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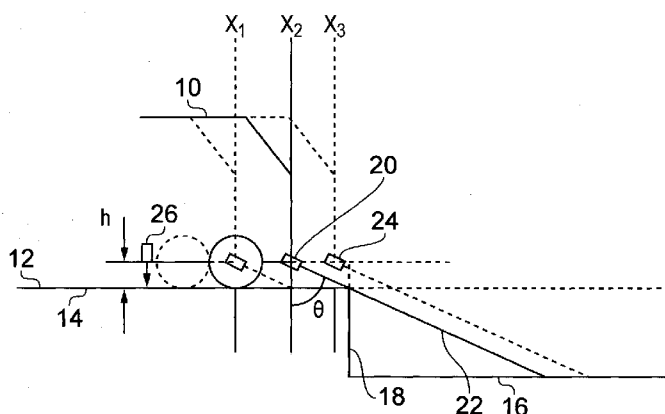


FIG. 1A

(57) Abstract: A sensor system detects changes in ground level or profile and is intended to prevent a car from reversing into an obstacle, such as a gully, kerb, ditch or a sloping roof. The system comprises one or more sensor means, each having a response axis at which its response is maximal, the, or each, sensor being mounted on a vehicle. In use the, or each, sensor response axis is at an angle with respect to the vertical and a control means receives signals from the one or more sensors and acts to analyse a series of one or more components of the signals, and issues a warning when a change of ground elevation is detected. Optionally a brake may be applied automatically so as to prevent the vehicle from moving towards the obstacle.

Improvements in obstacle detection for vehicles

Field of the Invention

This invention relates to an improvements in obstacle detection for vehicles, and more particularly, but not exclusively the invention relates to sensors and accident prevention systems for vehicles, and particularly relates to sensors and systems to prevent collision with obstacles at a low level – that is close to the ground and/or collision with an obstacle at a high level. An example of an obstacle at a low level is uneven or sloping ground, holes or sudden drops. An example of an obstacle at a high level is a garage roof, door or ceiling that is close to the roof of the vehicle.

Background of the Invention

Many sensors, accident prevention and drive control systems for vehicles are known, operating on a variety of physical sensing principles, for warning and prevention of collisions with obstacles, other vehicles, pedestrians or animals. In some cases the sensors or accident prevention systems are linked to a vehicle control so as to for example cut power, apply brakes, steer to avoid an obstacle, or to moderate a vehicle's speed so that it matches another vehicles.

The aforementioned sensors and systems are adapted to detect and respond to obstacles, vehicles or people that are present as projections above a surface such as the ground in such a way that a portion of the vehicle is liable to collide with them. Such sensors comprise capacitive sensors, that respond to capacitive coupling between a pair of plates arising from proximity of an object; vision systems in which the content of a scene is analysed to derive information about the position of obstacles relative to the vehicle; radar

sensors and ultrasonic acoustic reflection-based sensors, which may have a Doppler sensing capability for example to detect speed of the vehicle relative to the ground or another vehicle.

These sensors are adapted to look primarily parallel to the ground, and may be mounted for example on the bumper of the car, in many cases one sensor being provided at each corner.

Ground sensors for vehicles are also known, that detect the presence of the ground under or in the immediate surroundings of a vehicle, for purposes of measuring the speed of a vehicle over the ground – ultrasonic Doppler sensors are used for this purpose, for example, detecting acoustic signals scattered by the rough surface below the vehicle. Ground sensing is also known as a means for compensating certain types of obstacle sensors, for example those that have a relatively wide field of sensitivity such as capacitive sensors, against transient change in height of a vehicle above the ground, for example through roughness of the surface or action of the vehicle's suspension.

However, the prior art lacks sensors and accident prevention systems adapted to detect another common cause of vehicle mishap: the vehicle running into a ditch, a deep pothole, or over the edge of a drop, such as for example the edge of a roadway or raised area of ground, or a quayside. Such sensors and systems in contrast to those of the prior art described above need to be adapted to observe the ground immediately behind (and optionally in front of) the vehicle, and detect the presence of a change in ground elevation that threatens an accident. The system may then issue a warning, activate a further sensing system, or apply a control to the vehicle (e.g. the brake).

The prior art further lacks sensors and accident prevention systems for small, ground level obstacles that may seriously damage a vehicle in motion, such

as for example anti-reverse equipment as used in traffic management, protruding rocks or low kerbs that may damage the wheels or underside of the car. Further, hazards exist to children, animals and small valuable items that may be out of sight of a driver, especially in large or high vehicles, and improved devices for detection of such situations, warning and optionally automatic halting of the vehicles are needed.

The present invention aims to provide sensors and accident prevention systems that address the above deficiency.

Summary of the Invention

According to the present invention there is provided a sensor system to detect changes in ground level or profile, comprising: one or more sensor means, each having a response axis at which its response is maximal, the or each sensor being mounted on a vehicle, so that each sensor response axis is at an angle with respect to the vertical; a control means that receives signals from the one or more sensors and which acts to analyse a series of one or more components of the signals, and issues a warning when the result of the correlation indicates a change of ground elevation.

Preferably the axis of response is directed to intersect the ground at a distance behind or in front of the vehicle, so that the system may give warning before the vehicle reaches the obstacle.

In a preferred embodiment the control means samples the detector signal at a series of time points as the vehicle moves, and looks for a correlation in the samples that indicates a change in ground level, for example a depression or drop-off, or a raised obstacle or rising slope. In further embodiments the sensor system comprises a position sensor that measures the distance moved by the vehicle, from which the control means receives signals and produces a correlation of signals from the one or more sensor means with

information from the distance sensor. In some embodiments the position sensor may be provided as part of the vehicle, the sensor system being adapted to receive information from the position sensor. In other embodiments the position sensor may be provided as part of the sensor system itself.

In different embodiments, the sensor means may include: radar distance measuring sensors; optical sensors for example based on the detection of back-scattered light from a light source provided as part of the system; ultrasonic sensors based on echo timing; capacitance sensors, in which the degree of capacitive coupling between two plates is determined by the distance to a solid surface, such as the ground or an obstacle.

In preferred embodiments the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include one or more of: analysing the signal from an individual sensor to separate distance information from noise; comparing the signal from a number of sensors to determine correlations between sensor responses; comparing the sequence of signals over time from a given sensor or number of sensors to determine correlations in time for a given sensor or number of sensors taken together; using information from a vehicle speed sensor or a vehicle position sensor to determine the obstacle sensor output(s) as a function of position of the vehicle; determining the probability that a detected correlation indicates an obstacle; determining the likely location and nature of the obstacle; giving warning to a driver of the vehicle that an obstacle is present; optionally, taking control of an aspect of the vehicle's operation, such as cutting power and applying the brake.

In a preferred embodiment the sensor system comprises sensor means having a plurality of different response axes. Preferably the control means

uses the responses from each of the plurality of response axes in an algorithm to determine the position of the vehicle relative to the obstacle.

In a preferred embodiment the system comprises scanning means associated with one or more sensors that act in use to control the direction of the axis of response relative to a reference direction on the vehicle, for example to move the axis of response through an angle relative to the reference direction. Preferably the scanning means is adapted to position the axis as a number of pre-set angles with respect to the reference direction. Preferably the control means uses information derived from the sensor when the response axis is at a plurality of pre-set angles in an algorithm to determine the position of the vehicle relative to the obstacle. Preferably the scanning means is controlled and the angle is set by the control means.

In an alternative embodiment the system comprises a sensor array means having plurality of sensors, each having a response axis, the response axes being offset from one another by one or more chosen angles, so providing a plurality of response axes at different angles with respect to a reference direction on the vehicle, so producing a fan-like pattern of response axes. The response axes may be offset by a uniform angle, or may be offset by a variety of angles.

The sensor system preferably comprises more than one sensor means or sensor array means, for example at corners of the vehicle, mounted at a known height above the mean position of the ground. Sensors are advantageously provided at the rear corners of the vehicle, but may also be at the front corners, and any location is within the scope of the invention. In a preferred embodiment the system comprises sensor means positioned at more than one height on the vehicle, for example at more than one height at a corner of the vehicle. In preferred embodiments at least one sensor is located at a low position on the vehicle, for example at around the height of the vehicle bumper. In a further embodiment at least one sensor is located near

the top of the vehicle, for example near the rear corners of the roof, in order to detect obstacles that may foul the roof, such as a partly closed garage door, a height barrier, or an overhang on a building.

According to a further aspect of the invention is provided an accident warning and prevention system, comprising one or more sensor means as above, a control means, an operating program, and a vehicle control means operable by the control means to control or halt operation of the vehicle. In a preferred embodiment the vehicle control means acts to cut power and/or apply a brake to the vehicle, for example to bring it to a halt or to check its operation so as to prompt the user to halt or to avoid the obstacle. In a preferred embodiment the system comprises means to alert the driver to the existence of an obstacle, and optionally to its location and/or nature. In a preferred embodiment the system of the invention exchanges information with one or more components of the vehicle management system so as to effect control over the vehicle. In further preferred embodiments the system exchanges information with a vehicle display system, for example a parking guidance system, in order to give guidance and/or warning regarding obstacles of the kind the system is adapted to detect, and which are not readily detected by sensor systems of the prior art.

The system is preferably adapted to detect, warn against and optionally to act to control vehicle movement and protect against risk posed by hazards including for a typical road vehicle: quaysides, drop-offs, ditches, road edges, holes in the road, downward facing kerbs; raised kerbs, anti-back-up devices, obstacles close to the ground such as rocks or debris in the road; items in the vehicle's path such as childrens' toys, tools etc.; persons such as children or persons lying in the road, animals such as pets. The system may be adapted to any type of vehicle, including cars, trucks, construction and production plant, with number, location and type of sensor chosen accordingly. For larger vehicles, the type of hazard against which the system is adapted to

protect may differ, and the system may be adapted to protect against larger items than those above.

In an embodiment of the invention, the operating program comprises a means to analyse the sensor data to provide information on the nature and seriousness of the hazard, for example in a preferred embodiment the system is able to interpret the height of a sudden drop-off from the roadway, as being either a kerb over which a vehicle may pass with care, or a quayside, and to warn the driver and optionally to exert control of the vehicle, accordingly. Such warning and control may be exercised at a greater distance from a quayside than from a kerb. The system may comprise means to identify the nature of the hazard and inform a driver, for example by means of comparing sensor signals or a quantity derived from them with values in a look-up table that are characteristic of a hazard type.

In preferred embodiments the operating program further comprises an algorithm to assess the risk posed by the obstacle or hazard identified by the control means using the sensor information. Such an algorithm may have as inputs information comprising one or more of: sensor information regarding the location of a hazard relative to the vehicle; location relative to one or more wheels or components of the vehicle close to the ground; the speed and direction of the vehicle; the nature of the hazard: drop, raised, how deep/high, does the hazard have a component of movement relative to the vehicle's movement and to the ground, indicating a moving hazard such as a child; the attitude or orientation of the vehicle (for example, is it on an uphill or downhill slope towards the hazard); is the vehicle under power or braking.

The system may comprise a look-up table comprising data patterns against which sensor data patterns, or patterns of sensor data as correlated by the control means, are compared in order to identify the risk posed by the hazard. The system may use probabilistic estimation or interpolation to determine an optimum course of action if no pattern corresponds precisely to the pattern of

information from the sensors. The system may apply coefficients to weight the various forms of information gathered by the control means in order to assess the risk posed by the hazard.

The algorithm preferably then sends signals to the control means in order to carry out a chosen program of actions. The actions may be in sequence of severity and may be chosen according to the degree of risk. For example, on approaching a hazard such as a drop-off the system may give an initial warning to the driver; optionally a statement of the nature of the hazard, distance etc.; a final warning; then an emergency stop. For a more immediate hazard close to the vehicle, or for a moving hazard such as a child, the system may impose an immediate emergency stop. Warnings may be by a variety of means, for example visual, audible, physical (e.g. a temporary brake application).

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Brief Description of the Drawings

Figure 1a is a diagrammatic side view of a vehicle equipped with a sensor and/or a sensor system according to a first embodiment of the invention, reversing towards a hazard.

Figure 1b shows an example of a response from a sensor in the situation shown in figure 1a.

Figure 1c is a diagrammatic side view of a vehicle equipped with a sensor system according to a further embodiment of the invention having a plurality of sensors, reversing towards a hazard.

Figure 1d shows an example of a response from a number of sensors in the situation shown in figure 1c.

Figure 2a is a diagrammatic side view of a vehicle equipped with a sensor system according to a further embodiment of the invention, reversing towards a hazard.

Figure 2b shows an example of a typical response from a sensor in the situation shown in figure 2a.

Figure 3a is a diagrammatic side view of a vehicle equipped with a sensor system according to a further embodiment of the invention, reversing towards a hazard.

Figure 3b shows an example of a typical response from a sensor in the situation shown in figure 2a.

Figure 4a is a diagrammatic top view of a vehicle equipped with a sensor system according to an embodiment of the invention, reversing towards a hazard.

Figure 4b is a diagrammatic side view of a vehicle equipped with a sensor and system as shown in figure 4a.

Figure 4c shows an example of a typical response from a sensor in the situation shown in figures 4a and 4b.

Figure 5a is a diagrammatic side view of a vehicle equipped with a sensor system according to an embodiment of the invention, reversing towards a hazard at the roof level of the vehicle.

Figure 5b is a diagrammatic side view of a vehicle equipped with a sensor system according to an embodiment of the invention, reversing towards a further configuration of hazard at the roof level of the vehicle.

Figure 5c is a diagrammatic side view of a vehicle equipped with a sensor system according to a preferred embodiment of the invention, reversing towards a hazard at the roof level of the vehicle, with optional addition of a further sensor in a different location from the first.

Figure 6 is a block diagram of an apparatus and system according to the invention.

Figure 7 is a flow diagram illustrating a mode of operation of an embodiment of the system of the invention.

Detailed Description of the invention

Figure 1a shows a diagram of a vehicle 10 on a ground surface 12 having a first portion 14 and a second portion 16 separated by a hazard in the form of a step 18. A sensor 20 is provided, mounted on the rear of the vehicle, the sensor having an axis of response shown as 22. The sensor may be responsive to signals only along this axis, or may be responsive to a signals in a distribution of directions, preferably centred on this axis, with a sensitivity function centred on the axis.

For example, a sensor might be uniformly sensitive about the axis up to a given angle from the axis, and then insensitive; alternatively a sensor may have a continuously varying sensitivity with angle from the axis. In the discussion that follows it will be assumed that the sensor measures distance along the axis of response from the sensor to a point where the axis intersects a surface. In preferred embodiments the sensor is a radar-based distance

monitor that measures distance in terms of time of flight to a back-scatter point, for example by means of phase shift of pulses or interferometry, as known in the art for such sensors. In alternative embodiments different sensor principles and types may be used, for example optical backscattering sensors. Sensors will in general have significant sensitivity off-axis and will measure distance accurate only to within a range of distance; the following discussion will assume that the on-axis distance measurement is accurate and that allowance for the range of accuracy is incorporated into the sensor system, for example forming part of the operating program of the invention.

In preferred embodiments the axis of response 22 is set at an angle to a reference direction on the vehicle, in figure 1a shown as the vertical at the rear of the vehicle, the angle shown as α . As the vehicle moves towards the step 18 from position X1 via X2 to X3, the distance r along the axis of response as measured by the sensor to the point of backscatter is initially substantially uniform, being backscattering from portion 14 as shown in figure 1b, then goes through a step change at position X2 to a new higher value, being backscattering from portion 16, then remains constant as the vehicle reaches position X3.

If the step 18 is in fact a rising step as shown as 24, then r shows a fall from X2 to X3, as shown in figure 1b. In this way, a single sensor allows a drop or rising step to be detected and distinguished. The distance of the step from the sensor can be found from the height h of the sensor above the mean ground level below the car and the angle α . The profile of the portion 16 may be inferred from the change in r as the vehicle moves from X2 to X3.

In preferred embodiments a ground height sensor 26 is provided to give a measured value of h . In further preferred embodiments the sensor system comprises a control means (not shown) adapted to make repeated measurements of r as the vehicle moves, for example as a function of time or

vehicle position, and to interpret the measurements in terms of the nature of the step or hazard 18, as will be described later.

Figure 1c shows a diagram of a further embodiment in which two or more sensors are provided, mounted on a vehicle at different heights above the mean ground level, either at a common angle α with respect to vertical or at differing angles. Three sensors are shown: 20, 30 and 40, with corresponding axes of response 22, 32, 42. As they are at different heights the measured distances r to the ground along the axes will increase in the order $r(20) < r(30) < r(40)$. As the vehicle moves towards the step 18 from $X1$ to $X2$ the sensors will detect a step change in r at different positions x of the vehicle, or at different elapsed times during movement, as shown in figure 1d. By this means sensor 40 gives warning initially while the vehicle is distant from the step, sensor 30 gives warning at a closer distance, and sensor 20 closer still. In preferred embodiments the sequence of sensor responses is used by a control means to control a sequence of actions, including warning the driver and optionally halting the vehicle.

Additionally in preferred embodiments the information about r from the sensors may be used by the control means to interpret the profiles of the step and of the portions 14 and 16, so as to assess the risk associated with the hazard 18. In preferred embodiments the angle α of one or more sensors' axis of response may be set differently from that of others, so as to give a chosen profile of response to a step from the sensors, for example with one sensor giving early warning and two giving a more precise warning when the vehicle is close to the obstacle. It will be appreciated that any number from two sensors upwards may be used in this embodiment.

Figure 2a shows a further embodiment in which a sensor 20 is adapted to have more than one axis of response, shown as (a), (b) and (c), each axis being at a different angle α from vertical. The distances r measured along each axis will be different and will respond to a step 18 at different positions of

the vehicle, and at different times as a vehicle approaches the step, in a similar manner to that described above. Figure 2b illustrates a typical pattern of measured r values as the vehicle moves towards the step, with the r value along axis (a) remaining unchanged, the r value along axis (c) undergoing a step change first and that long axis (b) second as the vehicle moves from X1 to X2. Again, the difference in measured r values may be tracked and stored in memory to build up a profile of the ground before and beyond the step. Multiple axes of response may be provided in a preferred embodiment by means of multiple individual sensor components within a common sensor device, or by means of a single sensor component with means that allows one of a number of axis directions to be selected.

Figure 3a shows a further embodiment of a sensor system according to the invention, in which a sensor means 20 is mounted on a vehicle and is moveable by a scanning means 26 such that the axis of response is positioned with a controllable angle θ relative to the vertical, for example in positions 22, 32 and 42, at angles θ_1 , θ_2 and θ_3 to the vertical respectively. These axis positions allow the sensor to interpret the position and nature of the step 18 similarly to the multiple axes in the embodiment in figure 2a.

Scanning means 26 may comprise means as known in the art, for example a motor means coupled such that the sensor axis direction is moved by the motor, or a solenoid mechanism that acts to set two or more positions of the axis depending on the state of energisation of one or more solenoids. Such scanning means may move the sensor itself, or a response-directing element associated with the sensor, for example a mirror, lens, slit, screen or component of a transducer that controls a signal entry direction.

In a preferred embodiment the response of the system may be as in figure 3b, in which the value of $r = h/\cos(\theta)$ is illustrated as a function of θ . For flat ground with no step r increases continuously with θ as shown at 34. For a step-wise drop 18, r increases step-wise with θ as shown, then increases

continuously with θ (resulting from the distance r to a flat profile at a lower level as shown as 16). For a step-wise raised obstacle 24, r increases slowly with θ , then plateaus as the axis scans over the vertical face of the obstacle, then rises suddenly as the axis scans over the top of the obstacle.

It will be understood that r will vary with θ in a way that depends on the profile of the ground in portions 14 and 16 before and after the step, and that in all the embodiments above the system is also capable of responding to gradual slopes rather than steps. The invention is particularly well suited for use in mountainous or hilly areas.

In preferred embodiments the profile of the step is interpreted by a control means on the basis of difference in values of r derived from signals from the one or sensor axes, or functions of $r(\theta)$, the system, and that this information may be gathered as a function of distance of the vehicle from the obstacle, and/or of time, as the vehicle approaches it.

Now turning to figures 4a – 4c, the apparatus of the invention also comprises means to detect and interpret obstacles in an x-y position relative to the vehicle. This is useful for example if one wheel of a vehicle is approaching a drop or a hole, but others are not, and so may allow a decision to proceed over the obstacle under certain circumstances. Figure 4a shows a top view of a vehicle 10 having sensors 50 and 60 mounted on its rear corners, approaching a pit 58 behind one wheel. Sensor 50 is adapted to provide three response axes vertically, indicated in figure 4b as (1), (2) and (3). These measure distances r as described previously. In preferred embodiments, and for many sensor types in general, the axis of response will have a lateral extent or spread, as shown in figure 4a as 54 and 56, around a principal axis 52.

For example, for many types of sensor the response axis is in the form of a circular cone, though this may be an elliptical cone or a rectangular based

pyramid. The response of the sensor for response axes (1), (2) and (3) is shown in figure 4c as a function of the position of the pit 58 in the y-direction. At position Y1 of the pit, the extent of the lateral response lies within the pit 58, and the r values are closely defined as shown. At position Y2 of the pit, sensor axis (2) has a lateral extent that overlaps the edge of the pit, as shown by the ellipse at (2) in figure 4a. The signal returned from the sensor along axis (2) may then have a range of values, which may be interpreted as a fluctuation in r values as shown as 62 in figure 4c, with an variation in general between values r_2 and r_2' as shown in figure 4b.

Figures 5a - 5c illustrate an embodiment of the invention having sensor positions to achieve detection of a hazard behind a vehicle at a height above the ground, such as a height barrier, low bridge or a low roof or projection from a building. In figure 5a a sensor 70 having a central axis of response 72 and further axes such as 74 to 76 is mounted such that the central axis is parallel to the ground. As can be seen, for an object that is thin in the vertical direction as the differential response from the sensor along the three axes shown does not change greatly as the vehicle approaches an obstacle at close to the height of the vehicle.

The sensor system may still detect the front edge of the obstacle by means of axis 72, but other axes will not detect it. As shown in figure 5b, for a generalised object such as a partly open garage door, in this embodiment, the object may not be detected efficiently. Figure 5c shows a preferred embodiment in which a sensor 70 has a central axis inclined upwards from the horizontal. In position X1, only axis 74 intersects the obstacle. In position X2 axis 74 does not intersect, but axis 72 now does. The changing pattern of values of r measured along the axes may be interpreted in preferred embodiments by a control means to identify the hazard 90 and its position. In more preferred embodiments one or more further sensors 80 may be provided as a different height above ground to give a different view of the obstacle, with improvement in detection and interpretation.

Figure 6 shows a block diagram of a system 100 according to the invention. A control means 110 receives signals from a number of sensors 102, 104, 106, 108 as described above along signalling connections 114. In a preferred embodiment the four sensors 102-108 are provided at the rear corners of the vehicle: two at a low level, two at a high level, each sensor adapted to measure a distance r to the ground. In some embodiments one or more sensors are adapted to measure r at two or more response axis angles α . In preferred embodiments the control means controls the axis of response for one or more sensors by signalling along control lines 116. In preferred embodiments the sensors comprise control subsystems such that communication between the sensor(s) and the control means is by means of data links. Further sensors, for example one or more ground position or ground speed sensors 112 may be provided as part of the system to provide additional data, for example data on the height of the sensors 102-108 above ground level, to the control means, for example to provide height compensation data. In preferred embodiments the control means is in communication with a source of data 126 associated with the vehicle, for example information on: vehicle speed, whether powered or under braking, suspension conditions (for example, whether the vehicle is on a slope or the mass inside the vehicle).

The control means preferably comprises or is in communication with memory means 118, and the system preferably comprises an operating program 120, a look-up table 122 comprising pre-set data on expected sensor response patterns associated with known types of hazard, and optionally a risk-assessment algorithm 124 that in use operates to assess degrees of risk using for example information on the nature and location of the hazard and information about the vehicle conditions (e.g. speed, loading, position on a slope).

In preferred embodiments the control means outputs control signals to a driver audible warning means comprising a sound (e.g. speech) synthesiser 128 and a sound generator 130 and optionally a visible warning means 132, for example coupled to an in-vehicle display. In preferred embodiments the control means outputs signals to a vehicle control system 134, optionally part of the vehicle operating system that may act in use to slow or halt the vehicle.

Figure 7 shows a flow chart for operation of an embodiment of the invention, for example describing part of an operating program forming part of the system of the invention. It will be appreciated that this is an outline only, and that subsystems and subroutines will be included to control operation of portions of the system as will be apparent to the skilled person. In this embodiment, in operation the system samples pairs of values r_0 at time t_0 and r_1 at a later time t_1 , for one or all sensors, for each of the response axes or a subset of them as may be appropriate. These pairs are stored in a memory means and tracked over time. The control means tracks the sequence of values $dr = (r_1(t_1) - r_0(t_0))$ over time and interprets these in terms of distance moved by the vehicle. The set of values of dr with distances moved in the x and optionally the y direction may then be interpreted as a profile of the surface (including potential obstacles) behind the vehicle. In a preferred embodiment the system comprises means to interpret the presence of obstacles in the surface profile. In preferred embodiments this is done by means of comparing a matrix (the 'detection matrix) of values describing the surface profile, for example value of r or of a quantity derived from r , such as the height of the surface, with pre-set 'hazard matrices' stored in a look-up table in memory means forming part of the system, such matrices representing typical values that are associated with obstacles.

Such matrices may be an x , y , z or a 3D matrix of the surface topography, or they may be a 2D or 3D matrix for r , x (and optionally y) values as would be encountered by a vehicle approaching an obstacle. In this way the system may comprise models of typical hazards that can be compared with the

information about the vehicle's surroundings gathered by the system in use, in order to identify hazards. In some embodiments the system may also comprise models of typical non-hazard situations, and compare information about the vehicle's surroundings with these, in order more positively to exclude the likelihood of a hazard existing.

The detection matrix may be compared with the stored matrices to detect a match, allowing the system to recognise a likely hazard and its position relative to the vehicle. If a match is found, the control means may then determine how serious is the risk presented by the hazard. In an emergency it may stop the vehicle.

If the risk is lower, for example if the hazard is mild and distant, the system may then give an initial warning and then continue to observe values of $dr(x, y, t)$ as the vehicle moves. If there is no match, or no exact match, the system may be adapted to give a warning of an unidentified hazard. The system may later give a second warning, and await a driver response. According to the response and assessment of risk the system may allow progress towards to hazard, may limit the speed of progress, or may halt the vehicle. Warning to a driver may take known forms, such as audible, speech, visual, or a temporary checking of the vehicle to alert attention.

Various sensor principles are useable in the system. For example, radar distance sensors, optical sensors based on backscatter from the surface of the ground, ultrasonic sensors based on pulse time of travel or interference principles. Capacitive sensors, or other sensors that do not give distance information to a point on a surface directly, may be used together with appropriate signal processing means forming part of the system to extract distance information. In a preferred embodiment optical sensors based on time-modulated illumination may be used.

An optical sensor may comprise a light source and a detector. A light source may be built in to a sensor device or subassembly and may be modulated, for example using LED or laser diode illumination modulated electronically. The light source preferably has an illumination axis and pattern, for example a cone, analogous to the response axis of the sensor as described above. Modulation may be by mechanical means, for example shutter or actuated mirrors, as known in the art. In preferred embodiments phase sensitive detection is used with a known modulation pattern in order to achieve improved signal to noise ratio. The axis of response may be set or controlled by the inherent response characteristics of the sensor elements used, for example the entry cone angle of a photo detector. The axis may also be set in preferred embodiments by design of a housing in which the detector element is housed.

In preferred embodiments, the response axis of the sensor system is controlled by the angular response of the detector element, as mounted and housed within the sensor device. The illumination may be non-directional, or partly so, for example if a light source is used with a wide cone of illumination, such as a LED. In other preferred embodiments, the response of the sensor system may be less directional, for example having a broad cone of response, in which case the illumination may be directional, for example as produced by a laser diode, and so the axis of response of the sensor system, comprising illumination and detection means, may be determined primarily by the illumination direction. In some embodiments, a probe beam may be provided at one or more known heights from the ground and angles θ to a reference direction, so as to define the axis of response partly by means of an axis of illumination. Means to vary and control the probe beam direction, and means to interpret the resulting sensor responses, are provided and may function in a manner substantially as described above.

Devices suitable for use in the sensor system of the invention comprise light sources such as visible and IR LEDs or laser diodes; visible and IR

photodetectors such as photodiodes; steerable mirror devices or mountings for detectors, light sources or both to control the angle and direction of a response axis of a detector or an illumination axis of a light source.

It is to be appreciated that these Figures are for illustration purposes only and other configurations are possible.

The invention has been described by way of several embodiments, with modifications and alternatives, but having read and understood this description, further embodiments and modifications will be apparent to those skilled in the art. All such embodiments and modifications are intended to fall within the scope of the present invention as defined in the accompanying claims.

It is also understood that the device and system may be modified for use in building (diggers) or construction (cranes) equipment or military vehicles, such as tanks.

The invention may be provided in the form of a kit which is able to be retro-fitted onto cars, trucks and other ancillary vehicles, such as trailers or caravans or truck semi-trailers. Such systems are adapted to be retro-fitted to a trailer and an alarm provided in a car or cab of a vehicle that is towing the trailer or vehicle.

Other applications, where the invention may be used, include: farm, industrial or agricultural usage, such as a grain trailers or dumper trucks, which vehicles are often reversed towards a hopper, storage silo or grain dryer, and their contents tipped into a receptacle, hopper or pit.

Claims

1. A sensor system detects changes in ground level or profile, comprising: one or more sensor means, each having a response axis at which its response is maximal, the, or each, sensor being mounted on a vehicle, so that the, or each, sensor response axis is at an angle with respect to the vertical; a control means that receives signals from the one or more sensors and which acts to analyse a series of one or more components of the signals, and issues a warning when a change of ground elevation is detected.
2. A sensor system according to claim 1 wherein the axis of response is directed to intersect the ground at a distance behind the vehicle, so that the system provides a warning before the vehicle reaches an obstacle.
3. A sensor system according to claim 1 wherein the axis of response is directed to intersect the ground at a distance in front of the vehicle, so that the system provides a warning before the vehicle reaches an obstacle.
4. A sensor system according to any of claims 1 to 3 wherein the control means samples the detector signal at time intervals as the vehicle moves, and correlates samples that indicate an obstacle.
5. A sensor system according to claim 4 wherein the sensor system comprises a position sensor that measures the distance moved by the vehicle, from which the control means receives signals and produces a correlation of signals from the, or each, sensor.
6. A sensor system according to claim 5 wherein the position sensor is provided as part of the vehicle, the sensor system being adapted to receive information from the position sensor.

7. A sensor system according to any of claims 1 to 5 wherein the position sensor includes a radar distance measuring sensor.
8. A sensor system according to any of claims 1 to 5 wherein the position sensor includes an optical sensor.
9. A sensor system according to claim 8 wherein the optical sensor employs detection of back-scattered light from a light source.
10. A sensor system according to any of claims 1 to 5 wherein the position sensor includes an ultrasonic sensor based on echo timing.
11. A sensor system according to any of claims 1 to 5 wherein the position sensor includes capacitance sensors, in which the degree of capacitive coupling between two plates is determined by the distance to a solid surface, such as the ground or an obstacle.
12. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include analysing the signal from an individual sensor to separate distance information from noise.
13. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include comparing the signal from a number of sensors to determine correlations between sensor responses.
14. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program

providing instructions to the control means to carry out functions that include: comparing the sequence of signals over time from a given sensor or number of sensors to determine correlations in time for a given sensor or number of sensors taken together

15. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include: using information from a vehicle speed sensor or a vehicle position sensor to determine the obstacle sensor output(s) as a function of position of the vehicle.
16. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include: determining the probability that a detected correlation indicates an obstacle; determining the likely location and nature of the obstacle.
17. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include: giving warning to a driver of the vehicle that an obstacle is present;
18. A sensor system according to any preceding claim wherein the sensor system comprises an operating program and a memory means in communication with the control means, the operating program providing instructions to the control means to carry out functions that include taking control of an aspect of the vehicle's operation, such as cutting power and/or applying a brake.

19. A sensor system according to any preceding claim wherein the control means uses the responses from each of the plurality of response axes in an algorithm to determine the position of the vehicle relative to the obstacle.
20. A sensor system according to any preceding claim wherein a scanning means is associated with one or more sensors that in use control the direction of the axis of response relative to a reference direction on the vehicle, for example to move the axis of response through an angle relative to the reference direction.
21. A sensor system according to claim 20 wherein the scanning means is adapted to position the axis as a number of pre-set angles with respect to the reference direction.
22. A sensor system according to claim 20 or 21 wherein the control means uses information derived from the sensor when the response axis is at a plurality of pre-set angles in an algorithm to determine the position of the vehicle relative to the obstacle.
23. A sensor system according to any preceding claim wherein the system comprises a sensor array means having plurality of sensors, each having a response axis, the response axes being offset from one another by one or more chosen angles, so providing a plurality of response axes at different angles with respect to a reference direction on the vehicle, so producing a fan-like pattern of response axes.
24. A sensor system according to any preceding claim wherein more than one sensor means or sensor array means, are mounted at a known height above the mean position of the ground.
25. An accident warning and prevention system, comprising one or more sensor means, a control means, an operating program, and a vehicle

control means operable by the control means to control or halt operation of the vehicle.

26. An accident warning and prevention system, according to claim 25 wherein the vehicle control means acts to cut power and/or apply a brake to the vehicle, for example to bring it to a halt or to check its operation so as to prompt the user to halt or to avoid the obstacle.

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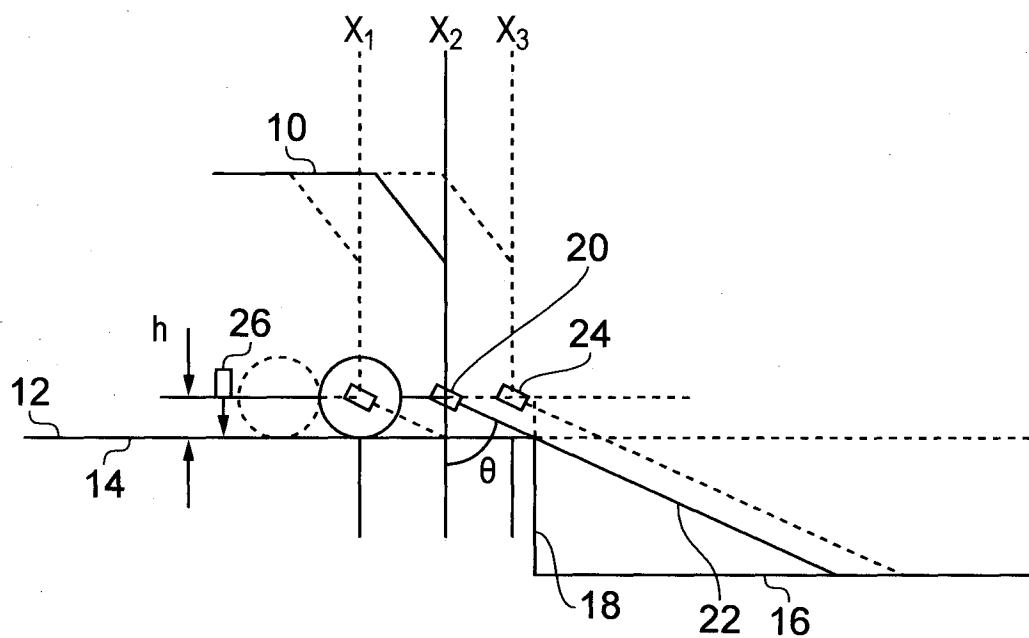


FIG. 1A

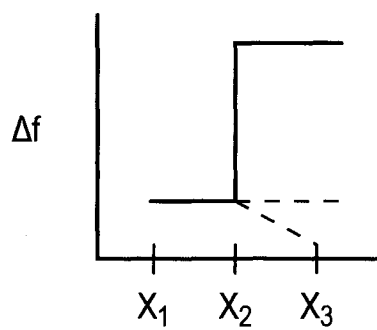


FIG. 1B

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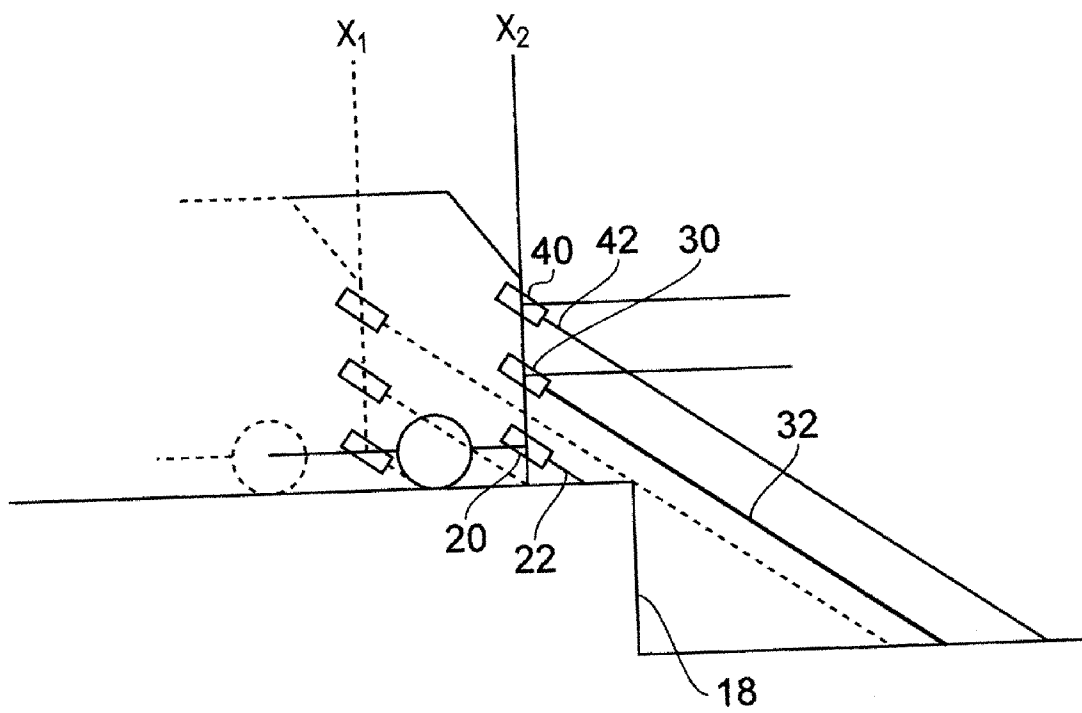


FIG. 1C

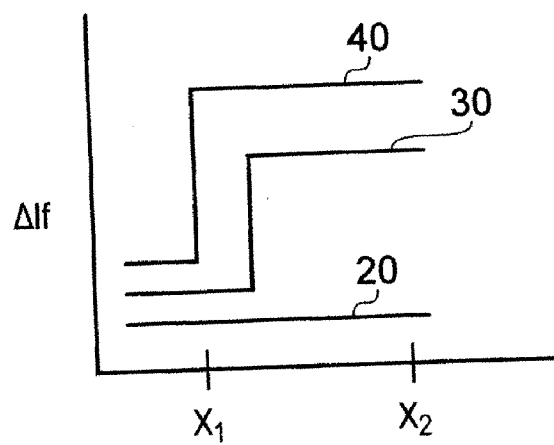


FIG. 1D

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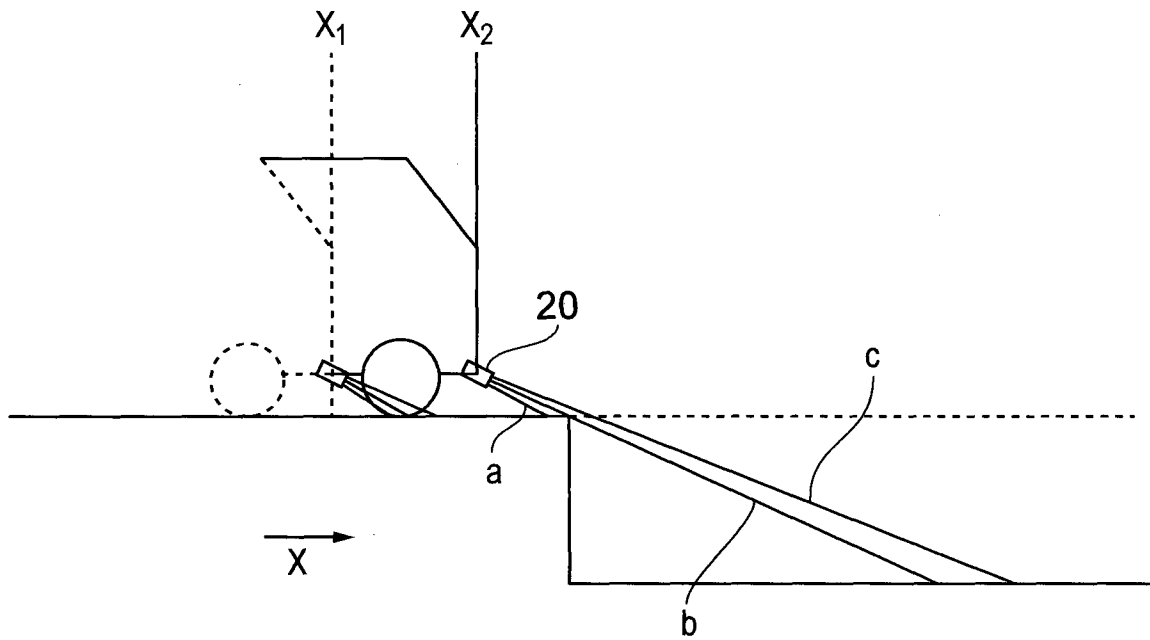


FIG. 2A

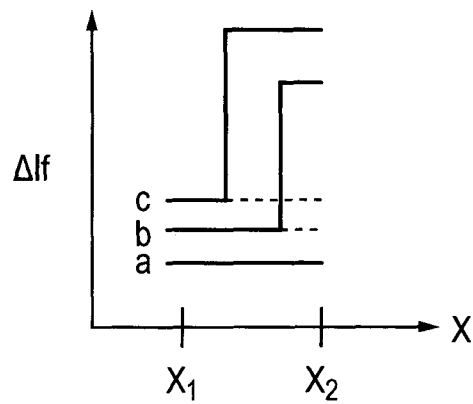


FIG. 2B

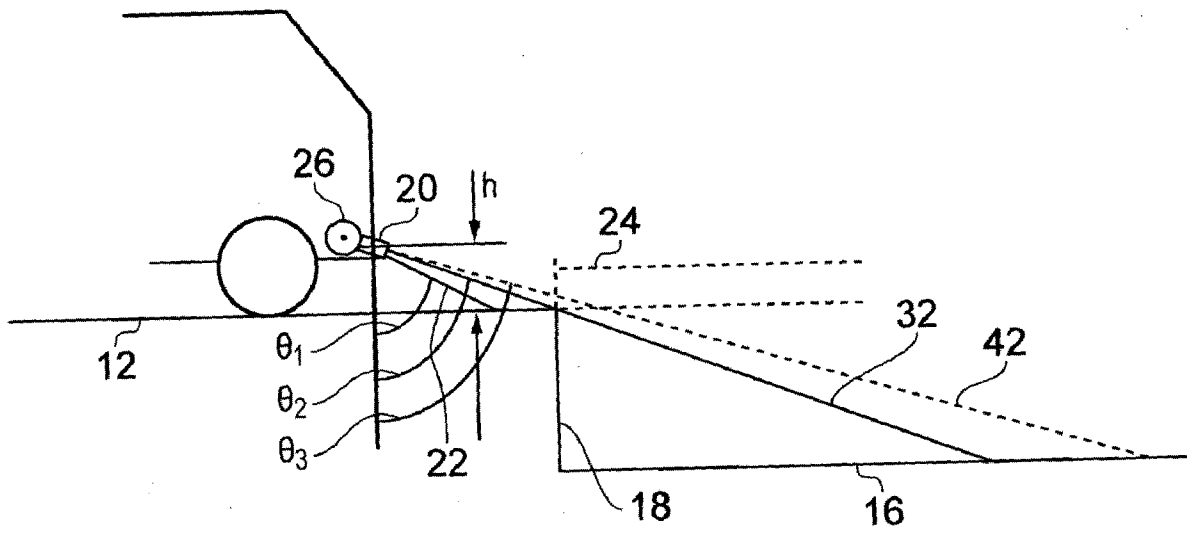


FIG. 3A

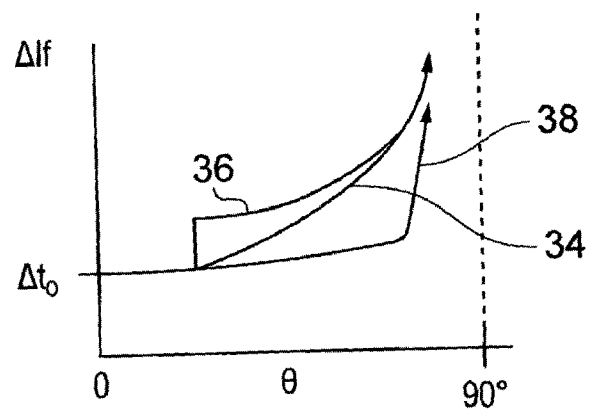


FIG. 3B

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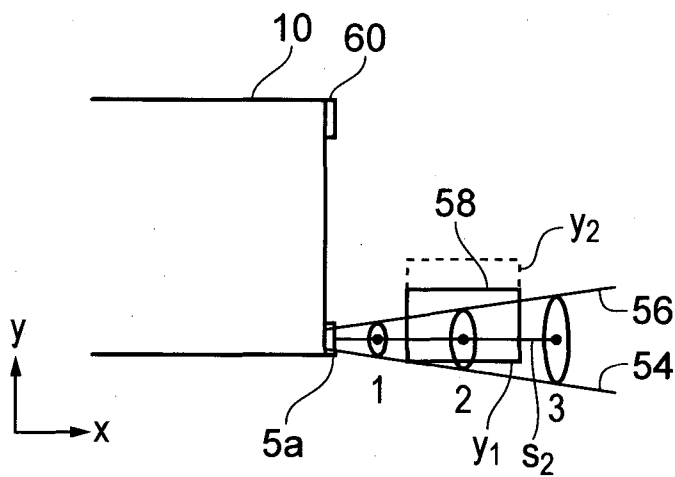


FIG. 4A

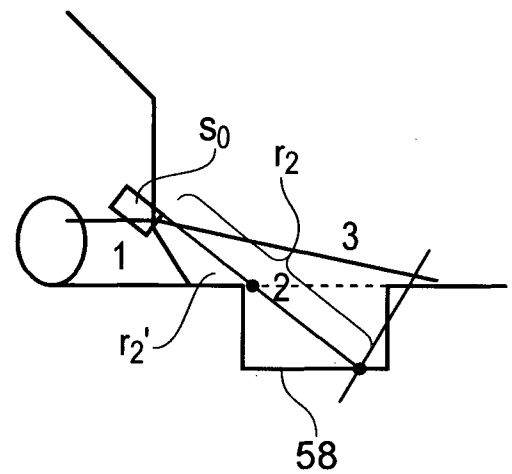


FIG. 4B

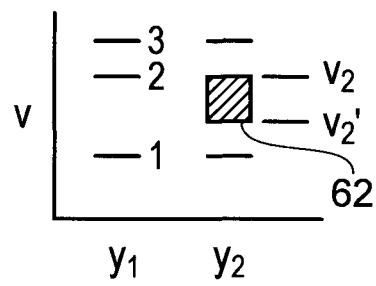


FIG. 4C

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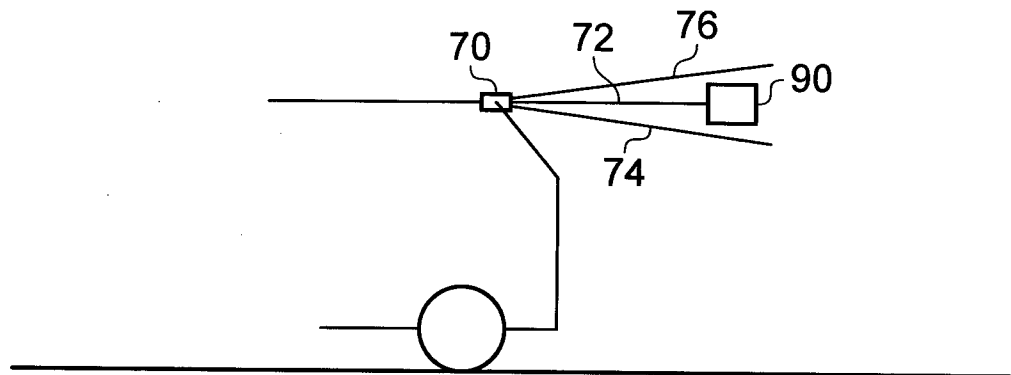


FIG. 5A

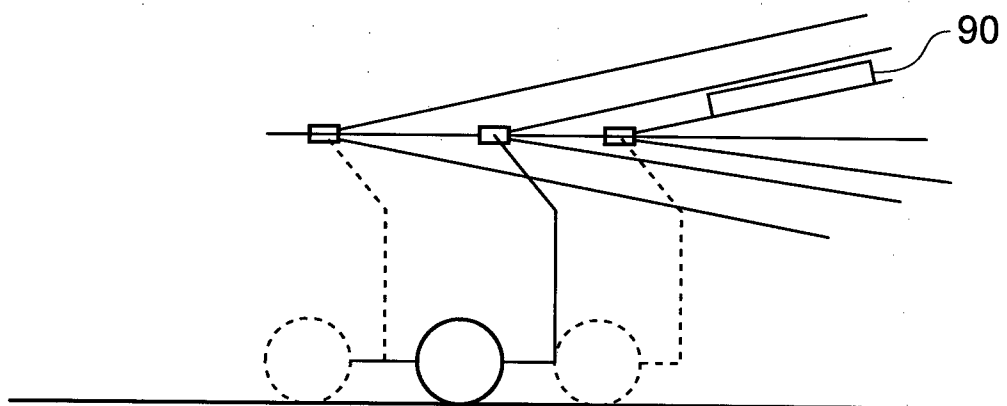


FIG. 5B

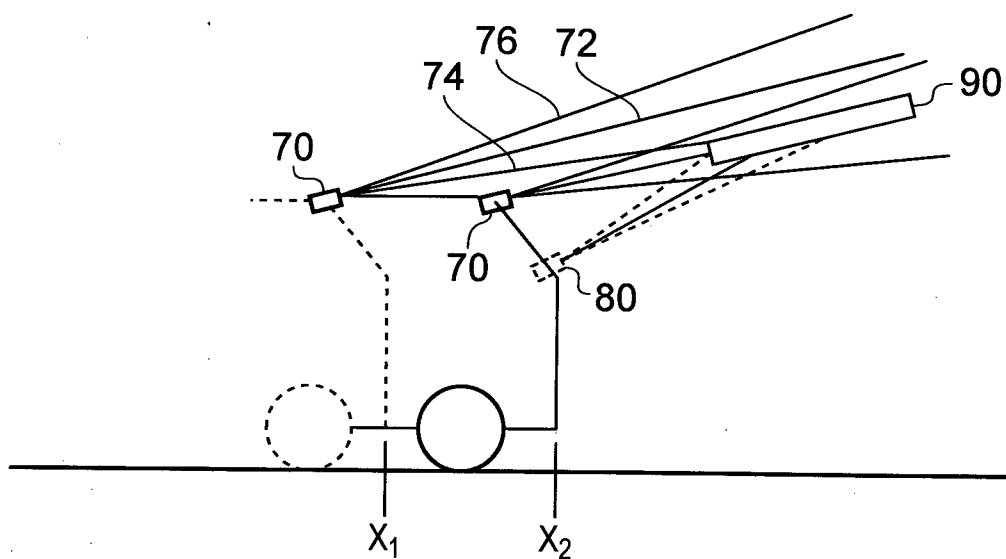


FIG. 5C

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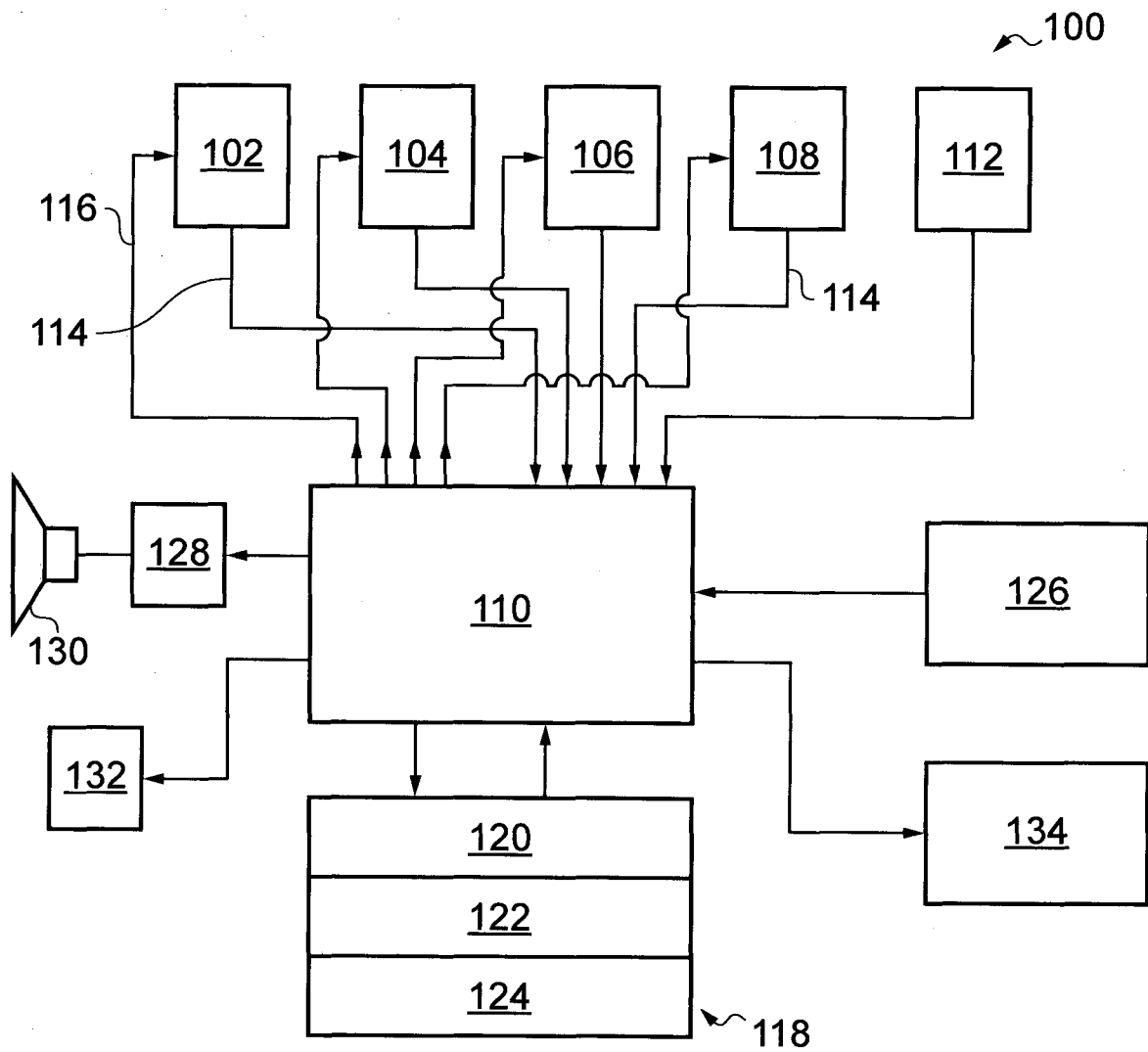


FIG. 6

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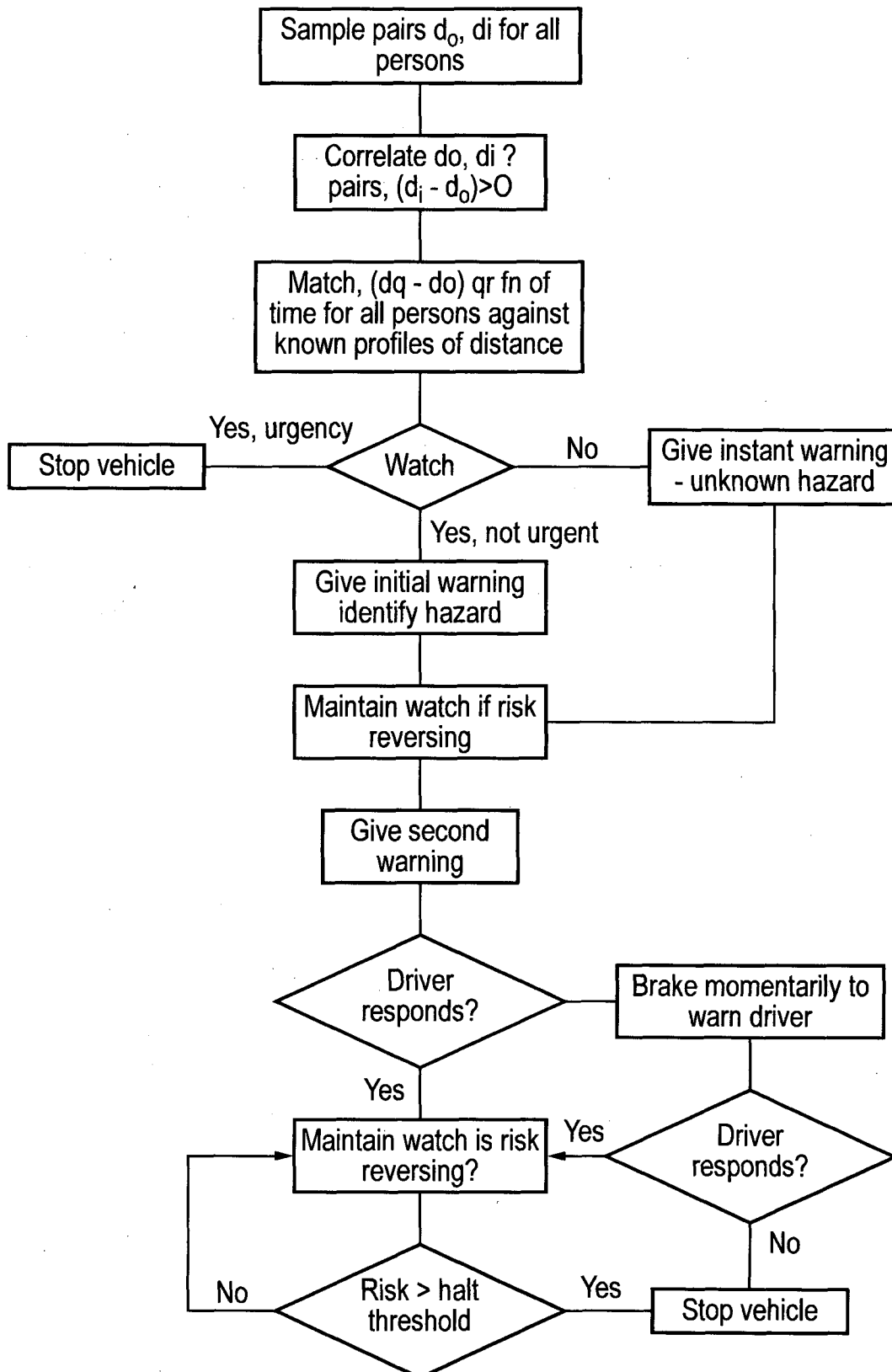


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2012/000138

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S13/93 G01S17/93 G01S15/93
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 103 47 980 A1 (VOLKSWAGEN AG [DE]) 17 March 2005 (2005-03-17)	1-3, 7-10, 12-26
Y	paragraphs [0003], [0012], [0028], [0029], [0030], [0031]; figures 1,3 -----	4-6
X	US 2010/302069 A1 (FRANK MICHAEL [DE] ET AL) 2 December 2010 (2010-12-02)	1,5, 7-10, 12-26
Y	paragraphs [0046], [0047], [0053] - [0055], [0075]; figures 3b,3c -----	4,6,11
Y	DE 100 01 838 A1 (ERICSSON TELEFON AB L M [SE]) 19 July 2001 (2001-07-19) paragraphs [0013], [0019], [0020] -----	4-6
Y	US 7 397 351 B1 (RUBIN EUGENE S [US] ET AL) 8 July 2008 (2008-07-08) column 3; figures 1,4,5 -----	11



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

3 September 2012

Date of mailing of the international search report

07/09/2012

Name and mailing address of the ISA/

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Authorized officer

Metz, Carsten

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IT2012/000138

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