METHOD AND SYSTEM FOR SAFE INTER-VEHICULAR DISTANCE DETERMINATION

Field of the Invention

[0001] The present invention generally relates to safe driving systems and method, and more particularly to a method and system for safe inter-vehicular distance determination.

Background of the Invention

[0002] More the highways, more the mobile vehicles, and higher the speeds. It is our dream, but unfortunately, all these will be translated into more accidents including collisions and overturns. One effective way to reduce the accidents is keeping a safe distance from a preceding vehicle while traveling along highways. There are many situations where a driver fails to keep the safe distance from the preceding vehicle. For example, a tail-gating driver will intentionally ignore the safe distance; a driver for long-haul truck may fail to keep the safe distance because of fatigue and drowsiness. It is apparent that a system that can alert the driver for his failure of keeping the safe distance will be beneficial.

[0003] There are attempts made for developing the safety systems that can detect the distance of a preceding vehicle. For example, US 2005/0225479 A1 discloses a device including a radar and a camera for detecting an object located in front of an automobile. More specifically, the radar detects a distance from the automobile to the front object, and the camera takes an image of the object. However, this system is complicated and expensive.

[0004] In addition, "black box" has been proposed in recording the driving performance of a vehicle. For example, US 2005/0099279 A1 discloses a vehicle "black box" that provides recording means by which driver action can be reviewed after an accident or collision. However, the cameras are disposed at the side of the vehicle so that they cannot be used for detecting the distance of a preceding vehicle.

[0005] Furthermore, video recorder has been equipped in many official vehicles. For example, a camera is mounted on the front of any police car for recording the events when a passenger car is pulled over for checking or traffic violation. However, the recording system is solely used for recording.

Summary of the Invention

[0006] Therefore, one of the objectives of the present invention is to provide a method and system that calculates the distance from a host vehicle to any preceding object using captured front images of the host vehicle and alerts the driver of the host vehicle whenever the host vehicle is too close to the preceding object.

[0007] In one aspect, the present invention provides a method for determining the distance from a host vehicle to any preceding object in the view of the host vehicle. In one embodiment, the method comprises obtaining a front image of the host vehicle; computing the environmental illumination condition as the average intensity of the front image; selecting an image region of interest (ROI); dividing the ROI into a predetermined number of overlapping regions (R1, R2, R3, .., Rn), wherein n is a definite integer; computing the distance from the sequential overlapping regions using both lowest valley of intensity and red regions; and selecting the smaller distance computed from either using lowest valley of intensity or red regions as the distance from the host vehicle to the preceding object. In one further embodiment, the method further comprises computing the safe distance of the host vehicle as the function of the host vehicle's speed and the environmental illumination condition; thereby the computed safe distance will be compared with the actual distance as computed so as to alert the driver of the host vehicle when the host vehicle is too close to the preceding object.

[0008] In another embodiment of the method, the preceding object is a car, a truck and a mobile vehicle. In yet another embodiment of the method, in the operation of obtaining a front image of the host vehicle, the front images are continuously captured by an image capturing means. In yet another further embodiment of the method, the image capturing means has a capacity of taking 25-100 frames per second.

[0009] In yet another embodiment of the method, in the operation of selecting an image region of interest (ROI), the ROI is defined within the same travel lane of the host

vehicle enveloped by two traffic separation lines. In yet another embodiment of the method, in the operation of dividing the ROI into a predetermined number of overlapping regions, the adjacent overlapping regions have 50% overlapping.

[0010] In another embodiment of the method, in the operation of computing the distance from the sequential overlapping regions using lowest valley of intensity, the computing comprises the following operations: computing the image intensity histogram for an overlapping region; selecting the sub-region with a predetermined lowest threshold of the intensity histogram; clipping any parts of the processed overlapping region with an intensity value that is higher than the predetermined lowest threshold; stretching the clipped image; selecting the lowest valley of the image intensity histogram of the stretched image as the image intensity threshold; checking whether in the above operation a lowest valley is selected; if there is no selected lowest valley, going back to process next overlapping region; if there is a selected lowest valley, determining the presence of wheel(s); and when two wheels are determined, computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located wheels; or when one wheel is determined, computing the distance based on the detected wheel. In another further embodiment of the method, the predetermined lowest threshold is 20%.

[0011] In another embodiment of the method, in the operation of computing the distance from the sequential overlapping regions using red regions, the computing comprises the following operations: selecting the image red region; ignoring the area of the red region that is too small; deciding whether there is an identifiable red region suitable for further processing; if no, going back to process a next overlapping region; if yes, going forward to the next step; performing morphological dilation operation to close the gap between red-light bulbs to cater for vehicle that has two small red-light bulbs on each side of the vehicle; when two or more red regions are detected, connecting red regions with near-horizontal line on the two nearest light bulbs; and computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located red-light bulbs; or when only one light bulb is detected, checking for its presence for a predetermined duration; and computing the distance based on the detected red-light bulb.

[0012] In another aspect, the present invention provides a vehicle safety alert system that detects the distance from a host vehicle to any preceding object to the host vehicle and alerts the driver of the host vehicle for unsafe closeness to the preceding object so as to reduce the collision with the preceding object. In one embodiment, the vehicle safety alert system comprises an image capturing means for continuously capturing the front images of the host vehicle; a microprocessor electronically connected to the image capturing means so as to obtain captured images from the image capturing means to compute the distance; and a display/alert means electronically connected to the microprocessor; wherein the display/alert means is capable of alerting the driver of the host vehicle whenever the host vehicle is too close to the preceding object; wherein the distance is computed by the following operations: obtaining one front image of the host vehicle; computing the environmental illumination condition as the average intensity of the front image; selecting an image region of interest (ROI) within the front image; dividing the ROI into a predetermined number of overlapping regions (R1, R2, R3, .., Rn), wherein n is a definite integer; computing the distance from the sequential overlapping regions using both lowest valley of intensity and red regions; and selecting the smaller distance computed from either using lowest valley of intensity or red regions as the distance from the host vehicle to the preceding object.

[0013] One advantage of the present invention is that it can use the images captured by video recorder cameras that have been installed in the front of many vehicles such police cars; it does not need extra cost for installing any electronic equipment.

[0014] These and additional objectives and advantages of the invention will become apparent from the following detailed description of preferred embodiments thereof in connection with the accompanying drawings.

Brief Description of the Drawings

[0015] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0016] FIG 1 shows a functional block diagram of the vehicle safety alert system in accordance with one embodiment of the present invention.

[0017] FIG 2A is an illustrative view of a vehicle traveling within traffic lanes, wherein the vehicle is mounted with a camera.

[0018] FIG 2B is an illustrative view of dividing an ROI into R1, R2, and R3 overlapping regions for the calculation of distances from the host vehicle to the preceding vehicle.

[0019] FIG 3 shows an integrated image analysis algorithm in accordance with one embodiment of the present invention.

[0020] FIG 4 shows a flowchart of the sub-algorithm A for calculating the distance of a preceding vehicle within overlapping regions of the ROI in accordance with one embodiment of the present invention.

[0021] FIG 5 shows a detailed flowchart of determining the presence of wheels in accordance with one embodiment of the present invention.

[0022] FIG 6 shows a flowchart of the sub-algorithm B for calculating the distance of a preceding vehicle within overlapping regions of the ROI in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0023] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0024] Throughout this application, where publications are referenced, the disclosures of these publications are hereby incorporated by reference, in their entireties, into this application in order to more fully describe the state of art to which this invention pertains.

[0025] In one aspect, the present invention provides a vehicle safety alert system that detects the distance from the host vehicle to any preceding object and alerts the driver for unsafe closeness to the preceding object so as to reduce the collision with the preceding object. FIG 1 shows a functional block diagram of the vehicle safety alert system in accordance with one embodiment of the present invention. As shown in FIG 1, the vehicle safety alert system **1** comprises an image capturing means **2**, a microprocessor **3**, and a display/alert means **4**. The image capturing means **2** may be a CCD, a camera, a video camera or any suitable electronic means that can capture images continuously. In one

embodiment, the image capturing means preferably has a speed of 25-100 frames/second. The frame rate is camera and system dependent. The image capturing means **2** is mounted at the front portion of the vehicle so that the front images of the vehicle including any preceding object can be taken. The preceding object may be any car, truck, and motorcycle. The image capturing means may be mounted by integration, welding, or attachment. FIG 2A is an illustrative view of a vehicle traveling within traffic lanes, wherein the vehicle is mounted with a camera.

[0026] The microprocessor **3** is embedded with programs for calculating the distances from the host vehicle to the preceding object, and has the capacity of storing all accessory information and programs for the calculation. The microprocessor **3** is electronically connected with the image capturing means **2** so that the captured images are outputted to and processed by the microprocessor **3**. In one embodiment, the image capture means **2** may output the captured images to the microprocessor by wireless communication. The microprocessor **3** may further comprise a recorder for recording the captured images, serving as a black-box for monitoring the driving conditions. This feature is useful for post-accident analysis. The microprocessor may be any electronic devices that are suitable for storing and executing electronic information.

[0027] The display/alert means **4** is electronically connected with the microprocessor **3** to alert the driver of unsafe closeness to the preceding object. The alert can be accomplished by sound or flashing light that is obvious to the driver. In one embodiment, the display/alert means may receive the captured images from the image capturing means directly and display with a screen the captured images.

[0028] In another aspect, the present invention provides a method for calculating the distance from a host vehicle to any preceding object in the view of the host vehicle so that the driver of the host vehicle will be alerted whenever the host vehicle is within the unsafe closeness to the preceding object. FIG 3 shows an integrated image analysis algorithm of the method in accordance with one embodiment of the present invention. As shown in FIG 3, the algorithm **10** starts **11** when the front images of the vehicle are captured by the image capturing means and stored within the microprocessor; then the environmental illumination condition is computed as the average intensity of the image captured **12**. Then, select the image region of interest (ROI) that is comprised of only the image region that falls on the same vehicle travel lane **13** as shown in FIG 2B. In one

embodiment, the vehicle travel lane is defined by two traffic separation lines as shown in FIG 2A and FIG 2B. Then, divide **14** the ROI into a fixed number of overlapping regions (R1, R2, R3, .., Rn, wherein n is a definite integer). FIG 2B shows an illustrative view of dividing an ROI into three overlapping regions (R1, R2, and R3). Then, the overlapping regions (R1, R2, R3, ..., Rn) will be computed sequentially based on sub-algorithm A **15** using lowest valley of intensity and sub-algorithm B **16** using red regions discussed in detail hereinafter. If no preceding vehicle in an overlapping region (e.g., R1) is detected based on sub-algorithms A and B, the subsequent overlapping regions (e.g., R2, R3, ..., Rn) will be computed in sequence until a preceding vehicle in one overlapping region is detected, or all overlapping regions will be computed when no preceding vehicle is detected.

[0029] Referring still to FIG 3, the distance from the host vehicle to the preceding vehicle will be computed **17** by taking the smaller distance value obtained from both the Image Analysis Algorithm A **15** and the Image Analysis Algorithm B **16**.

[0030] The safe distance will be computed as the function of the vehicle's speed and the environmental illumination condition. In general, the higher the vehicle speed the larger the desired safe distance. The relationship of vehicle speed and desired safe distance is proportional with a proportional constant.

[0031] The darker the environmental illumination condition, the longer the desired safe distance. In one embodiment, the environmental illumination conditions are classified into 2 categories: normal sunny day, and night time. Additional safety distance (say: 1.0 m) is added on the safe distance determined in step **17** for the case where illumination is not bright enough, which is decided upon, by setting a threshold on the average image intensity determined in step **12**.

[0032] Alerting tone, message display or audio alert can then be used to alert the driver should the detected distance as obtained in step **17** be lesser than the recommended safe distance to be maintained as determined in step **18**. In addition, the violation record will be logged if the distance determined is smaller than the safe distance derived from the vehicle speed and illumination condition.

[0033] Now referring to FIG 4, there is provided a flowchart of the sub-algorithm A for calculating the distance of a preceding vehicle within overlapping regions of the ROI in accordance with one embodiment of the present invention. For each overlapping region

(e.g., R1), the sub-algorithm A **15** initially computes **21** the image intensity histogram for the region, then selects **22** the sub-region with the lowest 20% of the intensity histogram for further processing, and then clips any parts of the processed overlapping region with an intensity value that is higher than the 20% lowest intensity value. It has been assumed that the sub-region with the lowest 20% of the intensity histogram would contain the wheels' image of a preceding vehicle if the preceding vehicle does exist in a processed overlapping region.

[0034] Still referring to FIG 4, the sub-algorithm A then uses histogram equalization method or contrast stretching method to stretch the clipped image **23**. Then, the stretched image is segmented through threshold algorithm, and the lowest valley of the image intensity histogram of the stretched image is selected as the image intensity threshold **24** for the threshold algorithm. In the decision step **25**, if there is no lowest valley that can be selected, the sub-algorithm A will go back to step **21** for next overlapping region until a lowest valley is detected or all overlapping regions are analyzed; if there is a lowest valley that can be selected, the sub-algorithm A will go on to step **26**. It has been assumed that the middle and higher valleys could be caused by the texture of the preceding vehicle. If the histogram is flat or single modal with no identifiable lowest valley, it implies that no vehicle is present in the processed overlapping region, or the vehicle is very far away. For the case where the vehicle is very far away, it will result in very small wheels' image and thus does not form an identifiable lowest valley.

[0035] Still referring to FIG 4, the step **26** determines the presence of wheel(s) in the processed overlapping region. The determination is based on the fact that the wheels of all types of vehicles are black and nonspecular reflective, and therefore such characteristics can be used to locate the wheels of the vehicle in front. Moreover, using the vehicle body will cause overlapping problem with vehicles nearby and thus complicate the image analysis tasks. As the wheel is always vertical or near-vertical with respect to the road, there should at least be one vertical wheel's boundary (or edge) that is along the lane's direction. Those vertical boundaries that are too small to contribute to the smallest wheel's size will be ignored.

[0036] Now referring to FIG 5, there is provided a detailed flowchart of determining the presence of wheels in step **26** in accordance with one embodiment of the present invention. When the lowest valley of the stretched histogram is selected in step **24**,

whether vertical wheel's edge that is bigger than a predetermined length is present is checked in step **30**. If no, the sub-algorithm A further checks whether there is any unprocessed overlapping regions left in step **31**; if at least one unprocessed overlapping region is left, the program proceeds to step **21** for selecting next unprocessed overlapping region; if no more unprocessed overlapping region is left, the program proceeds to step **27** for calculating the distance of the preceding vehicle. Now back to step **30**, if the answer is yes, the program checks whether it is a single wheel in step **32**; if the single wheel is present for a predetermined duration **34**, the preceding vehicle will be considered as a single wheel and the distance will be calculated accordingly in step **27**; and if it is not a single wheel but two wheels **33**, a near horizontal line that connects the two nearest wheels is selected for distance calculation in step **27**.

[0037] Once the wheels are identified, the distance from the vehicle to the one in front will then be computed **27** by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located wheels. This is more accurate than measuring the distance between wheels, as different vehicle types will have different distances between wheels. For situation when only one wheel is detected, the distance will be based on the detected wheel, as it is for the case of motorcycles. In this case, in order to prevent any chance of miss identification, the preceding vehicle will be considered as a motorcycle if a "single wheel" is present for a pre-determined duration. For cases where more than 2 wheels are detected, the 2 nearest wheels that are connected by a near-horizontal line are chosen for distance computation. The additional detected wheel(s), which are of much smaller areas and caused by vehicles far away, are therefore ignored.

[0038] Now referring to FIG 6, there is provided a flowchart of the sub-algorithm B for calculating the distance of a preceding vehicle within overlapping regions of the ROI in accordance with one embodiment of the present invention. The sub-algorithm B initially selects **40** the image red region for further processing, wherein the image red region is used to locate the red-light bulbs at the back of the preceding vehicle, especially during night driving. If the area of the red-region is too small, it will be ignored by the "area" feature **41**. Then the decision step **42** decides whether there is an identifiable red region suitable for further processing; if no, the program goes back to step **40** and a next overlapping

region is selected until all overlapping regions are processed; if yes, the program proceeds to step **43.**

[0039] Then, morphological dilation operation **43** is performed to close the gap between red-light bulbs to cater for vehicle that has two small red-light bulbs on each side of the vehicle. In step **44**, when two or more red regions are detected, connect red regions with near-horizontal line on the two nearest light bulbs; when only one light bulb is detected, check for its presence for a predetermined duration. Then, the program proceeds to step **45** for calculation of distance of the preceding vehicle.

[0040] The distance of the preceding vehicle will then be computed by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located red-light bulbs. This is more accurate than measuring the distance between the two red-light bulbs, as different vehicle types will have different distances between red-light bulbs, and the red-light bulbs differ in sizes too. The distance between the red-light bulbs is used in the proposed invention in confirming that the distance computed is error-free.

[0041] For situation when only one red-light bulb is detected, the distance will be based on the detected red-light bulb, as it is for the case of motorcycles. In this case, in order to prevent any chance of miss identification, it will be considered motorcycle if the "single red-light bulb" is detected as present for a predetermined duration.

[0042] For cases where more than 2 red-light bulbs are detected, the 2 nearest red light bulbs that are connected by a near-horizontal line are chosen for distance computation. The additional detected red-light bulb, which is further away from the lowest part of the captured image, is either caused by vehicles further away or the additional red-light bulb placed on the back mirror screen for certain types of vehicles.

[0043] Moreover, any violation and the degree of violation will also be logged for taxi/ bus/transportation companies who would like to keep a record of their driver performance in keeping safe distance from the front vehicle.

[0044] While the present invention has been described with reference to particular embodiments, it will be understood that the embodiments are illustrative and that the invention scope is not so limited. Alternative embodiments of the present invention will become apparent to those having ordinary skill in the art to which the present invention pertains. Such alternate embodiments are considered to be encompassed within the spirit

and scope of the present invention. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

CLAIMS

What is claimed is:

1. A method for determining the distance from a host vehicle to any preceding object in the view of the host vehicle, said method comprising the following operations:

obtaining a front image of the host vehicle;

computing the environmental illumination condition as the average intensity of the front image;

selecting an image region of interest (ROI);

dividing the ROI into a predetermined number of overlapping regions (R1, R2, R3, .., Rn), wherein n is a definite integer;

computing the distance from the sequential overlapping regions using both lowest valley of intensity and red regions; and

selecting the smaller distance computed from either using lowest valley of intensity or red regions as the distance from the host vehicle to the preceding object.

2. The method of claim 1, further comprising the following operations:

computing the safe distance of the host vehicle as the function of the host vehicle's speed and the environmental illumination condition;

thereby the computed safe distance will be compared with the actual distance as computed so as to alert the driver of the host vehicle when the host vehicle is too close to the preceding object.

3. The method of claim 1, wherein the preceding object is a car, a truck and a mobile vehicle.

4. The method of claim 1, wherein, in the operation of obtaining a front image of the host vehicle, the front images are continuously captured by an image capturing means.

5. The method of claim 4, wherein the image capturing means has a capacity of taking 25-100 frames per second.

6. The method of claim 1, wherein, in the operation of selecting an image region of interest (ROI), the ROI is defined within the same travel lane of the host vehicle enveloped by two traffic separation lines.

7. The method of claim 1, wherein, in the operation of dividing the ROI into a predetermined number of overlapping regions, the adjacent overlapping regions have 50% overlapping.

8. The method of claim 1, wherein, in the operation of computing the distance from the sequential overlapping regions using lowest valley of intensity, the computing comprises the following operations:

computing the image intensity histogram for an overlapping region;

selecting the sub-region with a predetermined lowest threshold of the intensity histogram;

clipping any parts of the processed overlapping region with an intensity value that is higher than the predetermined lowest threshold;

stretching the clipped image;

selecting the lowest valley of the image intensity histogram of the stretched image as the image intensity threshold;

checking whether in the above operation a lowest valley is selected; if there is no selected lowest valley, going back to process next overlapping region; if there is a selected lowest valley, determining the presence of wheel(s); and

when two wheels are determined, computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located wheels; or

when one wheel is determined, computing the distance based on the detected wheel.

9. The method of claim 8, wherein the predetermined lowest threshold is 20%.

10. The method of claim 1, wherein, in the operation of computing the distance from the sequential overlapping regions using red regions, the computing comprises the following operations:

selecting the image red region;

ignoring the area of the red region that is too small;

deciding whether there is an identifiable red region suitable for further processing; if no, going back to process a next overlapping region; if yes, going forward to the next step;

performing morphological dilation operation to close the gap between red-light bulbs to cater for vehicle that has two small red-light bulbs on each side of the vehicle;

when two or more red regions are detected, connecting red regions with near-horizontal line on the two nearest light bulbs; and

computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located red-light bulbs; or

when only one light bulb is detected, checking for its presence for a predetermined duration; and

computing the distance based on the detected red-light bulb.

11. A vehicle safety alert system that detects the distance from a host vehicle to any preceding object to the host vehicle and alerts the driver of the host vehicle for unsafe closeness to the preceding object so as to reduce the collision with the preceding object; said vehicle safety alert system comprising:

an image capturing means for continuously capturing the front images of the host vehicle;

a microprocessor electronically connected to the image capturing means so as to obtain captured images from the image capturing means to compute the distance; and

a display/alert means electronically connected to the microprocessor; wherein the display/alert means is capable of alerting the driver of the host vehicle whenever the host vehicle is too close to the preceding object;

wherein the distance is computed by the following operations:

obtaining one front image of the host vehicle;

computing the environmental illumination condition as the average intensity of the front image;

selecting an image region of interest (ROI) within the front image;

dividing the ROI into a predetermined number of overlapping regions (R1, R2, R3, .., Rn), wherein n is a definite integer;

computing the distance from the sequential overlapping regions using both lowest valley of intensity and red regions; and

selecting the smaller distance computed from either using lowest valley of intensity or red regions as the distance from the host vehicle to the preceding object.

12. The vehicle safety alert system of claim 11, wherein the microprocessor further comprising the following operations:

computing the safe distance of the host vehicle as the function of the host vehicle's speed and the environmental illumination condition;

thereby the computed safe distance will be compared with the actual distance as computed so as to give alert signals.

13. The vehicle safety alert system of claim 11, wherein the preceding object is a car, a truck and a mobile vehicle.

14. The vehicle safety alert system of claim 11, wherein the image capturing means has a capacity of taking 25-100 frames per second.

15. The vehicle safety alert system of claim 11, wherein, in the operation of selecting an image region of interest (ROI), the ROI is defined within the same travel lane of the host vehicle enveloped by two traffic separation lines.

16. The vehicle safety alert system of claim 11, wherein, in the operation of dividing the ROI into a predetermined number of overlapping regions, the adjacent overlapping regions have 50% overlapping.

17. The vehicle safety alert system of claim 11, wherein, in the operation of computing the distance from the sequential overlapping regions using lowest valley of intensity, the computing comprises the following operations:

computing the image intensity histogram for an overlapping region;

selecting the sub-region with a predetermined lowest threshold of the intensity histogram;

clipping any parts of the processed overlapping region with an intensity value that is higher than the predetermined lowest threshold;

stretching the clipped image;

selecting the lowest valley of the image intensity histogram of the stretched image as the image intensity threshold;

checking whether in the above operation a lowest valley is selected; if there is no selected lowest valley, going back to process next overlapping region; if there is a selected lowest valley, determining the presence of wheel(s); and

when two wheels are determined, computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located wheels; or

when one wheel is determined, computing the distance based on the detected wheel.

18. The vehicle safety alert system of claim 17, wherein the predetermined lowest threshold is 20%.

19. The vehicle safety alert system of claim 11, wherein, in the operation of computing the distance from the sequential overlapping regions using red regions, the computing comprises the following operations:

selecting the image red region;

ignoring the area of the red region that is too small;

deciding whether there is an identifiable red region suitable for further processing; if no, going back to process a next overlapping region; if yes, going forward to the next step;

performing morphological dilation operation to close the gap between red-light bulbs to cater for vehicle that has two small red-light bulbs on each side of the vehicle;

when two or more red regions are detected, connecting red regions with near-horizontal line on the two nearest light bulbs; and

computing the distance by taking the number of pixels from the lowest part of the captured image to the near-horizontal line that connects the two located red-light bulbs; or

when only one light bulb is detected, checking for its presence for a predetermined duration; and

computing the distance based on the detected red-light bulb.