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Vehicle controller, method, and computer program for vehicle control

Abstract

A vehicle controller includes a processor configured to detect, ahead of a host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane, detect one or more other vehicles traveling on the adjacent lane, determine whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section, and control acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle. The first and second vehicles are among the detected vehicles.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
(1) This application claims priority to Japanese Patent Application No. 2022-127313 filed on Aug. 9, 2022, the entire contents of which are herein incorporated by reference.
FIELD

(2) The present disclosure relates to a vehicle controller, a method, and a computer program for vehicle control.

BACKGROUND

(3) Techniques to adjust the distance between vehicles in autonomous driving of a vehicle or driving support to a vehicle driver on the assumption that another vehicle will cut into a lane being traveled by the vehicle from an adjacent lane have been proposed (see Japanese Unexamined Patent Publications JP2017-87923A and JP2013-177054A).

(4) A driving support device disclosed in JP2017-87923A determines whether a host vehicle lane being traveled by a host vehicle adjoins a merging lane or a reduced lane, when merging or reduction in the number of lanes is detected ahead of the host vehicle. The device increases a preset distance between vehicles only in the case where the host vehicle lane adjoins such a merging lane or a reduced lane and where, on the merging lane or the reduced lane, a vehicle slower than the host vehicle is detected at least a predetermined distance ahead of the host vehicle or a vehicle faster than the host vehicle is detected between a position within the predetermined distance and a position moving with the host vehicle.

(5) A controller of distance between vehicles disclosed in JP2013-177054A determines whether the location of detection is a merging point, when another vehicle is detected beside a host vehicle. When the location is a merging point, the controller executes control to yield right-of-way, assuming that the detected vehicle will probably cut in, and increases the distance between vehicles while cutting in is not finished. When a following vehicle that tries to cut in front of the host vehicle is further detected beside the host vehicle, the controller reduces the distance between vehicles; when such a following vehicle is not detected, the controller resets the distance between vehicles.

SUMMARY

(6) When multiple other vehicles are traveling on an adjacent lane merging with a host vehicle lane, control of a host vehicle to yield to a first vehicle traveling ahead among the multiple other vehicles may result in the host vehicle traveling side by side with a second vehicle following the first vehicle. In such a case, the host vehicle may obstruct a lane change of the second vehicle to the host vehicle lane, or make the driver of the second vehicle mistakenly believe that the host vehicle also yields to the second vehicle. In particular, if the driver of the second vehicle mistakenly believes that right-of-way is yielded, the second vehicle tries to cut in front of the host vehicle, which may cause danger. Additionally, in terms of collision avoidance, it is not desirable that the host vehicle detects the second vehicle trying to cut in front of the host vehicle and then reduces the distance between vehicles, as in the technique disclosed in JP2013-177054A.

(7) It is an object of the present disclosure to provide a vehicle controller that can appropriately adjust the positional relationship between a host vehicle and another vehicle traveling on an adjacent lane merging with a lane being traveled by the host vehicle.

(8) According to an embodiment, a vehicle controller is provided. The vehicle controller includes a processor configured to: detect, ahead of a host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane, detect one or more other vehicles traveling on the adjacent lane, determine whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section, and control acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles.

(9) In some embodiments, the processor of the vehicle controller controls acceleration or deceleration of the host vehicle so that space between the host vehicle and the first vehicle is smaller than space between the host vehicle and the second vehicle.

(10) Alternatively, in some embodiments, the processor controls acceleration or deceleration of the

host vehicle, depending on space between the first vehicle and the second vehicle, so that the ratio of space between the host vehicle and the first vehicle to space between the host vehicle and the second vehicle is constant.

(11) According to another embodiment, a method for vehicle control is provided. The method includes detecting, ahead of a host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane; detecting one or more other vehicles traveling on the adjacent lane; determining whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section; and controlling acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles.

(12) According to still another embodiment, a non-transitory recording medium that stores a computer program for vehicle control is provided. The computer program includes instructions causing a processor mounted on a host vehicle to execute a process including detecting, ahead of the host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane; detecting one or more other vehicles traveling on the adjacent lane; determining whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section; and controlling acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles.

(13) The vehicle controller according to the present disclosure has an advantageous effect of being able to appropriately adjust the positional relationship between the host vehicle and another vehicle traveling on an adjacent lane merging with a lane being traveled by the host vehicle.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** schematically illustrates the configuration of a vehicle control system equipped with a vehicle controller.

(2) FIG. **2** illustrates the hardware configuration of an electronic control unit, which is an embodiment of the vehicle controller.

(3) FIG. **3** is a functional block diagram of a processor of the electronic control unit, related to a vehicle control process.

(4) FIG. **4**A is a schematic diagram for explaining the vehicle control process according to the embodiment.

(5) FIG. **4**B is a schematic diagram for explaining the vehicle control process according to the embodiment.

(6) FIG. **5** is an operation flowchart of the vehicle control process.

DESCRIPTION OF EMBODIMENTS

(7) A vehicle controller, a method for vehicle control executed by the vehicle controller, and a computer program for vehicle control will now be described with reference to the attached drawings. In a merging section where an adjacent lane which is adjacent to a host vehicle lane being traveled by a host vehicle merges into the host vehicle lane, the vehicle controller adjusts the positional relationship between another vehicle traveling on the adjacent lane and the host vehicle. More specifically, the vehicle controller determines whether to allow one or more other vehicles traveling in the merging section to precede the host vehicle, and controls acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a

second vehicle following a first vehicle that is the rearmost of the other vehicles allowed to precede the host vehicle. In this way, the vehicle controller prevents obstructing a lane change to the host vehicle lane of another vehicle traveling in the merging section to which the host vehicle does not intend to yield right-of-way, and prevents making the driver of the other vehicle mistakenly believe that right-of-way is yielded.
(8) FIG. **1** schematically illustrates the configuration of a vehicle control system equipped with the vehicle controller. FIG. **2** illustrates the hardware configuration of an electronic control unit, which is an embodiment of the vehicle controller. In the present embodiment, the vehicle control system **1** is mounted on a vehicle **10**, which is an example of the host vehicle, and controls the vehicle **10**. The vehicle control system **1** includes a camera **2**, a GPS receiver **3**, a storage device **4**, and an electronic control unit (ECU) **5**, which is an example of the vehicle controller. The camera **2**, the GPS receiver **3**, and the storage device **4** are communicably connected to the ECU **5** via an in-vehicle network conforming to a standard such as a controller area network. The vehicle control system **1** may further include a range sensor (not illustrated) that measures the distances from the vehicle **10** to objects around the vehicle **10**, such as LiDAR or radar; a wireless communication terminal (not illustrated) for communicating with another device; and a navigation device (not illustrated) for setting a planned travel route of the vehicle **10**.
(9) The camera **2**, which is an example of a sensor for detecting the situation around the vehicle **10**, includes a two-dimensional detector constructed from an array of optoelectronic transducers, such as CCD or C-MOS, having sensitivity to visible light and a focusing optical system that forms an image of a target region on the two-dimensional detector. The camera **2** is mounted, for example, in the interior of the vehicle **10** so as to be oriented, for example, to the front of the vehicle **10**. The camera **2** takes pictures of a region in front of the vehicle **10** every predetermined capturing period (e.g., 1/30 to 1/10 seconds), and generates images representing the region. Each image obtained by the camera **2** is an example of a sensor signal. The vehicle **10** may include multiple cameras taking pictures in different orientations or having different focal lengths. For example, the vehicle **10** may include cameras for taking pictures of regions in front of the vehicle **10** and behind the vehicle **10**. In some embodiment, the vehicle **10** includes one or more cameras **2** (and range sensors) so that all the surroundings of the vehicle **10** can be detected with the cameras **2** or with the cameras **2** and the range sensors.
(10) Every time an image is generated, the camera **2** outputs the generated image to the ECU **5** via the in-vehicle network.
(11) The GPS receiver **3** receives GPS signals from GPS satellites at predetermined intervals, and determines the position of the vehicle **10**, based on the received GPS signals. The GPS receiver **3** outputs positioning information indicating the result of determination of the position of the vehicle **10** based on the GPS signals to the ECU **5** via the in-vehicle network at predetermined intervals. Instead of the GPS receiver, the vehicle **10** may include a receiver that receives positioning signals from satellites of another satellite positioning system to determine the position of the vehicle **10**.
(12) The storage device **4**, which is an example of a storage unit, includes, for example, a hard disk drive, a nonvolatile semiconductor memory, or an optical medium and an access device therefor. The storage device **4** stores a high-precision map, which is an example of map information. The high-precision map includes information indicating merging sections included in a predetermined region represented in the high-precision map. The high-precision map further includes the number and width of lanes of each road section and features on or around each road section. Examples of features represented in a high-precision map include road markings such as lane-dividing lines, various traffic signs, and structures such as curbstones, guardrails, and poles.
(13) The storage device **4** may further include a processor for executing, for example, a process to update a high-precision map and a process related to a request from the ECU **5** to read out a high-precision map. For example, every time the vehicle **10** moves a predetermined distance, the storage device **4** may transmit a request to obtain a high-precision map, together with the current position

of the vehicle **10**, to a map server via the wireless communication terminal (not illustrated). The storage device **4** may receive a high-precision map of a predetermined region around the current position of the vehicle **10** from the map server via the wireless communication terminal. Upon receiving a request from the ECU **5** to read out a high-precision map, the storage device **4** cuts out that portion of a high-precision map stored therein which includes the current position of the vehicle **10** and which represents a region smaller than the predetermined region, and outputs the cutout portion to the ECU **5** via the in-vehicle network.

(14) The ECU **5** executes autonomous driving control of the vehicle **10** or driving support to the driver of the vehicle **10**. In particular, the ECU **5** controls acceleration or deceleration of the vehicle **10** during travel of the vehicle **10** in a merging section so as to automatically adjust the positional relationship between the vehicle **10** and another vehicle traveling in an area around the vehicle **10**.

(15) As illustrated in FIG. **2**, the ECU **5** includes a communication interface **21**, a memory **22**, and a processor **23**. The communication interface **21**, the memory **22**, and the processor **23** may be configured as separate circuits or a single integrated circuit.

(16) The communication interface **21** includes an interface circuit for connecting the ECU **5** to the in-vehicle network. Every time an image is received from the camera **2**, the communication interface **21** passes the received image to the processor **23**. Every time positioning information is received from the GPS receiver **3**, the communication interface **21** passes the positioning information to the processor **23**. In addition, the communication interface **21** passes a high-precision map read from the storage device **4** to the processor **23**. Further, the communication interface **21** passes various types of information received by the wireless communication terminal (not illustrated) from another device and ranging signals received from the range sensor (not illustrated) to the processor **23**.

(17) The memory **22**, which is another example of a storage unit, includes, for example, volatile and nonvolatile semiconductor memories, and stores various types of data used in a vehicle control process executed by the processor **23**. For example, the memory **22** stores parameters of the camera **2** such as the focal length, the orientation, and the mounted position as well as various parameters for specifying a classifier used for detecting objects around the vehicle **10**. The memory **22** further stores positioning information, images of the surroundings of the vehicle **10**, ranging signals, and a high-precision map. Further, the memory **22** temporarily stores various types of data generated during the vehicle control process.

(18) The processor **23** includes one or more central processing units (CPUs) and a peripheral circuit thereof. The processor **23** may further include another operating circuit, such as a logic-arithmetic unit, an arithmetic unit, or a graphics processing unit. The processor **23** executes the vehicle control process on the vehicle **10** at predetermined intervals.

(19) FIG. **3** is a functional block diagram of the processor **23**, related to the vehicle control process. The processor **23** includes a merging section detection unit **31**, a vehicle detection unit **32**, a determination unit **33**, and a vehicle control unit **34**. These units included in the processor **23** are functional modules, for example, implemented by a computer program executed by the processor **23**, or may be dedicated operating circuits provided in the processor **23**.

(20) The merging section detection unit **31** detects, ahead of the vehicle **10**, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the vehicle **10** merges into the host vehicle lane. Such a merging section may be, for example, a section in which a lane, for example, from an interchange merges with a main lane of an expressway, which is a host vehicle lane (the former lane will be referred to simply as a “merging lane” below), i.e., a section in which a lane change can be made from a merging lane to a main lane. Alternatively, a merging section may be a subsection having a predetermined length (e.g., several dozen to several hundred meters) and extending to an endpoint beyond which vehicles cannot travel on a lane adjacent to a host vehicle lane, in a road section where the number of lanes decreases because of the structure of the road or traffic restrictions, for example, caused by roadwork. In this case, the adjacent lane on

which vehicles cannot travel beyond the endpoint is a merging lane merging with the host vehicle lane.
(21) First, the merging section detection unit **31** detects a host vehicle lane being traveled by the vehicle **10**. For example, the merging section detection unit **31** refers to the current position of the vehicle **10** indicated by the latest positioning information and a high-precision map to detect a lane including the current position of the vehicle **10** among individual lanes of a road section represented in the high-precision map as a host vehicle lane. Alternatively, the merging section detection unit **31** may compare the latest image obtained by the camera **2** with a high-precision map to detect a host vehicle lane. In this case, the merging section detection unit **31** detects individual features around the vehicle **10** from the image, and projects the detected individual features onto the high-precision map, assuming the position and orientation of the vehicle **10**. The merging section detection unit **31** then calculates the degree of matching between the individual features detected from the image and corresponding features represented in the high-precision map (e.g., the sum of squares of the distances between the detected individual features and the corresponding features in the high-precision map or its inverse). While variously changing the assumed position and orientation of the vehicle **10**, the merging section detection unit **31** identifies the position and orientation of the vehicle **10** for the case where the detected individual features match the corresponding features represented in the high-precision map the best. The merging section detection unit **31** then estimates the current position and orientation of the vehicle **10** to be the position and orientation of the vehicle **10** for the case where the detected individual features match the corresponding features represented in the high-precision map the best. The merging section detection unit **31** identifies a lane including the current position of the vehicle **10** as a host vehicle lane being traveled by the vehicle **10**, by referring to the high-precision map.
(22) To detect features represented in an image, the merging section detection unit **31** inputs the image into a classifier that has been trained to detect a feature. As such a classifier, the merging section detection unit **31** can use a deep neural network (DNN) having architecture of a convolutional neural network (CNN) type, such as Single Shot MultiBox Detector (SSD) or Faster R-CNN. Alternatively, as such a classifier, the merging section detection unit **31** may use a DNN having architecture of a self-attention network (SAN) type, such as Vision Transformer. Such a classifier is trained in advance with a large number of training images representing features to be detected, in accordance with a predetermined training technique, such as backpropagation.
(23) Upon identification of a host vehicle lane, the merging section detection unit **31** determines whether an adjacent lane merges into the host vehicle lane in a section from the current position of the vehicle **10** to a predetermined distance away along the travel direction of the vehicle **10**, by referring to the current position of the vehicle **10** indicated by the latest positioning information and a high-precision map. When such an adjacent lane exists, the merging section detection unit **31** detects a section in which a lane change can be made from the adjacent lane to the host vehicle lane, as a merging section.
(24) Alternatively, the merging section detection unit **31** determines whether traffic information received via the wireless communication terminal (not illustrated) indicates that traffic restrictions prohibiting travel on an adjacent lane are imposed on a section from the current position of the vehicle **10** to a predetermined distance away. When such traffic restrictions are indicated, the merging section detection unit **31** detects a predetermined length of section that ends at the location of the traffic restrictions, as a merging section. Alternatively, the merging section detection unit **31** may detect a signboard indicating that travel on a lane adjacent to the host vehicle lane is restricted or a sign indicating that an adjacent lane merges into the host vehicle lane, from an image obtained by the camera **2**. When such a signboard is detected, the merging section detection unit **31** may detect a predetermined length of section that ends at the location of the traffic restrictions indicated by the signboard, as a merging section. Similarly, when such a sign is detected, the merging section detection unit **31** may detect a section indicated by the sign in which a lane change can be made

from the adjacent lane to the host vehicle lane, as a merging section. The merging section detection unit **31** can detect such a signboard or a sign by inputting an image into a classifier that has been trained to detect a signboard or a sign. As such a classifier, the merging section detection unit **31** can use a classifier similar to the classifier for feature detection described in relation to detection of the host vehicle lane. Alternatively, the classifier for feature detection, which is used for detecting the host vehicle lane, may be trained in advance to detect a signboard or a sign too.

(25) The merging section detection unit **31** notifies information indicating the position and length of the detected merging section to the vehicle detection unit **32**, the determination unit **33**, and the vehicle control unit **34**.

(26) The vehicle detection unit **32** detects one or more other vehicles traveling on the lane adjacent to the host vehicle lane in the merging section. The vehicle detection unit **32** may further detect another vehicle traveling on the adjacent lane in a predetermined section nearer to the host vehicle than the merging section. The predetermined section may be, for example, a section of several dozen meters in length that ends at the start point of the merging section.

(27) The vehicle detection unit **32** detects another vehicle, for example, by inputting an image generated by the camera **2** whose capture area includes the merging section and the predetermined section into a classifier that has been trained to detect a vehicle. As such a classifier, the vehicle detection unit **32** can use a classifier similar to the classifier for feature detection described in relation to detection of the host vehicle lane. In the case where the vehicle **10** is equipped with multiple cameras **2**, the vehicle detection unit **32** may identify a camera **2** whose capture area includes the merging section and the predetermined section, based on the detected merging section and the current position of the vehicle **10**. The vehicle detection unit **32** then detects another vehicle traveling in the merging section or the predetermined section from an image generated by the identified camera **2**. Since positions in an image correspond one-to-one to directions viewed from the camera **2**, the vehicle detection unit **32** determines that the detected vehicle in an image is traveling in the merging section or the predetermined section, when the direction corresponding to a reference point in the region representing the detected vehicle is within the area of the merging section or the predetermined section viewed from the current position of the vehicle **10**.

(28) In the case where the vehicle **10** is equipped with one or more range sensors (not illustrated), the vehicle detection unit **32** may detect another vehicle, based on a ranging signal generated by a range sensor whose measurement area includes the merging section and the predetermined section. In this case also, the vehicle detection unit **32** detects another vehicle by inputting a ranging signal into a classifier that has been trained to detect a vehicle from a ranging signal. As such a classifier, the vehicle detection unit **32** can use a DNN having architecture of a CNN or SAN type, as in detection of a vehicle from an image.

(29) The vehicle detection unit **32** may further detect another vehicle traveling on the host vehicle lane ahead of the vehicle **10** as a vehicle ahead by inputting an image generated by the camera **2** that takes pictures of a region in front of the vehicle **10** or a ranging signal generated by the range sensor into the classifier. Specifically, the vehicle detection unit **32** determines the detected vehicle whose position in the image or the ranging signal is within a predetermined area corresponding to the region in front of the vehicle **10**, as a vehicle ahead. Alternatively, the vehicle detection unit **32** may further detect lane-dividing lines from the image, and detect a region sandwiched between the lane-dividing lines nearest to the vehicle **10** on the left and right of the vehicle **10** of the detected lane-dividing lines, as the host vehicle lane. The vehicle detection unit **32** may then determine the detected vehicle represented in a region in the image whose bottom overlaps the region representing the host vehicle lane in the image to a predetermined degree or more, as a vehicle ahead.

(30) Every time another vehicle is detected on the adjacent lane, the vehicle detection unit **32** notifies the determination unit **33** and the vehicle control unit **34** of the position at which the detected vehicle is represented in the image or the ranging signal. Similarly, every time a vehicle

ahead is detected on the host vehicle lane, the vehicle detection unit **32** notifies the determination unit **33** and the vehicle control unit **34** of the position at which the detected vehicle ahead is represented in the image or the ranging signal.

(31) The determination unit **33** determines whether to allow the detected vehicle (hereafter the “target vehicle”) to precede the vehicle **10** at a lane change of the target vehicle to the host vehicle lane in the merging section, when the vehicle **10** reaches a predetermined position nearer to the host vehicle than the merging section. The predetermined position may be, for example, a position that is a predetermined distance nearer to the current position of the vehicle **10** than the start position or the end position of the merging section. In some embodiments, when the predetermined position is set with respect to the end position of the merging section, the predetermined distance is set longer than the merging section.

(32) The determination unit **33** determines whether to allow the target vehicle to precede the vehicle **10**, based on the relative speed and the positional relationship between the target vehicle and the vehicle **10**. More specifically, when (i) the target vehicle precedes the vehicle **10** before reaching a reference position and is faster than the vehicle **10**, the determination unit **33** determines to allow the target vehicle to precede the vehicle **10**. In other words, the determination unit **33** determines to yield to the target vehicle. Conversely, when (ii) the vehicle **10** precedes the target vehicle at a reference position and is faster than the target vehicle, the determination unit **33** determines to allow the vehicle **10** to precede the target vehicle. In other words, the determination unit **33** determines not to yield to the target vehicle. The reference position may be, for example, a position nearer to the host vehicle than the end position of the merging section by a minimum distance required for a target vehicle to make a lane change from an adjacent lane to the host vehicle lane or the minimum distance plus a predetermined offset distance.

(33) When neither (i) nor (ii) above is satisfied (e.g., when the target vehicle precedes the vehicle **10** at the reference position and the vehicle **10** is faster than the target vehicle), the determination unit **33** determines to control the speed of the vehicle **10** to maintain the status quo.

(34) The determination unit **33** refers to the current speeds and acceleration of the vehicle **10** and the target vehicle, the relative distance between the vehicle **10** and the target vehicle in the travel direction of the vehicle **10**, and the current position of the vehicle **10**. Based on these pieces of information, the determination unit **33** estimates the speed values of the vehicle **10** and the target vehicle and the relative distances between the vehicle **10** and the target vehicle at respective times until the target vehicle and the vehicle **10** reach the reference position. The acceleration herein also includes deceleration. More specifically, the vehicle **10** or the target vehicle decelerates when the acceleration is a negative value, and the vehicle **10** or the target vehicle accelerates when the acceleration is a positive value. In addition, the determination unit **33** predicts the positions of the vehicle **10** and the target vehicle at respective times until the target vehicle and the vehicle **10** reach the reference position. In the case where the target vehicle precedes the vehicle **10** by at least a predetermined length and is faster than the vehicle **10** at a certain time, the determination unit **33** determines that condition (i) is satisfied. The predetermined length is set, for example, at zero to dozen meters.

(35) As the current speed of the vehicle **10**, the determination unit **33** uses the latest speed measured by a vehicle speed sensor (not illustrated) of the vehicle **10**. Similarly, as the current acceleration of the vehicle **10**, the determination unit **33** uses the latest acceleration measured by an acceleration sensor (not illustrated) of the vehicle. The determination unit **33** estimates the speed values of the vehicle **10** at respective times, which are assumed to vary by uniformly accelerated motion, and predicts the positions of the vehicle **10** at respective times. Similarly, the determination unit **33** estimates the speed values of the target vehicle at respective times, which are assumed to vary by uniformly accelerated motion, and predicts the positions of the target vehicle at respective times. The determination unit **33** estimates the current speed of the target vehicle by estimating the positions of the target vehicle at the times of generation of those images or ranging signals obtained

in the most recent certain period from which the target vehicle is detected. The bottom position of a target vehicle in an image corresponds one-to-one to the direction viewed from the camera **2** to the position at which the target vehicle is in contact with the road surface. Thus the determination unit **33** can estimate the distance and direction from the vehicle **10** to the target vehicle, based on the bottom position of the region representing the target vehicle in the image and parameters of the camera **2**, such as the height of the mounted position and the focal length of the camera **2**. When the target vehicle is detected from a ranging signal, the determination unit **33** can estimate the distance and direction from the vehicle **10** to the target vehicle based on the direction and distance where the target vehicle is represented in the ranging signal. The determination unit **33** can estimate the positions of the target vehicle at the times of generation of the images or the ranging signals in the most recent certain period, based on the positions of the vehicle **10** and the directions and distances viewed from the vehicle **10** to the target vehicle at the times of generation of the images or the ranging signals. The determination unit **33** estimates the current speed of the target vehicle by approximating the changes in the estimated positions of the target vehicle at the times of generation of the images or the ranging signals in the most recent certain period on the assumption that the target vehicle moves at a uniform acceleration. The determination unit **33** determines the acceleration obtained by the approximation as the acceleration of the target vehicle. When the target vehicle merges with the traffic on the host vehicle lane, the speed of the target vehicle is assumed to be substantially equal to that of the vehicle **10**. Thus the determination unit **33** may determine the acceleration of the target vehicle on the assumption that the speed of the target vehicle at the reference position is equal to that of the vehicle **10** at this time and that the target vehicle moves at a uniform acceleration. In addition, the determination unit **33** determines the relative distance between the target vehicle and the vehicle **10** in the travel direction of the vehicle **10**, based on the direction and distance to the target vehicle estimated on the basis of the latest image or ranging signal from which the target vehicle is detected. Further, the determination unit **33** uses the position of the vehicle **10** indicated by the latest positioning information obtained by the GPS receiver **3** as the current position of the vehicle **10**. Alternatively, the determination unit **33** may determine the current position of the vehicle **10**, based on comparison of an image with a high-precision map, as described in relation to the merging section detection unit **31**. Alternatively, when the current position of the vehicle **10** is determined by the merging section detection unit **31**, the determination unit **33** may obtain the current position of the vehicle **10** from the merging section detection unit **31**.
(36) In the case where the vehicle **10** precedes the target vehicle and the estimated speed of the vehicle **10** is greater than that of the target vehicle at a predicted time when the target vehicle or the vehicle **10** reaches the reference position, the determination unit **33** determines that condition (ii) is satisfied.
(37) When multiple other vehicles traveling in the merging section or the predetermined section are detected in an image, the determination unit **33** applies a tracking process, such as the KLT method, to vehicle regions representing the detected vehicles in time-series images obtained by the camera **2**. In this way, the determination unit **33** tracks each detected vehicle to associate vehicle regions representing the same detected vehicle in the time-series images with each other. To this end, the determination unit **33** applies, for example, a filter for extracting feature points, such as SIFT or Harris operator, to a vehicle region of interest in an image of interest, thereby extracting feature points from the vehicle region. The determination unit **33** then identifies those points in the vehicle regions in the images obtained earlier or later than the image of interest which correspond to the feature points in accordance with the applied tracking technique, thereby calculating optical flow. Alternatively, the determination unit **33** may apply another tracking technique applied for tracking a moving object detected from an image to the vehicle regions in the time-series images, thereby associating the vehicle regions representing the same detected vehicle with each other. When multiple other vehicles are detected from a ranging signal, the determination unit **33** may also track

each detected vehicle by applying a similar tracking process. For each detected vehicle traveling in the merging section, the determination unit **33** determines whether conditions (i) or (ii) above is satisfied to determine whether to yield right-of-way to the detected vehicle. When determining not to yield to one of the detected vehicles, the determination unit **33** also determines not to yield to the other vehicles following the one of the detected vehicles.

(38) The determination unit **33** notifies the vehicle control unit **34** of the predicted positions and the estimated speed values at respective times of the rearmost of the detected vehicles that are traveling in the merging section or the predetermined section and to which the determination unit **33** has determined to yield right-of-way (first vehicle). The determination unit **33** further notifies the vehicle control unit **34** of the predicted positions and the estimated speed values at respective times of a second vehicle following the first vehicle among the detected vehicles traveling in the merging section or the predetermined section. In the case where the first vehicle is not detected and where there is another vehicle satisfying neither condition (i) nor (ii) above, the determination unit **33** further notifies the vehicle control unit **34** that such a vehicle exists.

(39) The vehicle control unit **34** controls acceleration or deceleration of the vehicle **10**. In the present embodiment, the vehicle control unit **34** sets target acceleration or deceleration so as to make space where the first vehicle to which right-of-way is yielded will enter the host vehicle lane ahead of the vehicle **10**. In addition, the vehicle control unit **34** sets the target acceleration or deceleration so that the rear end of the vehicle **10** is ahead of the front end of the second vehicle following the first vehicle. In the following, acceleration and deceleration will be collectively referred to as acceleration, similarly to the acceleration in the description of the determination unit **33**.

(40) Specifically, the vehicle control unit **34** refers to the remaining distance from the current position of the vehicle **10** to the reference position, the speed of the vehicle **10**, and the predicted positions of the first vehicle at respective times, thereby determining the upper limit of the target acceleration of the vehicle **10** so as to make space where the first vehicle can enter ahead of the vehicle **10** before the first vehicle reaches the reference position. In addition, the vehicle control unit **34** refers to the remaining distance from the current position of the vehicle **10** to the reference position, the speed of the vehicle **10**, and the predicted positions of the second vehicle at respective times, thereby determining the lower limit of the target acceleration of the vehicle **10** such that the rear end of the vehicle **10** gets ahead of the front end of the second vehicle before the first vehicle reaches the reference position. When the absolute value of the upper limit of the target acceleration exceeds a predetermined limit value, the vehicle control unit **34** may set the upper limit so that the absolute value of the upper limit is not greater than the predetermined limit value. Similarly, when the absolute value of the lower limit of the target acceleration exceeds a predetermined limit value, the vehicle control unit **34** may set the lower limit so that the absolute value of the lower limit is not greater than the predetermined limit value. The vehicle control unit **34** then sets the target acceleration of the vehicle **10** below the upper limit and above the lower limit. More specifically, the vehicle control unit **34** may set the target acceleration of the vehicle **10** so that the space between the rear end of the first vehicle and the front end of the vehicle **10** (i.e., the space between the first vehicle and the host vehicle) becomes smaller than the space between the front end of the second vehicle and the rear end of the vehicle **10** (i.e., the space between the host vehicle and the second vehicle) before the first vehicle reaches the reference position. Alternatively, the vehicle control unit **34** may set the target acceleration of the vehicle **10** so that the space between the rear end of the first vehicle and the front end of the vehicle **10** becomes equal to the space between the front end of the second vehicle and the rear end of the vehicle **10** before the first vehicle reaches the reference position.

(41) When notified by the determination unit **33** that the first vehicle is not detected and there is another vehicle satisfying neither condition (i) nor (ii) above, the vehicle control unit **34** controls acceleration of the vehicle **10** so that the other vehicle can decide the position of merging on its

own initiative. For example, the vehicle control unit **34** sets the target acceleration of the vehicle **10** so as to keep the distance between the vehicle **10** and a vehicle ahead above a predetermined distance and to keep the speed of the vehicle **10** as uniform as possible below a set vehicle speed. Thus, when the vehicle ahead decelerates and the distance between the vehicle ahead and the vehicle **10** is about to fall below the predetermined distance, the vehicle control unit **34** sets the target acceleration so as to decelerate the vehicle **10**. Conversely, when the vehicle ahead accelerates and the distance between the vehicle ahead and the vehicle **10** increases, the vehicle control unit **34** sets the target acceleration so as to keep the speed of the vehicle **10** constant below a set vehicle speed.

(42) The vehicle control unit **34** sets the degree of accelerator opening so that the actual acceleration of the vehicle **10** is equal to the target acceleration. The vehicle control unit **34** then determines the amount of fuel injection according to the set degree of accelerator opening, and outputs a control signal depending on the amount of fuel injection to a fuel injector of an engine of the vehicle **10**. Alternatively, the vehicle control unit **34** determines electric power to be supplied to a motor according to the set degree of accelerator opening, and controls a driving circuit of the motor so that the determined electric power is supplied to the motor. In addition, the vehicle control unit **34** sets the amount of braking as necessary, and outputs a control signal depending on the set amount of braking to the brake of the vehicle **10**.

(43) FIGS. **4**A and **4**B are schematic diagrams for explaining the vehicle control process according to the present embodiment. In both of FIGS. **4**A and **4**B, a first vehicle **410** and a second vehicle **420** following the first vehicle **410** are traveling in a merging section **402** where an adjacent lane **401** merges into a host vehicle lane **400**. In this example, it is determined that the first vehicle **410** is allowed to precede the vehicle **10**, and that the second vehicle **420** is not allowed to precede the vehicle **10**.

(44) In the example illustrated in FIG. **4**A, the target acceleration of the vehicle **10** is set so that the space d**1** between the front end of the vehicle **10** and the rear end of the first vehicle **410** becomes smaller than the space d**2** between the rear end of the vehicle **10** and the front end of the second vehicle **420** before the first vehicle **410** reaches a reference position rp. The space d**1** may be set constant regardless of the space between the first vehicle **410** and the second vehicle **420**.

(45) In the example illustrated in FIG. **4**B, the target acceleration of the vehicle **10** is set so that the space d**1** between the front end of the vehicle **10** and the rear end of the first vehicle **410** becomes equal to the space d**2** between the rear end of the vehicle **10** and the front end of the second vehicle **420** before the first vehicle **410** reaches a reference position rp. In both examples illustrated in FIGS. **4**A and **4**B, the second vehicle **420** cannot get ahead of the vehicle **10**, which prevents making the driver of the second vehicle **420** mistakenly believe that right-of-way is yielded. In addition, since the vehicle **10** is ahead of the front end of the second vehicle **420**, the vehicle **10** will not obstruct a lane change of the second vehicle **420** to the host vehicle lane **400**.

(46) FIG. **5** is an operation flowchart of the vehicle control process executed by the processor **23**. The processor **23** executes the vehicle control process in accordance with the operation flowchart described below at predetermined intervals.

(47) The merging section detection unit **31** of the processor **23** detects a merging section in which an adjacent lane merges into a host vehicle lane, ahead of the vehicle **10** along the travel direction of the vehicle **10** (step S**101**). The vehicle detection unit **32** of the processor **23** detects one or more other vehicles traveling on the lane adjacent to the host vehicle lane in the merging section or a predetermined section nearer to the host vehicle than the merging section (step S**102**).

(48) For each of the one or more detected vehicles, the determination unit **33** of the processor **23** determines whether to allow the detected vehicle to precede the vehicle **10** at a lane change of the detected vehicle to the host vehicle lane in the merging section (step S**103**).

(49) The vehicle control unit **34** of the processor **23** sets the upper limit of target acceleration of the vehicle **10** so as to make space where a first vehicle that is the rearmost of the detected vehicles

allowed to precede can enter the host vehicle lane ahead of the vehicle **10** (step S**104**). The vehicle control unit **34** sets the target acceleration of the vehicle **10** below the upper limit of the target acceleration so that the rear end of the vehicle **10** is ahead of the front end of a second vehicle following the first vehicle (step S**105**). The vehicle control unit **34** controls acceleration of the vehicle **10** so that the vehicle **10** accelerates or decelerates according to the set target acceleration (step S**106**). The processor **23** then terminates the vehicle control process.

(50) As has been described above, the vehicle controller controls acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle among other vehicles traveling in a merging section. In this way, the vehicle controller can appropriately adjust the positional relationship between the host vehicle and another vehicle traveling on an adjacent lane merging with a lane being traveled by the host vehicle. As a result, the vehicle controller can prevent obstructing a lane change to the host vehicle lane of another vehicle traveling in the merging section to which the host vehicle does not intend to yield right-of-way, and prevent making the driver of the former vehicle mistakenly believe that right-of-way is yielded.

(51) According to a modified example, the vehicle control unit **34** may adjust the positional relationship between the first and second vehicles and the vehicle **10**, depending on the space between the first and second vehicles. For example, the vehicle control unit **34** may set the target acceleration, depending on the space between the first and second vehicles, so that the ratio of the space between the rear end of the vehicle **10** and the front end of the second vehicle to the space between the front end of the vehicle **10** and the rear end of the first vehicle becomes constant before the first vehicle reaches a reference position. Specifically, in some embodiments, the vehicle control unit **34** sets the ratio so that the space between the rear end of the vehicle **10** and the front end of the second vehicle is larger than the space between the front end of the vehicle **10** and the rear end of the first vehicle. The vehicle control unit **34** determines the space between the first and second vehicles, based on the predicted positions of the first and second vehicles at the time when it is determined by the determination unit **33** that the first vehicle is allowed to precede the vehicle **10**. By setting the target acceleration in this way, the vehicle control unit **34** can adjust the relative position of the vehicle **10**, depending on the space between the first and second vehicles, so as not to obstruct a lane change of the second vehicle to the host vehicle lane while maintaining space where the first vehicle can enter.

(52) When the merging section is congested, the space between the first and second vehicles may become smaller than the full length of the vehicle **10**. In such a case, provision of space where the first vehicle can enter the host vehicle lane ahead of the vehicle **10** may result in the front end of the second vehicle being ahead of the rear end of the vehicle **10**. Thus, when the space between the first and second vehicles is smaller than the full length of the vehicle **10** in the above-described embodiment or modified example, the vehicle control unit **34** may set the target acceleration so that the front end of the vehicle **10** is between the rear end of the first vehicle and the front end of the second vehicle. In this case also, the vehicle controller can prevent making the driver of the second vehicle mistakenly believe that right-of-way is yielded. The vehicle control unit **34** can determine the space between the first and second vehicles, based on the predicted positions of the first and second vehicles at respective times.

(53) The computer program for achieving the functions of the processor **23** of the ECU **5** according to the embodiment or modified examples may be provided in a form recorded on a computer-readable portable storage medium, such as a semiconductor memory, a magnetic medium, or an optical medium.

(54) As described above, those skilled in the art may make various modifications according to embodiments within the scope of the present disclosure.

Claims

1. A vehicle controller comprising: a processor configured to: detect, ahead of a host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane, detect one or more other vehicles traveling on the adjacent lane, determine whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section, control acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles, and when a space between the first vehicle and the second vehicle is smaller than a full length of the host vehicle, set a target acceleration of the host vehicle so that the front end of the host vehicle is between a rear end of the first vehicle and the front end of the second vehicle.
2. The vehicle controller according to claim 1, wherein the processor controls acceleration or deceleration of the host vehicle so that space between the host vehicle and the first vehicle is smaller than space between the host vehicle and the second vehicle, when the space between the first vehicle and the second vehicle is larger than the full length of the host vehicle.
3. The vehicle controller according to claim 1, wherein the processor controls acceleration or deceleration of the host vehicle, depending on space between the first vehicle and the second vehicle, so that a ratio of space between the host vehicle and the first vehicle to space between the host vehicle and the second vehicle is constant, when the space between the first vehicle and the second vehicle is larger than the full length of the host vehicle.
4. A method for vehicle control, comprising: detecting, ahead of a host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane; detecting one or more other vehicles traveling on the adjacent lane; determining whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section; controlling acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles, and when a space between the first vehicle and the second vehicle is smaller than a full length of the host vehicle, setting a target acceleration of the host vehicle so that the front end of the host vehicle is between a rear end of the first vehicle and the front end of the second vehicle.
5. A non-transitory recording medium that stores a computer program for vehicle control, the computer program causing a processor mounted on a host vehicle to execute a process comprising: detecting, ahead of the host vehicle, a merging section in which an adjacent lane adjacent to a host vehicle lane being traveled by the host vehicle merges into the host vehicle lane; detecting one or more other vehicles traveling on the adjacent lane; determining whether to allow at least one of the detected vehicles to precede the host vehicle at a lane change of the one of the detected vehicles to the host vehicle lane in the merging section; controlling acceleration or deceleration of the host vehicle so that a rear end of the host vehicle is ahead of a front end of a second vehicle following a first vehicle allowed to precede the host vehicle, the first and second vehicles being among the detected vehicles, and when a space between the first vehicle and the second vehicle is smaller than a full length of the host vehicle, setting a target acceleration of the host vehicle so that the front end of the host vehicle is between a rear end of the first vehicle and the front end of the second vehicle.