(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 012 211 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.01.2009 Bulletin 2009/02

(51) Int Cl.:
G05D 1/02 *(2006.01)*

(21) Application number: **07111671.9**

(22) Date of filing: **03.07.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(71) Applicant: **Ford Global Technologies, LLC**
Dearborn, MI 48126 (US)

(72) Inventors:
- **Szakaly, Alexander**
  SE-421 35, VÄSTRA FRÖLUNDA (SE)
- **Eidehall, Andreas**
  SE-414 65, GÖTEBORG (SE)
- **Pohl,Jochen**
  SE-412 55, GÖTEBORG (SE)

(74) Representative: **Mossmark, Anders Lennart**
Albihns AB
P.O. Box 142
401 22 Göteborg (SE)

(54) **A system for monitoring the surroundings of a vehicle**

(57) A surroundings monitoring system (10) for monitoring the surroundings (11) of a vehicle (1) comprising: a radar (22) being arranged to detect a road boundary (24) within a radar zone (26), said radar zone (26) being positioned a head of said vehicle (1), a shoulder edge determination unit (27) arranged to determine a lateral position of a shoulder edge (28) based on the detected road boundary (24), a vehicle position determination unit (29) being arranged to determine a lateral position (y(t)) of the vehicle (1) with respect to said shoulder edge (28).

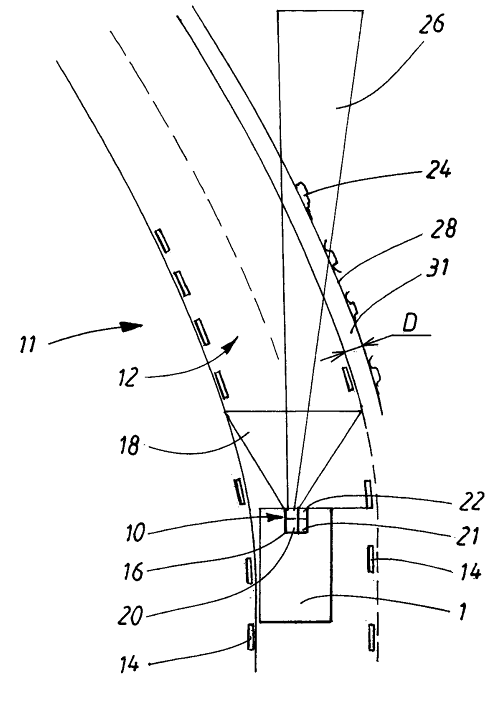


FIG. 2

EP 2 012 211 A1

Description

TECHNICAL FIELD

[0001] The invention relates to a surroundings monitoring system according to the preamble of claim 1. The invention particularly relates to a surroundings monitoring system which includes a radar arranged to detect a road boundary within a radar zone positioned ahead of the vehicle.

BACKGROUND ART

[0002] Systems for monitoring the surroundings of a vehicle are well known in the art. Various types of systems for monitoring the surroundings of a vehicle are known. All such systems include sensors retrieving information about the surroundings of a vehicle, processing means arranged to interpret the retrieved information, and intervention means arranged to activate specific functions dependent on how the processing means have interpreted the retrieved information. A specific type of surroundings monitoring system for monitoring the surroundings of a vehicle comprises a camera being mounted on a vehicle for detecting an image of a road in front of said vehicle. Such surroundings monitoring systems are useful for detection of the position of a vehicle within a lane. Knowledge of the position of a vehicle relative to a lane is of importance for active safety systems such as lane departure warning systems, which may alert a driver in the event the vehicle is about to leave a lane under certain conditions.

[0003] Surroundings monitoring systems which are arranged to detect lane markers ahead of the vehicle are well known in the art. Most such systems include a camera detecting an image of the road in front of the vehicle. An image recognition means provided in the system will interpret the image and specifically locate the position of lane markers. Image recognition means, which are well known in the art, identifies the presence and location of predefined objects in an image constituted by an array of pixels. The predefined objects may be constituted by simple objects such as lines, or circle segments or more complex objects such as vehicles. Lane markers are relatively easy to detect, since they are normally painted in a colour which forms a sharp contrast to the road surface, road shoulders and the environment external of the road which encloses the road.

[0004] A suitable image recognition system for determining the position of lane markers on a road surface makes use of a Hough transform to identify the position of the lane markers. The Hough transform, which is extensively described in the literature, is excellent for determination of the presence and position of simple objects such as lines in an image. In a more generalized form the transform can be used to determine the presence and location of circle segments and other geometrical shapes. A description of an image recognition system capable of determining complex patters is present in US3069654 by Paul Hough.

[0005] In order to accurately determine the position of the lane markers it is of importance that the image is of relatively high quality with sharp contrast. As the relative angle between the road surface and an optical axis of the camera decreases with the distance from the vehicle, the contrast between the lane marker and the road surface decreases as well. Lane markers can therefore only be detected within a relatively small vision zone positioned ahead of the vehicle. A normal vision zone extends about 20 - 50 meters from the vehicle.

[0006] As stated above, monitoring systems normally further comprises a lane departure warning unit, which is arranged to generate an intervention in the event said lane warning unit has determined that the vehicle is about to leave the lane. In order for a lane warning system to be commercially acceptable, the lane warning system should only normally be allowed to intervene when a driver is involuntary leaving a lane. In order to separate between cases where the driver is voluntary leaving the lane from cases where the driver is involuntary leaving the lane, several suggestions have been proposed. In some systems it has been proposed that warning signs should only be generated when the driver has not used the direction indicator. Considering the normal behavior of drivers, this has shown not to be sufficient to separate between voluntary and involuntary departure of the lanes.

[0007] In order to further improve the lane departure warning units, it has therefore been proposed to make use of information relating to the vehicles trajectory relative to the lane marker in order to separate between voluntary and involuntary departure from the lane. Frequently such systems base determination of whether to intervene or not on whether a measure of an estimated time to departure is below a threshold value or not. The time to departure will depend on the velocity of the vehicle, the vertical distance to the lane marker and the vehicles trajectory relative to the lane marker lane marker. In order to accurately determine if to intervene or not, the lateral position and lateral velocity of the vehicle relative to the lane marker must be determined with high accuracy.

[0008] In order to with sufficient accuracy determine the position of the vehicle relative to the lane marker and the lateral velocity of the vehicle relative to the lane markers, a vehicle position determination unit being arranged to determine a lateral position of a vehicle with respect to a lane defined by the lane markers detected by said camera must be able to determine the position of the vehicle relative to the lane marker with an accuracy in the cm range. The lateral velocity must also be determined with a high accuracy. In order to establish the lateral velocity, knowledge of the relative distance between the vehicle and lane marker is not sufficient. The curvature of the road must also be accounted for. The requirement of determining the curvature of the road adds to the uncertainty of the estimation, since both the position of lines identified in the image by the image recognition system and the inclination of the lines suffers from estimation errors.

[0009] In order to cope with the problem of determining the lateral position of a vehicle relative to the lane markers and the lateral velocity of the vehicle relative to the lane markers for a vehicle traveling at a relatively high speed by use of cameras having limited resolution, an image recognition system according to the state of the art is used to determine the lateral position of the vehicle relative to the lane marker by use of information from an instant image. An example of a suitable system is sold under the name MobilEye. In figure 1, such an image is shown. The lane markers 2 detected by the camera 2 within the vision zone 4 is used to determine the relative lateral position $y(t_0)$ at the time to. The image recognition system 6 detects the presence of the lane markers and establishes the lateral distance $y(t_0)$ of the vehicle relative to the lane markers 2 based on the position of the camera relative to the vehicle and the position of the lane markers relative to the camera. The determination of the relative position $y(t_0)$ of the vehicle with respect to the road may be determined by the use of known systems including a camera which detects the image of the road and an image recognition system which detects lane markers within the vision zone of the vehicle. By use of for instance a Hough transform, an estimate of the position of the lane markers can be detected with a sufficient degree of accuracy. The estimate of the position of the lane markers will represent a curved or straight line 8, which is used to determine the lateral position of the vehicle by geometric calculation. Since the resolution of cameras is limited, the exact position and curvature of the road geometry ahead of the vehicle is not determined. The estimated positions of the lane markers are primarily used to determine the current lateral position of the vehicle. The current lateral position of the vehicle in relation to the lane markers may be determined according to the method disclosed in Andreas Eidehall and Fredrik Gustafsson, "Combined road prediction and target tracking in collision avoidance" in Proceedings of IEEE Intelligent Vehicles Symposium 2004, pages 619-624.

[0010] In current surroundings monitoring systems including a road departure warning system a warning signal is generated depending of the vehicles relative position to the lane marker.

[0011] Even though progress have been made in the field of surroundings monitoring system including a departure warning unit, there still is a need to further improve such systems so that they better can separate between involuntary and voluntary departures and thereby to a higher degree alert the driver only when necessary.

DISCLOSURE OF INVENTION

[0012] It is an object of the invention to further improve surrounding monitoring system. In particular it is an object of the invention to improve a surroundings monitoring system including a departure warning unit, which is well adapted to normal behavior of drivers such that the systems capacity to separate between involuntary and voluntary departures is improved.

[0013] This object is achieved by a surroundings monitoring system according to the characterizing portion of claim 1.

[0014] A surroundings monitoring system according to the invention includes a radar being arranged to detect a road boundary within a radar zone, said radar zone being positioned a head of said vehicle and preferably extending further from said vehicle than said vision zone. The radar will detect objects positioned along the road boundary, such as guide rails, trees, stones etc. The detected objects will define a road boundary, which forms a transition from a generally flat surface to a border formed by the detected objects.

[0015] Since the detected road boundary does not form a continuous line, but a large set of detected objects forming an uneven interrupted border, it may be necessary to from the detected road boundary form a continuous line that estimates the road boundary.

[0016] The surroundings monitoring system therefore furthermore includes a shoulder edge determination unit arranged to determine a lateral position of a shoulder edge based on the detected road boundary. The shape of the shoulder edge is determined according to the same principles as is used for generally determining a road shape or the shape of the longitudinal extension of lane markers, but the road boundary detected by the radar is used as input data instead or in addition to lane markers detected by a camera. Suitably the process described in A. Polychronopoulos, et. al.; "Integrated object and road border tracking using a 77 GHz automotive radar",; IEE Proc. - Radar Sonar Navig., Vol 151, No 6, December 2004 may be used. The shape of the longitudinal extension may thus performed by adapting an curve to lane markers present in the detection zone of the camera such that the curve follows the lane markers. Once the shape of the shoulder edge is determined an exact lateral position of the shoulder edge is determined. Preferably the lateral position of the shoulder edge is selected such that it forms a tangent to parts of the road boundary within the detection zone being closest to the road centre.

[0017] The surroundings monitoring system according to the invention furthermore includes a road departure warning unit which is arranged to generate an intervention based on relative position of the vehicle to the shoulder edge. In Pohl, J. and Ekmark, j. (2003). Development of a haptic intervention system for unintended lane departure. In Proceedings of the 2003 SAE World Congress, Detroit, MI, USA., a suitable system for handling interventions due to unintentional road departures is described.

[0018] The intervention may be made in the event said road departure warning unit has determined that the vehicle approaches the road boundary and is positioned at a certain gap from the shoulder edge.

[0019] The surroundings monitoring system may furthermore include a warning line generation unit which is arranged to locate a warning line at a gap from the shoulder edge. The size of the gap may be dependent on the width of the road shoulder, which is the distance from the lane markers to the shoulder edge. The size of the gap may furthermore be dependent on the curvature radius of the road. In the event a warning line generation unit is included, the decision to intervene will be based on the relative lateral position of the vehicle with relation to the warning line, which depends on the position of the shoulder edge.

[0020] Preferably the shoulder edge determination unit, and, if included, the warning line determination unit and/or a lane marker position determination unit all use the same estimator for forming the respective shapes of the shoulder edge, warning line, and if included a lane marker position estimate. This may be done in a common road geometry determination unit using the estimating process disclosed in Andreas Eidehall and Fredrik Gustafsson, "Combined road prediction and target tracking in collision avoidance" in Proceedings of IEEE Intelligent Vehicles Symposium 2004, pages 619-624.

[0021] The timing of the intervention may thus be made dependent on an estimated time for the vehicle to cross the shoulder edge or preferably the warning line or distance to the shoulder edge or preferably warning line or a combination thereof, that is the timing of the intervention will be dependent on both the time for the vehicle to cross the shoulder edge and distance to the shoulder edge or preferably the time for the vehicle to cross the warning line and distance to the warning line.

[0022] By determining whether an intervention should be made or not by the road departure warning unit based on relative position of the vehicle to the shoulder edge being estimated from a detected road boundary instead of using a relative position to a lane marker, the surroundings monitoring system will be better adapted to an accepted behavior of drivers to temporarily use road shoulders. The system will be especially advantageous for curved roads where drivers tend to cut inner curves, where road shoulders exists and the driver have a clear sight of the road ahead of the vehicle. Preferably the decision whether an intervention should be made or not by the road departure warning unit is based on the relative position of the vehicle to a warning line which is positioned at a certain gap G from a shoulder edge

[0023] In a first embodiment of the invention, the surroundings monitoring system includes a road geometry determination unit, which is arranged to determine the road geometry ahead of the vehicle based on the road boundary detected by said radar. The road geometry determination may preferably be performed in the manner disclosed in A. Polychronopoulos, et. al.; "Integrated object and road border tracking using a 77 GHz automotive radar",; IEE Proc. - Radar Sonar Navig., Vol 151, No 6, December 2004. A road border geometry is determined in a road border assignment process, which estimates the road border geometry from measurement data obtained by the radar. A probalistic and a geometric method are disclosed as alternatives to assign the road borders. Preferably a weighted combination of both methods is used to obtain an accurate estimate of the road geometry.

[0024] In a second embodiment said surroundings monitoring system further comprises a camera being mounted on a vehicle for detecting an image of a road within a vision zone and an image recognition system being arranged to detect lane markers within said vision zone. The detection of lane markers can be used to improve the estimate of the road geometry by disregarding measurement data that are too distant from the lane markers.

[0025] In a third embodiment said surroundings monitoring system further comprises a camera being mounted on a vehicle for detecting an image of a road within a vision zone and an image recognition system being arranged to detect lane markers within said vision zone. In this embodiment, the road geometry may be completely determined from the position of the lane markers detected by the camera. The detection of lane markers can be used to improve the estimate of the by disregarding measurement data that are too distant from the lane markers. The road border geometry in the third embodiment is determined in a road border assignment process, which estimates the road border geometry from measurement data obtained by the radar.

[0026] The detected position of the lane markers can furthermore be used to determine the presence and extension of a road shoulder. In this event, the surroundings monitoring system further comprises a road shoulder assessment unit, which is arranged to assess the lateral extension of a road shoulder as the difference in lateral position of the shoulder edge estimated from the road boundary detected by the radar and a lane marker adjacent to said shoulder, which lane marker being detected by the camera.

[0027] The road departure warning unit may be furthermore arranged to intervene in dependence of the lateral extension of the road shoulder, i. e. on the difference in lateral position of the road boundary detected by said radar and a lane marker adjacent to said shoulder, which lane marker being detected by said camera. According to this embodiment, it is possible to adjust the timing of intervention in dependence of the existence and width of road shoulders. If large road shoulders exist, the vehicle may be allowed to pass the lane marker with a certain distance before an intervention is made, on the other hand if no road shoulder exists, but the lane marker coincides with a guard rail, a warning can be issued well before the lane marker.

[0028] The road departure warning system may furthermore be arranged to intervene in dependence of the curvature of the road. The dependence may preferably be of such a nature that such that the distance from a centre line of the lane to the point of intervention is increased for curves being convex toward the centre line and the distance from a centre line of the lane to the point of interception is decreased for curves being concave toward the centre line., that is the point of intervention is moved to the right at curves turning to the left and vice versa.

[0029] In the type of image recognition system referred to in the paragraph starting on page 4, line 5, where the relative lateral position is determined from the instant image, and where the relative lateral velocity is determined from estimating derivatives of the relative lateral position, the system is unaware of which type of curve is ahead of the vehicle. Such system may only determine what type of curve the vehicle is currently traveling in by use of a yaw rate sensor and the determined distance to the lane markers. In the event a vehicle is traveling in an S curve, where the centre of the curve moves from one side of the road to another side of the road, the current systems are unable to adapt the lane departure warning systems so as to allow certain type of curve cutting associated with S curves. With the new type of system, judgment of which type of curve is ahead of the vehicle is allowed for, which improves the capability of generating a lane departure warning system, which is more accurate in respect of alerting the driver only in situations when the driver unintentionally leaves the lane.

[0030] Generally the presence of a radar determining the road boundary ahead of the vehicle is beneficial for adapting lane warning departure systems to the actual road geometry. One advantage is that the existence and size of road shoulder may be assessed from estimating the distance to a road boundary detected by the radar to a lane marker detected by the camera. The lane warning system can thereafter be adapted to intervene in dependence on the existence and size of the road shoulder. Another advantage is that a lane warning system can be adapted to the road geometry such that the vehicle will be allowed to cut certain types of curves, while being prevented to cut other type of curves.

BRIEF DESCRIPTION OF DRAWINGS

[0031] An embodiment of the invention will be described below, with references to the appended drawings where:

- Fig. 1 shows a state of the art system for determining the lateral position of the vehicle with respect to lane markers,
- Fig. 2 shows a schematic drawing of a surroundings monitoring system determining the relative lateral position of a vehicle on a road with lane markers,
- Fig. 3 shows a block diagram of a surroundings monitoring system according to the invention,
- Fig. 4 shows a representation of a road boundary R ($\theta(x,y(t))$) for a vehicle,
- Fig 5a shows a road scenario for a road curved towards the left in the drawing, and
- Fig 5b shows a road scenario for a road curved towards the right in the drawing, and
- Fig. 5c is a schematic drawing showing the relations between the road boundary, shoulder edge, warning line, and lane marker.

EMBODIMENT(S) OF THE INVENTION

[0032] An embodiment will be described below with references to figures 2 and 3. Figure 2 shows a schematic drawing of a surroundings monitoring system 10 determining the relative lateral position y(t) of a vehicle 1 on a road 12 with lane markers 14. Figure 3 shows a block diagram of a surroundings monitoring system 10 according to the invention.

[0033] The surroundings monitoring system 10 includes a radar 22 being arranged to detect the road boundary 24 within a radar zone 26, said radar zone being positioned a head of said vehicle.

[0034] The radar is thus necessarily directed in the forward direction of the vehicle. The road boundary 24 detected by the radar 22 is formed by a reflected radar beam. All objects that vertically extend in the height direction along the road will be detected. Examples of objects which generate a sharp detectable reflection are parked cars, guard rails, solid objects such as rocks, houses, trees, animals and human beings. The lateral distance to the road boundary may be directly used as input to a road departure warning unit. The input data from the radar may however be first treated by a road geometry determination unit 23. The road geometry determination unit may retrieve its input data from a camera 16.. A suitable road boundary determination unit is sold under the trade name Mobil Eye. The road geometry determination unit may also be arranged as disclosed in A. Polychronopoulos, et. al.; "Integrated object and road border tracking using a 77 GHz automotive radar",; IEE Proc. - Radar Sonar Navig., Vol 151, No 6, December 2004. Preferably the road border geometry is determined in combined probalistic and geometric method disclosed in the document.

A road boundary 24 will thus be determined by detection of the reflected radar signal. A shoulder edge 28 will be determined from the detected road boundary in a shoulder edge determination unit 27. The road shoulder determination unit is arranged to determine the shape and lateral position of a shoulder edge based on the detected road boundary by forming an essentially continuous shoulder edge. The shoulder edge determination unit 27 is preferably included in a road geometry determination unit 26. The shoulder edge representation may be a curved or straight line. Since the radar with good accuracy may detect objects along the road which extend in the vertical direction, and which objects are positioned relatively far from the vehicle, a road boundary 24 and thus a shoulder edge 28 can be determined ahead of the vehicle at distances exceeding 150m. Hence, the use of a radar 22 to determine the road boundary ensures that the shoulder edge 28 can be determined at a distance extending further from said vehicle than an actual vision zone, in which lane markers are detected. A particular advantage in using a radar for detecting a road boundary, is that vertically extending objects can be detected with a good accuracy at a large distance, while the lane markers are difficult to detect at a large distance since the relative angle between the cameras optical axis and the surface of the lane marker becomes very small for distant lane markers. It is therefore very difficult to detect lane markers, if at all possible, at a distance exceeding 20 - 50 m.

[0035] The representation of the road boundary 24 is stored in a memory suitably as a vector R(θ((x,y)(t))) for angles θ relative to the heading direction θ of the vehicle positioned at the location (x,y) the time t. In figure 4, a representation of a road boundary R(θ(x,y(t))) for a vehicle is illustrated.

[0036] A vehicle position determination unit 29 included in the vehicle surroundings monitoring system is arranged to determine a lateral position y(t) of a vehicle on a road 12 with respect to a shoulder edge 28, or preferably a warning line 42 as will be explained below. The vehicle position determination unit may preferably include a camera 16 as an input device for deriving the actual lateral position of the vehicle. In this embodiment of the surroundings monitoring system 10, a camera 16 is mounted on a vehicle for detecting an image of a road within a vision zone 18. An image recognition system 20 is arranged to detect lane markers 14 in the image captured by the camera. The camera 16 and the image recognition system 20 may be any known arrangement which is able to capture an image of lane markers and determine the position of the vehicle relative to lane markers. Such arrangements are well known to a person skilled in the art. A suitable system is sold under the tradename MobilEye. The vision zone 18 preferably extends ahead of the vehicle as shown in figure 2. Alternatively, the camera can be directed in the rearward direction. This is possible since the main task of the image recognition system is to determine the current lateral position of the vehicle, which may be determined either by image recognition detecting the lane markers in the front or rear direction of the vehicle. The radar zone preferably extends further from the vehicle than the vision zone.

[0037] As the vehicle travels along the road, the camera will detect the lane markers 14 positioned along the road. A road shoulder assessment unit 30 is included in the surroundings monitoring system, which road shoulder assessment unit 30 is arranged to assess the lateral extension D of a road shoulder 31 as the difference in lateral position of the shoulder edge estimated from road boundary 24 detected by said radar 22 and a lane marker 14 adjacent to said shoulder 31, which lane marker 14 being detected by said camera 16. The road shoulder is thus a relatively plane surface limited on one side of a lane marker 14 detected by a camera, and on the other side of a shoulder edge preferably forming a tangent to vertically extending objects, detected by the radar, and which are defining a road boundary 24.

[0038] In a preferred embodiment of the invention the surroundings monitoring system includes a warning line generation unit 33 which is arranged to locate a warning line 42_R, 42_L at a gap from the shoulder edge 28. The size of the gap G may be dependent on the width D of the road shoulder, which is the distance from the lane markers 14 to the shoulder edge 28. The size of the gap G may furthermore be dependent on the curvature radius R of the road. In the event a warning line generation unit is included, the decision to intervene will be based on the relative lateral position of the vehicle 1 with relation to the warning line 42_R, 42_L, which depends on the position of the shoulder edge. If a warning line generation unit is not included the decision to intervene will be based on the relative lateral position of the vehicle 1 with relation to the position of the shoulder edge directly.

[0039] Preferably the shoulder edge determination unit 27, and, if included, the warning line determination unit 33 and/or a lane marker position determination unit all use the same estimator for forming the respective shapes of the shoulder edge, warning line, and if included an lane marker position estimate. This may be done in a common road geometry determination unit 23 using the estimating process disclosed in Andreas Eidehall and Fredrik Gustafsson, "Combined road prediction and target tracking in collision avoidance" in Proceedings of IEEE Intelligent Vehicles Symposium 2004, pages 619-624.

[0040] The equations governing the Kalman process which determines the road geometry and hence the geometry of the respective lines that is the shoulder edge, the warning line, a continuous line representing the lane markers is as follows:

$$d(y\_off) = v*Psi\_rel$$

$$d(Psi\_rel) = Psi\_abs - v*c\_0$$

$$d(c0) = v*c\_1$$

$$d(c1) = 0$$

Where,
y_off = host vehicle position relative to the center of the lane
Psi_rel = host vehicle heading angle relative to the lane
c0 = road curvature = 1/road radius
c1 = distance derivative of c0
v = host vehicle velocity
d= time derivative

[0041] The camera will be used to generate indata to estimate y_off och Psi_rel. c0 is measured from input data from the camera and radar as is disclosed in the reference.

Based on these equations the Kalman filter is created according to general practice.

[0042] The respective lines will then be a set of parallel curved lines off set a certain distance from each other.

[0043] The surroundings monitoring system furthermore comprises a road departure warning unit 32, which is arranged to generate an intervention in the event said road departure warning unit has determined that the vehicle is about to leave the road. The intervention may be provided in different forms, such as generation of a warning sign, activation of brakes, active steering of the vehicle, etc..The most common lane warning units will provide an intervention in the form of a warning alerting the driver. The warning may be visual or audial.

[0044] Generally a road departure warning unit 32 is arranged to determine that the vehicle is about to leave the road based on relative position of the vehicle to the warning line, which is positioned at a certain gap G from the shoulder edge 28. The size of the gap may be dependent on the lateral extension D of the road shoulder and/or of the curvature radius R of the road. The intervention will be made when the vehicle approaches the warning line and is positioned at a certain distance S from the warning line. The distance S may be determined in different manners. In one embodiment said road departure warning 32 unit is arranged to determine that the vehicle is about to leave the road, when an estimated time to departure T, that is the time T needed for the vehicle to cross the warning line, is below a threshold value, S: T≤ Threshold. In another embodiment road departure warning unit 32 is arranged to determine that the vehicle is about to leave the road, when an estimated distance to departure L, that is the distance required for the vehicle to travel in order to cross the warning line, is below a threshold value, S: L≤ Threshold. In a third embodiment the road departure warning unit 32 is arranged to determine that the vehicle is about to leave the road, that is to pass the warning line, when a value of a function f of an estimated distance to departure L and an estimated time to departure T is below a threshold value, S: f(T, L) ≤ Threshold.

[0045] The warning line positioned at a gap G from the road shoulder will form a continuous warning line running along the extension of the road boundary 24. In the event lane markers are detected by the image recognition system 20, the gap size can be made dependent of the position of the lane markers.

[0046] In an embodiment of the invention, the road shoulder assessment unit 30 is arranged to assess the lateral extension D of a road shoulder 31 as the difference in lateral position of the shoulder edge 28 determined from the road boundary 24 detected by said radar 22 and a lane marker 14 adjacent to said shoulder 31. By assessing that the lateral extension D is within a range, such that $D_{min} < D < D_{max}$, where D_{max} is smaller than a normal lane width, it is possible to exclude misinterpretation of a neighboring lane as a road shoulder, which may be used by the vehicle. This criterion can also be used to prevent that a neighboring lane traveling in the opposite direction is interpreted as road shoulder. Different rules may be applied for detected flat ground on the left and right side of the vehicle. For example only a road boundary to the right of the vehicle may be used when defining a road shoulder. This rule may be applicable in countries with right hand traffic. Consequently a rule that only a road boundary to the left of the vehicle may be used when defining a road shoulder may be used in countries with left hand traffic.

[0047] The lateral distance to an actual lane marker can be positive, that is an intervention is generated before the vehicle passes the actual lane marker, or negative, that is an intervention is made after the vehicle has passed the actual lane marker.

[0048] In figure 5a road curved towards the left in the drawing is shown. The road is provided with lane markers 14_L, 14_M, 14_R forming a left, middle and right delimitation of two lanes 34, 36. A vehicle 1 is travelling in the right lane 36 in the upwards direction in the figure. Warning lines 40_L, 40_R forms the fixed reference in lateral position for a road departure warning unit. The road departure warning unit compares the vehicles relative position to the warning lines in order to determine whether an intervention should be made or not. In one embodiment the warning lines marks the position at which in intervention will be made by a road departure warning unit in the event the vehicle will pass the warning lines 40_L, 40_R. In another embodiment the timing of the intervention can be based on an estimated time to departure T when the vehicle is assumed to cross the warning line. A warning line exists for the left and right side of the lane in which the vehicle travels. The warning lines are positioned at gap G from the shoulder edge estimated from the road boundary 24 detected by the radar.

[0049] The size of the gap is determined in a gap size determination unit 44, which calculates the position relative to a road boundary. Input to the gap size determination unit 44 is information from the road geometry determination unit 26, the shoulder assessment unit 30, a vehicle speed sensor 46 and a vehicle yaw rate sensor 48.

[0050] The gap size may be dependent on the following input variables alone or taken in combination:

- the curvature radius R determined by the road geometry determination unit 26,
- the presence and lateral extension D of road shoulders determined by road shoulder assessment unit 30,

[0051] The gap size can be expressed as G= T(D,R).

[0052] The timing of the intervention may be based on:

- a time to departure T, determined by the yaw rate sensor and a vehicle speed sensor and an estimated road geometry, and
- the distance to departure L.

[0053] The warning line 40_L is positioned at a distance Δ in the lateral direction to the lane markers 14_R. The magnitude of the distance Δ may be positive, that is the warning line will be positioned in the lane, or negative, that is the warning line will be positioned outside of the lane. In figure 5a, the warning line 40_R is positioned in the lane 36, which indicates that the distance Δ has a positive value, while the warning line 40_L is positioned outside of the lane 38, which indicates that the distance Δ has a negative value. If the distance Δ has a negative value an intervention will be made before the vehicle exits the lane, while if the distance Δ has a positive value an intervention will be made after the vehicle exits the lane.

[0054] As can be seen in figure 5a the lateral position of the warning line 40_L, 40_R with respect to the road boundary 24 is dependent on the curvature of the road such that a minimal lateral distance from a centre of curvature to said warning line is decreasing with a decreased radius of curvature of the road. This allows a vehicle to cut an inner curve with a certain distance, while preventing the vehicle to ride to close to the lane markers in an outer curve. Naturally, it is possible to set different rules for the left and right lane markers in the event, for instance it should not be allowed to pass a lane marker positioned adjacent to an other lane, while allowing the vehicle to pass lane markers which are facing a road boundary, especially in the event a rod shoulder is positioned on the other side of the lane marker.

[0055] In figure 5b road curved towards the right in the drawing is shown. The warning lines 42_L, 42_R marks the position at which in intervention will be made by a road departure warning unit in the event the vehicle will pass the warning lines 42_L, 42_R.

[0056] The warning lines are positioned at gap G from the shoulder edge estimated from the road boundary 24 detected by the radar.

[0057] The size of the gap is determined in a gap size determination unit 44, which calculates the position relative to a road boundary. Input to the gap size determination unit 44 is information from the road geometry determination unit 26, the shoulder assessment unit 30, a vehicle speed sensor 46 and a vehicle yaw rate sensor 48.

[0058] The gap size may be dependent on the curvature radius R determined by the road geometry determination unit 26, the presence and lateral extension D of road shoulders determined by road shoulder assessment unit 30. The gap size can be expressed as G= T(D, R).

[0059] It can here be noted that the warning lines 42_L, 42_R are shifted towards the right in stead of to the left as in figure 5a. This indicated that the warning lines are normally shifted in the same direction as the curvature of the road; that is to the left in a lane curved toward the left and to the right in a lane curved to the right. The magnitude of the shift; that is the size of the gap is dependent on the curvature radius such that a smaller curvature radius R will generate a larger gap.
Figure 5c is a schematic drawing showing the relations between the road boundary 24, shoulder edge 28, warning line 42_R, and lane marker 14.
Figure 5c shows the geometry of the road including discontinuous set of radar reflections forming a road boundary 24. A continuous shoulder edge 28 is determined from the radar reflections forming the road boundary 24 in a shoulder edge determination unit 27, which may be included in the road geometry determination unit 26. A warning line 42_R determined in a warning line generation unit is located at a gap G from the shoulder edge 28. A lane marker 14 is positioned to the left in the figure. A road shoulder extending between the lane marker 14 and shoulder edge 28 has a lateral extension D.

[0060] A decision to intervene is based on the relative lateral position S of a vehicle 1 to the warning line 42_R. The warning line 42_R is positioned at a distance Δ to the lane markers in the lateral direction. The position of the warning line 42_R may be on either side of the lane marker 14 depending on the geometry of the road and/or location of the shoulder edge relative to the lane marker.

[0061] The dependence of the curvature radius of the road for the gap G may be expressed as G=max(0,k/abs (R)), where k is set between 50 and 500, preferably between 80 and 150, that is k is preferably set to approximately 100.

Claims

1. A surroundings monitoring system (10) for monitoring the surroundings (11) of a vehicle (1) comprising:

a radar (22) being arranged to detect a road boundary (24) within a radar zone (26), said radar zone (26) being positioned a head of said vehicle (1), a shoulder edge determination unit (27) arranged to determine a lateral position of a shoulder edge (28) based on the detected road boundary (24), a vehicle position determination unit (29) being arranged to determine a lateral position (y(t)) of the vehicle (1) with respect to said shoulder edge (28), **characterized in that** said surroundings monitoring system (10) further comprises a road departure warning unit (32), which is arranged to generate an intervention based on relative lateral position of the vehicle (1) to the shoulder edge (28).

2. A surroundings monitoring system according to claim 1, **characterized in that** the system furthermore includes a warning line generation unit (33) which is arranged to locate a warning line (42_R, 42_L) at a gap G from the shoulder edge (28) and that the road departure warning unit (32), is arranged to generate an intervention based on relative position (S) of the vehicle (1) to the warning line (42_R, 42_L).

3. A surroundings monitoring system according to claim 2, **characterized in that** the magnitude of the relative position (S) of the vehicle (1) to the warning line (42_R, 42_L) at which an interventions is made (S=S(T)) is dependent on an estimated time (T) for the vehicle to cross the warning line (42_R, 42_L)

4. A surroundings monitoring system according to claim 2 or 3, **characterized in that** the magnitude of the relative position (S) of the vehicle (1) to the warning line (1) at which an interventions is made (S=S(T); S=S(T,L) is dependent on distance L to the warning line (42_R, 42_L).

4. A surroundings monitoring system according to any of claims 1 - 3, **characterized in that** said surroundings monitoring system (10) further comprises a road geometry determination unit (23), which is arranged to determine the road geometry ahead of the vehicle (1) based on the road boundary (24) detected by said radar (22).

5. A surroundings monitoring system according to any of claims 1 - 4, **characterized in that** said surroundings monitoring system (10) further comprises a camera (16) being mounted on the vehicle (1) for detecting an image of a road within a vision zone (18) and an image recognition system (20) being arranged to detect lane markers (2) within said vision zone (18);

6. A surroundings monitoring system according claim 5, **characterized in that** said surroundings monitoring system (10) further comprises a road shoulder assessment unit (30), which is arranged to assess the lateral extension (D) of a road shoulder (31) as the difference in lateral position of the road boundary (24) detected by said radar (26) and a lane marker (14) adjacent to said road boundary (24), which lane marker (14) being detected by said camera (16).

7. A surroundings monitoring system according to claim 6, **characterized in that** the extension of said gap (G) is dependent on the extension of the road shoulder (D).

8. A surroundings monitoring system according to any of claims 1 - 7, **characterized in that** the extension of said gap (G) is dependent on the curvature (C) of the road.

9. A surroundings monitoring system according to claim 8, **characterized in that** said gap (G) will form a warning line (40_R) running along the road boundary (24) and that a lateral position of the warning line with respect to the shoulder edge (28) is dependent on the curvature (R) of the road such that a minimal lateral distance from a centre of curvature to said warning line (40_R) is decreasing with a decreased radius of curvature of the road.

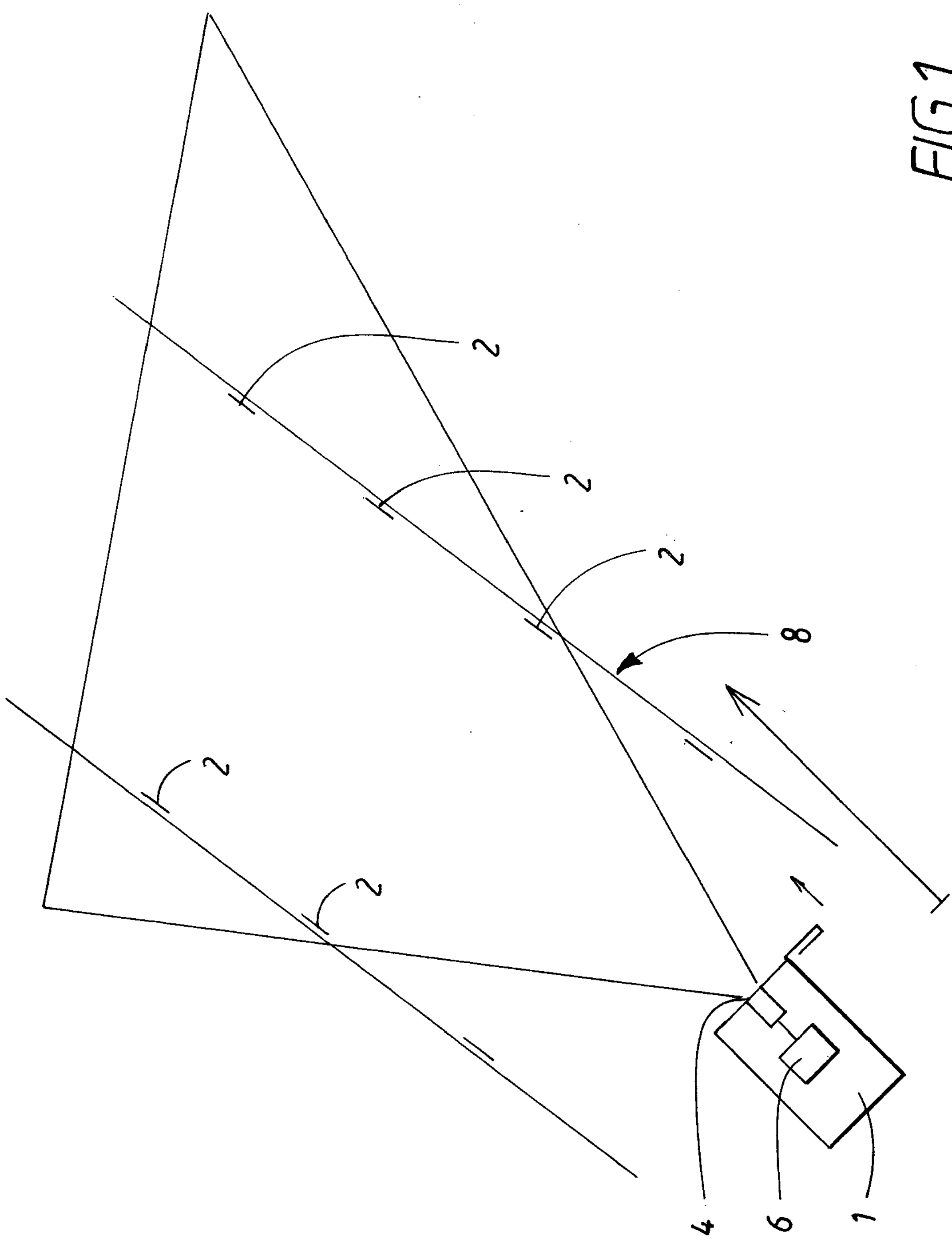


FIG.1

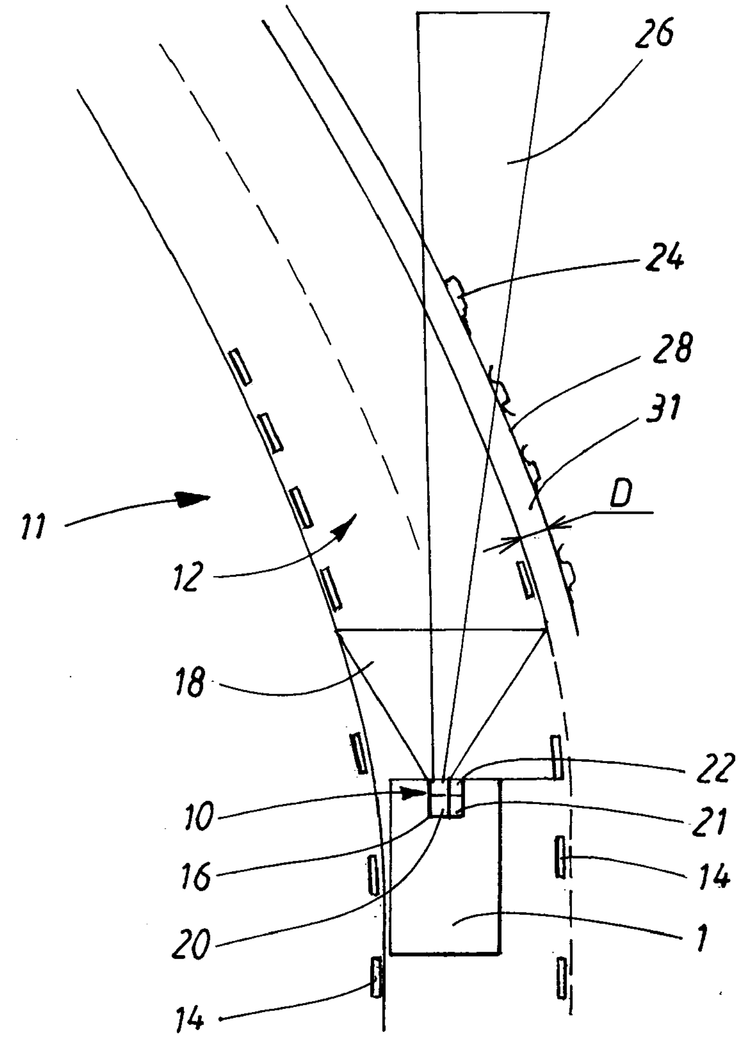


FIG. 2

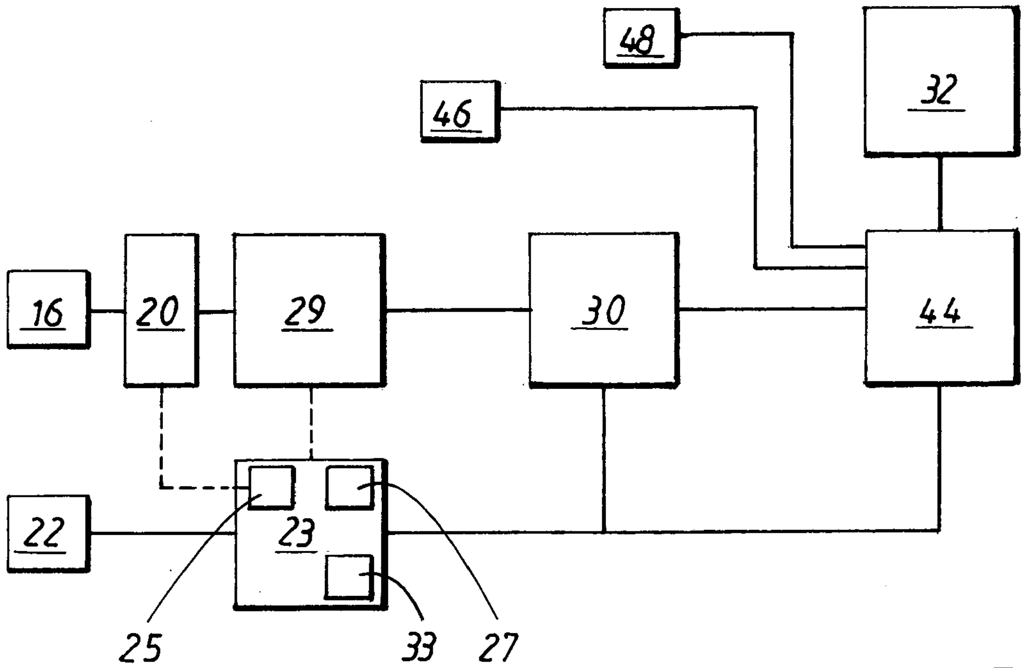


FIG. 3

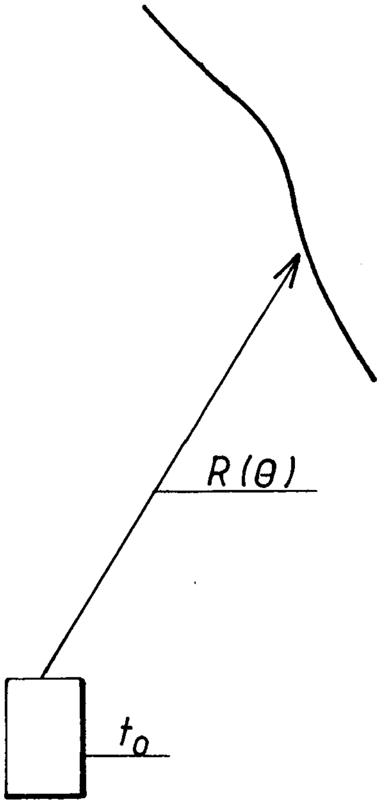
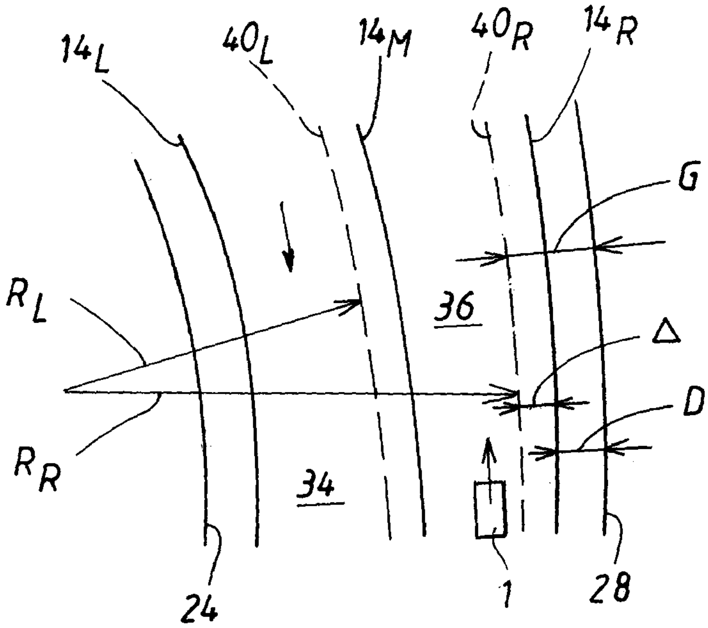
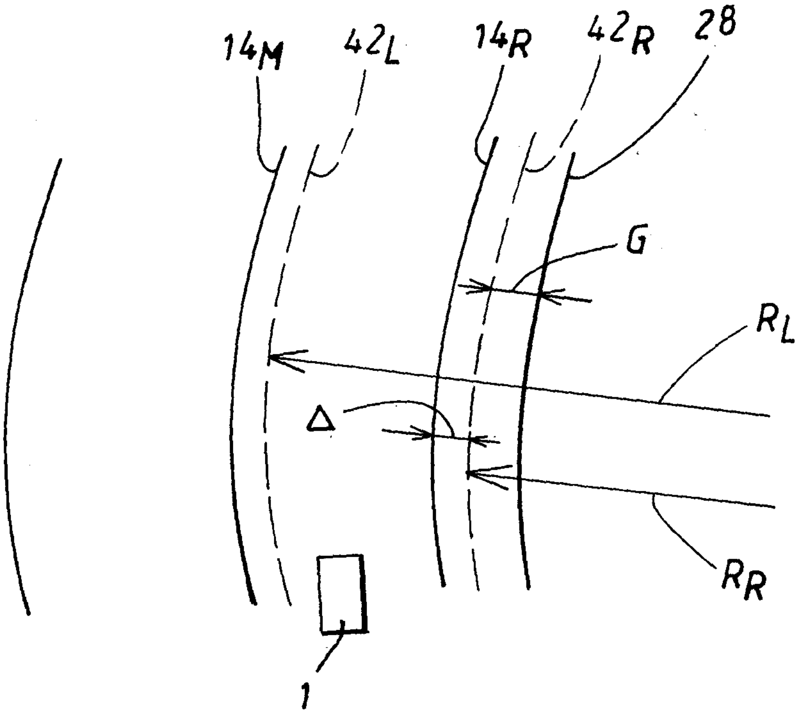


FIG.4



14L
40L
14M
40R
14R
G
RL
36
Δ
D
RR
34
24
1
28

FIG.5a



14M
42L
14R
42R
28
G
RL
Δ
RR
1

FIG.5b

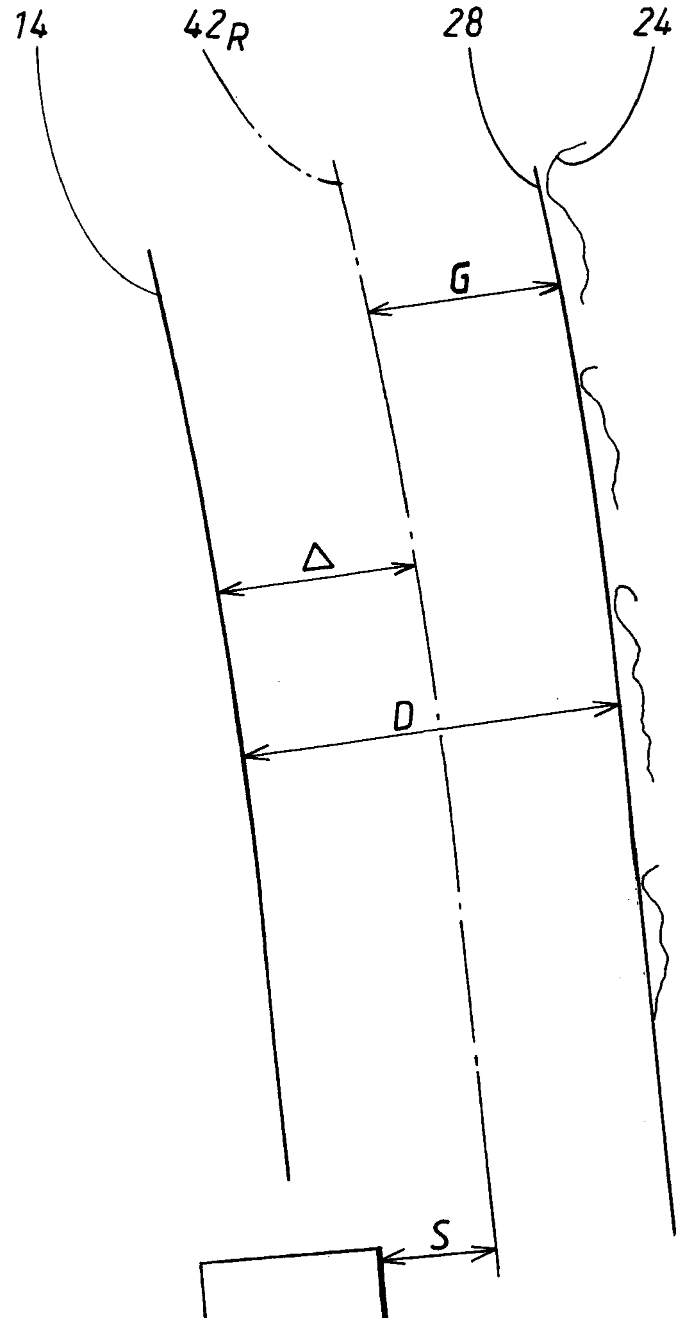


FIG.5c

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 1671

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2004 057296 A (DAIMLERCHRYSLER) 8 June 2006 (2006-06-08) * paragraphs [0016], [0017], [0029] *	1-7	INV. G05D1/02
X	DE 10 2005 039167 A (DAIMLERCHRYSLER) 22 February 2007 (2007-02-22) * paragraphs [0004], [0014], [0017]; claims 6,7 *	1,2,5-7	
X	DE 10 2005 003178 A (VOLKSWAGEN) 27 July 2006 (2006-07-27) * paragraphs [0008] - [0010]; figure 1 *	1-3,8	
X	EP 1 320 082 A (AUDI) 18 June 2003 (2003-06-18) * paragraphs [0008], [0014]; claims *	1,5	
X	DE 10 2005 039895 A (SIEMENS) 1 March 2007 (2007-03-01) * paragraphs [0002], [0022], [0026]; figure 2 *	1,5	TECHNICAL FIELDS SEARCHED (IPC)
A	DE 10 2005 025387 A (DAIMLERCHRYSLER) 4 May 2006 (2006-05-04)		G05D B60W G01S B60Q B60K G08G
A	DE 199 44 542 A (DAIMLERCHRYSLER) 12 April 2001 (2001-04-12)		
P,A	EIDEHALL ET AL: "Joint road geometry estimation and vehicle tracking" 1 October 2007 (2007-10-01), CONTROL ENGINEERING PRACTICE, PERGAMON PRESS, OXFORD, GB, PAGE(S) 1484-1494, XP022282170 ISSN: 0967-0661		

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	10 December 2007	Krieger, Philippe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 1671

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
D,A	POLYCHRONOPOULOS A ET AL: "Integrated object and road border tracking using 77 GHz automotive radars" IEE PROCEEDINGS: RADAR, SONAR & NAVIGATION, INSTITUTION OF ELECTRICAL ENGINEERS, GB, vol. 151, no. 6, 10 December 2004 (2004-12-10), pages 375-381, XP006023106 ISSN: 1350-2395 -----		
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Berlin	10 December 2007	Krieger, Philippe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 1671

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

10-12-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102004057296 A	08-06-2006	JP 2006155615 A US 2006132295 A1	15-06-2006 22-06-2006
DE 102005039167 A	22-02-2007	NONE	
DE 102005003178 A	27-07-2006	NONE	
EP 1320082 A	18-06-2003	DE 10161567 A1	03-07-2003
DE 102005039895 A	01-03-2007	WO 2007023103 A1	01-03-2007
DE 102005025387 A	04-05-2006	WO 2006037445 A1	13-04-2006
DE 19944542 A	12-04-2001	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 3069654 A, Paul Hough **[0004]**

Non-patent literature cited in the description

- **ANDREAS EIDEHALL ; FREDRIK GUSTAFSSON.** Combined road prediction and target tracking in collision avoidance. *Proceedings of IEEE Intelligent Vehicles Symposium,* 2004, 619-624 **[0009] [0020] [0039]**
- **A. POLYCHRONOPOULOS.** Integrated object and road border tracking using a 77 GHz automotive radar. *IEE Proc. - Radar Sonar Navig.,* December 2004, vol. 151 (6 **[0016] [0034]**
- **POHL, J. ; EKMARK, J.** Development of a haptic intervention system for unintended lane departure. *Proceedings of the 2003 SAE World Congress,* 2003 **[0017]**
- **A. POLYCHRONOPOULOS.** Integrated object and road border tracking using a 77 GHz automotive radar. *IEE Proc. - Radar Sonar Navig.,* December 2006, vol. 151 (6 **[0023]**