road being traveled along by the equipped vehicle.

37 Claims, 5 Drawing Sheets



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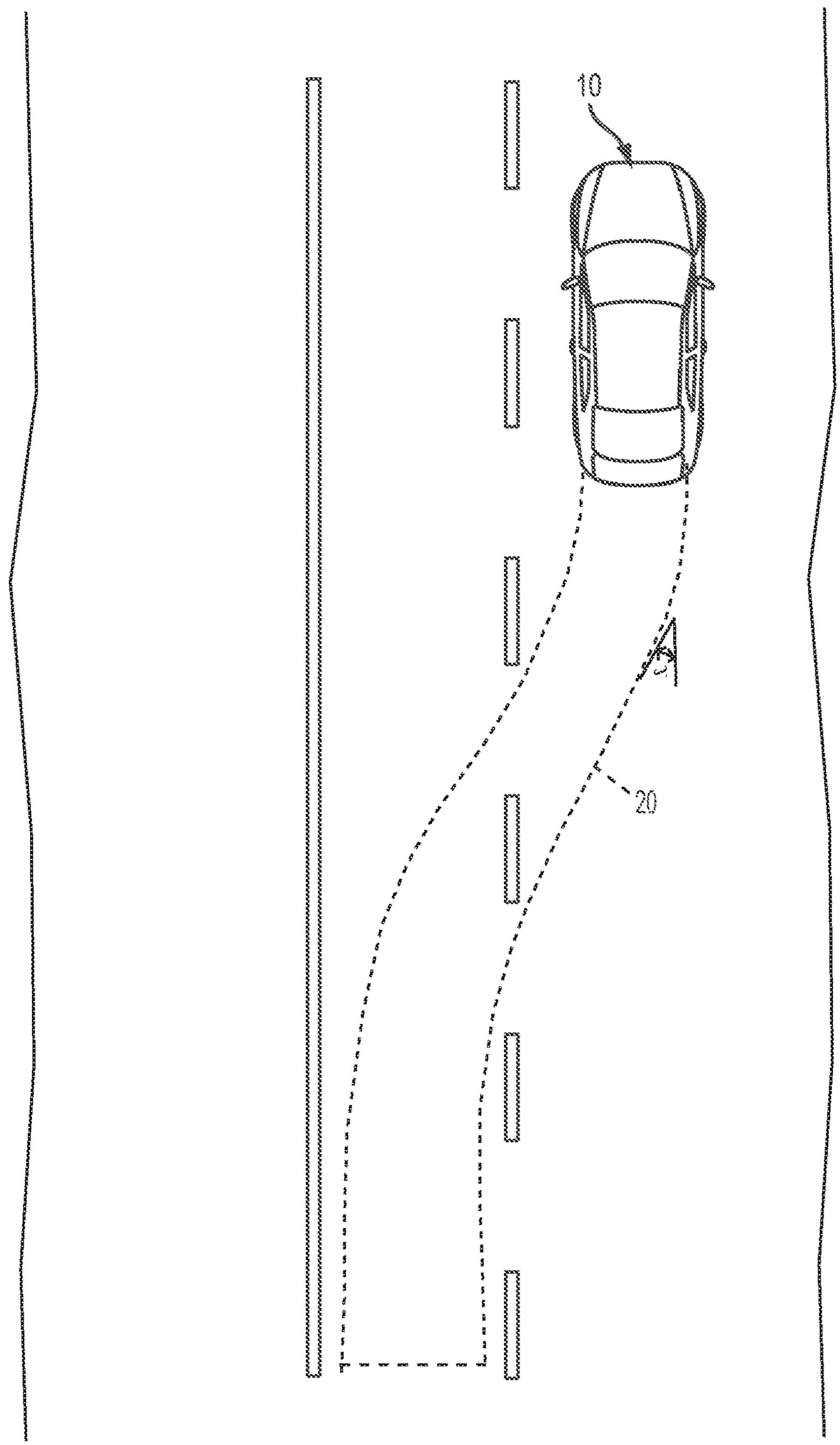

FIG. 1A

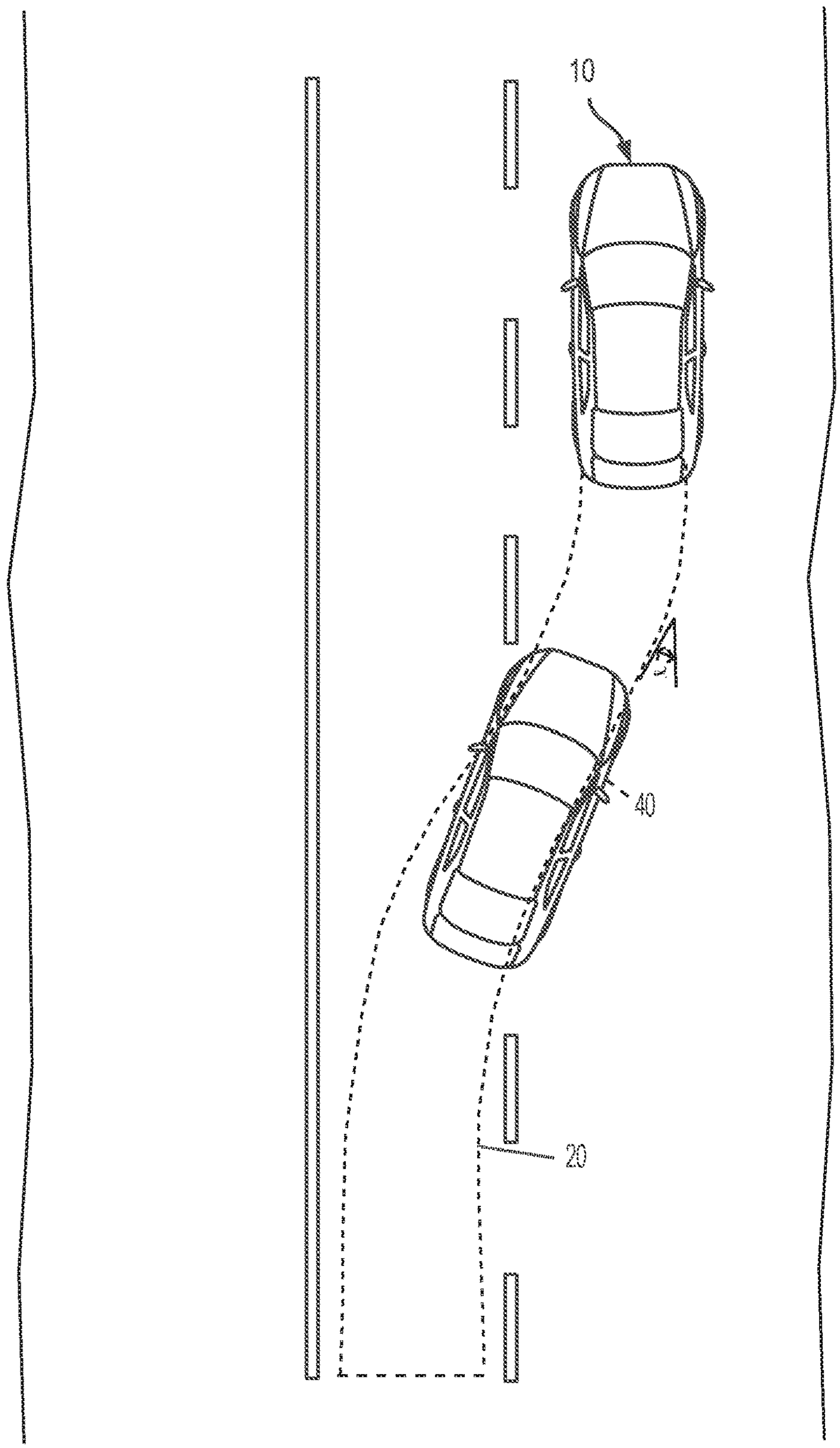

FIG. 1B

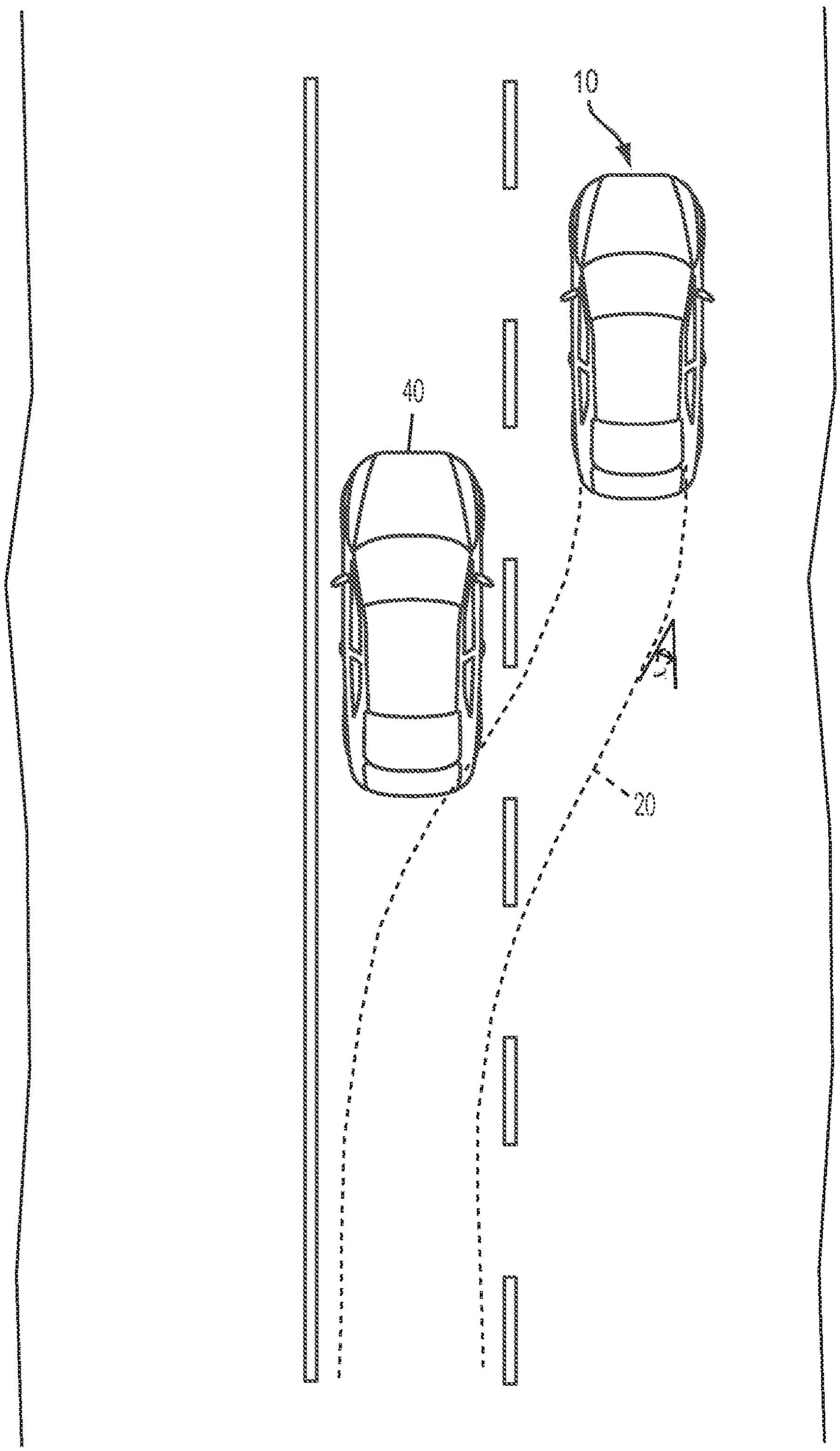

FIG. 1C

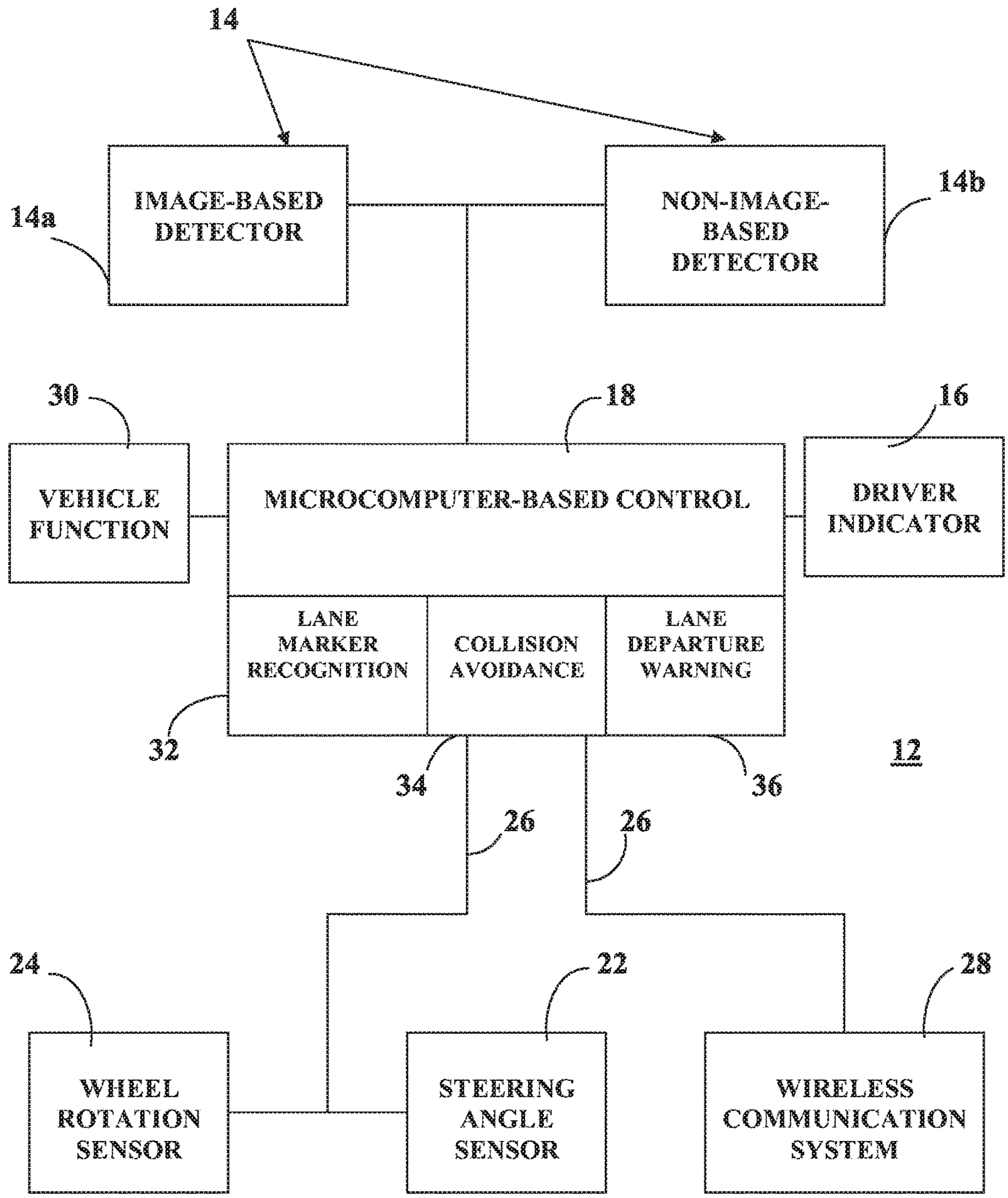
14
IMAGE-BASED DETECTOR
14a
NON-IMAGE-BASED DETECTOR
14b
30
VEHICLE FUNCTION
18
MICROCOMPUTER-BASED CONTROL
16
DRIVER INDICATOR
LANE MARKER RECOGNITION
COLLISION AVOIDANCE
LANE DEPARTURE WARNING
32
34
36
12
26
26
24
WHEEL ROTATION SENSOR
22
STEERING ANGLE SENSOR
28
WIRELESS COMMUNICATION SYSTEM

FIG. 2

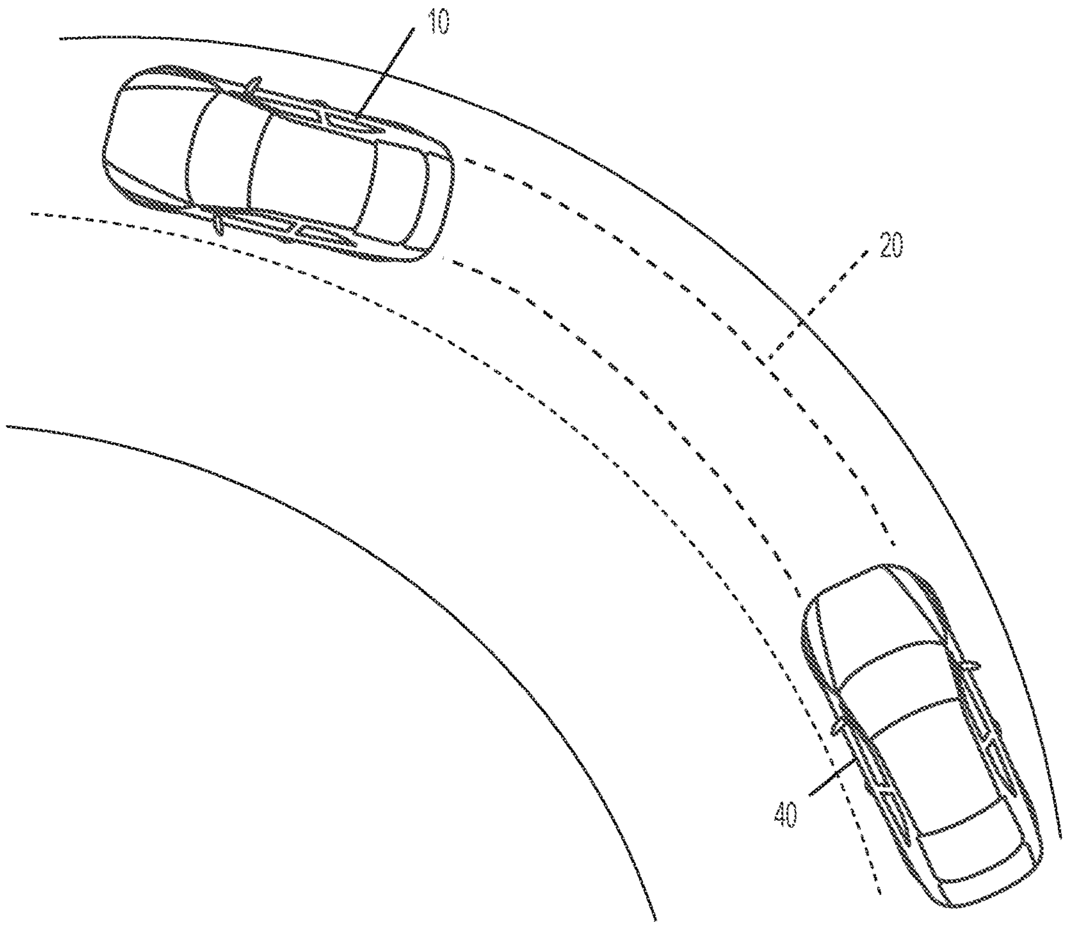

FIG. 3

DRIVER ASSISTANCE SYSTEM FOR A VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/997,831, filed Jan. 18, 2016, now U.S. Pat. No. 9,463,744, which is a continuation of U.S. patent application Ser. No. 13/919,483, filed Jun. 17, 2013, now U.S. Pat. No. 9,245,448, which is a continuation of U.S. patent application Ser. No. 12/483,996, filed Jun. 12, 2009, now U.S. Pat. No. 8,466,806, which is a continuation of U.S. patent application Ser. No. 12/058,155, filed Mar. 28, 2008, now U.S. Pat. No. 7,551,103, which is a continuation of U.S. patent application Ser. No. 11/735,782, filed Apr. 16, 2007, now U.S. Pat. No. 7,355,524, which is a continuation of U.S. patent application Ser. No. 11/108,474, filed Apr. 18, 2005, now U.S. Pat. No. 7,205,904, which is a continuation of U.S. patent application Ser. No. 10/209,173, filed on Jul. 31, 2002, now U.S. Pat. No. 6,882,287, which claims priority from U.S. provisional application Ser. No. 60/309,022, filed on Jul. 31, 2001, the disclosures of which are hereby incorporated herein by reference in their entireties.

TECHNICAL FIELD OF INVENTION

This invention relates to object detection adjacent a motor vehicle as it travels along a highway, and more particularly relates to imaging systems that view the blind spot adjacent a vehicle and/or that view the lane adjacent the side of a vehicle and/or view the lane behind or forward the vehicle as it travels down a highway.

BACKGROUND OF INVENTION

Camera-based systems have been proposed, such as in commonly assigned patent application Ser. No. 09/372,915, filed Aug. 12, 1999, now U.S. Pat. No. 6,396,397, the disclosure of which is hereby incorporated herein by reference, that detect and display the presence, position of, distance to and rate of approach of vehicles, motorcycles, bicyclists, and the like, approaching a vehicle such as approaching from behind to overtake in a side lane to the vehicle. The image captured by such vehicular image capture systems can be displayed as a real-time image or by icons on a video screen, and with distances, rates of approach and object identifiers being displayed by indicia and/or overlays, such as is disclosed in U.S. Pat. Nos. 5,670,935; 5,949,331 and 6,222,447, the disclosures of which are hereby incorporated herein by reference. Such prior art systems work well. However, it is desirable for a vehicle driver to have visual access to the full 360 degrees surrounding the vehicle. It is not uncommon, however, for a vehicle driver to experience blind spots due to the design of the vehicle bodywork, windows and the rearview mirror system. A blind spot commonly exists between the field of view available to the driver through the exterior rearview mirror and the driver's peripheral limit of sight. Blind Spot Detection Systems (BSDS), in which a specified zone, or set of zones in the proximity of the vehicle, is monitored for the presence of other road users or hazardous objects, have been developed. A typical BSDS may monitor at least one zone approximately one traffic lane wide on the left- or right-hand side of the vehicle, and generally from the driver's position to approximately 10 m rearward. The objective of these

systems is to provide the driver an indication of the presence of other road users located in the targeted blind spot.

Imaging systems have been developed in the prior art, such as discussed above, to perform this function, providing a visual, audio or tactile warning to the driver should a lane change or merge maneuver be attempted when another road user or hazard is detected within the monitored zone or zones. These systems are typically used in combination with a system of rearview mirrors in order to determine if a traffic condition suitable for a safe lane change maneuver exists. They are particularly effective when the detected object is moving at a low relative velocity with reference to the detecting vehicle, since the detected object may spend long periods of time in the blind spot and the driver may lose track of surrounding objects. However, prior art systems are inadequate in many driving conditions.

Known lane departure warning systems typically rely on visually detecting markers on the road on both sides of the vehicle for lane center determination. These markers must be fairly continuous or frequently occurring and generally must exist on both sides of the vehicle for the lane center position to be determined. Failure to detect a marker usually means failure of the departure-warning algorithm to adequately recognize a lane change event.

SUMMARY OF THE INVENTION

The present invention provides a Lane Change Aid (LCA) system wherein the driver of a motor vehicle traveling along a highway is warned if any unsafe lane change or merge maneuver is attempted, regardless of information available through the vehicle's rearview mirror system. The Lane Change Aid (LCA) system of the present invention extends the detection capability of the blind spot detection systems of the prior art.

A vehicle lane change aid system, according to an aspect of the invention, includes a detector that is operative to detect the presence of another vehicle adjacent the vehicle, an indicator for providing an indication that a lane change maneuver of the equipped vehicle may affect the other vehicle and a control receiving movement information of the equipped vehicle. The control develops a position history of the equipped vehicle at least as a function of the movement information. The control compares the detected presence of the other vehicle with the position history and provides the indication when a lane change maneuver may affect the other vehicle.

A vehicle lane change aid system, according to an aspect of the invention, includes an imaging device for capturing lane edge images and a control that is responsive to an output of the imaging device to recognize lane edge positions. The control is operable to distinguish between certain types of lane markers. The control may distinguish between dashed-lane markers and non-dashed-line markers.

A vehicle lane change aid system, according to an aspect of the invention, includes an imaging device for capturing lane edge images and a control that is responsive to an output of the imaging device to recognize lane edge positions. The control is operative to determine that the vehicle has departed a lane. The control may notify the driver that a lane has been departed. The control may further include oncoming vehicle monitoring and side object detection.

A vehicle lane change aid system, according to an aspect of the invention, includes a forward-facing imaging device for capturing images of other vehicles and a control that is responsive to an output of the imaging device to determine an imminent collision with another vehicle. The control may include a wireless transmission channel to transmit a safety warning to the other vehicle. The control may also activate a horn or headlights of the equipped vehicle of an imminent collision.

These and other objects, advantages and features of this invention will become apparent upon review of the following specification in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A-1C** are top plan views illustrating a vehicle equipped with a lane change aid system, according to the invention, traveling a straight section of road;

FIG. **2** is a block diagram of a lane change aid system, according to the invention; and

FIG. **3** is a top plan view illustrating a vehicle equipped with a lane change aid system traveling a curved section of road.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and the illustrative embodiments depicted therein, a Lane Change Aid (LCA) system **12** of the present invention as illustrated with a vehicle **10** includes a control **18** and an indicator and/or display system **16** that warns a vehicle operator if an intended, or attempted, lane change maneuver could cause an approaching rearward vehicle to brake and decelerate at an unsafe rate, or that otherwise constitutes a highway hazard. In Lane Change Aid (LCA) system **12**, the dimension, in the direction of travel, of a zone **20** to be monitored may be calculated based on an assumed maximum relative velocity between a detecting vehicle and an approaching rearward vehicle, and a safe braking and deceleration assumption. Depending on the assumptions made, the required detection zone may vary in length, such as extending rearward from 50 to 100 m, or more. At 100 m, the road curvature behind the vehicle may have a significant impact on the position of the lane of the detected vehicle, relative to the detecting vehicle. Since it is important to know which lane an approaching rearward vehicle is in, relative to the detecting vehicle, in order to provide the driver an appropriate warning, and to avoid many false warnings, the Lane Change Aid (LCA) system **12** includes developing and maintaining a lane position history **20** for the space rearward of the detecting vehicle.

By combining distance traveled with steering angle, the detecting vehicle path may be plotted. Details of the last approximately 100 m traveled are of value for lane change aids and may be stored by the Lane Change Aid (LCA) system. Data may be stored by several methods including the method described below.

Vehicle speed information in the Lane Change Aid (LCA) system **12** is typically derived from a wheel rotation sensor signal **24**, which consists of a number of pulses, n, per revolution of the road wheel, and available on a vehicle data bus **26**, such as a CAN or LIN bus, or the like. Sensing and signal detail may vary depending on vehicle design, but for any particular design, a distance, d, traveled between pulses can be established. Also, as each pulse is detected, the current value of the steering angle, +/−α, determined by a steering angle encoder **22** may be read from vehicle data bus **26**. Again, the sensing and signal detail may vary depending on vehicle design, but, for any particular vehicle design, an effective turning radius, r, for the vehicle can be established.

Image-based blind spot detection devices and lane change aids, generally shown at **14**, are but two of a variety of sensing devices and technologies and devices suitable for the purpose of monitoring the local environment in which a vehicle operates. Radar, infrared, sonar, and laser devices are all capable of interrogating the local environment for the presence of other road users or obstacles to be avoided. GPS systems can accurately determine the vehicle position on the earth's surface, and map data can provide detailed information of a mobile local environment. Other wireless communication systems **28** such as short-range wireless communication protocols, such as BLUETOOTH, can provide information such as the position of road works, lane restrictions, or other hazards, which can be translated by on-board vehicle electronics into position data relative to the vehicle position. Lane Change Aid (LCA) system **12** may integrate all the available information from a multiplicity of sensors including non-image-based detectors **14*b***, such as a radar sensor, such as a Doppler radar sensor, and at least one image-based detector **14*a*** such as a CMOS video camera imaging sensor, and converts the various sensor outputs into a single database with a common format, so that data from various sources, such as a Doppler radar source and a video camera source, may be easily compared, combined and maintained.

Consider a spherical space of radius R, and center (x, y, z)=(0, 0, 0) in Cartesian coordinates or (r, θ, β=(0,0,0)) in polar coordinates. It is convenient to describe the space in both coordinate systems since several operations will be used to fill the data space and to maintain it and a choice of systems allows for efficient computation methods. Let the center of this space (0, 0, 0) be at the center of the vehicle's rear axle, or nominal rear axle described by the line which passes through the center of the two rear non-steering wheels. Let the horizontal centerline of the vehicle, in the primary direction of travel, lie on (x, 0, 0), such that positive x values describe the space forward of the center of the vehicle's rear axle. Let the rear axle coincide with (0, y, 0), such that positive values of y describe the space to the right of the vehicle centerline when looking forward. (R, 90, 0) describes the positive y axis. Let positive z values describe the space above the centerline of the rear axle. (R, 0, 90) describes the positive z axis. This "sphere of awareness" **20** moves with the vehicle as it moves through space and provides a common frame of reference for all sensed or otherwise derived data concerning the vehicle's local environment.

For the purpose of storing vehicle path data, which may be used to improve the performance of lane change aid **12**, the discussion may be simplified by considering only the horizontal plane. The use of polar coordinates simplifies operations used in this application. The first data point, as the vehicle starts with no history, is at point (0, 0). The steering angle is read from the data bus and stored as α_0. When wheel rotation pulse, p_1 is detected, steering angle α_1 is recorded. Since the distance traveled between wheel pulses is known to be d, a new position for the previous data point can be calculated as $([2(1-\text{Cos }\alpha_0))]1/2, (180+\alpha_0))$. This point is stored and recorded as historical vehicle path data. When pulse p_2 is detected, the above calculation is repeated to yield $([2(1-\text{Cos }\alpha_1)]1/2, (180+\alpha_1))$ as the new position for the previous data point. This requires the repositioning of the original data to $([2(1-\text{Cos }\alpha_0)]1/2+[2(1-\text{Cos }\alpha_1)]1/2, [(180+\alpha_0)+\alpha_1])$. This process is continued until the distance from the vehicle, R, reaches the maximum required value, such as 100 m in the case of a lane change aid. Data beyond this point is discarded. Thus, a continuous record of the vehicle path for the last 100 m, or whatever distance is used, may be maintained. By maintaining a running record of the path traveled, rearward approaching vehicles detected by a lane change aid image analysis system may be positioned relative to that path as can be seen by comparing the other vehicle **40** in FIGS. **1**B and **1**C. In FIG. **1**B, other vehicle **40** is overlapping zone **20** so an indication of potential conflict may be delayed or discarded. In FIG. **1**C, the other vehicle **40** is moving outside of other vehicle **40** and in a blind spot of vehicle **10** so an indication of potential conflict would be given to the driver with indicator **16**. Thus, a determination may be made if the approaching vehicle is in the same, adjacent or next but one lane, etc. By this means, the number of inappropriate or unnecessary warnings may be reduced.

Lane change aid system **12** may include a controller, such as a microprocessor including a digital signal processor microcomputer of CPU speed at least about 5 MIPS, more preferably at least about 12 MIPS and most preferably at least about 30 MIPS, that processes inputs from multiple cameras **14***a* and other sensors **14***b* and that includes a vehicle path history function whereby, for example, an object, such as a rear-approaching car or motorcycle or truck, or the like, is selected and its presence highlighted to the driver's attention, such as by icons on a dashboard or interior mirror-mounted display, based on the recent history of the side and rear lanes that the host vehicle equipped with the controller of this invention has recently traveled in. An example is over a previous interval of about 60 seconds or less, or over a longer period such as about 3 minutes or more. The vehicle path history function works to determine the lane positioning of an approaching other vehicle, and whether the host vehicle is traveling on, or has recently traveled on, a straight road as illustrated in FIGS. **1**A, **1**B and **1**C, or a curved road portion as illustrated in FIG. **3**.

Control **18** may comprise a central video processor module such as is disclosed in commonly assigned provisional patent application Ser. No. 60/309,023, filed Jul. 31, 2001, and utility patent application filed concurrently herewith, now U.S. patent application Ser. No. 10/209,181, filed Jul. 31, 2002, and published Feb. 6, 2003 as U.S. Publication No. US 2003/0025793, the disclosures of which are hereby incorporated herein by reference. Such video processor module operates to receive multiple image outputs from vehicle-mounted cameras, such as disclosed in commonly assigned patent application Ser. No. 09/793,002, filed Feb. 26, 2001, now U.S. Pat. No. 6,690,268, the disclosure of which is hereby incorporated herein by reference, and integrates these in a central processing module to allow reaction to the local vehicle environment. Optionally, and when bandwidth limitations exist that limit the ability to send raw image data, particularly high-resolution images, from a remote camera to a central processing unit across robust transmission means, such as a fiber-optic cable or a high-density wireless link, distributed processing can occur, at least local to some of the image capture sensors. In such an at least partial distributed processing environment, the local processors are adapted to preprocess images captured by the local camera or cameras and any other device such as a Doppler radar sensor viewing a blind spot in an adjacent side lane and to format this preprocessed data into a standard format and transmit this standard formatted data. The data can be transmitted via a wired network or a wireless network or over a vehicle bus system, such as a CAN bus and/or a LIN bus, or the like, to the central processor for effective, centralized mapping and combination of the total local environment around the vehicle. This provides the driver with a display of what is happening in both the right and the left side lanes, and in the lane that the host vehicle is itself traveling in.

In this regard, the vehicle can be provided with a dedicated bus and central processor, as described above, for providing a vehicle environment awareness, which can be both internal such as might be provided by interior cabin or trunk monitors/sensors that determine occupant presence, head position and/or movement, eye movement, air bag deployment, microphone aiming, seat positioning, air conditioning and/or heating targeting, audio controls, and the like, or can be external to the vehicle such as in blind spot detecting or lane change detecting. The present invention includes provision of an automatic environment awareness function that comprises automatic gathering of sensor-derived data collection and transmission in a standard format via a vehicle bus network, the data including data relating to the vehicle environment such as the exterior environment, for example, the presence of rear-approaching traffic in side and rear lanes to the host vehicle as captured by rear-facing CMOS or CCD cameras on the side of the host vehicle, such as included in a side view mirror assembly on either or both sides of the host vehicle and/or as detected by a rear lane/side lane-viewing Doppler radar sensor, and preferably includes processing in a central video processing unit.

The information relating to the external environment can be relayed/displayed to the driver in a variety of ways. For example, a blind-spot vehicle-presence indication can be displayed adjacent the exterior mirror assembly, such as inside the vehicle cabin local to where the exterior mirror assembly is attached to the vehicle door so that the indicator display used, typically an LED flashing light source, or the like, is visible to the driver but not visible to any traffic/drivers exterior to the vehicle, but is cognitively associated with the side of the vehicle to which that particular nearby exterior mirror is attached to, and as disclosed in commonly assigned U.S. Pat. Nos. 5,786,772; 5,929,786 and 6,198,409, the disclosures of which are hereby incorporated herein by reference. Optionally, a vibration transducer can be included in the steering wheel that trembles or otherwise vibrates to tactilely warn the driver of the presence of an overtaking vehicle in a side lane that the driver is using the steering wheel to turn the driver's vehicle into where an overtaking or following vehicle may constitute a collision hazard. Hazard warnings can be communicated to the driver by voice commands and/or audible warnings, and/or by heads-up-displays. The coordinate scheme for data collection of the present invention enables an improved blind spot and/or lane change detection system for vehicles and particularly in busy traffic on a winding, curved road.

The present invention includes the fusion of outputs from video and non-video sensors, such as, for example, a CMOS video camera sensor and a Doppler radar sensor, to allow all-weather and visibility side object detection. The present invention includes the fusion of outputs from video and non-video sensors, such as, for example, a CMOS video camera sensor and a Doppler radar sensor, to allow all-weather and visibility side object detection. The present invention can be utilized in a variety of applications such as disclosed in commonly assigned U.S. Pat. Nos. 5,670,935; 5,949,331; 6,222,447; 6,201,642; 6,097,023; 5,715,093; 5,796,094 and 5,877,897 and commonly assigned patent application Ser. No. 09/793,002 filed Feb. 26, 2001, now U.S. Pat. No. 6,690,268, Ser. No. 09/372,915, filed Aug. 12, 1999, now U.S. Pat. No. 6,396,397, Ser. No. 09/767,939, filed Jan. 23, 2001, now U.S. Pat. No. 6,590,719, Ser. No. 09/776,625, filed Feb. 5, 2001, now U.S. Pat. No. 6,611,202, Ser. No. 09/799,993, filed Mar. 6, 2001, now U.S. Pat. No. 6,538,827, Ser. No. 09/493,522, filed Jan. 28, 2000, now U.S. Pat. No. 6,426,492, Ser. No. 09/199,907, filed Nov. 25, 1998, now U.S. Pat. No. 6,717,610, Ser. No. 08/952,026, filed Nov. 19, 1997, now U.S. Pat. No. 6,498,620, Ser. No. 09/227,344, filed Jan. 8, 1999, now U.S. Pat. No. 6,302,545, International Publication No. WO 96/38319, published Dec. 5, 1996, and International Publication No. WO 99/23828, published May 14, 1999, the disclosures of which are collectively incorporated herein by reference.

Lane change aid system **12** may include a lane marker type recognition algorithm, or capability **32**. Lane marker type recognition capability **32** utilizes classifying lane markers as one of many specific types for the purpose of interpreting the original purpose of the lane marker and issuing reliable and meaningful warnings based on this interpretation. As an example, a double line on the left side of a left-hand drive vehicle typically indicates a no-encroachment zone or no passing zone. A solid line with adjacent dashed line will indicate either an ability to pass safely if the dashed line is on the near side of the solid line or a do not encroach zone if the dashed line is on the far side of the solid line. Road edges can be distinctly recognized and classified as no-encroachment zones. Conversely, dashed lines may have no significance to lane departure warning algorithms since they merely indicate lane edge positions. Recognizing dashed lines as such gives the ability to not initiate nuisance warnings. The recognition algorithm can further be enhanced by recognizing road features when lane markers are too weak or missing. Features, such as curbs, road seams, grease or rubber slicks, road signs, vehicles in same, neighboring, and/or opposing lanes when recognized, could be used to interpret lane-vehicle positioning and issue intelligent warning alerts to the driver. Fewer false or nuisance type warnings with improved real warning functionality and speed can be realized with this improvement. Operation under difficult lighting and environmental conditions can be extended.

Note that collision avoidance functionality **34** can optionally be achieved using a forward-facing camera **14***a* in the present invention. For example, should the forward-looking camera detect an oncoming car likely to collide with the vehicle equipped with the present invention, or if another vehicle tries to pull in front of it, the system of the present invention can issue a warning (visual and/or audible) to one or both drivers involved. Such warning can be flash headlights and/or sound car horn. Similarly, the system can detect that the driver of the vehicle equipped with the present invention is failing to recognize a stop sign and/or a signal light, or some other warning sign and the driver can be warned visually, such as with a warning light at the interior mirror in the vehicle cabin, or audibly, such as via a warning beeper, or tactilely, such as via a rumble/vibration transducer that vibrates the steering wheel to alert the driver of a potential hazard.

System **12** may also include a lane departure warning algorithm, or system **36**. For example, when a left-hand drive vehicle equipped with system **10** is making a left-hand turn generally across a line on the road. System **36** can monitor for a lane crossing and combine it with detection of an oncoming vehicle. The system **12** may also calculate closing speed for warning of potential impact of closing vehicles.

Also, the vehicle can be provided on its front fender or elsewhere at the front of the vehicle with a side-looking camera as an image-based detector **14***a* operable to warn the driver when he/she is making a left turn across lanes of traffic coming from his/her left (left-side warning) and then again when he/she is about to enter traffic lanes with traffic coming from his right (right-side warning). While executing this turn, the system of the present invention may utilize the detection of the lane markers when the driver's car is about to enter the specific lane combined with oncoming vehicle detection as a means of predictive warning before he actually enters the danger zone.

System **12** is also capable of performing one or more vehicle functions **30**. For example, should the lane departure warning system **36** detect that the vehicle equipped with the system is intending to make or is making a lane change and the driver has neglected to turn on the appropriate turn signal indicators, then the system performs a vehicle function **30** of automatically turning on the turn signals on the appropriate side of the vehicle.

The lane departure warning system **36** of the present invention is operable to differentiate between solid and dashed lines and double lines on the road being traveled. Also, should the vehicle be equipped with a side object detection (SOD) system such as a Doppler radar unit or a camera vision side object detection system that detects the presence of overtaking vehicles in the adjacent side lane, then the SOD system can work in conjunction with the lane departure warning system such that as the lane departure system detects that the driver is making a lane change into a side lane when the SOD system detects an overtaking vehicle in that same side lane, then the driver is alerted and warned of the possible hazard, such as by a visual, audible and/or tactile alert.

As indicated above, the forward-facing camera can include stoplight or sign detection, and the system can further include a broadcast with wireless communication system **28** on a safety warning band when the forward-facing camera detects the stoplight or sign and determines the vehicle is not going to stop based on current speed and deceleration. This would warn crossing drivers of an unsafe condition. Such alerts can dynamically vary depending on road surface conditions (wet, snow, ice, etc.) as visually detected and determined by the forward-facing, road-monitoring camera. For example, wet or snowy roads would change the distance and/or speed at which it would warn based on camera vision recognition of stoplights and/or stop signs. When approaching a stoplight when it changes or the vehicle does not slow down for the light after the driver was warned, the system can blow the horn and/or flash the lights to warn vehicles at the stoplight of the oncoming vehicle. The car may also broadcast one of the safety alerts radar detectors pick up.

Changes and modifications in the specifically described embodiments can be carried out without departing from the principles of the invention, which is intended to be limited only by the scope of the appended claims, as interpreted according to the principles of patent law including the doctrine of equivalents.

The invention claimed is:

1. A driver assistance system for a vehicle, said driver assistance system comprising:

a vision system comprising a first camera disposed at a vehicle equipped with said driver assistance system, said first camera having a field of view forward of the equipped vehicle that encompasses a road being traveled along by the equipped vehicle;

wherein the road has at least three lanes comprising (i) a first lane along which the vehicle is traveling, (ii) a second lane immediately adjacent the first lane, and

(iii) a third lane immediately adjacent the second lane at the opposite side of the second lane from the first lane;

a control disposed at or in the equipped vehicle and comprising a data processor;

wherein said data processor comprises an image processor;

wherein image data captured by said first camera is provided to said control and is processed by said image processor;

wherein said data processor processes data at a processing speed of at least 30 MIPS;

wherein, responsive to processing by said image processor of image data captured by said first camera, lane markers on the road being traveled along by the equipped vehicle are detected;

wherein, responsive to processing by said image processor of image data captured by said first camera, said control determines the first, second and third lanes of the road being traveled by the equipped vehicle;

a sensing system operable to detect other vehicles present exterior the equipped vehicle;

wherein said sensing system comprises a second camera disposed at the equipped vehicle and having a field of view at least rearward and sideward of the equipped vehicle as the equipped vehicle travels along the road;

wherein said sensing system further comprises a radar sensor disposed at the equipped vehicle and having a field of sensing at least rearward and sideward of the equipped vehicle as the equipped vehicle travels along the road;

wherein image data captured by said second camera is provided to said control;

wherein radar data generated by said radar sensor is provided to said control;

wherein said control receives vehicle data relating to the equipped vehicle via a vehicle bus of the equipped vehicle;

wherein, responsive at least in part to processing at said data processor of radar data generated by said radar sensor and of image data captured by said second camera, said control detects another vehicle present on the road being traveled along by the equipped vehicle and approaching the equipped vehicle from its rear;

wherein, with the equipped vehicle traveling along the first lane, and responsive at least in part to processing at said data processor of radar data generated by said radar sensor and of image data captured by said second camera, said control determines that the other vehicle is travelling in a next but one lane to the lane the second lane or in the third lane of the road along which the equipped vehicle is travelling;

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the second lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control generates an alert that a lane change by the equipped vehicle from the first lane to the second lane is not safe; and

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the third lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control determines that a lane change from the first lane to the second lane can proceed without hazard of impact with the other vehicle detected travelling in the third lane.

2. The driver assistance system of claim **1**, wherein said control is operable to detect a lane change maneuver of the equipped vehicle to a lane adjacent to the lane the equipped vehicle is travelling along.

3. The driver assistance system of claim **2**, wherein said radar sensor comprises a Doppler radar sensor.

4. The driver assistance system of claim **2**, wherein, responsive at least in part to processing at said data processor of image data captured by said second camera, said control develops a vehicle path history of the other vehicle.

5. The driver assistance system of claim **4**, wherein determination by said control that the lane change can proceed without hazard of impact with the other vehicle detected travelling in the third lane utilizes said vehicle path history.

6. The driver assistance system of claim **1**, wherein said radar sensor has a field of sensing to a side of and rearward of the equipped vehicle as the equipped vehicle travels along the road.

7. The driver assistance system of claim **6**, wherein said control is operable to detect a lane change maneuver of the equipped vehicle from the first lane to the second lane.

8. The driver assistance system of claim **7**, wherein detection of the lane change maneuver by said control is based at least in part on vehicle steering data received at said control via said bus.

9. The driver assistance system of claim **7**, wherein, responsive to said control detecting the lane change maneuver of the equipped vehicle, said control determines that the lane change can proceed without hazard of impact with the other vehicle detected approaching from the rear in the third lane.

10. The driver assistance system of claim **9**, wherein said vehicle bus system comprises at least one of (a) a CAN bus of the vehicle and (b) a LIN bus of the vehicle.

11. The driver assistance system of claim **10**, wherein the other vehicle detected in the third lane is overtaking the equipped vehicle.

12. The driver assistance system of claim **11**, wherein said control determines a position history of the other vehicle.

13. The driver assistance system of claim **7**, wherein detection of the lane change maneuver by said control is irrespective of activation by a driver of the equipped vehicle of a turn signal indicator of the equipped vehicle.

14. The driver assistance system of claim **1**, wherein said vision system further comprises at least one other camera disposed at the equipped vehicle and having a field of view exterior the equipped vehicle, and wherein said sensing system further comprises at least one other radar sensor disposed at the equipped vehicle and having a field of sensing exterior the equipped vehicle, and wherein image data captured by said at least one other camera is provided to and processed at said control, and wherein radar data generated by said at least one other radar sensor is provided to and processed at said control.

15. The driver assistance system of claim **1**, wherein said camera comprises a forward-viewing camera disposed in an interior cabin of the equipped vehicle at and behind a windshield of the equipped vehicle and viewing through the windshield to capture image data at least forward of the equipped vehicle.

16. The driver assistance system of claim **15**, wherein, responsive at least in part to processing of radar data generated by said radar sensor and of image data captured by said camera, said control determines a hazard of collision of the equipped vehicle with another vehicle.

17. The driver assistance system of claim **16**, wherein, responsive at least in part to said control determining said hazard of collision with the other vehicle, said control controls a system of the equipped vehicle to mitigate potential collision with the other vehicle that is in hazard of collision with the equipped vehicle.

18. The driver assistance system of claim **17**, wherein, responsive at least in part to said control determining said hazard of collision, said control controls activation of at least one of (i) a horn system of the equipped vehicle to mitigate potential collision with the other vehicle that is in hazard of collision with the equipped vehicle and (ii) a lighting system of the equipped vehicle to mitigate potential collision with the other vehicle that is in hazard of collision with the equipped vehicle.

19. The driver assistance system of claim **17**, wherein, responsive at least in part to said control determining said hazard of collision, said control controls a wireless transmission system of the equipped vehicle to transmit a safety warning to the other vehicle that is in hazard of collision with the equipped vehicle.

20. A driver assistance system for a vehicle, said driver assistance system comprising:

a vision system comprising a first camera disposed at a vehicle equipped with said driver assistance system, said first camera having a field of view forward of the equipped vehicle that encompasses a road being traveled along by the equipped vehicle;

wherein the road has at least three lanes comprising (i) a first lane along which the vehicle is traveling, (ii) a second lane immediately adjacent the first lane, and (iii) a third lane immediately adjacent the second lane at the opposite side of the second lane from the first lane;

wherein said first camera comprises a forward-viewing camera disposed in an interior cabin of the equipped vehicle at and behind a windshield of the equipped vehicle and viewing through the windshield to capture image data at least forward of the equipped vehicle;

a control disposed at or in the equipped vehicle and comprising a data processor;

wherein said data processor comprises an image processor;

wherein image data captured by said first camera is provided to said control and is processed by said image processor;

wherein said data processor processes data at a processing speed of at least 30 MIPS;

wherein, responsive to processing by said image processor of image data captured by said first camera, lane markers on the road being traveled along by the equipped vehicle are detected;

wherein, responsive to processing by said image processor of image data captured by said first camera, said control determines the first, second and third lanes of the road being traveled by the equipped vehicle;

a sensing system operable to detect other vehicles present exterior the equipped vehicle;

wherein said sensing system comprises a first radar sensor disposed at the equipped vehicle and having a field of sensing exterior of the equipped vehicle as the equipped vehicle travels along the road;

wherein radar data generated by said first radar sensor is provided to said control;

wherein said control receives vehicle data relating to the equipped vehicle via a vehicle bus of the equipped vehicle;

wherein said vision system further comprises a second camera disposed at the equipped vehicle and having a field of view at least rearward and sideward of the equipped vehicle as the equipped vehicle travels along the road, and wherein said sensing system further comprises a second radar sensor disposed at the equipped vehicle and having a field of sensing at least rearward and sideward the equipped vehicle as the equipped vehicle travels along the road, and wherein image data captured by said second camera is provided to and processed at said control, and wherein radar data generated by said second radar sensor is provided to and processed at said control;

wherein, responsive at least in part to processing at said data processor of radar data generated by at least one of said first and second radar sensors of said sensing system and of image data captured by at least one of said first and second cameras of said vision system, said control determines a hazard of collision of the equipped vehicle with another vehicle;

wherein, with the equipped vehicle traveling along the first lane, and responsive at least in part to processing at said data processor of radar data generated by said radar sensor and of image data captured by said second camera, said control determines that the other vehicle is travelling in the second lane or in the third lane of the road along which the equipped vehicle is travelling;

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the second lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control generates an alert that a lane change by the equipped vehicle from the first lane to the second lane is not safe;

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the third lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control determines that a lane change from the first lane to the second lane can proceed without hazard of impact with the other vehicle detected travelling in the third lane; and

wherein, responsive at least in part to said control determining said hazard of collision with the other vehicle, said control controls a system of the equipped vehicle to mitigate potential collision with the other vehicle.

21. The driver assistance system of claim **20**, wherein, responsive at least in part to said control determining said hazard of collision, said control controls activation of at least one of (i) a horn system of the equipped vehicle to mitigate potential collision with the other vehicle that is in hazard of collision with the equipped vehicle and (ii) a lighting system of the equipped vehicle to mitigate potential collision with the other vehicle.

22. The driver assistance system of claim **20**, wherein, responsive at least in part to said control determining said hazard of collision, said control controls a wireless transmission system of the equipped vehicle to transmit a safety warning to the other vehicle.

23. The driver assistance system of claim **20**, wherein the other vehicle is approaching the equipped vehicle from rearward of the equipped vehicle, and wherein said control is operable to detect a lane change maneuver of the equipped vehicle to the second lane the equipped vehicle is travelling along, and wherein detection of the lane change maneuver by said control is based at least in part on vehicle steering data received at said control via said bus.

24. The driver assistance system of claim **23**, wherein radar data generated by at least one of said first and second radar sensors of said sensing system and image data captured by at least one of said first and second cameras of said vision system are fused at said control.

25. The driver assistance system of claim **23**, wherein radar data generated by at least one of said first and second radar sensors of said sensing system and image data captured by said first camera of said vision system are fused at said control.

26. The driver assistance system of claim **23**, wherein said first radar sensor has a field of sensing to a side of and rearward of the equipped vehicle as the equipped vehicle travels along the road, and wherein radar data generated by said first radar sensor of said sensing system and image data captured by at least one of said first and second cameras of said vision system are fused at said control.

27. The driver assistance system of claim **23**, wherein, responsive at least in part to processing at said data processor of at least one of (i) radar data generated by at least one of said first and second radar sensors of said sensing system and (ii) image data captured by at least one of said first and second cameras of said vision system, said control determines that the other vehicle is travelling in the third lane.

28. A driver assistance system for a vehicle, said driver assistance system comprising:

a vision system comprising a first camera disposed at a vehicle equipped with said driver assistance system, said first camera having a field of view that encompasses a road being traveled along by the equipped vehicle;

wherein said first camera comprises a forward-viewing camera disposed in an interior cabin of the equipped vehicle at and behind a windshield of the equipped vehicle and viewing through the windshield to capture image data at least forward of the equipped vehicle;

wherein the road has at least three lanes comprising (i) a first lane along which the vehicle is traveling, (ii) a second lane immediately adjacent the first lane, and (iii) a third lane immediately adjacent the second lane at the opposite side of the second lane from the first lane;

a control disposed at or in the equipped vehicle and comprising a data processor;

wherein said data processor comprises an image processor;

wherein image data captured by said first camera is provided to said control and is processed by said image processor;

wherein said data processor processes data at a processing speed of at least 30 MIPS;

wherein, responsive to processing by said image processor of image data captured by said first camera, lane markers on the road being traveled along by the equipped vehicle are detected;

wherein, responsive to processing by said image processor of image data captured by said first camera, said control determines the first, second and third lanes of the road being traveled by the equipped vehicle;

a sensing system operable to detect other vehicles present exterior the equipped vehicle;

wherein said sensing system comprises a first radar sensor disposed at the equipped vehicle and having a field of sensing exterior of the equipped vehicle as the equipped vehicle travels along the road;

wherein radar data generated by said first radar sensor is provided to said control;

wherein said control receives vehicle data relating to the equipped vehicle via a vehicle bus of the equipped vehicle;

wherein said first radar sensor has a field of sensing at least to a side of and rearward of the equipped vehicle as the equipped vehicle travels along the road;

wherein said sensing system further comprises a second camera disposed at the equipped vehicle and having a field of view at least rearward and sideward of the equipped vehicle as the equipped vehicle travels along the road;

wherein image data captured by said second camera is provided to said control;

wherein, responsive at least in part to processing at said data processor of radar data generated by said first radar sensor and of image data captured by said second camera, said control detects another vehicle present on the road being traveled along by the equipped vehicle that is approaching the equipped vehicle from rearward of the equipped vehicle;

wherein said control is operable to detect a lane change maneuver of the equipped vehicle toward the second lane;

wherein detection of the lane change maneuver by said control is based at least in part on vehicle steering data received at said control via said bus;

wherein, responsive to said control detecting a lane change maneuver of the equipped vehicle, said control determines that the lane change can proceed without hazard of impact with the other vehicle approaching the equipped vehicle from rearward of the equipped vehicle;

wherein, with the equipped vehicle traveling along the first lane, and responsive at least in part to processing at said data processor of radar data generated by said first radar sensor and of image data captured by said second camera, said control determines that the other vehicle is travelling in the second lane or in the third lane of the road along which the equipped vehicle is travelling;

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the second lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control generates an alert that a lane change by the equipped vehicle from the first lane to the second lane is not safe; and

wherein, responsive to determination that the other vehicle is approaching the equipped vehicle and is traveling in the third lane, and responsive to said control detecting a lane change maneuver of the equipped vehicle toward the second lane, said control determines that a lane change from the first lane to the second lane can proceed without hazard of impact with the other vehicle detected travelling in the third lane.

29. The driver assistance system of claim **28**, wherein said vehicle bus system comprises a CAN bus of the equipped vehicle.

30. The driver assistance system of claim **28**, wherein said control determines a position history of the other vehicle approaching the equipped vehicle from rearward of the equipped vehicle.

31. The driver assistance system of claim **28**, wherein detection of the lane change maneuver by said control is irrespective of activation by a driver of the equipped vehicle of a turn signal indicator of the equipped vehicle.

32. The driver assistance system of claim **28**, wherein said sensing system further comprises a second radar sensor disposed at the equipped vehicle and having a field of sensing exterior the equipped vehicle, and wherein image data captured by said second camera is provided to and processed at said control, and wherein radar data generated by said second radar sensor is provided to and processed at said control.

33. The driver assistance system of claim **32**, wherein, responsive at least in part to processing of radar data generated by at least one of said first and second radar sensors of said sensing system and of image data captured by at least one of said first and second cameras of said vision system, said control determines a hazard of collision of the equipped vehicle with the other vehicle approaching the equipped vehicle from rearward of the equipped vehicle.

34. The driver assistance system of claim **33**, wherein, responsive at least in part to said control determining said hazard of collision with the other vehicle approaching the equipped vehicle from rearward of the equipped vehicle, said control controls a system of the equipped vehicle to mitigate potential collision with the other vehicle approaching the equipped vehicle from rearward of the equipped vehicle.

35. The driver assistance system of claim **34**, wherein radar data generated by at least one of said first and second radar sensors of said sensing system and image data captured by at least one of said first and second cameras of said vision system are fused at said control.

36. The driver assistance system of claim **34**, wherein radar data generated by at least one of said first and second radar sensors of said sensing system and image data captured by said first camera of said vision system are fused at said control.

37. The driver assistance system of claim **34**, wherein radar data generated by said first radar sensor of said sensing system and image data captured by at least one of said first and second cameras of said vision system are fused at said control.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,099,610 B2
APPLICATION NO. : 15/289341
DATED : October 16, 2018
INVENTOR(S) : Kenneth Schofield

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9
Line 51, Claim 1, remove “a next but one lane to the lane” after “travelling in”

Signed and Sealed this
Eleventh Day of December, 2018

Andrei Iancu
Director of the United States Patent and Trademark Office