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(54) **Title**: DRIVER ASSISTANCE SYSTEM

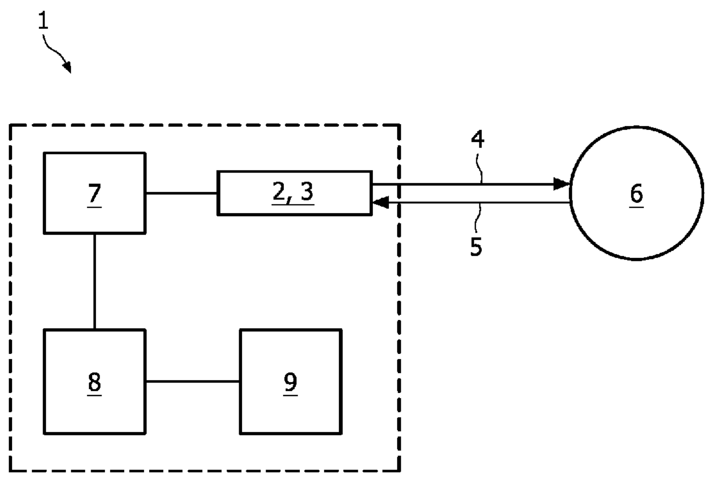

FIG. 1

(57) Abstract: The invention relates to a driver assistance system for assisting a driver ofa vehicle with parking the vehicle, wherein the driver assistance system (1) comprises alaser (2) having a laser cavity (3) for emitting a first light beam (4) which is to bereflected byan object (6), wherein the first light beam (4) and the reflectedlight beam (5) interfere within the laser cavity (3). The driver assistance system further comprises a detector (7) for detecting the interference within the laser cavity (3) and a determination unit (8) for determining therelative velocity as well as therelative distance between the driver assistance system (1) and the object (6) on the basis of the interference within the laser cavity (3). An assisting unit (9) assists the driver of the vehicle with parking the vehicle on the basis of at least one of the determined relative velocity and the determined relative distance.

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DRIVER ASSISTANCE SYSTEM

FIELD OF THE INVENTION

The present invention relates to a driver assistance system, a method and a computer program for assisting a driver of a vehicle with parking the vehicle. The invention relates further to a vehicle comprising the driver assistance system.

BACKGROUND OF THE INVENTION

US 2007/0181810 A1 discloses vehicle-based LIDAR systems and methods using multiple lasers in automobile applications for various safety systems, such as: collision avoidance systems, pedestrian detection systems, adaptive cruise control, blind spot monitoring systems, lane-change assist systems, automatic emergency braking systems and lane/road departure systems. Each laser in an array of lasers is sequentially activated so that a corresponding optical element mounted with respect to the array of lasers produces respective interrogation beams in different directions. Light from these beams is reflected by objects in a vehicle's environment, and detected so as to provide information about the objects to vehicle operators and/or passengers.

Such a system has the drawback that there is signal distortion when a detector of a first laser-detector-system receives backscattered light which is emitted by a laser of a second laser-detector system. This results in cross talk between sensors of an array and in inexact distance measurements. So, the information provided to the vehicle’s operator is unreliable.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a driver assistance system, used for assisting a driver of a vehicle with parking the vehicle, with more reliable information for parking the vehicle.

In a first aspect of the present invention, a driver assistance system for assisting a driver of a vehicle with parking the vehicle is presented, wherein the driver assistance system comprises:

- a laser having a laser cavity for emitting a first light beam which is to be reflected by an object, wherein the reflected light beam is a second light beam and wherein the first and second light beams interfere within the laser cavity,
- a detector for detecting the interference within the laser cavity,
- a determination unit for determining the relative velocity as well as the relative distance between the driver assistance system and the object on the basis of the interference within the laser cavity, and
- an assisting unit for assisting the driver of the vehicle with parking the vehicle on the basis of at least one of the determined relative velocity and the determined relative distance.

The invention is based on the idea that the driver of the vehicle is assisted based on more reliable information of the relative velocity and/or the relative distance between the vehicle and the object, when the relative velocity as well as the relative distance information are obtained from the interference within the laser cavity, which is a self-mixing interference (SMI)-based measurement. The laser having the laser cavity, the detector and the determination unit form a SMI sensor, which is used for determining the relative velocity as well as the relative distance by measuring the interference within the laser cavity. This usage of a SMI sensor provides the advantage that there is no cross talk between this SMI sensor and possible further SMI sensors, thereby improving the reliability of the determination of relative distance and relative velocity between the vehicle and the object. Furthermore, the determination of relative distance and relative velocity on the basis of the interference within the laser cavity allows determining the relative distance and relative velocity at substantially the same time and independently of each other, i.e., for example, the determination of the relative distance does not influence the determination of the relative velocity, which further improves the reliability of the information on which the assistance to the driver is based. Thus, the driver of the vehicle is assisted by the driver assistance system of the invention on the basis of more reliable information, which is particularly relevant during the parking process, as parking places are usually narrow and surrounded by barriers and the parking process should be carried out quickly in order to avoid any disturbance of other vehicles in the flow of traffic.

In a preferred embodiment, the detector is adapted to detect a first interference of the first light beam and the second light beam by detecting a first beat frequency, when a first frequency of the first laser beam is increased, and to detect a second interference of the first light beam and the second light beam by detecting a second beat frequency, when the first frequency is decreased, wherein the determination unit is adapted to determine the relative distance and the relative velocity on the basis of a difference between the first and second beat frequency and on the basis of the sum of the first and second beat frequency. This allows determining the relative velocity and the relative distance simultaneously, which results in updated determination results being provided at a high rate. When measuring distance as well as velocity at the same time, the time necessaryfor determining the relative velocity and relative distance is further decreased and, thus, disturbing objects can be quickly discriminated, e.g. a bicycle driver in front of a parking place.

Preferentially, the driver assistance system is adapted to increase and/or decrease the first frequency by modulating the power supply of the laser. Power modulation of the laser power does not require any additional circuits to modulate the frequency of the emitted laser light. Thus, complex and expensive circuitry for modulating the frequency are not necessary for the driver assistance system. If the laser is operated with a defined current shape (e.g. a periodic sawtooth or triangular current), the output frequency of the laser almost instantaneously follows those current variations, due to the simultaneously changed optical resonator length.

Preferably, the detector is adapted to detect a first interference of the first light beam and the second light beam by detecting the beat frequency of the first interference, when a first frequency of the first laser beam is maintained constant, and to detect a second interference of the first light beam and the second light beam by detecting the beat frequency of the second interference, when the first frequency is increased or decreased, wherein the determination unit is adapted to determine the relative velocity on the basis of the beat frequency of the first interference and to determine the relative distance on the basis of the difference between the beat frequency of the first interference and the beat frequency of the second interference. Also in this embodiment, the driver assistance system is preferentially adapted to increase and/or decrease the first frequency by modulating the power supply of the laser. Since the first frequency of the first laser beam is maintained constant during detecting the first interference and since this first interference is used for determining the relative velocity, the relative velocity can be determined, wherein, for example, the laser is operated with constant current, i.e. simpler driving electronics can be used for determining the relative velocity. Furthermore, since the alternation between detecting the first and second interferences can be done at a high rate, also in this embodiment a substantially simultaneous determination of relative velocity and relative distance can be achieved. Preferentially, the alternation period is smaller than 1 ms. Therefore, the time difference between determining the relative velocity and determining the relative distance is preferentially smaller than 1 ms, i.e. the determination of the relative velocity and the determination of the relative distance is performed substantially at the same time.

The invention is not limited to the determination of only one relative velocity and only one relative distance. The driver assistance system is able to determine several relative velocities and several relative distances. Furthermore, the driver assistance system is able to determine the relative distance and the relative velocity of more than one object, i.e. relative velocities and relative distances of several objects can be determined by the driver assistance system. Furthermore, the driver assistance system can comprise several lasers, several detectors and/or several determination units for determining several relative velocities and several relative distances of different objects at the same time.

The assisting unit can be any unit which assists the driver of a vehicle with parking the vehicle on the basis of the determined relative velocity and/or determined relative distance. For example, if a driver is looking for a parking space having dimensions which are appropriate for his vehicle, he can drive along a row of vehicles parked at, for example, a side of a street, and while passing the parked cars, the relative distance and the relative velocity of the driving vehicle and the respective parked cars can continuously be measured, wherein the dimensions of the parking space can be determined from the continuously measured relative distances between the driving vehicle and the respective parked cars, the driving speed of the driving car and the time points at which the different relative distances and/or relative velocities have been measured. If the dimensions of a parking space, which have been determined in this way, correspond to the dimensions which are needed for parking the car, the assisting unit can output a signal to the driver that an appropriate parking space has been found.

Preferentially, the assisting unit is adapted to disregard a determined relative velocity and a determined relative distance of the object, if the determined relative velocity is within a predefined velocity range and/or if the determined relative distance is within a predefined distance range. It is further preferred that the laser, the detector and the determination unit are adapted to determine groups of relative velocities and relative distances, wherein the relative velocity and the relative distance of the same group correspond to the same time, wherein the assisting unit is adapted to disregard a determined relative distance of a group while assisting the driver of the vehicle, if the relative velocity of the same group is within the predefined velocity range. It is further preferred that the predefined velocity range depends on the velocity of the driver assistance system. This allows disregarding objects which might temporally cover or hide a parking space like, for example, a driving bicycle in front of the parking space, by disregarding the determined relative distance and the determined predefined velocity of, for example, the bicycle, wherein this predefined velocity is within the predefined velocity range. The predefined velocity range is preferentially chosen such that relative velocities which correspond to an absolute velocity of an object larger than 3 km/h, more preferably larger than 5 km/h and most preferably 10 km/h, are disregarded by the assisting unit while assisting the driver of a vehicle.

In an embodiment, the determination unit is adapted for classifying the groups of relative velocities and relative distances with respect to the relative velocity and/or the relative distance, wherein to each class a predefined relative velocity range and/or relative distance range is assigned, and wherein a group is classified in a certain class if the relative velocity and/or the relative distance of this group is within the velocity range and/or the distance range assigned to the respective class. Furthermore, in an embodiment, the assisting unit is adapted for considering the groups of relative distance and relative velocity in dependence on their classification, while simultaneously assisting the driver of the vehicle with parking the vehicle.

Often, a parking space is surrounded by a plurality of objects, e.g. parked and driving vehicles, passengers etc., which compose a complex parking situation for a driver assistance system and are to be taken into account when assisting the driver with parking the vehicle. In a preferred embodiment, the driver assistance system processes the information about the objects, viz. the determined relative velocities and distances, by classifying the relative velocities into classes of velocities. Depending on the classes of velocity, the assisting unit is adapted to e.g. recognize if an object whose velocity is classified in a particular class of velocities can be ignored when assisting the driver of the vehicle. This helps, for example, to quickly determine the real width of a free parking space even in the case were the parking space is hidden by a “moving target” (like a bicycle driver in front of the parking space).

For example, a class can be defined by groups whose relative velocity is - v_o, wherein v_o is the absolute velocity of the vehicle. Relative distances and relative velocities of groups within this class correspond to non-moving objects like parked cars. The assisting unit can then be adapted to use relative distances of groups of this class only for assisting the driver of the vehicle. Furthermore, a class can be defined by a relative distance smaller than a distance value which is preferentially smaller than 20 m, more preferably smaller than 15 m and most preferably smaller than 10 m and which is preferentially predetermined, wherein only relative distances which belong to this class, i.e. which are smaller than the predefined distance value, are used for assisting the driver of the vehicle. The predefined distance value can be also determined depending on the actual velocity of the vehicle, wherein, for example, the distance value increases with increasing velocity of the vehicle. Preferentially, the distance value is proportional to the velocity of the vehicle, for example, equal to v_o multiplied by 1 s.

In a further aspect of the present invention, a method of assisting a driver of a vehicle with parking the vehicle is presented, wherein the method comprises the steps of:

- emitting a first light beam which is to be reflected by an object, wherein the reflected light beam is a second light beam,
- making the first and second light beam interfere with each other,
- detecting the interference,
- determining the relative velocity as well as the relative distance between the vehicle and the object on the basis of the interference, and
- assisting the driver of the vehicle with parking the vehicle on the basis of at least one of the determined relative velocity and determined relative distance.

In a further aspect of the present invention, a vehicle with a driver assistance system as defined in claim 1 is presented.

In a further aspect of the present invention, a computer program for assisting a driver of a vehicle with parking the vehicle is presented, wherein the computer program comprises program code means for causing a driver assistance system as defined in claim 1 to carry out the steps of the method as defined in claim 7, when the computer program is run on a computer controlling the driver assistance system.

It will be understood that the driver assistance system of claim 1, the method of claim 7, the vehicle of claim 8 and the computer program of claim 9 have similar and/or identical preferred embodiments, as defined in the dependent claims.

It will be understood that a preferred embodiment of the invention can also be any combination of the dependent claims with a respective independent claim.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the following drawings:

Fig. 1 shows schematically and exemplarily an embodiment of a driver assistance system,

Fig. 2 illustrates in a side view and a top view a working scheme for the driver assistance system for driving a vehicle backwards into a parking space,

Fig. 3 shows schematically and exemplarily an embodiment of an arrangement of a sensor array of the driver assistance system,

Fig. 4 illustrates in a side view and a top view a working scheme for finding an appropriate parking space into which a vehicle can be driven backwards,

Fig. 5 shows schematically and exemplarily a diagram of an operating scheme of an individual sensor of the driver assistance system to determine distance and velocity,

Fig. 6 shows schematically and exemplarily a diagram of another operating scheme of an individual sensor of the driver assistance system to determine distance and velocity, and

Fig. 7 shows a flow chart illustrating an embodiment of a method of assisting a driver of a vehicle with parking the vehicle.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows schematically and exemplarily an embodiment of a driver assistance system. The driver assistance system 1 comprises a laser 2, a detector 7, a determination unit 8 and an assisting unit 9.

The laser 2, of which only the laser cavity 3 is shown in Fig. 1, emits a first light beam 4 which is to be reflected by an object 6, wherein the reflected light beam is a second light beam 5. The first and second light beams 4, 5 interfere within the laser cavity 3, resulting in an interference pattern which is detected by detector 7. The detector 7 may be integrated in the laser 2, in particular, in the laser cavity 3, or may be arranged separately. The detector 7 can be a photodiode detecting the laser light within or outside the laser cavity 3, wherein the interference is detected by detecting modifications of the detected laser light caused by the interference within the cavity.

The output of the detector 7 is coupled to a determination unit 8 which determines the relative distance and relative velocity between the system 1 and the object 6 on the basis of the output signal of the detector 7.

The interference pattern within the laser cavity 3 comprises information about distance and velocity between the driver assistance system 1, in particular, the laser 2, and the object 6. This information is analyzed by the determination unit 8. Preferred determination methods will be explained further below with reference to Figs. 5 and 6 . The output of the determination unit 8 representing the relative distance and relative velocity between driver assistance system 1 and the object 6 is input to the assisting unit 9, which assists the driver of the vehicle with parking the vehicle, and which, for example, determines the dimensions of a parking space in dependence on the determined relative velocity and/or the relative distance.

The assisting unit 9 is, for example, a display which provides the driver with information as to if and how to park the vehicle, an automatic parking unit which parks the vehicle automatically or a combination of both. The driver assistance system 1 is thus adapted to assist the driver in operations which are involved in a parking process, e.g. finding a parking place, parking the car, checking distances to objects et cetera.

The laser 2 comprising the cavity 3 and the detector 7 preferentially form a self-mixing interference (SMI) sensor. In addition to the SMI sensor, other sensors, in particular infrared sensors and/or video systems, can be used for providing the assisting unit 9 with information for assisting the driver with parking the vehicle. The SMI sensor is preferably based on a vertical-cavity surface-emitting laser (VCSEL). By using the SMI sensor the spatial resolution can be increased and the response time and the redundancy of the measurements needed for a driver assistance system can be increased. The sensor is preferably based on a vertical-cavity surface-emitting laser (VCSEL).

A SMI sensor makes use of the effect that laser light of a first light beam 4, which is scattered back from the object 6 and re-enters the laser cavity 3 as a second light beam 5, interferes with the resonating radiation and thus influences the output properties of the laser. Thus, the laser cavity 3 is exposed to feedback and reacts by a change in output power. The laser output signal, which contains information about the interference within the cavity, is measured by the detector 7, which is, for example, a photodiode, which can even be integrated in the laser. As long as the intensity of the second light beam 5 coupled back into the cavity is significantly lower (<< 1%) than that of the first light beam 4, the response to the back-coupled light of the second light beam 5 is linear, and the resulting variations in output power or frequency contain traceable information on the velocity or the distance of the object 6 with respect to the sensor and, thus, the driver assistance system 1. By driving the laser 2 accordingly and by an appropriate signal analysis by the determination unit 8, which will be explained further below, the sensor and the determination unit 8 detect relative velocities and relative distances. In an embodiment, the assisting unit 9 then e.g. optically and/or acoustically indicates whether the parking space is appropriate on the basis of the determined relative velocity and determined relative distance.

The VCSEL is a type of semiconductor laser diode with laser beam emission perpendicularly from the top surface, unlike edge-emitting semiconductor lasers (also in-plane lasers) which emit from surfaces formed by cleaving the individual chip out of a wafer. An advantage of a VCSEL array is that the SMI-signals of each array element are not influenced by reflected light of other array elements or other noise signals like stray light. This enables reduced complexity (i.e. lower cost) of the driving schemes of the sensors and/or of the signal detection hard-and software. The working principle of SMI laser sensors is, however, not restricted to surface emitting laser diodes. The SMI effect can also be harvested in other lasers, for example, in edge emitting laser devices.

Optionally, when combined with optics and electronics, the driver assistance system 1 of the present invention provides improved performance in comparison with technologies such as supersonic, Radar, video etc.. Especially in comparison with supersonic systems (featuring a lower cost relative to the other systems), detection accuracy (spatial resolution) and response time of the sensor is strongly improved. For example, a video camera can generate a video signal, which can be used in combination with the determined relative velocity and/or relative distance to generate a quasi three-dimensional video, because the relative distance and/or relative velocity of objects shown by the video signal are known. Alternatively or in addition, a present three-dimensional video can be corrected by using the determined relative distance and/or relative velocity of objects shown by the video signal, thereby improving the reliability of the three-dimensional video. Furthermore, the determined relative distance and/or the determined relative velocity can be used for determining relevant information on the video, wherein the video can be reduced to this reduced information, for example, by only showing the relevant information, for example, by only showing parked cars or other non-moving objects, which have been identified, or their dimensions. Moreover, the determined relative distance and/or relative velocity can be used for determining a region of interest, where, for example, an obstacle is present. Other elements of a combined driver assistance system such as, for example, a video camera, can be adapted to focus on the determined region of interest.

Advantages of the driving assistance system 1 are a reduced response time, an increased spatial resolution, a reduced signal distortion and improved reliability. These advantages will be illustrated in the following.

The response time is reduced. In a SMI sensor, distances and velocities are quite small and, the SMI-frequencies being in the kHz-range, longer distances and/or higher relative velocities are accompanied by significantly increased frequencies (up to MHz). Therefore, even with some signal averaging, the response time of the measurement becomes very quick (< ms). In contrast, known ultrasonic detectors are typically working with pulse repetition rates of 10 – 100 Hz, i.e. their response time is much larger than 10 ms. Because of the increased response time, the velocity of a vehicle comprising the driver assistance system 1 can be increased when the driver is looking for a suited parking space, and also semi- or fully-automatic parking of the vehicle takes much less time, i.e. the velocity of the vehicle is not limited to a low speed

, e.g., when the driver is looking for a suited parking space, and also semi-automatic parking of the vehicle may take much less time than would be needed by a driver of ordinary skill.

Spatial resolution is increased. Compared to ultrasonic sensors and Radar systems, the laser 2, which is preferentially the laser of a SMI sensor, in particular of a VCSEL, provides a much lower divergence of the emitted radiation of the first light beam 4, which can even be further reduced using VECSEL technology or a suitable collimation lens. With respect to recognition of an object 6 having dimensions x_0, y_0 and z_0 at a distance r, all four parameters can be measured with higher accuracy. Furthermore, velocity information of measurements in time can be used to get a higher redundancy.

Thus, the advantages achieved include a higher spatial resolution due to lower divergence, wherein the spatial resolution can be further increased by advanced signal processing, e.g. getting two, three or more distances from one detector 7 due to several frequency components, wherein more measurements per time interval possibly lead to a higher significance. For example, a relative distance r can be measured with cm-resolution, which is much better than with ultrasonic sensors. Small concrete pillars, towing hitches and also bushes are detected with high significance and even distances smaller than tenths of a cm can be measured with high accuracy.

Signal distortion is reduced. For ultrasonic as well as Radar/Lidar sensors, special measures must be taken to counteract crosstalk of the sensors at least in an array-like arrangement. The scattered signal emitted from a first sensor may hit a detector of a second sensor, which may disturb the wanted response to said first emitted signal. One possible measure is a special driving scheme of the single lasers and the transfer of this scheme to the detectors for filtering. Further, supersonic sensors have problems with strong noise caused by fair wind. The determination of relative velocity and relative distance based on the detected interference of the first and second light beam within the laser cavity, as performed by the driver assistance system, which preferentially uses two or more lasers, in particular, VCSELs working in the SMI-mode, which are preferentially arranged in an array, does not generate any disturbance, in particular crosstalk, if operated in a suited gain regime. A suited gain regime is, for example, one where the interaction between the emitted and reflected wave within the cavity responds linearly. This is the case with mainly the fundamental beat frequency, i.e. no higher harmonics of the beat frequency.

Reliability is improved. In parallel with a distance measurement to an object 6, a velocity measurement relative to the vehicle is performed with the driver assistance system 1. A speed and distance measurement via SMI sensors overcomes disadvantages of driver assistance systems measuring either the relative distance or the relative velocity. Further, cameras, especially 3D cameras, need rather complex image analysis procedures and reliability of image recognition is quite low.

Thus, the usage of self-mixing interference techniques for determining the relative distance and the relative velocity leads to an improved response time, spatial resolution and redundancy, wherein particularly the parallel determination of the relative distance and the relative velocity improves the reliability.

Preferably, the system comprises at least a laser and a second detector forming a second sensor, and the sensor and second sensor are arranged in an array. Due to the arrangement in an array of at least two sensors it is possible to obtain accurate and reliable results from the distance and velocity determination, also in the case that a sensor is damaged, erroneous, soiled et cetera.

Fig. 2 illustrates in a side view and a top view a working scheme for the driver assistance system for driving a vehicle backwards into a parking space.

A sensor array 201 comprising several sensors, wherein each sensor is formed by a laser comprising a laser cavity and a detector, is positioned at the rear of a vehicle 101 to be parked. To park the vehicle 101 between different objects, for example, vehicles 102 and 103, the additional challenge is not to collide with the small concrete pillar 202 as an additional object in between said vehicles.

At least one first light beam of the sensor array 201 hits the pillar 202. The reflected light, i.e. the second light beam (not shown in Fig. 2), interferes in the cavity of the laser of the respective sensor with the first light beam, and the interference is detected by the detector of the respective sensor and the determination unit 8 determines the relative velocity and the relative distance from the detected interference. Even if a part of the first light beam passes the pillar 202 and is, for example, reflected by the vehicle 103, the interference signal, which is preferentially a SMI-signal, has a frequency component corresponding to the pillar 202 at the smaller distance. Signals reflected at longer distances , for example reflected by the vehicle 103, will additionally have a higher frequency component. Therefore, the signal corresponding to the concrete pillar 202 can be simply separated from other longer-range signals. The pillar 202 is detected with significance.

Furthermore, due to the quick response time the pillar 202 will not be overseen, even at a quite high backward velocity of the parking vehicle. And even at very small distances to the pillar 202 or the other vehicle 103, the sensor gives reliable distance information.

Fig. 3 shows one possible arrangement of a sensor array of the driver assistance system, which might be the array 201.

The array comprises sensors 630 equipped with a focusing micro-lens structure 330 and an additional concave lens 830. The regions of highest sensitivity 730 are distributed in space with respect to the angle with the axis of symmetry. Adaptation of the lenses 330 and 830 leads to more converging or diverging rays of the sensors (depending on the demand).

Fig. 4 illustrates in a side view and a top view a working scheme for finding an appropriate parking space 333 into which a vehicle can be driven backwards using the driver assistance system 1 comprising the self-mixing interference sensors, which are formed by the laser 2 comprising the laser cavity and the detector 7. By using this driver assistance system, improved spatial resolution, response time and reliability are achieved.

A vehicle 301 is searching a free parking space of a sufficient size 333 for parking the vehicle. The vehicle drives along the already parked vehicles 302 to 305. A sensor array 203 is positioned at the front of the vehicle in such a way that several positions on one side in front of the vehicle are monitored by the laser beams 204, which are first light beams of lasers comprising a laser cavity. A cyclist 306 covers a part of the free space.

The parking space 333 should be large enough for parking vehicle 301 if the person riding the bicycle 306 does not “cover” the free space. Without the cyclist 306, the distance measurements performed by each sensor of the sensor array 203 enable an accurate size of the parking place 333 to be derived. Due to the use of SMI detection at the sensor array, the response time is fast, and thus the speed of the searching vehicle 301 may be high.

Also, if, for example, the cyclist 306 covers the free spacet 333, the driver assistance system 1 of the invention is able to detect whether the parking space

333 should be selected or not, on the basis of the self-mixing interference technique used at the sensor array 203. In parallel with the used distance measurement, each sensor element delivers at the same time or at substantially the same time, relative velocity information from the object 6 in its view. Further, due to the absence of crosstalk, each sensor of the entire array delivers independent results. “Substantially at the same time” means preferentially that the time difference between determining the relative velocity and determining the relative distance is smaller than 1 ms. For a car driving at 50 km/h such a time difference corresponds to an uncertainty in distance measurement of less than 2 cm for typical distances in meters.

The laser light signals reflected from all parked vehicles 302 to 305 will have the same relative velocity Δv_0 (relative to the velocity of the vehicle 301); only the laser light signal reflected from the person riding the bicycle 306 will have a different velocity Δv_1 due to the speed of the bicycle 306.

The laser 2, the detector 7 and the determination unit 8, i.e., in this embodiment, the SMI sensor, are adapted to determine groups of relative velocities and relative distances, wherein the relative velocity and the relative distance of the same group correspond to substantially the same time, wherein the assisting unit 9 is adapted to disregard a determined relative distance of a group when it is assisting the driver of the vehicle, if the relative velocity of the same group is within the predefined velocity range.

In the example with the cyclist 306, the relative velocity Δv_1 is within the predefined velocity range, which is, preferentially, defined by velocities higher than 1 km/h, more preferably higher than 3 km/h, still more preferably higher than 5 km/h and most preferably higher than 10 km/h. Thus, the assisting unit 9 disregards the relative velocity Δv_1 and the corresponding relative distance of the same group when it is assisting the driver of the vehicle.

In an embodiment, the distance information can be sorted by the corresponding velocities Δv_0, Δv_1, and the predefined velocity range can be predefined such that only those relative distances which correspond to Δv_0 , which corresponds to the speed v_0 of the searching vehicle 301 ($\Delta v_0 = v_0$), are used as relevant for free parking place finding by the assisting unit 9. Therefore, the driver assisting system 1, which comprises a SMI-based sensor, allows finding an appropriate parking space 333, even if the parking space 333 is covered by a moving object, for example, a cyclist 306.

Such sorting into velocity classes is even possible during acceleration/braking of the vehicle 301, due to the short response time of the sensor, which is preferentially in the ms range.

Fig. 5 shows schematically an exemplary diagram of an operating scheme of an individual sensor of the driver assistance system to determine distance and velocity simultaneously.

Fig. 5 refers to an increasing-decreasing frequency ν of the laser 2 using, for example, a triangle-like shape. The increasing and decreasing of the frequency ν of the laser light beam 4 emitted from the laser 2 is preferably done periodically. The frequency modulation of the frequency of the sensor can be realized, for example, by a saw tooth-like current waveform with a certain dc offset.

With a rising or decreasing frequency ν^+ or ν^- of the laser 2, a beat frequency $\Delta\nu_x$ is observed when the relative velocity between the driver assistance system 1 and object 6 is zero, i.e., for example, if the driver assistance system 1 and the object 6 are not moving; in this case, a purely relative distance measurement can be carried out.

If the relative velocity between the driver assistance system 1 and the object 6 is not zero, i.e., for example, if the system 1 and/or the object 6 are moving, an additional contribution $\Delta\nu_v$ is added to the beat frequency $\Delta\nu_x$ due to the Doppler effect. So, for an increasing first frequency the effective beat frequency is $\Delta\nu^+ = |\Delta\nu_v + \Delta\nu_x|$, which is detected by the detector 7 as a first interference within the laser cavity 3. For a decreasing frequency ν^- of the laser 2, there is a sign difference between the Doppler beat frequency $\Delta\nu_v$ and beat frequency $\Delta\nu_x$, i.e. the effective beat frequency is $\Delta\nu^- = |\Delta\nu_v - \Delta\nu_x|$, which is detected by the detector 7 as a second interference within the laser cavity 3. The beat frequency is the SMI frequency.

The beat frequency $\Delta\nu_x$ and the beat frequency $\Delta\nu_v$ can now be determined from the difference and sum of the measured effective beat frequencies $\Delta\nu^+$ and $\Delta\nu^-$, if it is known whether the beat frequency $\Delta\nu_x$ is larger than $\Delta\nu_v$ or smaller than $\Delta\nu_v$. This can be known in advance. For example, during finding a parking space the sign of $\Delta\nu_v$ is generally negative and the absolute value of $\Delta\nu_v$ is larger than $\Delta\nu_x$, i.e. $\Delta\nu_v$ is smaller than $\Delta\nu_x$. Furthermore, with known velocity v_o of the vehicle, which is, for example, separately measured, the below defined value of α_o can be chosen such that it is known whether $\Delta\nu_v$ is larger than $\Delta\nu_x$ or smaller than $\Delta\nu_x$, in particular, the value α_o can be chosen such that $\Delta\nu_v >> \Delta\nu_x$ or $\Delta\nu_v << \Delta\nu_x$.

Fig. 6 shows schematically and exemplarily a diagram of another operating scheme of an individual sensor of the driver assistance system to determine distance and velocity, wherein alternately a first interference of the first light beam and the second light beam is detected by detecting the beat frequency of the first interference, when a first frequency of the first laser beam 4 is maintained constant, and a second interference of the first light beam and the second light beam is detected by detecting the beat frequency of the second interference, when the first frequency is increased or decreased, and wherein the determination unit 8 is adapted to determine the relative velocity on the basis of the beat frequency of the first interference and to determine the relative distance on the basis of the difference between the beat frequency of the first interference and the beat frequency of the second interference.

During a constant frequency phase, e.g. constant dc-offset, the effective measured first frequency $\Delta\nu_0$ is the beat frequency due to the Doppler shift $\Delta\nu_v$ and thus a pure velocity measurement is carried out. In this constant-operation phase, the velocity can be directly deduced from the SMI frequency, i.e. the beat frequency, of the sensor.

In the phase of a rising frequency ν^+ of the laser 2, a beat frequency $\Delta\nu_x$ is additionally observed, i.e. the effective beat frequency is $\Delta\nu = \Delta\nu_x + \Delta\nu_v$. As $\Delta\nu_v$ has been measured in the prior phase, the distance x is directly derivable from $\Delta\nu_x$. The same holds when the laser frequency ν^- is decreased.

The calculation of the relative distance, based on the frequency shift $\Delta\nu_x$ and of the relative velocity, based on the frequency shift $\Delta\nu_v$ is well known from textbooks on laser physics.

For example, the relative distance x can be determined from the laser frequency ν_o by means of a frequency shift $\Delta\nu_x$ ($= \nu_1 - \nu_o$) by using the following equation:

$$x = (\Delta\nu_x \cdot c)/(2 \cdot \alpha_0) \ . \qquad (1)$$

In this equation, c is the velocity of light and α_o defines the variation of the laser frequency in time [$\nu(t) = \nu_0 + \alpha_0 \cdot t$, see Figs. 5 and 6].

The relative velocity v_{rel} can, for example, be determined from the frequency shift $\Delta\nu_{v}$ by using the following equation

$$v_{rel} = (\Delta\nu_{v} \cdot c)/(2 \cdot \nu_{0}) \quad . \quad (2)$$

The described driver assistance system 1 assists the driver in situations involved in parking the vehicle, e.g. to find a sufficiently large parking space for a vehicle and to support the parking procedure of the vehicle. Another example is to check the overhead clearance when entering a parking garage. By using the driver assistance system 1 to monitor the area above the vehicle for overhead clearance, advantages such as quick, reliable distance, i.e. height, information with very good spatial resolution are present. So, service pipes in parking decks are also monitored, for example. Also, by using the driver assistance system 1 at the front of the vehicle the effective free width of the vehicle can be monitored.

In the following, an exemplarily embodiment of a method of assisting a driver of a vehicle with parking the vehicle will be described with reference to a flow chart shown in Fig. 7.

In step 101, a first light beam 4 which is to be reflected by an object 6 is emitted by the laser 2, wherein the light beam reflected by the object 6 is a second light beam 5. In step 102, the second light beam 5 is fed back into a cavity 3 of the laser 2 and the first and the second light beams 4 and 5 interfere within the laser cavity 3. This interference can be called self-mixing interference. In step 103, this interference is detected by the detector 7, in particular, by detecting a frequency of an intensity modulation of the laser light caused by this interference. In step 104, a relative velocity and a relative distance between the vehicle and the object 6 are determined by the determination unit 8 on the basis of the self-mixing interference, in particular, as described above with reference to Fig. 5 or 6. In step 105, the assisting unit 9 assists the driver of the vehicle with parking the vehicle on the basis of the determined velocity and the determined relative distance..

Although in the above described embodiments VCSEL elements and VECSEL elements are used, in other embodiments, other configurations can be used, which comprise a laser having a laser cavity for emitting a first light beam which is to be reflected by an object, wherein the reflected light beam is a second light beam and wherein the first and second light beams interfere within the laser cavity, wherein a detector, for example, a photodiode, detects the interference within the laser cavity, for example, by detecting intensity changes of the laser light caused by this interference, and wherein the determination unit determines a relative velocity as well as a relative distance between the driver assistance system and the object on the basis of the interference within the laser cavity, in particular, on the basis of intensity changes of the laser light caused by the interference.

In the above described embodiments, the vehicle is a car, however, in other embodiments, it can be another vehicle, for example, a truck or a bus.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

A single unit or device may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Calculations and determinations like the determination of the relative distance and the relative velocity on the basis of a detected interference between a first light beam and a second light beam performed by one or several units or devices can be performed by any other number of units or devices. The calculations and determination and/or the control of the driver assistance system in accordance with the above described method of assisting a driver of a vehicle with parking the vehicle can be implemented as program code means of a computer program and/or as dedicated hardware.

A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium, supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope thereof.

CLAIMS:

1. A driver assistance system for assisting a driver of a vehicle with parking the vehicle, wherein the driver assistance system (1) comprises:

a laser (2) having a laser cavity (3) for emitting a first light beam (4) which is to be reflected by an object (6), wherein the reflected light beam is a second light beam (5) and wherein the first and second light beams (4, 5) interfere within the laser cavity (3),

a detector (7) for detecting the interference within the laser cavity (3),

a determination unit (8) for determining the relative velocity as well as the relative distance between the driver assistance system (1) and the object (6) on the basis of the interference within the laser cavity (3), and

an assisting unit (9) for assisting the driver of the vehicle with parking the vehicle on the basis of at least one of the determined relative velocity and determined relative distance.

2. The driver assistance system as defined in claim 1, wherein

the detector (7) is adapted to detect a first interference of the first light beam and the second light beam by detecting a first beat frequency, when a first frequency of the first laser beam (4) is increased, and to detect a second interference of the first light beam and the second light beam by detecting a second beat frequency, when the first frequency is decreased,

the determination unit (8) is adapted to determine the relative distance and the relative velocity on the basis of a difference between the first and second beat frequencies and on the basis of the sum of the first and second beat frequencies.

3. The driver assistance system as defined in claim 1, wherein

the detector (7) is adapted to detect a first interference of the first light beam and the second light beam by detecting the beat frequency of the first interference, when a first frequency of the first laser beam (4) is maintained constant, and to detect a second interference of the first light beam and the second light beam by detecting the beat frequency of the second interference, when the first frequency is increased or decreased,

the determination unit (8) is adapted to determine the relative velocity on the basis of the beat frequency of the first interference and to determine the relative distance on the basis of the difference between the beat frequency of the first interference and the beat frequency of the second interference.

4. The driver assistance system as defined in claim 1, wherein the assisting unit (9) is adapted to disregard a determined relative velocity and/or a determined relative distance of the object when the assisting unit is assisting the driver of the vehicle, if the determined relative velocity is within a predefined velocity range and/or if the determined relative distance is within a predefined distance range.

5. The driver assistance system as defined in claim 4, wherein the laser (2), the detector (7) and the determination unit (8) are adapted to determine groups of relative velocities and relative distances, wherein the relative velocity and the relative distance of the same group correspond to the same time, wherein the assisting unit (9) is adapted to disregard a determined relative distance of a group when it is assisting the driver of the vehicle, if the relative velocity of the same group is within the predefined velocity range.

6. The driver assistance system as defined in claim 4, wherein the predefined velocity range depends on the velocity of the driver assistance system.

7. A method of assisting a driver of a vehicle with parking the vehicle, wherein the method comprises the steps of:

emitting a first light beam (4) which is to be reflected by an object (6), wherein the reflected light beam is a second light beam (5),

making the first and second light beams (4, 5) interfere with each other,

detecting the interference,

determining the relative velocity as well as the relative distance between the vehicle and the object (6) on the basis of the interference, and

assisting the driver of the vehicle with parking the vehicle on the basis of at least one of the determined relative velocity and the determined relative distance.

8. A vehicle with a driver assistance system as defined in claim 1.

9. A computer program for assisting a driver of a vehicle with parking the vehicle, the computer program comprising program code means for causing a driver assistance system as defined in claim 1 to carry out the steps of the method as defined in claim 7, when the computer program is run on a computer controlling the driver assistance system.

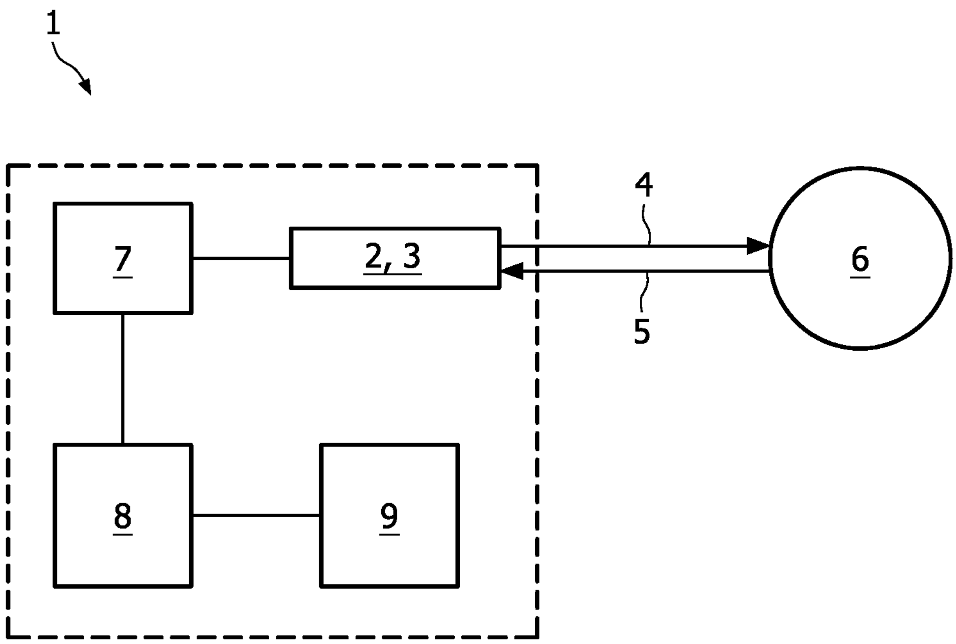

FIG. 1

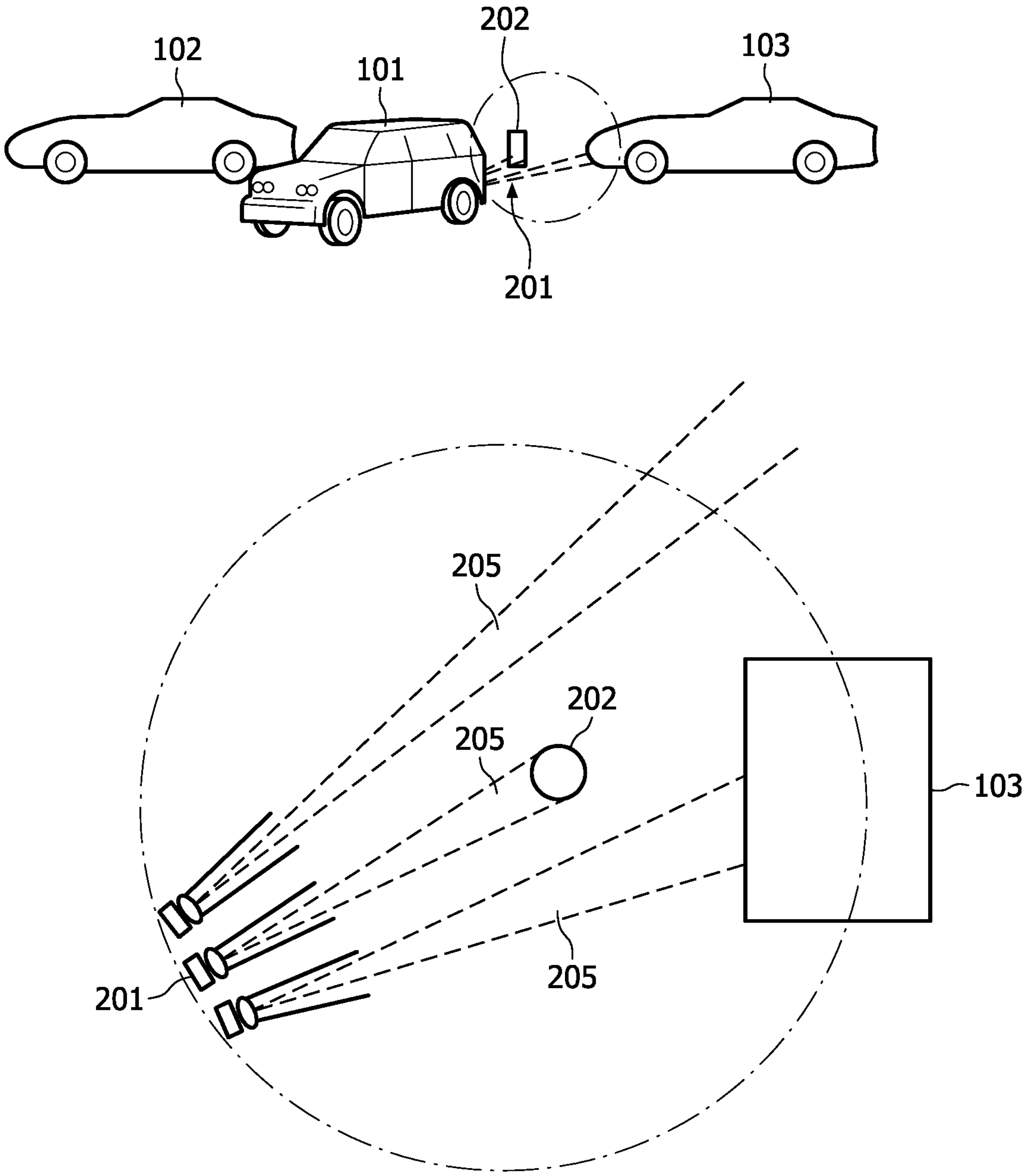

FIG. 2

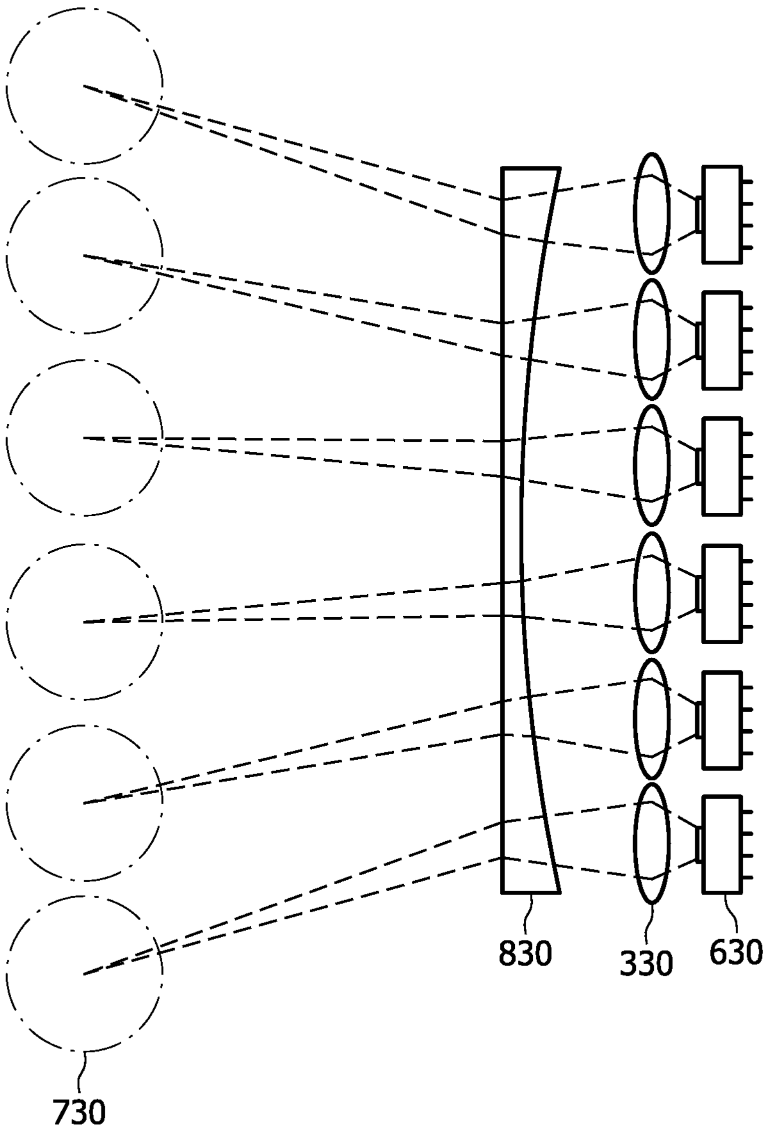

FIG. 3

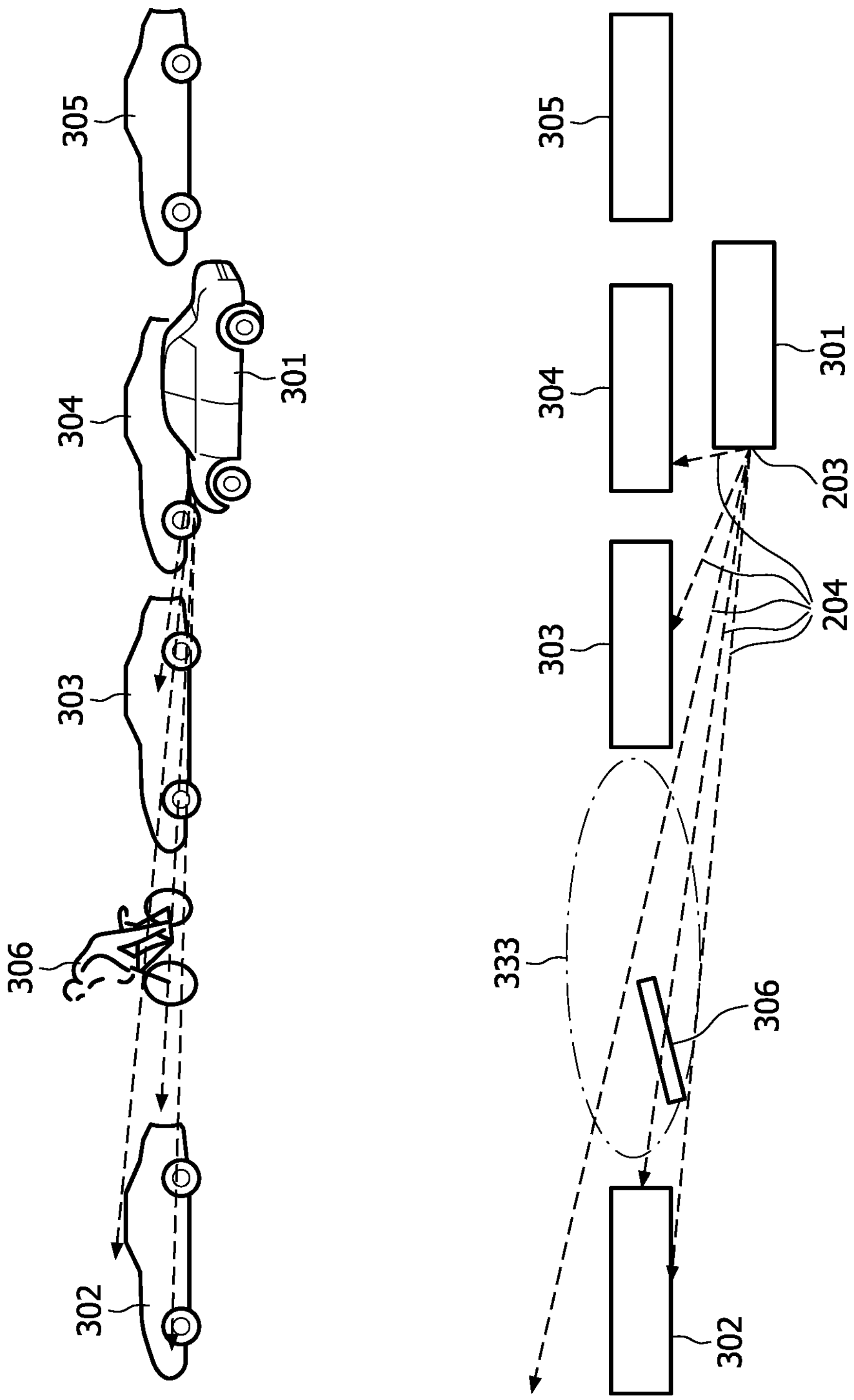

FIG. 4

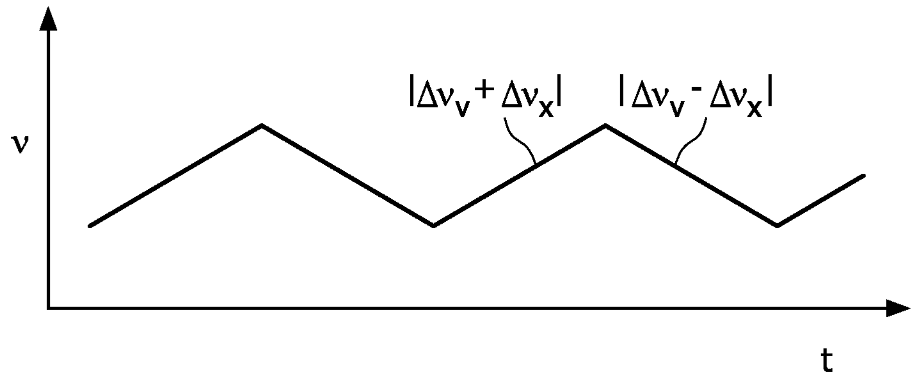
ν
$|\Delta\nu_v + \Delta\nu_x|$
$|\Delta\nu_v - \Delta\nu_x|$
t

FIG. 5

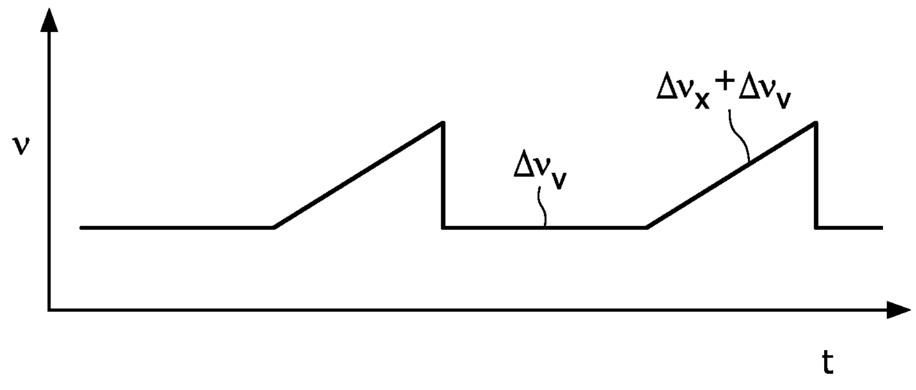
ν
$\Delta\nu_x + \Delta\nu_v$
$\Delta\nu_v$
t

FIG. 6

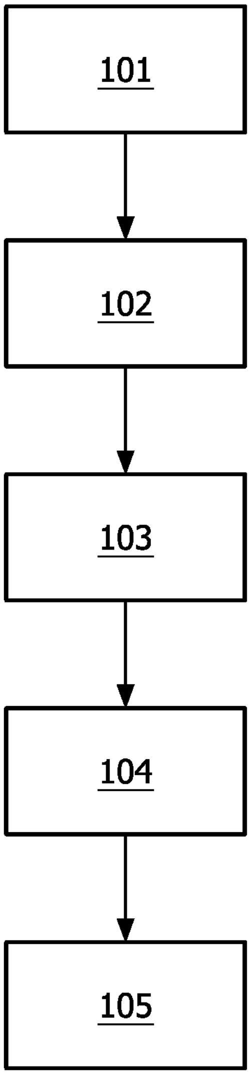

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/052434

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S17/93 G01S17/32 G01S17/87

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2 689 980 A (PEUGEOT [FR]; CITROEN SA) 15 October 1993 (1993-10-15) page 5, line 1 - page 6, line 25; figures 1-3	1-9
Y	DE 103 17 254 A1 (GEIGLE ENRICO [DE]) 4 November 2004 (2004-11-04) abstract	1-9
A	GB 2 443 662 A (FIRECOMMS LTD [IE]) 14 May 2008 (2008-05-14) abstract	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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	Date of mailing of the international search report
15 October 2009	22/10/2009

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/052434

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
FR 2689980	A	15-10-1993	NONE		
DE 10317254	A1	04-11-2004	NONE		
GB 2443662	A	14-05-2008	WO 2008055640	A1	15-05-2008