

METHOD AND SYSTEM FOR DETECTING DISTANCE TO FRONT VEHICLE

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of distance detection, and in particular, to a method and system for detecting a distance to a front vehicle.

BACKGROUND

[0002] Along with the development of economy, the automobile population is increased year by year, and safe driving becomes a non-negligible problem. The proportion of automobile rear-end accidents in total traffic accidents is high through statistical analysis. In order to reduce the occurrence of the automobile rear-end accidents, a vehicle distance detection and early warning technology is developed as required, and the principle of the detection and early warning is that when the vehicle distance is too close to a touch threshold, a driver is reminded of collision or braking measures are automatically taken so as to reduce the occurrence of the rear-end accidents.

[0003] The common vehicle distance detection and early warning technology comprises two types, wherein the first type is a visual solution based on a common camera, comprising firstly identifying a target, and then obtaining a distance to a front vehicle according to a monocular or binocular distance measurement algorithm and giving early warning; the second type is that the millimeter wave radar transmits electromagnetic waves to the front area and receives echoes to measure the distance, the speed and the angle of a front object, so as to obtain the distance to the front vehicle and give an early warning. The two types of early warning technology have advantages and disadvantages respectively, the solution based on the common

camera is low in cost, the position of the front vehicle in the field of view can be accurately identified, more semantic information is provided, but the distance and accuracy of distance measuring of the visual solution are far less than those of a millimeter wave radar. On the contrary, although the millimeter wave radar has a high distance measuring accuracy, the field of view is relatively narrow, any semantic information cannot be returned, and it is difficult to accurately identify the position of the front vehicle in a two-dimensional space.

SUMMARY

[0004] The following presents a simplified summary of the disclosure in order to provide a basic understanding of some aspects of the disclosure. However, it should be understood that this summary is not an exhaustive overview of the disclosure. It is not intended to identify key or critical elements of the disclosure, nor is it intended to be used to limit the scope of the disclosure. Its sole purpose is to present some concepts related to the disclosure in a simplified form as a prelude to the more detailed description that is presented later.

[0005] The object of the present disclosure is to provide a method and system for detecting a distance to a front vehicle, which can simultaneously ensure distance measurement accuracy and positioning accuracy.

[0006] In order to achieve the above object, an aspect of the present disclosure provides a method for detecting a distance to a front vehicle, comprising:

- acquiring an RGB image and a depth image of a front view of a host vehicle;

- setting a target area frame in the RGB image;

- extracting size data corresponding to a plurality of vehicles

in the RGB image;

for each of the plurality of vehicles:

determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;

calculating an overlap rate of the constraint frame of the vehicle and the target area frame;

calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;

determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

[0007] In some embodiments, the acquiring an RGB image and a depth image of a front view of a host vehicle includes:

simultaneously collecting the RGB image and the depth image by using a depth camera installed on the host vehicle; or

collecting the RGB image by using a 2D camera installed on the host vehicle, and collecting the depth image by using a millimeter wave radar/distance sensor installed on the host vehicle.

[0008] In some embodiments, the determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle includes:

constructing a virtual coordinate system in the RGB image;

extracting a coordinate of an upper left corner point of the vehicle in the RGB image based on the virtual coordinate system, and drawing a rectangular constraint frame including the vehicle in the RGB image according to the size data of the vehicle.

[0009] In some embodiments, the calculating an overlap rate of the constraint frame of the vehicle and the target area frame includes:

calculating an intersection over union IOU of the constraint frame of the vehicle and the target area frame by adopting an intersection over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$, as the overlap rate,

wherein, *Car* denotes an area of the constraint frame of the vehicle, and *ROI* denotes an area of the target area frame.

[0010] In some embodiments, the calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image includes:

calculating a normalized distance between the vehicle and the target area frame by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2},$$

wherein, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a predetermined target point in the target area frame, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

[0011] In some embodiments, the target area frame is a trapezoidal area frame right in front of the host vehicle selected from the RGB images, and the target point is a center point of the target area frame.

[0012] In some embodiments, the determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image includes:

screening, from the plurality of vehicles, vehicles with the

overlap rate larger than a first threshold value of overlap rate or the normalized distance smaller than a distance threshold value, as a first set of target vehicles;

screening, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

screening, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

extracting a vehicle distance corresponding to the front target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

[0013] In some embodiments, the method for detecting the distance to the front vehicle may further comprises:

sequentially carrying out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle,

wherein, the abnormal window detection processing detects an abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle distance values before and after the abnormal window in time windows.

[0014] Another aspect of the present disclosure provides a system for detecting a distance to a front vehicle, comprising:

an image acquisition unit configured to acquire an RGB image and a depth image of a front view of a host vehicle;

a target area frame setting unit configured to preset a target area frame in the RGB image;

a size data extraction unit configured to extract size data corresponding to a plurality of vehicles in the RGB image;

a constraint frame determination unit configured to determine, for each of the plurality of vehicles, a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;

an overlap rate calculation unit configured to calculate, for each of the plurality of vehicles, an overlap rate of the constraint frame of the vehicle and the target area frame;

a distance calculation unit configured to calculate, for each of the plurality of vehicles, a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;

a front target vehicle determination unit configured to determine a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

[0015] In some embodiments, the image acquisition unit is configured to:

simultaneously collect the RGB image and the depth image by using a depth camera installed on the host vehicle; or

collect the RGB image by using a 2D camera installed on the host vehicle, and collect the depth image by using a millimeter wave radar/distance sensor installed on the host vehicle.

[0016] In some embodiments, the constraint frame determination unit is configured to:

construct a virtual coordinate system in the RGB image;

extract a coordinate of an upper left corner point of the vehicle in the RGB image based on the virtual coordinate system, and drawing a rectangular constraint frame including the vehicle in the

RGB image according to the size data of the vehicle.

[0017] In some embodiments, the overlap rate calculation unit is configured to:

calculate an intersection over union IOU of the constraint frame of the vehicle and the target area frame by adopting an intersection over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$, as the overlap rate,

wherein, *Car* denotes an area of the constraint frame of the vehicle, and *ROI* denotes an area of the target area frame.

[0018] In some embodiments, the distance calculation unit is configured to:

calculate a normalized distance between the vehicle and the target area frame by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2},$$

wherein, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a predetermined target point in the target area frame, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

[0019] In some embodiments, the target area frame is a trapezoidal area frame right in front of the host vehicle selected from the RGB images, and the target point is a center point of the target area frame.

[0020] In some embodiments, the front target vehicle determination unit is configured to:

screen, from the plurality of vehicles, vehicles with the overlap rate larger than a first threshold value of overlap rate or the normalized distance smaller than a distance threshold value, as a first set of target vehicles;

screen, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

screen, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

extract a vehicle distance corresponding to the front target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

[0021] In some embodiments, the system for detecting the distance to the front vehicle may further comprise:

a motion filtering unit configured to sequentially carry out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle,

wherein, the abnormal window detection processing detects an abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle distance values before and after the abnormal window in time windows.

[0022] Yet another aspect of the present disclosure provides a computer-readable storage medium on which a computer program is stored, wherein when the program is executed by a processor, causes the processor to perform the following processes:

acquiring an RGB image and a depth image of a front view of a host vehicle;

setting a target area frame in the RGB image;

extracting size data corresponding to a plurality of vehicles in the RGB image;

for each of the plurality of vehicles:
determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;
calculating an overlap rate of the constraint frame of the vehicle and the target area frame;
calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;
determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

[0023] According to one or more embodiments of the present disclosure, a method and system for detecting a distance to a front vehicle that simultaneously ensure the distance measuring accuracy and the positioning accuracy can be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The accompanying drawings, which are included to provide a further understanding of the disclosure and are incorporated in and constitute a part of this disclosure, illustrate embodiment(s) of the disclosure and together with the description serve to explain the disclosure and not to limit the disclosure. In the drawings:

[0025] Fig. 1 is a schematic flow chart of the method for detecting the distance to the front vehicle according to embodiments of the present disclosure;

[0026] Fig. 2 is an exemplary structural block diagram of the system for detecting the distance to the front vehicle according to embodiments of the present disclosure;

[0027] Fig. 3 is an exemplary configuration block diagram of the computing device according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0100] In order to make the above objects, features and advantages of the present disclosure more comprehensible, a technical solution in an embodiment of the present disclosure will be described clearly and completely with reference to the accompanying drawings in the embodiment of the present disclosure. Apparently, the described embodiments are merely a few of the embodiments of the present disclosure and are not intended to be exhaustive. All other embodiments, which can be derived by a person of ordinary skill in the art from the disclosure without creative effort, are within the scope of the disclosure.

[0101] Fig. 1 is a schematic flow chart of the method for detecting the distance to the front vehicle according to embodiments of the present disclosure.

[0102] As shown in Fig. 1, in step S101, an RGB image and a depth image of a front view of a host vehicle are acquired.

[0103] In some embodiments, the RGB image and the depth image of the front view of the host vehicle may be collected in real time by an image acquisition unit installed on the host vehicle (e.g., the head of the vehicle). All vehicles of the current view angle may be included in the RGB image. In addition, vehicle distance information between each of the vehicles and the host vehicle in the RGB image can be extracted from the depth image.

[0104] In some embodiments, the RGB image and the depth image of the front view may be collected simultaneously by using a depth camera installed on the host vehicle. In some other embodiments, the RGB image of the front view may be collected using a 2D camera installed on the host vehicle, and the depth image of the front view may be

collected by using a millimeter wave radar/distance sensor installed on the head of the host vehicle.

[0105] In the specific implementation process, if the depth camera is selected, a match of the collected RGB image and depth image of the front view of the vehicle has been automatically completed, that is, the vehicle distance from each vehicle may be directly extracted from the depth image, without the necessity of matching and adjusting again when the depth camera is installed; if a combination scheme of the 2D camera and the millimeter wave radar/distance sensor is selected, the 2D camera and the millimeter wave radar/distance sensor need to be matched and corrected when installed, so that the output RGB image and depth image can be matched and correspond to each other. Illustratively, the depth camera may be an Intel RealSense active infrared stereo depth camera D435.

[0106] In step S102, a target area frame is set in the RGB image.

[0107] The target area frame represents an area where a front vehicle is likely to occur. In some embodiments, the target area frame may be set right in front of the host vehicle. In some embodiments, the target area frame may be a trapezoidal area frame. In some embodiments, a fixed point may be screened in the target area frame as a target point, which may represent a desired position where a front vehicle occurs. In some embodiments, the target point may be a center point of the target area frame.

[0108] In some embodiments, a right front trapezoidal area of the depth camera or the 2D camera may be selected from the RGB image as a target region frame; and a center point of the target area frame may be selected and defined as a target point. Certainly, in the actual operation process, the settings of the target area frame and the target point may be finely adjusted according to an engineer's experience. For example, when the depth camera is installed on the front left of the vehicle head, the target area frame and the target point may be selectively disposed at a position shifted to the left in the middle

of the RGB image.

[0109] In step S103, size data corresponding to a plurality of vehicles in the RGB image is extracted.

[0110] In some embodiments, a vehicle detection algorithm may be used to identify all vehicles in the RGB image and extract the size data for each vehicle respectively. In some embodiments, the size data of the vehicle may include width data, height data, and the like of the vehicle.

[0111] In some embodiments, a pre-trained vehicle detection model may be used to acquire all vehicles in the RGB image and identify size data for each of the vehicles therein. In particular, the vehicle detection model may be obtained , for example, by training a COCO data set using a target detection algorithm (e.g., Faster RCNN, SSD, YOLO, etc.).

[0112] In step S104, for each of the plurality of vehicles, a constraint frame of the vehicle is determined in the RGB image based on the size data of the vehicle.

[0113] In some embodiments, a virtual coordinate system may be constructed in the RGB image. For example, a virtual coordinate system may be constructed in the RGB image with the depth camera or the 2D camera as the origin. Then, the coordinate of the upper left corner point of each vehicle in the RGB image are extracted based on the virtual coordinate system, and a rectangular constraint frame including the vehicle is drawn in the RGB image according to the acquired size data of the corresponding vehicle.

[0114] In specific implementation, since the coordinate of the upper left corner point of the vehicle is available and the size data (e.g., width and height data) of the vehicle is also known, based on the upper left corner point of the vehicle, a width of the vehicle in the RGB image is used as the width of the rectangular constraint frame, and a height of the vehicle in the RGB image is used as the length of the rectangular constraint frame, so that the rectangular

constraint frame corresponding to the vehicle can be quickly drawn in the RGB image.

[0115] It should be understood that in the above method, coordinates of other points (e.g., upper right corner point, lower left corner point, lower right corner point, etc.) of the vehicle in the RGB image may also be extracted to draw the constraint frame. In addition, a shape of the constraint frame is not limited to a rectangle, and may be any shape designed according to actual needs.

[0116] In step S105, for each of the plurality of vehicles, an overlap rate of the constraint frame of the vehicle and the target area frame is calculated.

[0117] In some embodiments, an intersection over union of the vehicle and the target area may be calculated as the overlap rate based on an area of the constraint frame of the vehicle and an area of the target area frame.

[0118] Specifically speaking, the intersection over union IOU of the constraint frame of each vehicle and the target area frame may be calculated by using an intersection over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$,

where *Car* denotes an area of the constraint frame of the vehicle, and *ROI* denotes an area of the target area frame.

[0119] In step S106, for each vehicle of the plurality of vehicles, a normalized distance between the vehicle and the target area frame is calculated based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image.

[0120] In some embodiments, a normalized distance between the vehicle and the target area frame is calculated by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2}$$

where, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a target point, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

[0121] In step S107, a front target vehicle is determined from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and a vehicle distance between the front target vehicle and the host vehicle is obtained according to the depth image.

[0122] In some embodiments, the front target vehicle may be locked by using an unsupervised front vehicle screening algorithm based on the overlap rate and normalized distance corresponding to each vehicle.

[0123] The unsupervised front vehicle screening algorithm is as follows:

- making statistics for the overlap rates and the normalized distances corresponding to a plurality of vehicles in the RGB image, respectively;

- screening, from the plurality of vehicles, vehicles with the overlap rate larger than a first threshold value of overlap rate or the normalized distance smaller than a distance threshold value, as a first set of target vehicles;

- screening, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

- screening, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

- extracting a vehicle distance corresponding to the front

target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

[0124] The aforementioned first threshold value of overlap rate, second threshold value of overlap rate, and distance threshold value may be arbitrarily selected according to practical experience, and the selection of the threshold values is not limited in the present disclosure.

[0125] It should be noted that, in the above embodiment, the front target vehicle may be positioned by using a neural network-based front vehicle screening algorithm in addition to the unsupervised front vehicle screening algorithm. A specific method comprises:

generating a labeled training sample set $S=\{x_i, y_i\}$ by pre-training and screening a front target vehicle, wherein x_i represents vehicle characteristics and comprises three dimensional vectors which are respectively an overlap rate (intersection over union IOU), a normalized distance $Dist_norm$ and a vehicle distance from the host vehicle, y_i represents a screening result of the front target vehicle, and y_i can automatically output an identification result according to the three dimensional vector values in x_i . For example, when the y_i outputs 1, it indicates that the vehicle is the front target vehicle, and when the y_i outputs 0, it indicates that the vehicle is not the front target vehicle. A classifier may select different neural network frameworks to train the sample set, and the neural network frameworks may be AlexNet, VGG and the like.

[0126] In the method for detecting the distance to the front vehicle as provided in the embodiments, the manner of combining the RGB image and the depth image is adopted, so that the position of each vehicle in the RGB image as well as the distance from the host vehicle can be accurately positioned, and the distance measuring accuracy and the positioning accuracy can be ensured simultaneously. In addition, the front target vehicle is locked by adopting the unsupervised front vehicle screening algorithm based on the overlap rate and the

normalized distance of each vehicle, and meanwhile the vehicle distance to the front target vehicle is obtained by combining the depth image, so that the distance to the front vehicle is accurately and quickly detected.

[0127] In the embodiment of the present disclosure, the obtained vehicle distance between the front target vehicle and the host vehicle may also be optimized.

[0128] In some embodiments, the median filtering, the abnormal window detection processing, and the Kalman filtering may be sequentially carried out on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle.

[0129] Because the accuracy of the target detection algorithm is not 100%, a certain false detection rate would be caused by isolated noise points of jumping of some previous and next frames, and the isolated noise points can be filtered and smoothed by using the median filtering. In particular, the median filtering is a commonly used time sequence filtering algorithm. Since isolated noise caused by false detection of a target detection algorithm is similar to salt and pepper noise and presents a characteristic of pulse, the isolated noise can be removed by adopting the median filtering, that is, in a time window with the length of T_n centered at the current time, a median is selected as a filtered distance of the current time after the vehicle distances of the front target vehicle is sorted, and illustratively, T_n is generally set to be 5, at which the effect is better.

[0130] Since screening errors caused by factors such as adjacent lane interference frequently occur occasionally, there will exist a large false screening probability to filter the aforementioned interference factors by using the existing threshold value comparison method. It has been found experimentally that this false screening exhibits in the detection result as an abnormal window (distinguished from the

noise point in median filtering) with a maintenance time period of T_e , also referred to as an isolated window. Values at times before and after the isolated window are approximately continuous. The vehicle distances of the front target vehicle before and after the isolated window are fitted through abnormal window detection, and a value within the isolated window is replaced with a fitting result of the vehicle distances, thus accurately filtering of the aforementioned interference factors may be achieved. For example, the vehicle distances of the front target vehicle before and after the isolated window can be fitted by using a third-order polynomial function fitting, and the interpolation calculation result of the function is used as the fitting result of the vehicle distances to replace the value within the isolated window.

[0131] Through median filtering and abnormal window detection, visual errors caused by RGB image identification are substantially removed, and measurement errors caused by depth image measurement can be removed by adopting Kalman filtering. The Kalman filtering is an optimized autoregressive data processing algorithm. In a dynamic system with an approximately linear change of state and a measurement result interfered by Gaussian noise, the regressive data processing algorithm filters a measured value under the condition that a state transition equation and a measurement variance are both known, and can be applied to the fields of robot navigation, control, sensor data fusion, radar missile tracking and computer graphics processing. The state transition equation of the Kalman filtering is shown as follows:

$$X(k) = AX(k-1) + BU(k) + W(k)$$

[0132] $X(k)$ denotes a state variable of the system at the time k , that is, a vehicle distance between the front target vehicle and the host vehicle and a vehicle speed of the front target vehicle in the present embodiment; A is a state transition matrix which can be derived by adopting a first-order constant velocity model; $BU(k)$ denotes an

external control item; $W(k)$ is a state change due to other unknown interferences, and without more information, it can be replaced with Gaussian noise with a known variance, the variance is set to be larger, the smaller the confidence in the state equation is, that is, the degree of motion randomness of the distance to the front vehicle is considered to be higher.

[0133] In the specific implementation, the time window maintained by false detection and missed detection is about 1-15 frames, and presents a property similar to peak noise. Through median filtering and abnormal window detection processing sequentially on the vehicle distance between the front target vehicle and the host vehicle, the present embodiment can remove noise of false detection and missed detection and improve the accuracy of the screening of the front target vehicle. In addition, the Kalman filtering is carried out on the vehicle distance between the front target vehicle and the host vehicle to obtain an optimized vehicle distance between the front target vehicle and the host vehicle, and the measurement accuracy of the vehicle distance can be ensured.

[0134] FIG. 2 is an exemplary block diagram of a forward vehicle distance detection system according to an embodiment of the present disclosure.

[0135] In some embodiments, a system 200 may include processing circuitry 201. The processing circuitry 201 of the system 200 provides various functions of the system 200. In some embodiments, the processing circuitry 201 of the system 200 may be configured to perform the method for detecting the distance to the front vehicle described above with reference to Fig. 1.

[0136] The processing circuitry 201 may refer to various implementations of a digital circuitry system, an analog circuitry system, or a mixed-signal (a combination of analog and digital) circuitry system that perform functions in a computing system. The processing circuitry may include, for example, circuitry such as an

Integrated Circuit (IC), an Application Specific Integrated Circuit (ASIC), a portion or circuitry of a separate processor core, an entire processor core, a separate processor, a programmable hardware device such as a Field Programmable Gate Array (FPGA), and/or a system including multiple processors.

[0137] In some embodiments, the processing circuitry 201 may include an image acquisition unit 202, a target area setting unit 203, a size data extraction unit 204, a constraint frame determination unit 205, an overlap rate calculation unit 206, a distance calculation unit 207, and a front target vehicle determination unit 208.

[0138] The image acquisition unit 202 is configured to acquire an RGB image and a depth image of a front view of a host vehicle; the target area frame setting unit 203 is configured to preset a target area frame in the RGB image; the size data extraction unit 204 is configured to extract size data corresponding to a plurality of vehicles in the RGB image; the constraint frame determination unit 205 is configured to determine, for each of the plurality of vehicles, a constraint frame of the vehicle in the RGB image according to the size data of the vehicle; the overlap rate calculation unit 206 is configured to calculate, for each of the plurality of vehicles, an overlap rate of the constraint frame of the vehicle and the target area frame; the distance calculation unit 207 is configured to calculate, for each vehicle of the plurality of vehicles, a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image; the front target vehicle determination unit 208 is configured to determine a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtain a vehicle distance between the front target vehicle and the host vehicle according to the depth image. The aforementioned units 202 to 208

may be configured to perform steps S101 to S107, respectively, in the aforementioned method for detecting the distance to the front vehicle as shown in Fig. 1.

[0139] In some embodiments, the system 200 may also include a memory (not shown). The memory of the system 200 may store information generated by the processing circuitry 201 as well as programs and data for the operation of the system 200. The memory may be a volatile memory and/or a non-volatile memory. For example, memory may include, but is not limited to, Random Access Memory (RAM), Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM), Read Only Memory (ROM), and flash memory. In addition, the system 200 may be implemented at the chip level, or may also be implemented at the device level by including other external components.

[0140] In some embodiments, the system 200 may include a motion filtering unit (not shown) configured to sequentially carry out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle, wherein the abnormal window detection process detects an abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle distance values before and after the abnormal window in time windows.

[0141] It should be understood that the above-described units are only logical modules divided according to the specific functions implemented by the units, and are not intended to limit the specific implementation. In actual implementation, the above-described respective units may be implemented as separate physical entities, or by a single entity (e.g., a processor (CPU, DSP, or the like), an integrated circuit, or the like).

[0142] The system for detecting the distance to the front vehicle provided by the embodiment of the disclosure and the method for detecting the distance to the front vehicle provided by the embodiment of the disclosure belong to the same inventive concept, can execute the method for detecting the distance to the front vehicle provided by any embodiment of the disclosure, and have the corresponding functional modules and beneficial effects for performing the method for detecting the distance to the front vehicle. For details of the technology not described in detail in the present embodiment, reference may be made to the method for detecting the distance to the front vehicle provided in the embodiment of the present disclosure, which is not described in detail herein.

[0143] Fig. 3 is an exemplary configuration block diagram of the computing device according to embodiments of the present disclosure.

[0144] A computing device 300 is an instance of a hardware device to which the above-described aspects of the present disclosure may be applied. The computing device 300 may be any machine configured to perform processing and/or computing. The computing device 300 may be, but is not limited to, a workstation, a server, a desktop computer, a laptop computer, a tablet computer, a Personal Data Assistant (PDA), a smart phone, an on-board computer, or a combination thereof.

[0145] As shown in Fig. 3, the computing device 300 may include one or more elements that may be connected to or communicate with a bus 302 via one or more interfaces. The bus 302 may include, but is not limited to, an Industry Standard Architecture (ISA) bus, a Micro Channel Architecture (MCA) bus, an Enhanced ISA (EISA) bus, a Video Electronics Standards Association (VESA) local bus, and a Peripheral Component Interconnect (PCI) bus, among others. The computing device 300 may include, for example, one or more processors 304, one or more input devices 306, and one or more output devices 308. The one or more processors 304 may be any kind of processor and may include, but is not limited to, one or more universal processors or special

processors (such as a special processing chip). The processor 304 may correspond to, for example, the processing circuitry 201 in Fig. 2, and is configured to implement the functions of respective units of the system for detecting the distance to the front vehicle of the present disclosure. The input device 306 may be any type of input device capable of inputting information to a computing device and may include, but is not limited to, a mouse, a keyboard, a touch screen, a microphone, and/or a remote controller. The output device 308 may be any type of device capable of presenting information and may include, but is not limited to, a display, speakers, a video/audio output terminal, a vibrator, and/or a printer.

[0146] The computing device 300 may also include or be connected to a non-transitory storage device 314, which may be any non-transitory storage device that can implement data storage, and may include, but is not limited to, a disk drive, an optical storage device, solid-state memory, a floppy disk, a flexible disk, a hard disk, a magnetic tape, or any other magnetic medium, a compact disk, or any other optical medium, cache memory, and/or any other memory chip or module, and/or any other medium from which a computer can read data, instructions, and/or code. The computing device 300 may also include a Random Access Memory (RAM) 310 and a Read-Only Memory (ROM) 312. The ROM 312 may store programs, practical programs, or processes to be executed in a non-volatile manner. The RAM 310 may provide volatile data storage and store instructions related to the operation of the computing device 300. The computing device 300 may also include a network/bus interface 316 coupled to a data link 318. The network/bus interface 316 may be any type of device or system capable of enabling communication with external devices and/or networks and may include, but is not limited to, a modem, a network card, an infrared communication device, a wireless communication device, and/or a chipset (such as a Bluetooth[™] device, a 802.11 device, a WiFi device, a WiMax device, a cellular communication facility, etc.).

[0147] In addition, one or more embodiments of the present disclosure may be implemented as follows.

[0148] Scheme 1: a device for detecting a distance to a front vehicle, comprising:

- one or more processors;
- a memory having stored thereon computer-executable instructions that, when executed by the one or more processors, cause the one or more processors to:
 - acquire an RGB image and a depth image of a front view of a host vehicle;
 - set a target area frame in the RGB image;
 - extract size data corresponding to a plurality of vehicles in the RGB image;
 - for each of the plurality of vehicles:
 - determine a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;
 - calculate an overlap rate of the constraint frame of the vehicle and the target area frame;
 - calculate a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;
 - determine a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtain a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

[0149] Scheme 2: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

- simultaneously collect the RGB image and the depth image by

using a depth camera installed on the host vehicle; or

collect the RGB image by using a 2D camera installed on the host vehicle, and collect the depth image by using a millimeter wave radar/distance sensor installed on the host vehicle.

[0150] Scheme 3: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

construct a virtual coordinate system in the RGB image;

extract a coordinate of an upper left corner point of the vehicle in the RGB image based on the virtual coordinate system, and draw a rectangular constraint frame including the vehicle in the RGB image according to the size data of the vehicle.

[0151] Scheme 4: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

calculate an intersection over union IOU of the constraint frame of the vehicle and the target area frame by adopting an intersection over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$, as the overlap rate,

wherein, Car denotes an area of the constraint frame of the vehicle, and ROI denotes an area of the target area frame.

[0152] Scheme 5: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

calculate a normalized distance between the vehicle and the target area frame by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2},$$

wherein, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a predetermined target point in the target area frame, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

[0153] Scheme 6: in the device for detecting the distance to the front vehicle of Scheme 5, the target area frame is a trapezoidal area frame right in front of the host vehicle selected from the RGB images, and the target point is a center point of the target area frame.

[0154] Scheme 7: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

screen, from the plurality of vehicles, vehicles with the overlap rate larger than a first threshold value of overlap rate or the normalized distance smaller than a distance threshold value, as a first set of target vehicles;

screen, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

screen, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

extract a vehicle distance corresponding to the front target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

[0155] Scheme 8: in the device for detecting the distance to the front vehicle of Scheme 1, the computer-executable instructions, when executed by the one or more processors, cause the one or more processors to:

sequentially carry out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle,

wherein, the abnormal window detection processing detects an abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle distance values before and after the abnormal window in time windows.

[0156] All the above-mentioned optional technical solutions may be combined arbitrarily to form the optional embodiments of the present disclosure, and no further description is provided herein. In the several embodiments provided in the present disclosure, it should be understood that the disclosed method, apparatus and system may be implemented in other ways. For example, the above-described apparatus embodiments are merely illustrative, for example, the division of the modules is only a kind of logical functional division, there may be other division means in practical implementation, for example, multiple modules or components may be combined or integrated into another system, or some features may be omitted, or not performed.

[0157] It should be noted that in the description of the present disclosure, the terms "first", "second", and the like are used for descriptive purposes only and are not to be construed as indicating or implying a relative importance or order. Further, in the description of the present disclosure, unless otherwise specified, "a plurality" means two or more.

[0158] The various aspects, embodiments, implementations, or features of the foregoing examples may be used alone or in any combination. Various aspects of the foregoing embodiments may be implemented by software, hardware, or a combination of hardware and

software.

[0159] For example, the foregoing embodiments may be embodied as computer readable code on a computer readable medium. The computer readable medium is any data storage device that can store data which can thereafter be read by a computer system. Examples of a computer-readable medium include read-only memory, random-access memory, CD-ROMs, DVDs, magnetic tape, hard drives, solid-state drives, and optical data storage devices. The computer readable medium can also be distributed over network coupled computer systems so that the computer readable code is stored and executed in a distributed fashion.

[0160] For example, the foregoing embodiments may take the form of hardware circuitry. The hardware circuitry may include any combination of combinational logic circuits, clock storage devices (such as floppy disks, flip-flops, latches, etc.), finite state machines, memories such as static random access memories or embedded dynamic random access memories, custom designed circuitry, programmable logic arrays, etc..

[0161] Although the present disclosure has been described with reference to the embodiments, the scope of the present disclosure is not limited thereto, and any person skilled in the art can easily conceive of changes or substitutions within the technical scope of the present disclosure and should be covered by the scope of the present disclosure. Therefore, the protection scope of the present disclosure shall be subject to the protection scope of the claims.

What is claimed is:

1. A method for detecting a distance to a front vehicle, characterized by comprising:

acquiring an RGB image and a depth image of a front view of a host vehicle;

setting a target area frame in the RGB image;

extracting size data corresponding to a plurality of vehicles in the RGB image;

for each of the plurality of vehicles:

determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;

calculating an overlap rate of the constraint frame of the vehicle and the target area frame;

calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;

determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

2. The method of claim 1, characterized in that, the acquiring

an RGB image and a depth image of a front view of a host vehicle includes:

simultaneously collecting the RGB image and the depth image by using a depth camera installed on the host vehicle; or

collecting the RGB image by using a 2D camera installed on the host vehicle, and collecting the depth image by using a millimeter wave radar/distance sensor installed on the host vehicle.

3. The method of claim 1, characterized in that, the determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle includes:

constructing a virtual coordinate system in the RGB image;

extracting a coordinate of an upper left corner point of the vehicle in the RGB image based on the virtual coordinate system, and drawing a rectangular constraint frame including the vehicle in the RGB image according to the size data of the vehicle.

4. The method of claim 1, characterized in that, the calculating an overlap rate of the constraint frame of the vehicle and the target area frame includes:

calculating an intersection over union IOU of the constraint frame of the vehicle and the target area frame by adopting an intersection

over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$, as the overlap rate,

wherein, Car denotes an area of the constraint frame of the vehicle, and ROI denotes an area of the target area frame.

5. The method of claim 1, characterized in that, the calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image includes:

calculating a normalized distance between the vehicle and the target area frame by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2},$$

wherein, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a predetermined target point in the target area frame, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

6. The method of claim 5, characterized in that, the target area frame is a trapezoidal area frame right in front of the host vehicle selected from the RGB images, and the target point is a center point of the target area frame.

7. The method of claim 1, characterized in that, the determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth

image includes:

screening, from the plurality of vehicles, vehicles with the overlap rate larger than a first threshold value of overlap rate or the normalized distance smaller than a distance threshold value, as a first set of target vehicles;

screening, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

screening, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

extracting a vehicle distance corresponding to the front target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

8. The method of claim 1, characterized in that, the method further comprises:

sequentially carrying out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle,

wherein, the abnormal window detection processing detects an

abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle distance values before and after the abnormal window in time windows.

9. A system for detecting a distance to a front vehicle, characterized by comprising:

an image acquisition unit configured to acquire an RGB image and a depth image of a front view of a host vehicle;

a target area frame setting unit configured to preset a target area frame in the RGB image;

a size data extraction unit configured to extract size data corresponding to a plurality of vehicles in the RGB image;

a constraint frame determination unit configured to determine, for each of the plurality of vehicles, a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;

an overlap rate calculation unit configured to calculate, for each of the plurality of vehicles, an overlap rate of the constraint frame of the vehicle and the target area frame;

a distance calculation unit configured to calculate, for each of the plurality of vehicles, a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;

a front target vehicle determination unit configured to determine

a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtain a vehicle distance between the front target vehicle and the host vehicle according to the depth image.

10. The system of claim 9, characterized in that, the image acquisition unit is configured to:

simultaneously collect the RGB image and the depth image by using a depth camera installed on the host vehicle; or

collect the RGB image by using a 2D camera installed on the host vehicle, and collect the depth image by using a millimeter wave radar/distance sensor installed on the host vehicle.

11. The system of claim 9, characterized in that, the constraint frame determination unit is configured to:

construct a virtual coordinate system in the RGB image;

extract a coordinate of an upper left corner point of the vehicle in the RGB image based on the virtual coordinate system, and draw a rectangular constraint frame including the vehicle in the RGB image according to the size data of the vehicle.

12. The system of claim 9, characterized in that, the overlap rate calculation unit is configured to:

calculate an intersection over union IOU of the constraint frame of the vehicle and the target area frame by adopting an intersection

over union formula $IOU = \frac{Car \cap ROI}{Car \cup ROI}$, as the overlap rate,

wherein, *Car* denotes an area of the constraint frame of the vehicle, and *ROI* denotes an area of the target area frame.

13. The system of claim 9, characterized in that, the distance calculation unit is configured to:

calculate a normalized distance between the vehicle and the target area frame by adopting a normalized distance formula

$$dist_norm = \sqrt{\left(\frac{Car.x - Target.x}{Car.width}\right)^2 + \left(\frac{Car.y - Target.y}{Car.height}\right)^2},$$

wherein, *Car.x* denotes an abscissa value of a center point of the constraint frame, *Car.y* denotes an ordinate value of the center point of the constraint frame, *Target.x* denotes an abscissa value of a predetermined target point in the target area frame, *Target.y* denotes an ordinate value of the target point, *Car.width* denotes width data of the vehicle, and *Car.height* denotes height data of the vehicle.

14. The system of claim 13, characterized in that, the target area frame is a trapezoidal area frame right in front of the host vehicle selected from the RGB images, and the target point is a center point of the target area frame.

15. The system of claim 9, characterized in that, the front target vehicle determination unit is configured to:

screen, from the plurality of vehicles, vehicles with the overlap rate larger than a first threshold value of overlap rate or the

normalized distance smaller than a distance threshold value, as a first set of target vehicles;

screen, from the first set of target vehicles, vehicles with the overlap rate larger than a second threshold value of overlap rate, as a second set of target vehicles, wherein the second threshold value of overlap rate is smaller than the first threshold value of overlap rate;

screen, from the second set of target vehicles, a vehicle with the maximum overlap rate, as the front target vehicle;

extract a vehicle distance corresponding to the front target vehicle from the depth image as the vehicle distance between the front target vehicle and the host vehicle.

16. The system of claim 9, characterized in that, the system further comprises:

a motion filtering unit configured to sequentially carry out median filtering, abnormal window detection processing and Kalman filtering on the vehicle distance between the front target vehicle and the host vehicle in a time window with a predetermined length centered at the current time, to obtain an optimized vehicle distance between the front target vehicle and the host vehicle,

wherein, the abnormal window detection processing detects an abnormal window in the time window with the predetermined length, and replaces a vehicle distance value in the abnormal window with a vehicle distance fitting result which is calculated based on vehicle

distance values before and after the abnormal window in time windows.

17. A computer-readable storage medium on which a computer program is stored, characterized in that, when the program is executed by a processor, causes the processor to perform the following processes:

- acquiring an RGB image and a depth image of a front view of a host vehicle;

- setting a target area frame in the RGB image;

- extracting size data corresponding to a plurality of vehicles in the RGB image;

- for each of the plurality of vehicles:

- determining a constraint frame of the vehicle in the RGB image according to the size data of the vehicle;

- calculating an overlap rate of the constraint frame of the vehicle and the target area frame;

- calculating a normalized distance between the vehicle and the target area frame based on the size data of the vehicle, a position of the constraint frame of the vehicle in the RGB image, and a position of the target area frame in the RGB image;

- determining a front target vehicle from the plurality of vehicles according to the overlap rate and the normalized distance corresponding to each of the plurality of vehicles, and obtaining a vehicle distance between the front target vehicle and the host vehicle according to the depth image.